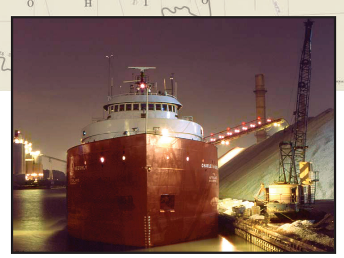
Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping






United States Environmental Protection Agency

Office of Transportation and Air Quality
EPA-420-R-12-005
April 2012

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Assessment and Standards Division
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List of Acronyms

µm	Micrometers
µg	Microgram
$\mu g/m^3$	Microgram per Cubic Meter
ACE	Army Corps of Engineers
AE	Auxiliary Engine
AEO	Annual Energy Outlook (an EIA publication)
AFC	Average Daily Fuel Consumption
AIRS	Aerometric Information Retrieval System
AMVER	Automated Mutual-Assistance Vessel Rescue
AQ	Air Quality
AQCD	Air Quality Criteria Document
ARB	Air Resources Board (California)
ASPEN	Assessment System for Population Exposure Nationwide
ASTM	American Society for Testing and Materials
ATB	Articulated Tug-Barge
BenMAP	Benefits Mapping and Analysis Program
bhp	Brake Horsepower
BSFC	Brake Specific Fuel Consumption
C	Celsius
C1	Category 1; marine diesel engines up to 7 liters per cylinder displacement
C2	Category 2; marine diesel engines 7 to 30 liters per cylinder
C3	Category 3; marine diesel engines at or above 30 liters per cylinder
CA	California
CAA	Clean Air Act
CAIR	Clean Air Interstate Rule (CAIR) (70 FR 25162, May 12, 2005)
CARB	California Air Resources Board
CB	Chronic Bronchitis
CDC	Centers for Disease Control
CFR	Code of Federal Regulations
CMAQ	Community Multiscale Air Quality
CN	Canadian National
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COI	Cost of Illness
COPD	Chronic Obstructive Pulmonary Disease
CPI-U	Consumer Price Index - All Urban Consumers
C-R	Concentration Response
cyl	Cylinder
DE	Diesel Exhaust
DM&IR	Duluth, Missabe and Iron Range Railway
DMA	Distillate Marine Grade A fuel
DMB	Distillate Marine Grade B fuel
DMC	Distillate Marine Grade C fuel, reclassified as RMA-10
DMX	Distillate Marine Grade X fuel; a light distillate used mainly in emergency or C1 engines
DOE	Department of Energy
DOT	Department of Transportation
DPM	Diesel Particulate Matter
DV	Design Values
DWT	Dead Weight Tonnage
EC	East Coast Region
EC	Elemental Carbon
ECA	Emission Control Area
EEZ	Exclusive Economic Zone

EF	Emission Factor
EIA	Energy Information Administration (part of the U.S. Department of Energy)
EPA	Environmental Protection Agency
F	Fahrenheit
FR	Federal Register
FRM	Federal Reference Method
g	Gram
g/bhp-hr	Grams per Brake Horsepower Hour
g/kW-hr	Grams per Kilowatt Hour
gal	Gallon
GEOS	Goddard Earth Observing System
GI	Global Insight
GIFT	Geospatial Intermodal Freight Transport model (Energy and Environmental Research Associates, developed with funding from the United States Maritime Administration)
GIS	Geographic Information System
GL	Great Lakes Region
GLF	Great Lakes Fleet
GL/SLS	Great Lakes/St. Lawrence Seaway
GRT	Gross Registered Tonnage
GT	Gas Turbine
HAD	Health Assessment Document for Diesel Engine Exhaust
HC	Hydrocarbon
HE	Hawaii East Region
HEI	Health Effects Institute
HES	Health Effects Subcommittee
HFO	Heavy Fuel Oil
hp	Horsepower
hp-hr	Horsepower Hour
hrs	Hours
HW	Hawaii West Region
IARC	International Agency for Research on Cancer
ICD	International Classification of Diseases
ICOADS	International Comprehensive Ocean-Atmospheric Data Set
IFO	Intermediate Fuel Oil
IMO	International Maritime Organization
IMPROVE	Interagency Monitoring of Protected Visual Environments
IRIS	Integrated Risk Information System
ISO	International Standardization Organization
ISORROPIA	Inorganic Aerosol Thermodynamics Module
JAMA	Journal of the American Medical Association
km	Kilometer
kt	Kiloton (1,000 metric tons)
kts	Knots
kW	Kilowatt
kWh	Kilowatt Hour
L	Liter
L/cyl	Liters Per Cylinder
LF	Load Factor
LGC	Large Gas Carrier
LNG	Liquefied Natural Gas
LoLo	Lift on-Lift off
LPG	Liquefied Petroleum Gas
LRS	Lower Respiratory Symptoms
LSI	Lake Superior and Ishpeming (Railroad)
m^3	Cubic Meters
MARAD	U.S. Maritime Administration

MARPOL	The International Convention for the Prevention of Pollution of Ships
MCIP	Meteorology-Chemistry Interface Processor
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
MI	Myocardial Infarction (in Chapter 5)
mm	Millimeter
Mm^{-1}	Inverse Megameter
MOBILE6	Vehicle Emission Modeling Software
MRAD	Minor Restricted Activity Days
MSD	Medium Speed Diesel (engine)
MW	Megawatt
MWh	Megawatt Hours
N	Nitrogen
N/A	Not Applicable
NAAQS	National Ambient Air Quality Standards
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NATA	National Air Toxic Assessment
NCAR	National Center for Atmospheric Research
NCLAN	National Crop Loss Assessment Network
NEI	National Emissions Inventory
NH_3	Ammonia
NIOSH	National Institute of Occupational Safety and Health
nm	Nautical Mile
NMHC	Nonmethane Hydrocarbons
NMIM	National Mobile Inventory Model (EPA software tool)
NMMAPS	National Morbidity, Mortality, and Air Pollution Study
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NONROAD	EPA's Non-road Engine Emission Model
NONROAD2005	EPA's Non-road Engine Emission Model Released in 2005
NO_X	Oxides of Nitrogen
NP	North Pacific Region
NRC	National Research Council
NRT	Net Registered Tonnage
O/D	Origin/Destination
O_3	Ozone
OAQPS	Office of Air Quality Planning and Standards
OC	Organic Carbon
OEHHA	Office of Environmental Health Hazard Assessment
OEM	Original Equipment Manufacturer
OGV	Ocean-Going Vessel
PM	Particulate Matter
PM AQCD	EPA Particulate Matter Air Quality Criteria Document
PM_{10}	Coarse Particulate Matter (diameter of 10 µm or less)
$PM_{2.5}$	Fine Particulate Matter (diameter of 2.5 µm or less)
PM NAAQS	Particulate Matter National Ambient Air Quality Standards
POM	Polycyclic Organic Matter
ppb	Parts per Billion
ppm	Parts per Million
R&D	Research and Development
RfC	Reference Concentration
RIA	Regulatory Impact Analysis
RM	Residual Marine
RMA-10	Residual Marine fuel formerly DMC

rpm	Revolutions per Minute
RoPax	Roll on-Roll off passenger
RoRo	Roll on-Roll off
RSZ	Reduced Speed Zone
S	Sulfur
SAB	Science Advisory Board
SAB-HES	Science Advisory Board - Health Effects Subcommittee
SCR	Selective Catalyst Reduction
SFC	Specific Fuel Consumption
SI	Spark Ignition
SLS	St. Lawrence Seaway
SMAT	Speciated Modeled Attainment Test
SO_2	Sulfur Dioxide
SO_X	Oxides of Sulfur
SOA	Secondary Organic Carbon Aerosols
SP	South Pacific Region
SSD	Slow Speed Diesel (engine)
ST	Steam Turbine
STEEM	Waterway Network Ship Traffic, Energy and Environment Model
TSD	Technical Support Document
ULSD	Ultra Low Sulfur Diesel fuel
URS	Upper Respiratory Symptoms
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
VLCC	Very Large Crude Carrier
VLGC	Very Large Gas Carrier
VOC	Volatile Organic Compound
VOS	Voluntary Observing Ships
VSL	Value of Statistical Life
WTP	Willingness-to-Pay

Executive Summary

This report is an analysis of the economic impacts of EPA's Category 3 marine rule on Great Lakes shipping. Category 3 marine engines are diesel engines with per cylinder displacement at or above 30 liters. These engines are used for propulsion power on large vessels, including many Great Lakes cargo vessels, and they emit high levels of pollutants that contribute to unhealthy air in many areas of the United States.

EPA's final Category 3 marine rule is part of a Coordinated Strategy to reduce emissions from all Category 3 marine engines that operate in the United States, including those that operate on the U.S. portions of the Great Lakes and St. Lawrence Seaway (75 FR 22896, April 30, 2010).[A] The Coordinated Strategy consists of new national and international requirements that will significantly reduce emissions of particulate matter (PM), sulfur oxides (SO_X) and nitrogen oxides (NO_X) from Category 3 marine engines and their fuels. The long-term NO_X limits for new Category 3 engines will require the use of high-efficiency advanced aftertreatment technology similar to that already required to be used on diesel trucks, locomotives, and smaller marine engines that are operated in the United States. The long-term fuel sulfur limits are the international limits that apply in specially designated Emission Control Areas (ECAs), including the recently-designated North American ECA, and will dramatically reduce PM and SO_X emissions from Category 3 marine engines.

We received many comments from Great Lakes stakeholders about the Coordinated Strategy during our Category 3 rulemaking process, particularly about the fuel sulfur requirements. These commenters said that applying stringent ECA fuel sulfur requirements to Great Lakes Category 3 ships would increase ship fuel costs and could ultimately lead to a transportation mode shift in the Great Lakes region away from ships and toward less efficient ground transportation which, in turn, could increase emissions overall. Some commenters also indicated that increased marine fuel costs could affect the Great Lakes market for crushed stone, by causing users to change their source of stone from quarries in the upper Great Lakes to quarries located closer to their facility that would not require marine transportation. In addition, commenters argued that increased marine fuel costs could lead electricity and steel producers to shift production out of the Great Lakes region.

We included several compliance flexibility provisions in the final Category 3 marine rule to address these concerns of Great Lakes stakeholders. In addition, we performed supplemental analysis to estimate the inventory and cost impacts of applying the ECA fuel sulfur requirements to the Great Lakes. Finally, we indicated that we would perform an analysis of the economic impacts of the final rule on Great Lakes shipping. This report contains that analysis.

Great Lakes stakeholder input was essential in the development of this study, and the industry provided vital assistance with respect to the choice of scenarios studied, the methodology used, and important data inputs. A key stakeholder contribution was the identification of Great Lakes shipping routes that industry members believe are at risk of transportation mode shift as a result of increased costs of ECA fuel. A number of different trade

[A] For the purpose of this study, "Great Lakes" refers to the five Great Lakes and the St. Lawrence Seaway.

routes were submitted by various individuals and companies for EPA's consideration, from which, with help from the stakeholders, we developed O/D pairs that characterize the 16 scenarios that form the basis of this analysis.[B] Great Lakes Stakeholders also provided advice as we developed our methodology to assess transportation mode shift, and commented on the data we used to carry out the analysis.[C]

Consistent with stakeholder comments, this economic impact analysis examines three potential effects of increased fuel costs associated with the use of reduced sulfur ECA fuel by Great Lakes shipping: 1) transportation mode shift, 2) source shift, and 3) production shift.

For each of the sixteen at-risk O/D pairs (four each of coal, iron ore, grain, and crushed stone), the optimal transportation route that contains a marine link was identified, and the incremental change in fuel costs associated with using ECA-compliant fuel for that route was estimated.

Transportation mode shift is evaluated for the twelve coal, iron ore, and grain routes by comparing the ECA-adjusted freight rates for the marine-based routes to freight rates for the next cheapest means of shipping, the all-rail alternative. This analysis, contained in Chapter 2, shows that compliance with the ECA fuel sulfur limits is unlikely to lead to transportation mode shift on these at-risk routes. For ten of the twelve scenarios examined, ECA-adjusted marine freight rates are expected to remain well below the next least expensive shipping mode, all-rail. For one of the two remaining scenarios, an All-Rail Alternative route could not be identified, although the results for a similar case suggest that no transportation mode shift would be indicated. For the other scenario, the results of the analysis are inconclusive due to mis-specification of the scenario.

Source shift is evaluated for the four crushed stone routes by examining certain features of the crushed stone markets for each of the relevant using facilities. This analysis, contained in Chapter 3, shows that the estimated increase in marine fuel costs is not expected to change the competitive dynamics of these markets and therefore no source shift is expected.

Finally, production shift is evaluated for electricity and steel markets using a retail revenue approach. This analysis, also contained in Chapter 3, shows that the estimated increase in marine fuel costs for transporting coal and iron ore is not expected to shift electrical and steel production out of the Great Lakes region both because these cost increases are small in comparison to sector revenues and because the magnitude of the cost increases is well within the bounds of historic electricity and steel price fluctuations. Chapter 3 also contains a more detail analysis for steel destined for use in the Detroit, Michigan area.

The analyses contained in Chapters 2 and 3 of this report were peer reviewed pursuant to EPA's *Science Policy Council Peer Review Handbook*, 3rd edition (*Peer Review Handbook*). The peer review is described in Chapter 8.

[B] "Origin/destination (O/D) pairs" refers to specific starting and ending points of shipping routes on the Great Lakes. Section 2.4 describes the selection of the O/D pairs and shipping routes.

[C] The selection of the 16 routes is briefly described below and in more detail in Chapter 2 of this report. Twelve of the 16 O/D pairs were identified by stakeholders as being at risk for transportation mode shift. The other four O/D pairs, for the transportation of crushed stone, were identified as being at risk of source shift to local quarries.

The remainder of this Executive Summary provides additional background and a brief overview of the findings of this study.

The Arthur M. Anderson heads into Port Huron in the early morning fog. Source: Photo taken by Barant Downs, August 16, 2007.

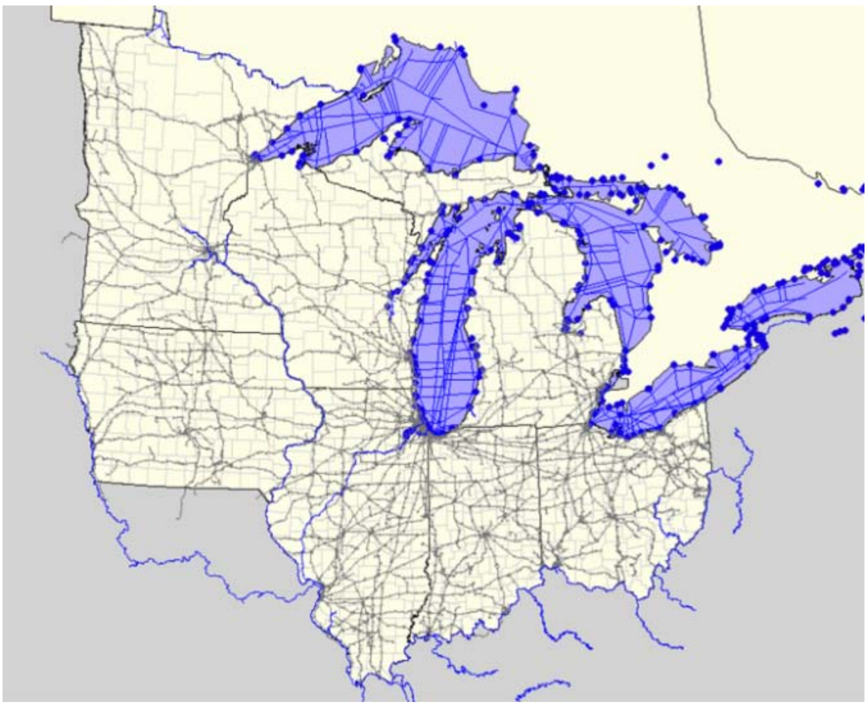
The Great Lakes and Category 3 Ships

The Great Lakes are an important part of our transportation system, for the region and for the nation. Today, as illustrated in Figure ES-1, Great Lakes ships, called Lakers, carry bulk raw materials such as iron ore, coal, grain, and crushed stone from one end of the lakes, where they are mined or grown, to the other, where they are used in local manufacturing, shipped farther inland, or shipped to the rest of the world. For the future, the Great Lakes are one of eighteen marine highway corridors included in the United States Maritime Administration's *America's Marine Highway Program*. The goal of this program is "to offer relief to landside corridors that suffer from traffic congestion, excessive air emissions, or other environmental concerns and other challenges" particularly through the transport of containerized goods and highway truck trailers on lift-on/lift-off (LoLo) or roll-on/roll-off (RoRo) vessels. Shifting to marine transportation is expected to ease rail and highway congestion and reduce energy consumption.

Great Lakes cargo vessels can be as large as or larger than ocean-going vessels, measuring up to 1,000 ft in length. Similar to ocean-going vessels, many Lakers have Category 3 marine diesel engines (per cylinder displacement at or above 30 liters). Unlike smaller Category 1 and Category 2 marine engines, these slow speed/high power Category 3 engines use emission control technology that is comparable to that used by nonroad engines in the early 1990s. In addition, they typically use fuel that is the residue of the refining process. This residual fuel, also called heavy fuel oil (HFO), has a sulfur content that is significantly higher than the 15 ppm limit that applies to distillate diesel fuel used in smaller marine engines, highway trucks, nonroad equipment, and locomotives operated in the United States.[D] According to the International Maritime Organization, the current global average sulfur content of HFO is about 23,500 ppm.

As a result, ships with Category 3 engines, including those that operate on the Great Lakes, emit high levels of pollutants that contribute to unhealthy air in many areas of the country. Nationally, in 2009, emissions from Category 3 marine engines accounted for about 10 percent of mobile source emissions of nitrogen oxides (NO_X), about 24 percent of mobile source diesel $PM_{2.5}$ emissions (with $PM_{2.5}$ referring to particles with a nominal mean aerodynamic diameter less than or equal to 2.5 μm), and about 80 percent of mobile source emissions of sulfur oxides (SO_X).

Figure ES--1 Great Lakes Docks, Waterways and Railroads



Source: Department of Geography and Planning: Center for Geographic Information Sciences and Applied Geographics (GISAG), 2007

More than 27 million people live in the U.S. portions of the Great Lakes basin and are affected by emissions from ships operating on the five lakes, including Category 3 vessels. The impacted population is even larger considering people living on the Canadian side of the lakes and along the St. Lawrence Seaway. Several areas, including Chicago, Detroit, Cleveland, and Buffalo, which each have commercial ports, do not achieve National Ambient Air Quality Standards for particulate matter, ozone, or both. Ships with Category 3 engines that use heavy fuel oil contribute to nonattainment in these and other areas on the Great Lakes.

The Coordinated Strategy advanced by the Category 3 marine rule, described below and in Chapter 1, will significantly reduce NO_X, PM and SO_X emissions from these engines. We

[D] EPA's 15 ppm fuel sulfur limit began to apply to land-based nonroad, locomotive, and marine distillate fuel produced or sold in the United States in 2010 and it will be fully phased-in for these sources by 2014.

project that by 2030 this Coordinated Strategy will reduce annual emissions of NO_X, sulfur oxides (SO_X), and particulate matter (PM) by 1.2 million, 1.3 million, and 143,000 tons, respectively, and the magnitude of these reductions would continue to grow well beyond 2030. These nationwide reductions are estimated to annually prevent between 12,000 and 30,000 PM-related premature deaths, between 210 and 920 ozone-related premature deaths, 1,400,000 work days lost, and 9,600,000 minor restricted-activity days. The estimated annual monetized health benefits of the Coordinated Strategy in 2030 would be between $110 and $270 billion, while the annual cost of the overall program in 2030 would be significantly less, at approximately $3.1 billion.[E]

EPA's Coordinated Strategy for Category 3 Engines and Fuels

EPA's Coordinated Strategy addresses emissions from all Category 3 marine engines that operate in the United States, including those that operate on the U.S. portions of the Great Lakes and St. Lawrence Seaway (75 FR 22896, April 30, 2010). The combination of this Coordinated Strategy and EPA's previously adopted standards for smaller marine diesel engines amount to a comprehensive program to reduce emission from all marine sources.[F] The overall program is consistent with the technology forcing goals EPA has applied in all of our other mobile source regulatory programs and will result in significant human health and welfare benefits.

The Coordinated Strategy for Category 3 engines consists of three parts:

(i) national engine emission standards for Category 3 engines installed on U.S. vessels and national sulfur limits for fuel produced or sold in the United States, adopted under the Clean Air Act;

(ii) international engine standards for all marine diesel engines above 130 kW and international fuel sulfur limits that apply worldwide, contained in the 2008 amendments to the International Convention for the Prevention of Pollution from Ships, called MARPOL Annex VI and implemented in the United States through the Act to Prevent Pollution from Ships (APPS); and

(iii) additional more stringent engine standards and fuel sulfur limits that apply to ships operating in specially designated emission control areas (ECAs), including the North American and U.S. Caribbean Sea ECAs, designated by amendment to MARPOL Annex VI and implemented in the United States through APPS.[G,H]

[E] In this report, estimates of monetized benefits and engineering compliance costs are presented in 2006$, consistent with the Category 3 marine rule analyses.

[F] New Category 2 and smaller diesel propulsion engines (per cylinder displacement up to 30 liters) installed on U.S. vessels, including those operating on the Great Lakes, are required to meet stringent national emission limits to reduce oxides of nitrogen (NO_X) and particulate matter (PM) emissions (see 40 CFR 94 and 1043). Our national fuel program limits the sulfur content of distillate marine diesel fuel produced or sold in the United States to 500 ppm, with an even cleaner 15 ppm sulfur standard phasing in by mid-2014 (see 40 CFR part 84).

[G] The North American ECA was approved by IMO in July 2009; the amendment to MARPOL Annex VI designating this ECA was adopted in March 2010. The 10,000 ppm fuel sulfur limit will begin to apply in August 2012; this is reduced to 1,000 ppm beginning January 1, 2015.

The engine and fuel requirements of the Coordinated Strategy are applicable to U.S. ships through EPA's Clean Air Act regulations (contained in 40 CFR 1042), and to all ships while they are operating in U.S. internal waters and the U.S. portions of the North American ECA, including the U.S. portions of the Great Lakes and St. Lawrence Seaway, through MARPOL Annex VI and associated regulations adopted through EPA's authority set out in the Act to Prevent Pollution from Ships (contained in 40 CFR 1043).[I,J]

The designation of the North American ECA through amendment to MARPOL Annex VI, and its domestic application under the Act to Prevent Pollution from Ships, is an important part of the Coordinated Strategy. ECA designation ensures that all ships operating within 200 nautical miles from the U.S. coastal baseline (except where limited by the Exclusive Economic Zones of other countries) use lower sulfur fuel. Beginning August 1, 2012,[K] the sulfur content of fuel used onboard vessels operating in the North American ECA cannot exceed 10,000 ppm. Beginning January 1, 2015, the fuel sulfur limit is reduced to 1,000 ppm. In addition, new vessels constructed beginning in 2016 will be required to meet stringent NO_X emission standards while they are operating within the ECA region.

The regulatory text included in our Category 3 marine rule made clear that a vessel operating in U.S. internal waters shoreward of a designated ECA that can be accessed by ocean-going vessels must meet the Annex VI ECA requirements.[L] In addition to U.S. coastal ports and U.S. rivers that are navigable from the ECA (such as the Mississippi River, the Puget Sound, the Chesapeake Bay), this includes those portions of the Great Lakes and St. Lawrence Seaway in which the North American ECA is enforceable by the United States.

Great Lakes Provisions in the Final Category 3 Marine Rule

We received many comments from Great Lakes stakeholders during our Category 3 rulemaking process, particularly with respect to the application of the stringent ECA fuel sulfur limits to Category 3 ships operating on the Great Lakes. Great Lakes shipping industry stakeholders told EPA that the requirement to use fuel with a sulfur content at or below 1,000 ppm would increase their operating costs and would ultimately lead to a transportation mode shift in the Great Lakes region away from ships and toward trucks or rail. Such a shift to less efficient ground transportation, in turn, could increase emissions overall. Some commenters also indicated that increased operating costs could affect the market for crushed stone, leading users to change their source of stone from quarries located in the upper Great Lakes to local quarries.

[H] The U.S. Caribbean Sea ECA was approved by IMO in July 2010; the amendment to MARPOL Annex VI designating this ECA was adopted in July 2011. The 10,000 ppm fuel sulfur limit will begin to apply in January 2014; this is reduced to 1,000 ppm beginning January 1, 2015.

[I] For a full description of the North American ECA, see Section 1.4.3.1 of Chapter 1.

[J] Canada is currently developing their program for ships operating on the Canadian portions of the Great Lakes and the St. Lawrence Seaway.

[K] Pursuant to Regulation 14.7 of MARPOL Annex VI, "During the first twelve months immediately following an amendment designating a specific emission control area … ships operating in that emission control area are exempt [from the fuel sulfur requirements]." Therefore, while the amendment to Annex VI with respect to the North American ECA goes into force in August 2011, the fuel requirements are applicable beginning in August 2012.

[L] In the regulatory text, an internal waterway in which the ECA requirements apply is called an "ECA associated area."

In addition, commenters argued that increased marine fuel costs could lead electricity and steel producers to shift production out of the Great Lakes region.

To address these stakeholder concerns, and consistent with Congressional recommendation, we included three Great Lakes-specific provisions in our final Category 3 marine rule. Each of these provisions is available to any ship operating on the U.S. portions of the Great Lakes, including foreign vessels.

(i) We adopted a steamship exemption: Great Lakes steamships are excluded from the ECA fuel standards. This provision avoids immediate retirement of steamships, which may not be able to operate safely on distillate diesel fuel. However, we expect these vessels will be retired eventually because of their higher fuel usage when compared to diesel engines (a steam engine can consume up to twice as much fuel as modern diesel engines).

(ii) We included an economic hardship provision: a Great Lakes ship owner may petition EPA for a temporary exemption from the long-term (2015) ECA fuel sulfur requirement. The owner must show that despite taking all reasonable business, technical, and economic steps to comply with the fuel sulfur requirements, the burden of compliance costs would create a serious economic hardship for the company. The Agency will evaluate each application on a case-by-case basis.

(iii) We adopted a fuel availability waiver: a Great Lakes ship may use fuel that exceeds the 10,000 ppm interim ECA fuel sulfur limit until January 2015 on the condition that the ship operator purchases fuel with the lowest sulfur content available. This provision addresses the concern that fuel meeting the interim 10,000 ppm standard may not be available on the Great Lakes due to the nature of this marine fuel market. There are some reporting requirements for owners exercising this fuel waiver.

We also performed additional analyses of the inventory and air quality impacts of the Coordinated Strategy for the Great Lakes region specifically, and estimate the cost of applying the ECA requirement to Lakers.

Finally, to address concerns that the application of the ECA fuel requirements on the Great Lakes would result in transportation mode shift, source shift, and/or production shift, we indicated we would perform a comprehensive study to analyze the potential for these impacts. This report contains that study.

The James R. Barker heading downbound at Mission Point in Sault Ste. Marie, MI – 2008. Source: Photograph taken by and used with permission from Dick Lund, accessed here: http://www.dlund.20m.com/images_2008/SOO062908an.JPG.

Scope of this Economic Impact Analysis

This study looks at the impacts of applying the long-term 1,000 ppm ECA fuel sulfur limit to Great Lakes shipping. The study examines the impacts on only Category 3 ships since ships powered by Category 2 and smaller engines typically use distillate diesel fuel that is subject to more stringent fuel sulfur limits (currently 500 ppm in the United States, reduced to 15 ppm by 2014).

The analysis assumes uniform application of the ECA fuel sulfur requirements across the entire marine Great Lakes/St. Lawrence Seaway system. It should be noted that the Canadian program to implement the ECA standards is still under development. As a result, this analysis is conservative in that it applies the more expensive ECA fuel to the entire marine segment.

This study focuses on the long-term ECA fuel requirements, the 1,000 ppm sulfur limit applicable in 2015. This standard represents by far the most costly part of the fuel sulfur control program as it is expected to require switching to higher price distillate diesel fuel or the use of an exhaust gas cleaning system (scrubber). In contrast, the interim 10,000 ppm sulfur limit, which will apply when the North American ECA goes into effect in August 2012, is expected to be achievable through the use of lower price reduced sulfur residual fuel and will therefore have a much smaller impact on operating costs.

This analysis does not consider the impacts of the Coordinated Strategy's engine requirements. The Tier III standards, which apply to engines installed on ships constructed beginning in 2016 while they are operating in an ECA, is not included because new ships are built only rarely for the Great Lakes fleet and therefore it is difficult to anticipate how many, if any, vessels would be affected in any given year. The Tier II NO_X standards, which apply at all times to engines installed on ships constructed beginning in 2011, and the NO_X requirements for existing engines[M] are also not included in this analysis because they apply to ships whether or not they are operated in a designated ECA. Finally, while we present the cost of retrofitting existing vessels with new engines in our Chapter 6 cost analysis, we do not include the impacts of engine retrofitting in our economic analysis because there is no requirement to retrofit an existing vessel with a cleaner, newer engine.

Results of this Economic Impact Study

A detailed description of how the O/D pairs that characterize the sixteen scenarios that make up this analysis were chosen as well as the results of the transport mode shift, source shift, and production shift analyses is contained in Chapters 2 and 3 of this report.

Once the sixteen O/D pairs were selected, the optimal transportation route that contains a marine link was identified for each. These routes were developed by ICF International and its subcontractor, Energy and Environmental Research Associates (EERA), using the Geospatial Intermodal Freight Transport (GIFT) model that EERA developed with funding from the United States Maritime Administration (MARAD). This optimal transportation route is intended to maximize the use of the Great Lakes across the overall route.

ICF and EERA also estimated a route-based freight rate for each scenario that incorporates the combined marine and rail segments. This is called the Base Case freight rate. Then, the incremental change in fuel costs associated with using ECA-compliant fuel was estimated using an activity-based fuel consumption and cost model that accounts for vessel operation “at sea” and “in port.” This information is used to estimate a revised freight rate for the route, called the ECA Case freight rate. These freight rates are reported in Table ES-1.

Transportation Mode Shift

The transportation mode shift analysis was carried out on the coal, iron ore, and grain scenarios. [N] For this analysis, ICF and EERA developed an all-rail alternative route for each of the twelve scenarios. While eleven of the twelve O/D pairs can be linked by rail, it was discovered that the mine and using facility in Scenario 6 cannot: the originating mine has no access to a national rail line or highway. ICF and EERA estimated an all-rail freight rate for the remaining eleven scenarios, called the All-Rail Alternative Route freight rate. The ECA Case freight rate was then compared to the All-Rail Alternative Route freight rate for that scenario to determine which route has the higher freight rate. If the freight rate for the ECA Case is less than that of the All-Rail Alternative Route, then no transportation mode shift to rail is indicated for these at-risk routes.

[M] The MARPOL Annex VI standards for existing engine apply to marine diesel engines with a power output of more than 5,000 kW and per cylinder displacement at or above 90 liters installed on a ship constructed on or after 1 January 1990 but prior to 1 January 2000 (Regulation 13.7.1). Note that this requirement depends on the availability of a certified approved method (i.e., remanufacture system).

[N] The four crushed stone routes are analyzed separately, as stakeholders indicated that increased marine fuel costs would lead to source shift (customers would shift their source of crushed stone from quarries located in northern Michigan, transported in part by ship, to local quarries, transported by truck).

As shown in Table ES-1, the ECA Case freight rate for the marine transportation mode is expected to remain well below the next cheapest shipping mode – rail – for ten of the twelve transportation mode shift scenarios examined, and therefore no transportation mode shift is indicated. The results for Scenarios 2 and 6 are discussed below.

Table ES-1 Overview of Scenario Results [a, b]

	Scenario	Base Case Total Freight Rate	ECA Case Total Freight Rate	Base to ECA (% Diff)	All-Rail Total Freight Rate	ECA to All-Rail (% Diff)
1	Coal from Montana to Wisconsin	$19.99	$20.23	1.2%	$21.71	-7.3%
2	Coal from Colorado to Wisconsin	-- [c]	-- [c]	-- [c]	-- [c]	-- [c]
3	Coal from Montana to southern Michigan	$21.19	$22.00	3.8%	$27.44	-24.7%
4	Coal from Montana to northern Michigan	$25.28	$26.41	4.5%	$28.12	-6.5%
5	Iron Ore from Michigan to Ontario	$4.12	$4.47	8.5%	$5.22	-16.8%
6	Iron Ore from Quebec to Indiana	$16.10	$18.77	16.6%	-- [d]	-- [d]
7	Iron Ore from Minnesota to Indiana	$6.21	$7.14	15.0%	$11.99	-67.9%
8	Iron Ore from Minnesota to Ohio	$6.83	$7.73	13.2%	$18.37	-137.6%
9	Grain from Illinois to Quebec	$22.00	$24.11	9.6%	$46.75	-93.9%
10	Grain from Minnesota to Quebec	$19.78	$21.82	10.3%	$59.57	-173.0%
11	Grain from Minnesota to New York	$22.43	$23.93	6.7%	$36.62	-53.0%
12	Grain from Ontario to Ohio	$9.12	$9.95	9.1%	$11.80	-18.6%
13	Stone from Michigan to Ohio	$10.89	$11.15	2.4%	--	N/A
14	Stone from Michigan to Ohio	$8.91	$9.14	2.6%	--	N/A
15	Stone from Michigan to Minnesota	$12.04	$12.39	2.9%	--	N/A
16	Stone from Michigan to Pennsylvania	$6.51	$6.82	4.8%	--	N/A

[a] Taken from Table 76 of contractor report, Appendix 2C.
[b] Modeled baseline freight rates using 2007 fuel prices adjusted for the Great Lakes market, reported in 2008$
[c] Results are inconclusive due to mis-specification of the scenario. See discussion in text.
[d] No all-rail alternative exists for this route; results for a partial-rail alternative case would resemble those of Scenario 9. See discussion in text.

Scenario 2 consists of coal transported from the Elk Creek Mine in Colorado through South Chicago to the Georgia Pacific paper mill in Green Bay, Wisconsin. The initial results for this scenario, reported in Appendix C to this chapter, suggest that the route-based freight rate for the All-Rail Alternative ($24.43) is less than both the Base Case and the ECA freight rates ($26.03 and $26.64, respectively). This contrary result led EPA to perform additional research with regard to this facility. The information obtained by EPA indicates that, due to quality specifications for the coal used by this facility, the western bituminous coal used in this paper mill is blended with other coal to obtain the product needed. The blended coal is obtained from a source in South Chicago, where the KCBX Terminal can store up to 1 million net tons of coal on site and can blend up to three coals for a customer. Consequently, this case was mis-specified. However, it is unclear whether the transportation costs for this case should be based solely on the cost of transporting coal from the terminal in Chicago to the facility in Green Bay, or whether some portion of the transportation cost from the mine head(s) should be included. This question could be important because this facility also receives coal by ship from Sandusky and Ashtabula, Ohio, and vessels operating from those facilities are also required to use ECA-compliant fuel. For these reasons, and because freight rates for a revised scenario are not readily available, it is not possible to determine the potential for transportation mode shift impacts for this route.

Scenario 6 consists of iron ore transported from Quebec Cartier Mining Co., in Quebec, to ArcelorMittal, in Burns Harbor, Indiana. Transportation mode shift to rail is impractical for this scenario because there is no access to a national highway or rail line at the mine in Quebec. However, this scenario is similar to Scenario 9, which also involves transportation of cargo (grain) the length of the St. Lawrence Seaway, and the All-Rail Alternative route for that scenario can be used to estimate the likelihood of transportation mode shift for Scenario 6. As indicated in Table ES-1, the All-Rail Alternative freight rate for Scenario 9 exceeds the ECA Case freight rate and no transportation mode shift is indicated. The use of this rail alternative would likely be even less favorable for Scenario 6 because it would require transportation by ship to the rail port on the opposite shore of the Gulf of St. Lawrence, with associated cargo transfers.

Source Shift

The source shift analysis was performed by EPA for the four crushed stone routes identified by stakeholders as being at risk for source shift to local quarries. The analysis is based on marine freight rates developed by ICF International and EERA using the same methodology as in the transportation mode shift analysis described above. We followed the competitive radius methodology used in the study included in the Canadian Shipowners' Association comments on the Category 3 marine rule. This methodology examines how an increase in total marine transportation costs increases the competitive radius around each using facility, potentially increasing the number of local quarries that could service it and thus changing the competitive dynamics of that market for crushed stone.

This analysis shows an increase in competitive radius of less than 10 miles for all scenarios. This small increase in the competitive radius, four percent or less, would not be expected to result in a change in the competitive structure of the local crushed stone markets for these four at-risk routes. A geographic examination the increase in competitive radius indicates that the number of quarries that could service each of the four facilities would not increase significantly. Therefore, no source shift is indicated for these at-risk routes.

Production Shift

The production shift analysis was performed by EPA to examine whether higher ship operating costs associated with the use of ECA-compliant fuel would lead manufacturers to move the production of steel and electricity out of the Great Lakes region. Based on a retail revenue analysis, we estimate that the increase in coal and iron ore transportation costs will amount to less than 0.5 percent of electrical sector revenues and less than 0.1 percent of steel sector revenues. This small increase in transportation costs is well within historic variations in electricity and finished steel prices. As a result, the use of ECA-compliant fuel is not expected to result in movement of production away from the Great Lakes region especially given relocation costs and, in the steel case, the cost of importing finished steel produced outside the United States and transporting it to steel users in the Great Lakes area.

Stakeholder Participation

EPA performed the analysis contained in this report in response to comments received from Great Lakes stakeholders during our Category 3 rulemaking process. As a result, we solicited industry stakeholder input during all phases of the analysis, especially with respect to the routes studied, the methodology used, and key data inputs such as cargo types, vessel characteristics, and cargo transfers. Appendix A to Chapter 2 contains more details about stakeholder outreach, including a list of workshop attendees and an index of external correspondence.

EPA engaged with various Great Lakes industry stakeholders throughout the development of this analysis. Our first outreach with stakeholders was through a presentation to industry members at Marine Community Day on February 11, 2010. At this conference, EPA explained to stakeholders that we were developing a research strategy and evaluating existing modeling tools and various ways to assess the economic impacts of our rule on Great Lakes Shipping. The goal of the analysis, we noted, would be to see if a transportation cost increase of the order we expected as a result of applying the ECA fuel requirements to the Great Lakes, in combination with the dynamics of transportation in the Great Lakes region, would potentially lead shippers to shift away from marine transportation to one of the land-based alternatives, rail or truck. We also indicated we were developing ways to engage stakeholders to obtain input on the methods we would be using and the data we would need to carry out the study.

During the spring of 2010, we evaluated existing models and methodologies that could be used to perform this analysis. We also engaged a contractor who began to develop the analytic tools and carry out test modeling for several example cargo/route combinations.

We hosted a workshop in Ann Arbor on June 10, 2010, to present our proposed transportation mode shift methodology and to solicit data inputs from industry stakeholders. Under contract with EPA through ICF, Dr. James Winebrake of the University of Rochester and Dr. James Corbett of the University of Delaware described their Geospatial Intermodal Freight Transport (GIFT) model and cost function approach. They also presented the results of applying this methodology to two fairly typical transportation scenarios examining the cost impacts of the ECA fuel program for two fairly typical transportation scenarios: coal shipped from Montana to Monroe and St. Clair, Michigan, and iron ore shipped from Minnesota to Gary, Indiana. This methodology was well received by the workshop participants. At the close of that workshop we indicated that the next step in EPA's study would be to define the shipping routes that would be included in the analysis, and we requested industry assistance identifying those Great Lakes shipping routes most likely to be at risk for transportation mode shift due to competition from landside alternatives.

At the request of attendees, EPA followed up on the Ann Arbor workshop with an e-mail, dated June 16, 2010, that provided additional details about the methodology we intended to use for the transportation mode shift analysis and contained a list of the data inputs that would be needed. The e-mail was sent to workshop attendees as well as the two primary trade associations for Great Lakes carriers: Lake Carriers' Association and the Canadian Shipowners' Association. In that e-mail, EPA again requested stakeholder assistance in identifying sensitive routes that might be at risk for transportation mode shift.

We again presented a summary of our analytic approach and results for the two initial scenarios at the 74th International Joint Conferences of the Canadian Shipowners' Association and Lake Carriers' Association in Niagara-on-the-Lake, Ontario, on June 21, 2010, and requested additional stakeholder input.

Several stakeholders responded directly to EPA with confidential information about the trade routes they believe might be at risk for transportation mode shift as a result of increased fuel costs. Using this information, EPA prepared a list of 16 routes to be included in the analysis. After obtaining agreement of those stakeholders who had shared their recommendations, on July 12, 2010 we forwarded our draft list of at-risk routes to the primary industry trade organizations for dissemination to their members and requested comments or revisions. We received no adverse comment on this list of routes. The specific data needed to perform the analysis for each route were then gathered by EPA's contractor. We forwarded draft data sheets along with associated route maps to the trade associations on August 13, 2010, again with a request that they forward the information to their members for review and comment. The final data inputs used in this analysis are based on the comments we received on these data sheets.

In addition, EPA exchanged e-mails and had telephone conversations with various stakeholders with regard to their questions and concerns about the study.

In summary, stakeholder input was solicited during all phases of this project with regard to the study methodology, the choice of at-risk routes to be analyzed, and the data used to characterize these routes in the analysis. The assistance provided by stakeholders was highly valuable and allowed us to focus this analysis on those routes identified by shipping interests as being most likely to be adversely affected by the application of the ECA fuel requirements to the Great Lakes.

Organization of this Report

Chapter 1 of this report contains additional information about the Coordinated Strategy for Category 3 marine diesel engines and their fuels as well as additional background information about our national marine emission control program for Category 1 and 2 marine diesel engines. This chapter also contains a brief review of other studies of the environmental and economic benefits of marine transportation on the Great Lakes.

Chapter 2 contains our analysis of transportation mode shift. This analysis was performed by ICF International and its subcontractor, Energy and Environmental Research Associates (EERA) under contract for EPA.

Chapter 3 contains our analysis of source and production shift, as well as an analysis of the emission impacts of any possible shifts. These analyses were performed by EPA.

Chapters 4 and 5 contain an emission inventory and air quality analysis of ship emissions on the Great Lakes. This analysis is derived from the national level analysis performed for our Category 3 marine rule.

Chapter 6 contains information about the costs of complying with the Coordinated Strategy requirements for Great Lakes shipping.

Chapter 7 contains a brief industry characterization of those ships on the Great Lakes that will be subject to the Coordinated Strategy requirements.

Chapter 8 contains documentation of the peer review process, as well as responses to peer reviewers' comments that are not addressed elsewhere in this report.

CHAPTER 1: The Great Lakes and EPA's Marine Emission Control Program

The purpose of the analyses contained in this report is to examine the economic impacts of EPA's Category 3 marine rule, particularly the fuel sulfur limits, on Great Lakes shipping.

Category 3 marine engines are diesel engines with per cylinder displacement at or above 30 liters that are used for propulsion power on large vessels, including many Great Lakes cargo vessels. These high horsepower engines typically use heavy fuel oil (HFO, also called residual fuel). The average sulfur content of this fuel is currently about 23,500 ppm,[1] which is many times higher than the 15 ppm sulfur limit that applies to fuel used in highway trucks, land-based nonroad equipment, locomotives, and smaller marine diesel engines.[A] Category 3 engines also use emission control technology that is comparable to that used by nonroad engines in the early 1990s.

This chapter provides background information with respect to Great Lakes shipping and describes EPA's three-part Coordinated Strategy to reduce emissions from Category 3 marine engines and their fuel.[B] We also summarize the concerns of Great Lakes stakeholders with respect to this Coordinated Strategy, particularly with respect to the application of the North American Emission Control Area (North American ECA) fuel sulfur requirements to ships operating on the Great Lakes.[C] Finally, we provide a review of several recent studies of the economic benefits of Great Lakes shipping, the impacts of fuel cost increases on Great Lakes shipping, and the expected impacts of the Baltic Sea and North Sea ECA fuel sulfur limits on European marine transportation.

1.1 The Great Lakes Transportation System

The Great Lakes and the St. Lawrence Seaway are an important part of our transportation system, for the region and the nation. The system is ice-free about nine months of the year, and during that time a variety of ships carry large quantities of bulk raw materials such as iron ore, coal, grain, and crushed stone from one end of the lakes, where they are mined or grown, to the other, where they are used in manufacturing, shipped farther inland, or shipped to the rest of the world. These materials are important for the production of iron and steel, cement, and electricity, as well as agricultural exports.

[A] EPA's 15 ppm fuel sulfur limit began to apply to land-based nonroad, locomotive, and marine distillate fuel produced or sold in the United States in 2010; it will be fully phased-in for these sources by 2014.
[B] Chapter 7 describes the Great Lakes shipping sector in greater detail.
[C] For the purpose of this study, "Great Lakes" refers to the Great Lakes and St. Lawrence Seaway.

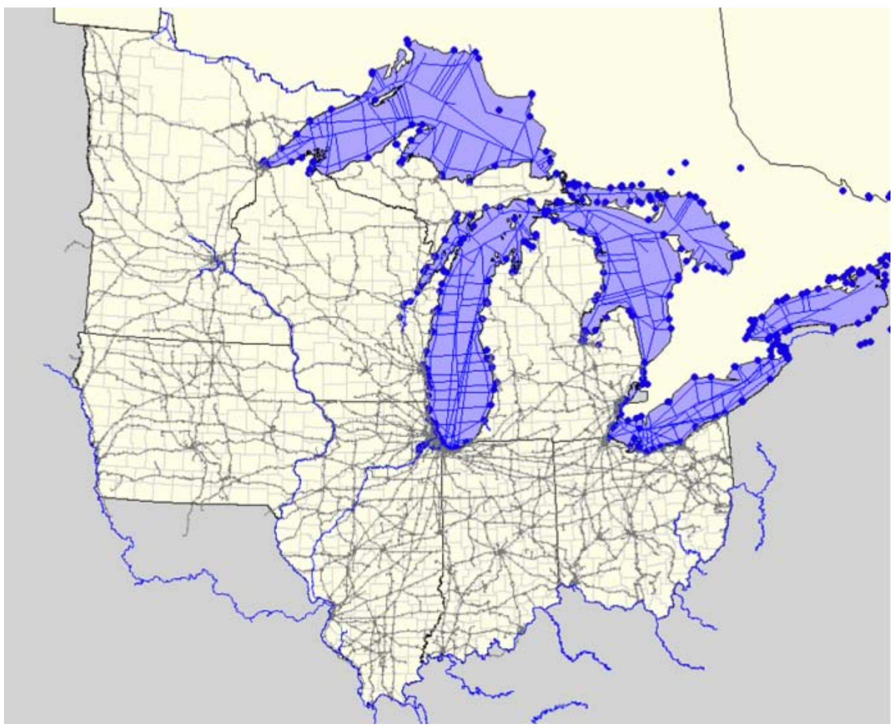
The Maumee passes the Detroit Renaissance Center heading downbound on the Detroit River in 2008. Source: Photo taken by and used with permission from Blake Kischler.

Historically, producers of steel, iron, cement, and electricity have chosen to locate their facilities on the Great Lakes because these manufacturers require vast quantities of raw materials such as coal, iron ore, and stone, and the Great Lakes provides a low-cost way to transport large shipments of these materials from mines to using plants. The Great Lakes also offer a vast reservoir of water that is needed for these production processes.[2] Today nearly all of the commodities shipped on the Great Lakes continue to be bulk goods, but there are renewed efforts to promote the system for transportation of other types of cargo as well. The Great Lakes are one of eighteen Marine Highway Corridors included in the United States Maritime Administration's *America's Marine Highway Program.*[3] The goal of this program is "to offer relief to landside corridors that suffer from traffic congestion, excessive air emissions, or other environmental concerns and other challenges," particularly through the transport of containerized goods and highway truck trailers on LoLo vessels (lift-on/lift-off, for containers) or RoRo vessels (roll-on/roll-off, for trailers). Shifting to marine transportation is expected to ease rail and highway congestion and reduce energy consumption.[D,E]

[D] The Great Lakes are also important for recreational use and fishing. However, those activities are not considered in this report as those vessels do not use Category 3 marine diesel engines.
[E] One peer reviewer noted skepticism "that the Great Lakes waterways would be an economically acceptable routing for intermodal short-sea container shipping" both because ships purpose-built for transporting containers on the Great Lakes would be small (200 containers) and because there are no container ports (Belzer). Another peer reviewer explained that short-sea shipping is an important growth industry for the Great Lakes (Hull). See also the U.S. Maritime Administration Study in sections 1.7.2 and 1.7.3, below.

The interconnectedness of Great Lakes shipping with the area's economy is illustrated in Figure 1-1. According to *Greenwoods Guide to Great Lakes Shipping 2007*, there are about130 commercial ports and docks on the Great Lakes that can handle shipments of coal, iron ore, and stone; still others handle grain and other bulk goods. These ports and docks range from very large public commercial facilities like those in Duluth and Superior, Minnesota, to small private docks that may service one plant. Actual cargo origins and destinations can be located well inland of the Great Lakes and marine transportation is a link in an intermodal transportation chain from producer to user. For example, coal can be transported by rail to from coal mines in Montana to the port at Duluth, Minnesota, and then transported by ship to power plants on the St. Clair River in Michigan. Similarly, stone can be transported by ship from mines on the shores of Lake Michigan through Toledo, Ohio, and then by rail to the Ohio River Valley and then by river barge for use in exhaust cleaning scrubbers at electric power plants located on the river.

Figure 1-1 Great Lakes Maritime Docks, Waterways and Railroads



Source: Department of Geography and Planning: Center for Geographic Information Sciences and Applied Geographics (GISAG), 2007

The amount of cargo shipped on the Great Lakes is significant. The data in Table 1-1 show that the amount of cargo shipped annually on the five Great Lakes (excluding the St. Lawrence River system downstream of Buffalo, NY) equals about half of the amount of cargo shipped annually on the Mississippi River system.

Table 1-1 Annual Shipments, Great Lakes and Mississippi River (million short tons)

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Mississippi River Total	327	317	316	308	313	299	314	313	295
Great Lakes Dry Bulk[a,b]	177	166	164	155	170	165	170	157	157

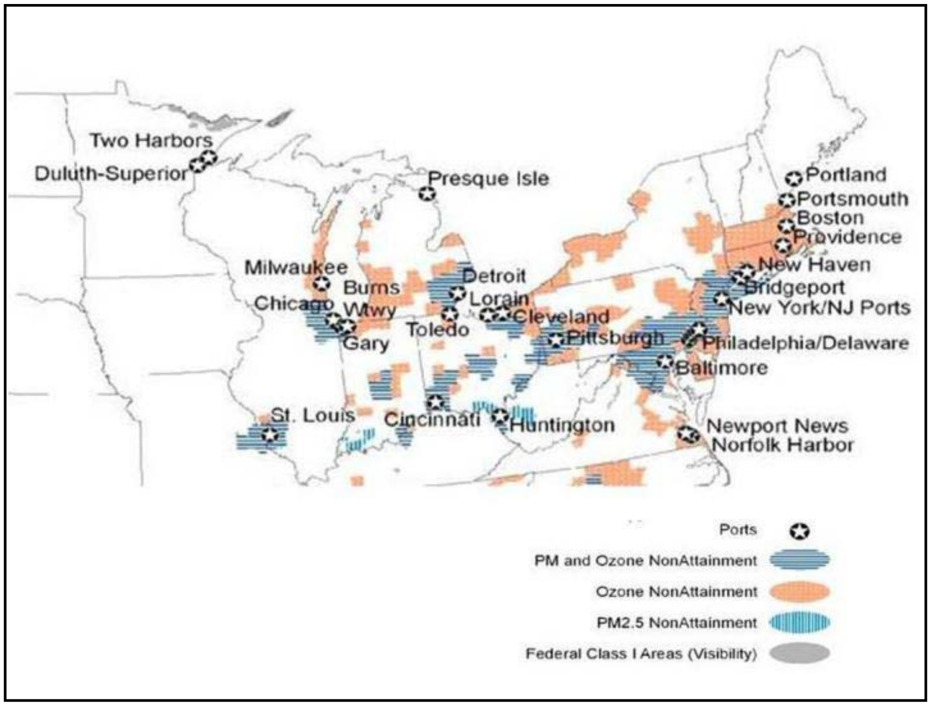
Note:
[a] A majority of the cargo shipped on the Great Lakes is dry bulk (see Chapter 7)
Sources: http://www.lcaships.com/TONPAGE.HTM, http://www.shipowners.ca/index.php?page=annual-report-and-statistics, http://www.seaway.ca/en/seaway/facts/traffic/index.html

Category 3 marine engines emit high levels of pollutants that contribute to unhealthy air in many areas of the country. Nationally, in 2009, emissions from all Category 3 marine engines accounted for about 10 percent of mobile source emissions of nitrogen oxides (NO_X), about 24 percent of mobile source diesel $PM_{2.5}$ emissions (with $PM_{2.5}$ referring to particles with a nominal mean aerodynamic diameter less than or equal to 2.5 µm), and about 80 percent of mobile source emissions of sulfur oxides (SO_X). Category 3 ships on the Great Lakes account for about three percent of Category 3 activity in the United States, as measured by fuel consumption.

More than 27 million people living in the U.S. portions of the Great Lakes basin are affected by ship emissions from the Great Lakes, including emissions from Category 3 vessels.[4,F] The impacted population is even larger considering people living on the Canadian side of the lakes and along the St. Lawrence Seaway. As shown in Figure 1-2, several areas, including Chicago, Detroit, Cleveland, and Buffalo, which each have commercial ports, do not achieve National Ambient Air Quality Standards for particulate matter, ozone, or both. Ships with Category 3 engines that use HFO contribute to nonattainment in these and other areas on the Great Lakes.

[F] Interested readers should refer to Chapters 4 and 5 for a more complete description of the inventory contribution, air quality impacts, and human health and welfare impacts of Category 3 ship emissions in the Great Lakes area.

Figure 1-2 Great Lakes Nonattainment Areas (based on data through May 2007)



Source: EPA

1.2 Marine Engines and Their Fuels

Marine diesel engines range in power from very small engines used to propel sailboats to huge engines used to power ocean-going ships. To address emissions from such a wide variety of engines, we created regulatory categories based on size, as measured by displacement in liters per cylinder (l/cyl). The commercial marine diesel engine categories are set out in Table 1-2.[G]

For the purposes of this report, Category 3 vessels are vessels with Category 3 main propulsion engines. Similarly, Category 2 vessels have Category 2 main propulsion engines and steamships have steam propulsion engines.

Table 1-2 also sets out the types of fuel used by the different categories of marine diesel engines. Fuel type is important because the sulfur content of the fuel used in an engine has a direct impact on the engine's particulate emissions, with higher sulfur fuel associated with higher PM emissions. Marine diesel fuels are either distillate or residual fuels. There are two main types of distillate marine fuels: marine gas oil (MGO, also known as distillate marine grade A or DMA), and marine diesel oil (MDO, also known as distillate marine grade B or DMB). These distillate fuels are similar to distillate diesel fuel used in land-based diesel engines. The current global average sulfur content of these marine distillate fuels is about 3,900 ppm, which is comparable to the historic limit for nonroad diesel fuel that was used in the United States in the early 1990s.[5] EPA's fuel program currently limits the sulfur content of marine distillate fuel sold in the United States to 500 ppm, with a 15 ppm limit phasing in by 2014.

[G] EPA also has standards for recreational marine diesel engines and for gasoline (spark-ignition) marine engines. These engines are not the subject of this report and therefore their standards are not included in this section.

Residual fuel, also called heavy fuel oil (HFO) is relatively dense ('heavy') and is created as a refining by-product from typical petroleum distillation (hence the name "residual"). Residual fuels typically are composed of heavy, residuum hydrocarbons and can contain various contaminants such as heavy metals, water and sulfur compounds. Ships using this fuel must be equipped with specialized fuel handling equipment such as centrifuges, heaters, and unique storage tanks. As a result, this fuel is used primarily in larger vessels with Category 3 or steam propulsion engines. The sulfur content of residual fuel can be as high as 45,000 ppm; however, the global average is about 23,500 ppm.[6] Category 2 and smaller marine diesel engines typically use distillate fuels, although they can be modified to use HFO when they are used for auxiliary power on Category 3 vessels or steamships. Auxiliary boilers can be modified to use either distillate fuel or HFO.

Table 1-2 Types of Commercial Marine Diesel Engines, Their Uses and Fuels Described in EPA Marine Diesel Engine Rules

ENGINE TYPE	ENGINE SIZE	USE	FUEL
Small marine diesel engine	Less than 37 kW	Propulsion or Auxiliary on any ship	Marine Gas Oil (MGO or DMA) Marine Diesel Oil (MDO or DMB)
Category 1	Above 37 kW; Per cylinder displacement less than 5 or 7 liters, depending on model year	Propulsion or Auxiliary on any ship	MGO or MDO
Category 2	Per cylinder displacement 5 or 7 liters, depending on model year, to 30 liters	Propulsion or Auxiliary on larger ships	MGO or MDO Can use Heavy Fuel Oil (HFO) in some cases
Category 3	Per cylinder displacement at or above 30 liters	Propulsion only	HFO, MGO, MDO
Steam Boilers	Up to 50 mW or higher	Propulsion or Auxiliary on larger ships	HFO, MGO, MDO

The Great Lakes cargo fleet is different from the cargo fleets that operate in U.S. coastal ports or on our inland river system. The vast majority of cargo ships that enter our coastal ports are foreign ocean-going vessels propelled by Category 3 marine engines, while nearly all the cargo ships on our inland river system are U.S. tug-barge combinations propelled by Category 2 or smaller marine engines. In contrast, the cargo statistics reported in Table 1-3 show that about two-thirds of the cargo moved on the Great Lakes is carried by U.S. ships, with most of the remainder carried by Canadian ships. The fleet statistics reported in Table 1-4 show that Great Lakes ships are propelled by both Category 2 and Category 3 engines.

Table 1-3 Great Lakes Cargo, by Flag, All Ships, 2004-9 (million short tons; all vessel sizes)

	2004	2005	2006	2007	2008	2009
Total	170.0	165.4	169.5	157.1	157.1	111.2
U.S.[a]	111.3	107.7	109.7	104.0	101.0	66.5
Canadian [b]	44.8	42.2	40.4	37.0	38.2	28.7
Foreign [c]	13.9	15.5	19.4	16.0	18.0	16.0

Notes:
[a] http://www.lcaships.com/TONPAGE.HTM
[b] http://www.shipowners.ca/index.php?page=annual-report-and-statistics
[c] http://www.seaway.ca/en/seaway/facts/traffic/index.html

The U.S. and Canadian fleets of Category 3 vessels are also different from each other. Table 1-4 shows that while the Canadian fleet has more Category 3 vessels, the U.S. fleet is larger with respect to vessel cargo capacity. The average cargo capacity of a U.S. Category 3 iron ore carrier is 59,400 gross tons, compared to 29,700 gross tons for a similar Canadian ship. The average cargo capacity of a U.S Category 3 coal ship is 47,900 net tons, compared to 27,700 net tons for a similar Canadian ship. Due to their size, many U.S. ships operate only on the Great Lakes since they are too large to enter the St. Lawrence Seaway due to canal restrictions (these are called "captive" vessels since they cannot exit the Great Lakes). More information on the U.S. and Canadian Great Lakes fleets can be found in Chapter 7.

Table 1-4 Distribution of U.S. and Canadian Vessels on the Great Lakes, by Engine Type and Flag (gross tons)

	U.S. Fleet	Canadian Fleet
C3 Vessels		
Number of vessels	12	68
Total fleet tonnage	295,000	1,054,000
Average vessel tonnage	24,600	15,500
C2 Vessels		
Number of vessels	32	20
Total fleet tonnage	402,000	197,000
Average vessel tonnage	12,600	9,850
Steamships[a]		
Number of vessels	13	8
Total fleet tonnage	150,000	116,000
Average vessel tonnage	11,500	14,500

Note:
[a] The number of steamships includes both twelve diesel-powered steamships and one coal-fired steamship currently operating as a car-ferry.
Source: Greenwoods Guide to Great Lakes Shipping 2010. Harbor House Publishing (2010)

1.3 Emission Control Program for Category 2 and Smaller Marine Diesel Engines, and their Fuels

While EPA's Category 2 marine engine program is not the subject of this analysis, a description of the emission control program for these engines and fuels is included for completeness.

The vast majority of vessels with Category 2 or smaller marine propulsion engines (engines up to 30 liters per cylinder) that operate in U.S. ports and waters, including the inland waterway system, are flagged in the United States. These vessels include river tugs and pushboats, port tug and assist vessels, ferries, fishing vessels, offshore supply ships, and some small cargo vessels. They typically operate on distillate fuel and only rarely use residual fuel.

EPA's program for new Category 2 and smaller marine engines installed on U.S. vessels consists of several tiers of emission limits adopted under the Clean Air Act (see 40 CFR 94 and 1042). The most recent standards were adopted in 2008 (73 FR 25098, May 6, 2008). These standards include emission limits for PM and oxides of nitrogen (NO_X) that are projected to require the use of high efficiency advanced aftertreatment technologies similar to that which will be used on new trucks and locomotives. When fully phased in, these standards are expected to reduce PM emissions by about 90 percent and NO_X emissions by about 80 percent, compared to the current Tier 2 marine standards.[7] In 2030 this rule, which also includes standards for locomotives, is projected to annually prevent up to 1,100 PM-related premature deaths, 120,000 lost work days, and 1.1 million minor restricted activity days. The estimated monetized health benefits of the rule are estimated to be about $11 billion, compared to estimated costs of about $74 million.

EPA's Clean Air Act requirements for marine distillate fuel were adopted in our Clean Air Nonroad Diesel Rule (69 FR 38958, June 29, 2004; see 40 CFR part 84). These standards limit the sulfur content of marine distillate diesel fuel produced and sold in the United States to 500 ppm beginning in 2007, and an even cleaner 15 ppm standard will be completely phased-in by mid-2014.[H,8] While we did not estimate separate benefits and costs for the marine fuel requirements, the overall benefits of the rule are estimated to be $80 billion compared to estimated costs of about $1.7 billion.

Finally, it is worth noting that the fleet of Category 2 cargo vessels that operates on the Great Lakes is different from the fleet of Category 2 cargo vessels that operates in U.S. coastal ports and other inland waterways, in two important ways. First, Great Lakes Category 2 ships can be very large, with cargo capacity of 63,000 tons or more and length up to 1,000 feet. While ocean vessels of this size typically have Category 3 engines to provide power needed for all conditions that may arise on the open seas, Lakers have lower power requirements and can be equipped with smaller Category 2 engines that operate on cleaner burning distillate fuel. As a result, about 20 percent of the combined U.S. and Canadian Great Lakes diesel fleet are Category 2 ships, representing about 31 percent of total ship tonnage. Second, while most Category 2 cargo ships operating in U.S. coastal ports and inland waterways are flagged in the United States, a large portion of the Category 2 cargo ships that operate on the Great Lakes are foreign. Twenty of the 52 Great Lakes Category 2 cargo ships, or about 38 percent, fly a Canadian flag. This is important because it means that this transportation market is more international, although due to the Jones Act the ability of foreign vessels to carry cargo between two U.S. ports is limited.[I,9]

1.4 EPA's Coordinated Strategy for Category 3 Marine Diesel Engines and Their Fuels

Category 3 marine engines are used on all types of ocean-going vessels (container ships, tankers, bulk carriers) as well as on many of the bulk carriers operated on the Great Lakes.

[H] Fuels covered in this program include any No. 1 and 2 distillate fuels used, intended for use, or made available for use in nonroad, locomotive, or marine diesel engines. Fuels under this category include those meeting the American Society for Testing and Materials (ASTM) D 975 or D 396 specifications for grades No. 1-D and No. 2-D. Fuels meeting ASTM DMX and DMA specifications also would be covered. Distillate fuels with a T-90 distillation point greater than 700ºF, when used in Category 2 or 3 marine diesel engines, are not covered by these standards; this includes Numbers 4, 5, and 6 fuels (e.g., IFO Heavy Fuel Oil Grades 30 and higher), as well as fuels meeting ASTM specifications DMB, DMC, and RMA-10 and heavier.

[I] Jones Act is "[t]he common reference for Section 27 of the Merchant Marine Act of 1920 (41 Stat. 988), which requires that all water transportation of goods between U.S. ports be on U.S.-built, -owned, -crewed, and -operated ships. The purpose of the law is to support the U.S. merchant marine industry[.]"

EPA's three-part Coordinated Strategy to address emissions from Category 3 engines and their fuels was proposed in a Notice of Proposed Rulemaking published on August 28, 2009 (74 FR 44442), and adopted in a Final Rule published on April 30, 2010 (75 FR 22896). The Coordinated Strategy applies to U.S. vessels through the Clean Air Act, and to U.S., Canadian, and vessels from other countries while they are operating in the U.S. portions of the North American ECA, including the U.S. portions of the Great Lakes, through MARPOL Annex VI and the Act to Prevent Pollution from Ships.[J] The combination of these national and international measures results in a comprehensive program that covers both U.S. and foreign vessels, and will achieve significant emission reductions from this sector.[K] When fully phased in, the Coordinated Strategy's engine and fuel requirements are expected to reduce NO_X emissions by about 80 percent, PM emission by about 85 percent, and SO_X emissions by about 97 percent compared to current standards.

The projected benefits of the Coordinated Strategy are substantial. As detailed in the Regulatory Impact Analysis for our Category 3 marine rule, we project that by 2030 this Coordinated Strategy will reduce annual emissions of NO_X, SO_X, and particulate matter by 1.2 million, 1.3 million, and 143,000 tons, respectively, and the magnitude of these reductions would continue to grow well beyond 2030.[10] These nationwide reductions are estimated to annually prevent between 12,000 and 30,000 PM-related premature deaths, between 210 and 920 ozone-related premature deaths, 1,400,000 work days lost, and 9,600,000 minor restricted-activity days. The estimated annual monetized health benefits of this Coordinated Strategy in 2030 would be between $110 and $270 billion.[L] The estimated costs of this Coordinated Strategy are significantly less, with annual costs of about $3.1 billion in 2030. The transportation market impacts of the higher fuel cost would be small on a per-unit shipped basis, with an increase of less than 3 percent per container (about $18), about 1.5 percent per passenger ($6.60/day) for cruise ships, and about $0.56 per tonne ($0.51/ton) for bulk goods.

Our benefit and cost analyses for the Coordinated Strategy were performed on a national basis. In response to comments on our proposal (see Section 1.5.1), we also performed additional analyses of the inventory and air quality impacts of the Coordinated Strategy for the Great Lakes region and estimates of the cost of applying the ECA requirement to Lakers.[11] For the six states bordering the Great Lakes, we estimated the monetized $PM_{2.5}$ benefits in 2030 to be between $1.5 and $3.7 billion, compared to total projected costs of about $0.05 billion.

1.4.1 Clean Air Act Standards for Category 3 Marine Engines

The first element of EPA's Coordinated Strategy set out in our Category 3 marine rule is our Clean Air Act emission control program for Category 3 marine engines and their fuels.

The Clean Air Act engine standards for Category 3 engines apply to new engines installed on U.S. vessels (40 CFR parts 94 and 1042). Our 2010 Category 3 rule set near-term

[J] Canada is currently developing their program for ships operating on the Canadian portions of the Great Lakes and the St. Lawrence Seaway.
[K] Interested readers should refer to our Category 3 rulemaking for more information about the compliance and enforcement of these programs.
[L] In this report, estimates of monetized benefits and engineering compliance costs are presented in 2006$, consistent with the Category 3 marine rule analyses.

Tier 2 NO_X standards that go into effect in January 2011 and will achieve a 20 percent reduction from Tier 1 standards that are currently in place. The long-term Tier 3 standards go into effect in January 2016 and represent an 80 percent reduction from Tier I levels. The Tier 3 NO_X standards are expected to require the use of high efficiency advanced technology emission controls such as selective catalytic reduction (SCR). These NO_X standards, set out in Table 1-5, are equivalent to the international engine standards described in Section 1.4.2.

Table 1-5 Category 3 Engine Emission NO_X Limits

Tier	Area of Applicability	Model Year	Maximum In-Use Engine Speed	
			Less than 130 RPM	130-2,000 RPM[a]
Tier 1	All U.S. navigable waters and EEZ	2004-2010	17.0	$45.0 \cdot n^{(-0.20)}$
Tier 2	All U.S. navigable waters and EEZ	2011-2015	14.4	$44.0 \cdot n^{(-0.23)}$
Tier 2	All U.S. navigable waters and EEZ, excluding ECA and ECA associated areas	2016 and later	14.4	$44.0 \cdot n^{(-0.23)}$
Tier 3	ECA and ECA associated areas	2016 and later	3.4	$9.0 \cdot n^{(-0.20)}$

Note:
[a] Applicable standards are calculated from n (maximum in-use engine speed, in RPM. There are no Category 3 engines with engine speed >2,000 rpm.

The Clean Air Act marine fuel standards apply to fuels produced and sold in the United States. Our 2010 Category 3 marine rule included regulations to allow the production and sale of 1,000 ppm sulfur fuel for use in Category 3 marine vessels while they are operating in the North American ECA (see 40 CFR 80). Without this change, fuel with sulfur content up to 1,000 ppm would be required to be used in the North American ECA by U.S. Category 3 vessels and all foreign vessels but fuel production in the United States would be limited to below 500 ppm. While our national fuel programs allows the production and sale of fuel with sulfur content above 1,000 ppm (i.e., residual fuel), this fuel can be sold for use only on vessels equipped with alternative devices, procedures, or compliance methods that achieve equivalent emission control as operating on 1,000 ppm sulfur fuel (for example, the vessel is equipped with a certified SO_X scrubber), or for use outside the North American ECA.

1.4.2 2008 Amendment to MARPOL Annex VI

The second element of EPA's Coordinated Strategy set out in our Category 3 marine rule is the 2008 amendments to Annex VI to the International Convention for the Prevention of Pollution from Ships (called MARPOL Annex VI).

MARPOL Annex VI sets out international emission requirements for ships, including NO_X standards and fuel sulfur limits. The MARPOL Annex VI program is an important part of our Coordinated Strategy because it extends engine and fuel controls to all ships and is enforceable by any country that is a Party to the Annex. The United States became a party to MARPOL Annex VI by depositing its instrument of ratification with International Maritime Organization (IMO) on October 8, 2008. This was preceded by the President signing into law the Maritime Pollution Prevention Act of 2008 (Public Law 110-280) on July 21, 2008, which contains amendments to the Act to Prevent Pollution from Ships (APPS, 33 USC 1901 et seq.). The amendments also authorize the U.S. Coast Guard and EPA to enforce the provisions of

Annex VI against domestic and foreign vessels and to develop implementing regulations, as necessary. In addition, APPS gives EPA sole authority to certify engines installed on U.S. vessels to the Annex VI requirements (40 CFR 1043).

The 2008 amendments to MARPOL Annex VI are based on the position advanced by the United States Government as part of the international negotiations.[12] There are two sets of engine and fuel requirements. The first set is the global engine and fuel requirements. The new global engine NO_X limits consists of Tier II standards that apply to engines installed vessels constructed beginning in January 2011. These standards will achieve a 20 percent reduction from the current Tier I levels, and are the same as the EPA Tier 2 and Tier 3 standards set out in Table 1-5. The new global fuel sulfur limits consist of a near-term limit of 35,000 ppm that applies beginning in 2012 and a long-term limit of 5,000 ppm that applies beginning in 2020. The long-term fuel sulfur limit is subject to a fuel availability review to be completed in 2018.

The second set of international standards is the requirements that apply in specially designated Emission Control Areas (ECAs), described in Section 1.4.3.

1.4.3 Designation of Emission Control Areas

The third element of EPA's Coordinated Strategy for Category 3 engines and their fuels is designation of Emission Control Areas (ECAs) for the United States.

The ECA approach contained in MARPOL Annex VI was developed as a way to ensure greater air pollution reductions in specially designated areas while avoiding a requirement to use high cost emission control equipment and fuels in areas such as the open ocean that are not in need of that level of environmental protection. The criteria for ECA designation are set out in Appendix III to MARPOL Annex VI and require demonstration of a need to prevent, reduce, and control emissions of SO_X, PM, and/or NO_X from ships operating in the specified area.

All ships operating in designated ECAs are required to comply with the more stringent international engine standards and fuel sulfur limits. The ECA NO_X standards apply to engines installed on vessels constructed beginning in 2016: while these vessels operate in a designated ECA their engines must achieve an 80 percent reduction from the current Tier 1 levels. The ECA fuel sulfur limit, originally 15,000 ppm, decreases to 10,000 ppm in 2010 and to 1,000 ppm in 2015.

The ECA standards are applicable to all ships that operate in U.S. designated ECAs through APPS (see 40 CFR 1043). Currently, the North American ECA has been designated by amendment to MARPOL Annex VI; the U.S. Caribbean ECA is expected to be adopted in July 2011.

1.4.3.1 North American ECA

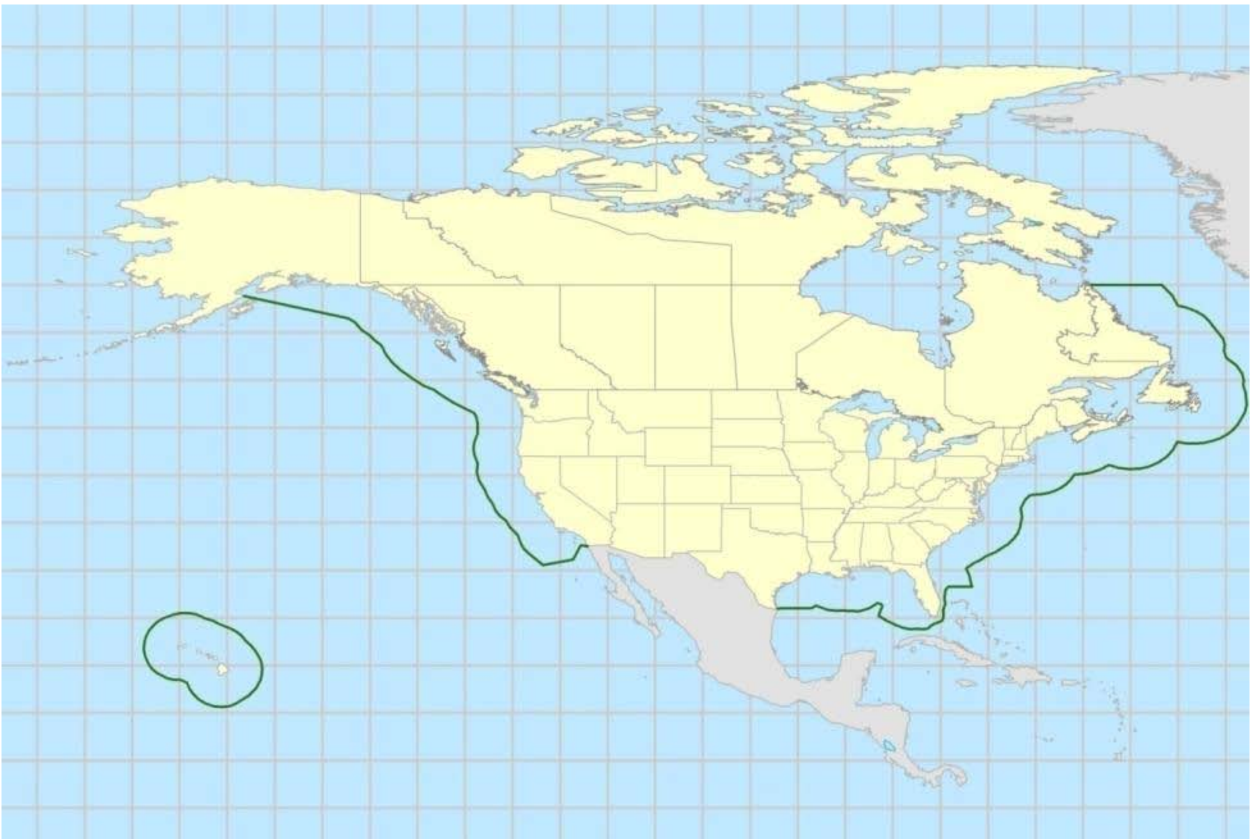
The North American ECA, which was proposed jointly by the governments of the United States, Canada, and France,[M] was designated through an amendment to MARPOL Annex VI adopted by the Parties to Annex VI at a meeting held at IMO on March 26, 2010. This

[M] The archipelago of Saint Pierre and Miquelon is a French territorial collectivity.

amendment will enter into force on August 1, 2011, and the fuel sulfur requirements will begin to apply on August 1, 2012.

As illustrated in Figure 1-3, the North America ECA extends about 200 nautical miles from the coastal baseline of the United States and Canada except where this distance would enter the Exclusive Economic Zones (EEZ) of a neighboring country.

Figure 1-3 North American ECA



Source: EPA

- On the Pacific Coast, the ECA is bounded in the north such that it includes the approaches into Anchorage, Alaska, but not the Aleutian Islands or points north. It continues contiguously to the south including the Pacific coasts of Canada and the U.S., with its southernmost boundary at the point where California meets the border with Mexico.

- On the Atlantic/Gulf Coast, the ECA is bounded in the west by the border of Texas with Mexico and continues contiguously to the east around the peninsula of Florida and north up the Atlantic coasts of the U.S. and Canada to the 60th North parallel.

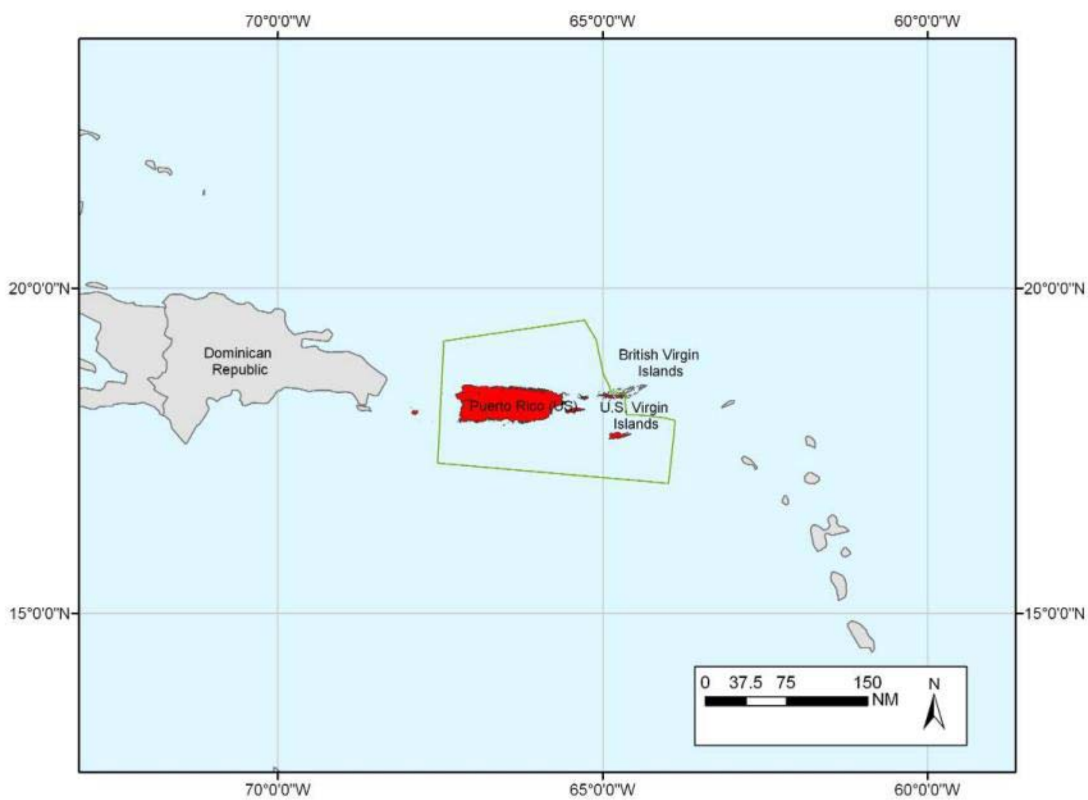
- The Southeastern Hawaiian Islands are also included: Hawaii, Maui, Oahu, Molokai, Niihau, Kauai, Lanai, and Kahoolawe.

The regulatory text included in our 2010 Category 3 Marine rule made clear that a vessel operating in U.S. internal waters shoreward of a designated ECA that can be accessed by ocean-going vessels must meet the Annex VI ECA requirements.[13] In addition to U.S. coastal ports and U.S. rivers that are navigable from the ECA (such as the Mississippi River, the Puget Sound, the Chesapeake Bay), this includes those portions of the Great Lakes and St. Lawrence Seaway in which the North American ECA is enforceable by the United States. As a result, the North American ECA requirements are applicable to all vessels operating on the U.S. side of the Great Lakes and St. Lawrence Seaway, including Canadian and other foreign vessels. U.S. regulations at 40 CFR 1043 contain provisions that implement the ECA engine standards and fuel sulfur requirements and set out certain compliance provisions. Canada is currently developing their national program with respect to implementation of the ECA requirements.

1.4.3.2 U.S. Caribbean Sea ECA

In July 2011, the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) adopted an amendment to MARPOL Annex VI designating the U.S. Caribbean Sea ECA covering the Commonwealth of Puerto Rico and the U.S. Virgin Islands. This amendment will enter into force on January 1, 2013, and the fuel sulfur requirements will begin to apply on January 1, 2014. The area covered by this ECA is illustrated in Figure 1-4.

Figure 1-4 U.S. Caribbean ECA



Source: EPA

- The western edge of the proposed area would generally run north-south to the east of the Mona Passage, 12 or more nautical miles (nm) from the west coast of the main island of Puerto Rico.
- The eastern edge of the proposed area would generally run north-south, but also extend eastward through the area between the U.S. Virgin Islands and the British Virgin Islands as well as eastward toward the area between Saint Croix and Anguilla and Saint Kitts.
- The northern edge of the proposed area would extend about 50 nm from the territorial sea baselines of Puerto Rico and the U.S. Virgin Islands.
- The southern edge of the proposed area would extend about 40 nm from the territorial sea baselines of Puerto Rico and the U.S. Virgin Islands.

1.4.3.3 Additional U.S. ECAs

EPA is continuing its review of the areas of Alaska, Hawaii, and U.S. territories not already covered by an existing or proposed ECA, with a view to determining if ECA designation is appropriate.

1.4.4 Summary

Our Coordinated Strategy for Category 3 engines and their fuels is a comprehensive program that covers marine diesel engines and their fuels on all vessels, U.S. and foreign, which operate in areas that affect U.S. air quality and will significantly reduce emissions from foreign and domestic vessels, with significant benefits for human health and welfare throughout the country.

Finally, it should be noted that, like Category 2 marine engines, the land-based alternatives to Category 3 vessel transportation on the Great Lakes are also subject to stringent emission controls. Technology-forcing standards applicable to heavy-duty trucks became effective in 2007 (particulate matter) and 2010 (NO_X), and the diesel fuel used in these engines has been subject to a 15 ppm sulfur limit since 2006. Technology-forcing standards will begin to apply to locomotives in 2015; their fuel will be subject to a 15 ppm sulfur limit beginning in 2012.[N]

[N] One peer reviewer noted "[i]f ultra-low sulfur fuel requirements are being placed on trucks and locomotives, but not on [Category 3]marine engines, this would represent an indirect subsidy to marine. While the road to implementation may be markedly different, the requirements should represent a level playing field to the degree possible." (Kruse)

The Hon. James L. Oberstar (formerly named the Charles M. Beeghly) passes under the Blue Water Bridge in Port Huron, MI. Source: Photo taken by Barant Downs, August 16. 2007.

1.5 The Coordinated Strategy and the Great Lakes

We received comments from nearly 50 persons and organizations regarding the provision in our Category 3 marine proposal clarifying that the North American ECA, once approved at IMO, would also apply to the U.S. portions of the Great Lakes. These commenters represented a wide spectrum of stakeholders, including companies that own vessels, and their employees; companies that use the products transported by ship on the Great Lakes, including steel and utility companies; regional associations; port authorities; fuel providers; and environmental and governmental groups.[14] Their comments and our responses to them are summarized below.

1.5.1 Concerns of Great Lakes Stakeholders

The Great Lakes stakeholder comments on the C3 marine rule are primarily about the application of the ECA fuel sulfur limits to the Great Lakes.

Great Lakes commenters told EPA that the Great Lakes transportation market is fundamentally different from the ocean marine transportation market. The ocean market ships goods between the United States and Europe, Asia, South America, and Africa, and there are no reasonable alternatives to shipping by vessel for the vast majority of these products. According to these commenters, the nature of transportation in the Great Lakes region, however, is more like the Mississippi River system than the international marine system. In the Great Lakes, ship operators move goods from one area of the country to another and are in competition with rail and truck transportation modes. These commenters indicated that, for the reasons explained below, an increase in operating costs associated with the requirement to use ECA-compliant fuel in the Great Lakes would put marine at a competitive disadvantage in the Great Lakes and cause a transportation mode shift away from ships and toward trucks or rail, which could increase emissions overall by moving cargo to less efficient ground transportation.

According to these commenters, application of the ECA fuel sulfur requirements on the Great Lakes would lead to two changes in the Great Lakes shipping conditions, both of which would result in upward pressure on marine freight rates. First, the application of the ECA fuel requirements on the Great Lakes would require all vessels that currently use HFO (steamships and Category 3 vessels) to use higher-price marine distillate oil (MGO or MDO). This would increase their operating costs beginning January 1, 2015, or even earlier if fuel meeting the ECA interim fuel sulfur limit of 10,000 ppm is not available on the Great Lakes when the interim fuel sulfur limit goes into effect in August 2012. While the program would also allow operators to continue to use lower-price HFO if they install and use an exhaust gas cleaning system (scrubber) that achieves an equivalent sulfur emission reduction, industry stakeholders told EPA that scrubber systems that operate in fresh water conditions are currently unavailable and the ability of these systems to meet washwater discharge requirements is still unclear.

Second, commenters argued that steamships cannot safely use MDO and therefore the Great Lakes steamship fleet would have to be retired. They indicated that steamships operating on the Great Lakes were designed and constructed in the 1940s and 1950s and were meant to operate solely on HFO. Using MDO in these old boilers systems could raise safety concerns due to a higher risk of explosion because of the different fuel properties of distillate fuel. Commenters said that it would not be possible to replace U.S. steamships due to the high cost of building new Jones Act vessels in U.S. shipyards and the long lead time for building new ships. As a result, the number of cargo ships operating on the Great Lakes would decrease.

The combination of fewer ships in the fleet and higher operating costs for the ships that remain would put upward pressure on ship freight rates. These increased marine rates would then make rail and truck transportation more financially attractive, leading to a transportation mode shift. Since trucks and rail have higher emissions per ton-mile, the net result could be the opposite of the environmental improvements intended by the requirements.

Commenters were also concerned that the increase in freight rates would affect the market for crushed stone, leading users to change their source from stone transported from the upper Great Lakes to local quarries, also resulting in a loss of cargo for Great Lakes carriers.

Finally, some commenters said there could be a production shift for steel manufacturing and electricity generation as a result of increased transportation costs for iron ore and coal. Such a production shift would also adversely affect the Great Lakes shipping sector.[O]

[O] One peer reviewer commented that "from the economic perspective, if the higher cost of fuel causes customers to source their products more nearby, then the products must be close enough substitutes that they should not travel such distances in the first place. In other words, if close substitutes do not shift closer then society must be subsidizing excessive freight transport distance, which would be bad public policy because the economics of the move would not pay the full cost. The researchers find that even those shifts do not occur, so the case is moot. Especially whether the product is iron ore or Michigan stone that is high in calcium carbonate, the product is sufficiently unique that it does not provoke a shift." (Belzer)

1.5.2 Great Lakes Provisions in the Final Category 3 Marine Rule

Our final Category 3 marine rule contains three regulatory provisions that address the issues raised by Great Lakes stakeholders described above: a steamship exemption, an economic hardship provision, and a fuel availability waiver. We also agreed to perform an analysis to evaluate the economic impacts of the Category 3 rule on Great Lakes shipping.

1.5.2.1 Great Lakes Regulatory Provisions

The Great Lakes ECA regulatory provisions are contained in 40 CFR 1043.95. These provisions are available to any vessel, including a foreign vessel that operates exclusively on the Great Lakes, defined as all the streams, rivers, lakes, and other bodies of water that are within the drainage basin of the St. Lawrence River, west of Anticosti Island. These provisions are available to foreign as well as U.S. vessels that operate on the U.S. side of the Great Lakes.

First, to address the technical and safety concerns raised by the use of distillate fuel in steam engines, and consistent with Congressional direction, Great Lakes steamships are excluded from the ECA fuel standards.[15] This provision avoids immediate retirement of steamships, which may not be able to operate safely on distillate fuel. However, we expect these vessels will be retired eventually because of their higher fuel usage when compared to diesel engines (they can consume almost twice as much fuel as modern diesel engines). For the purpose of this exclusion, a Great Lakes steamship means a vessel operating exclusively on the Great Lakes and Saint Lawrence Seaway whose primary propulsion is a steam turbine or steam reciprocating engine. Ships with diesel propulsion engines with auxiliary boilers are not eligible. In addition, the steamship must have been in service on the Great Lakes prior to October 30, 2009.

Second, the regulations contain a provision that provides for relief in the event of serious economic hardship. This economic hardship provision allows Great Lakes ship owners to petition EPA for a temporary exemption from the 2015 fuel sulfur standards. The owner must show that despite taking all reasonable business, technical, and economic steps to comply with the fuel sulfur requirements, the burden of compliance costs would create a serious economic hardship for the company. The Agency will evaluate each application on a case-by-case basis.

Third, the regulations contain a fuel availability waiver, to address the concerns about availability of 10,000 ppm sulfur fuel on the Great Lakes. This provision is available to Category 3 Great Lakes vessels that are not covered by the steamship exclusion. The 10,000 ppm ECA fuel sulfur limit applies on the Great Lakes when the North American ECA goes into effect, in August 2012, and continues until the more stringent 1,000 ppm ECA fuel sulfur limit goes into effect January 1, 2015. The Great Lakes fuel waiver is available if marine residual fuel meeting the 10,000 ppm sulfur limit is not available. Under this provision, it will not be a violation of our standards for a Great Lakes vessel operator to purchase and use marine residual fuel with sulfur content above 10,000 ppm provided the fuel purchased is the lowest sulfur marine residual fuel available at the port. There are some reporting requirements for this waiver.

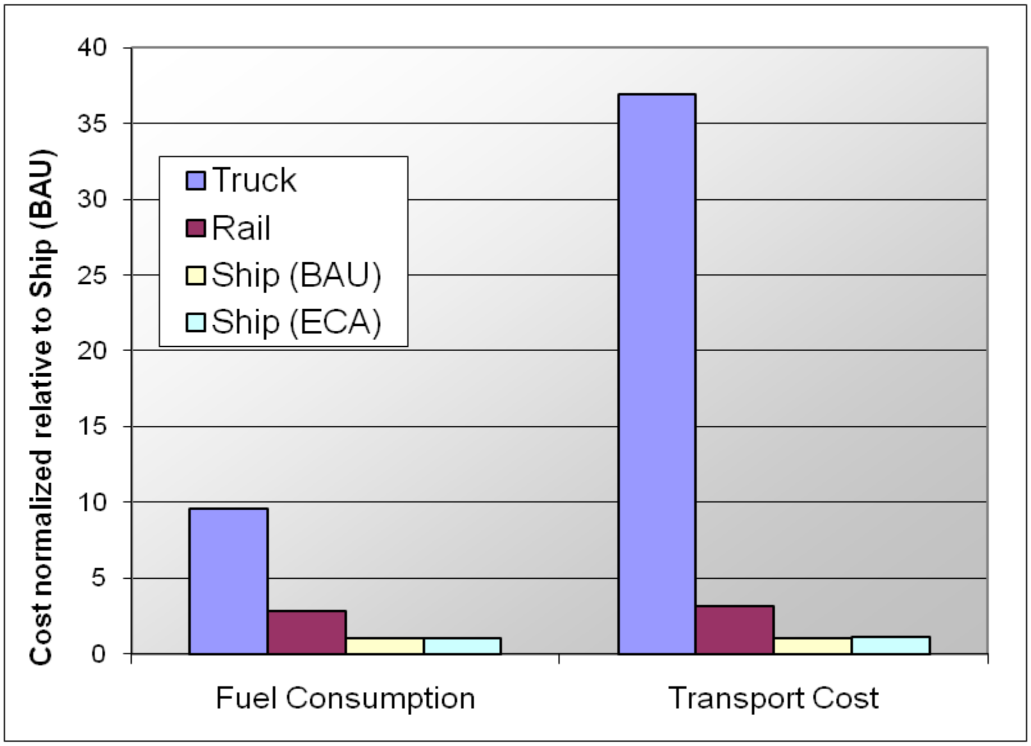
1.5.2.2 Economic Impact Analysis

As noted above, we performed an extensive economic analysis to examine the inventory contribution, air quality impacts, benefits, and costs for all vessels covered by the Category 3 marine rule, including Great Lakes Vessels.[16] We also performed additional analyses of the inventory and air quality impacts of the rule for the Great Lakes region and estimates of the cost of applying the ECA requirement to Lakers.[17] That analysis breaks out in greater detail the inventory and air quality impacts and expected health benefits of applying the ECA requirements to the Great Lakes region and was based on the national estimates; no new modeling was performed. According to this analysis, the estimated monetized $PM_{2.5}$ benefits in 2030 for the six states bordering the Great Lakes are estimated to be between $1.5 and $3.7 billion. In comparison, the total projected costs for all Great Lakes vessels in 2030 are significantly less and estimated at $0.05 billion.

We also performed an initial analysis of the potential for transportation mode shift and production shift as a result of increased operating costs for Great Lakes vessels.[18] We indicated we would follow this initial analysis with a more detailed study to evaluate the economic impacts of the Category 3 rule on Great Lakes shipping.

Our initial transportation mode shift analysis was based on a comparison of fuel consumption rates and transport costs for marine and the land-based alternatives, rail and truck transportation. The analysis uses the marine price of diesel fuel for all modes and therefore is a conservative estimate with respect to the rail and truck alternatives, which are or will be required to use fuel with a maximum sulfur content of 15 ppm that is expected to be more expensive than 1,000 ppm marine fuel. Figure 1-5 presents the results of this analysis, with fuel consumption and transport costs normalized such that the shipping business as usual (BAU) case is equal to 1.0. This analysis indicates that the ECA fuel requirements are not expected to change the relative cost advantage of marine over rail or truck transportation with respect to fuel consumption or transportation costs. Therefore, compliance with the ECA fuel sulfur requirements by ships operating on the Great Lakes would not be expected to result in significant mode shifts to other forms of transportation.

Figure 1-5 Relative Cost per Ton-Mile by Transportation Mode



Source: Samulski, Michael. Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder – Information in Support of Applying Emission Control Area (ECA) Requirements to the Great Lakes Region. EPA-HQ-OAR-2007-0586. December 15, 2009.

The initial source shift analysis was performed for a steel production scenario. The analysis estimated the additional costs associated with transporting the three primary raw materials for making steel (iron ore, limestone, and coke) from various locations on the Great Lakes to Indiana Harbor on ships using ECA compliant fuel and compared this with the additional costs of transporting imported steel to Detroit, roughly 1,700 miles through the coastal ECA area, the St. Lawrence Seaway, Lake Ontario, and Lake Erie. [P] The analysis assumed that finished steel is transported from Indiana Harbor to Detroit by truck, which would not be affected by the ECA fuel requirement. This analysis, summarized in Table 1-6, indicates that the increase in cost for domestic steel is less that the increase in cost for imported steel. The cost increase is also less than the historical month-to-month fluctuation in steel prices (steel prices doubled between 2008 and 2009).

[P] Note that this supplemental steel analysis only considers ship traffic in one direction and assumes that the vessels will perform useful work on the return voyages (i.e., there is a backhaul). One peer reviewer (Hull) indicated that the backhaul for steel coils is typically grain. If we were to assume no backhaul for either the domestic or the imported steel case, this would increase the estimated transportation costs but the increase would apply to both cases proportionally and therefore no production shift would be expected. If we were to assume a backhaul for the imported steel but no backhaul for the domestic steel, this would increase the estimated transportation cost for the domestic case but a production shift would still not be expected. Since the empty backhaul would consume less fuel (due to the lighter load), the transportation cost increase for the round-trip domestic case would be less than double the one-way case and therefore the price impacts for the domestic case still would be less than the imported steel case with a backhaul.

Table 1-6 Impact of Great Lakes ECA on Steel Cost

	Domestic Steel	Imported Steel
Increased fuel cost [$/ton-mile]	$0.0009	$0.0009
Shipping distance in ECA [nautical miles]	870	1,700
Increased fuel cost [$/ton of steel]	$0.90	$1.75
Price of cold rolled steel (June 2009) [$/ton][a]	$525	$525
% cost increase for steel	**0.2%**	**0.3%**

[a] Source: http://www.steelonthenet.com/prices.html

The remainder of this report contains a more detailed analysis of the economic impacts of the Category 3 marine rule on the Great Lakes. In Chapter 2 we examine twelve O/D pairs[Q] that are at risk for transportation mode shift. For all but one of these scenarios, freight rates for marine transportation are expected to remain well below the next cheapest shipping mode, rail, after the application of the ECA fuel sulfur requirements, and therefore no transportation mode shift is indicated. For the one exception, the initial results suggested the all rail alternative has a lower route-based freight rate than either the Base Case or ECA Case freight rates. Chapter 2 explains why EPA believes this scenario was mis-specified. In Chapter 3 we look at the potential for source shift for crushed stone and production shift for electricity and steel. Those analyses also show that source shift and production shift are not expected. Chapters 4 through 7 contain an expanded discussion of our estimates of the inventory, air quality impacts, health and environmental benefits, and costs of this program. The analyses contained in Chapters 2 and 3 of this report were peer reviewed pursuant to EPA's *Science Policy Council Peer Review Handbook*, 3rd edition (*Peer Review Handbook*).[R] The peer review is described in Chapter 8.

1.6 Other Studies of the Environmental and Economic Benefits of Marine Transportation in the United States

In recent years several studies have been performed to examine the environmental and economic impacts of marine transportation compared to other transportation modes. These include studies examining the health and human welfare impacts of marine transportation compared to other modes, the economic benefits of marine transportation, and the impacts of changing fuel prices. This section briefly describes the methodology and main findings of several of these studies, many of which were referred to in comments submitted in response to our Category 3 marine proposal.

[Q] "Origin/destination (O/D) pairs" refers to specific starting and ending points of shipping routes on the Great Lakes. Section 2.4 describes the selection of the O/D pairs and shipping routes.
[R] These guidelines can be found at http://www.epa.gov/peerreview/. Further, the Office of Management and Budget's (OMB's) Information Quality Bulletin for Peer Review and Preamble (found in the EPA's *Peer Review Handbook*, Appendix B) contains provisions for conducting peer reviews across federal agencies and may serve as an overview of EPA's peer review process and principles.

1.6.1 Studies Related to the Health and Human Welfare Benefits of Marine Transportation

1.6.1.1 Minnesota Department of Transportation Study, 1991.

The study estimates the environmental impacts of an assumed mode shift from marine to rail or truck transportation for four O/D pairs in Minnesota.[19] The purpose of the study was to evaluate the human health and welfare impacts that may result from policy decisions that reject developing, maintaining, or improving waterways. The methodology involves estimating annual increases in air emissions and accidents based on fuel use, tons of cargo transported, and emission and accident rates.

The authors estimate the increase in fuel use that can be expected to occur if cargo currently transported by ship were shifted to other modes. They report an increase in annual fuel use by 826% (shift to trucks) or 331% (shift to rail), an increase in annual exhaust emissions by 709% (shift to trucks) or 470% (shift to rail), and an increase in probable accidents annually by 5,967 accidents (shift to trucks) or 290% (shift to rail).

The results of this study are dated in that it uses fuel efficiencies estimates from a report published in 1980; EPA emission rates from 1973 and 1989 reports; and accident rates from a report published in 1986 (trucks), from an analysis of accidents in 1980 (rail), and from 1986-1990 (marine). In addition, "emissions" are not distinguished by pollutant. As a result, the impacts cited above are not reflective of the current truck, rail, and marine fleet characteristics, and the results should be taken as indicators and not as absolute values relevant to the year under consideration in this study, 2015. Nevertheless, this study is relevant in that it shows the advantages of marine over rail or truck transportation for the routes considered.

These results also reflect an ongoing disconnect between concerns regarding mode shift and environmental impacts such as increased CO_2 emissions. As we show later in Chapter 2, fuel costs are 40-50 percent of marine shipping costs. This percentage is lower for trucking. However, even if the only cost for trucking were fuel costs, trucking rates would be at minimum four times higher than marine rates. This is because truck fuel consumption is estimated at about 9 times that of marine, per ton of goods moved.

1.6.1.2 Ontario Marine Transportation Study, November 2006.

This is an analysis of the opportunities for the marine transportation mode in Ontario, Canada.[20] The report focuses on container and passenger opportunities, and describes about a dozen routes on which marine could be an alternative to rail or truck transportation. The report also quantifies the net benefits of a switch to the marine mode for two routes: Hamilton to Oswego truck ferry (Can$ 1.7 M annually) and Toronto to Niagara passenger ferry (Can$ 1M annually), with regard to reductions in air pollution, greenhouse gases, tire disposal, congestion costs, accidents, and noise and amenity. The report also describes the barriers to realizing these opportunities, including regulatory and nonregulatory constraints.

Like the Minnesota DOT study and the DOT/MARAD study summarized below, this study suggests that human health and welfare impacts should be examined in those scenarios where an intermodal shift is indicated to be likely. However, while this study examines the potential environmental benefits of an intentional shift from truck or rail mode to marine, it does not contain an analysis of freight rates, operational costs, or the impacts of changes in either the supply or the demand sides of the market for any of these three sectors. It envisions a wholesale change of market behavior on certain routes, and does not look at the implications of a change in operational costs or how transport sectors suppliers or their customers will react to those costs. Fuel supply and prices are taken as given and are unchanging in this analysis and therefore are not helpful for a study of impacts of an operational cost increase on marine shipping.

The Canadian-flagged Algowood heads upbound at Mission Point in Sault Ste. Marie, MI. Source: Photo taken by and used with permission from Dick Lund, available here: http://www.dlund.20m.com/rbl1a.html.

1.6.1.3 U.S Department of Transportation Maritime Administration Study, December 2007 as amended March 2009.

This study is similar to the Minnesota DOT study described above, with updated inputs.[21] It estimates the impacts of completely closing the Mississippi and Illinois Rivers in St. Louis, Missouri, and shifting all cargo to truck transportation as a way to quantify the benefits of river transportation. Two scenarios were modeled, one in which no improvements were made to road infrastructure to accommodate the increased traffic, and one in which improvements were made. The impacts after 10 years are estimated to be about a 210 percent increase in the number of trucks per lane-mile per day; crashes, injuries, and fatalities would increase from 36 percent to 45 percent, depending on the improvements scenario; and emissions would increase 37 percent to 52 percent, depending on the improvements scenario.

It should be noted that this analysis was for river traffic, characterized by tug-barge combinations, and emissions are based on fuel usage. Like the Minnesota DOT study, this study shows the important environmental benefits of marine transportation.

1.6.2 Studies Related to the Benefits of Short-Sea Shipping

Short sea shipping generally means the transportation of containerized or packaged goods by ship, either on LoLo (lift-on/lift-off) ships for containers, or RoRo (roll-on/roll-off ships) for truck trailers. Short-sea shipping takes advantage of the economies of scale of marine transportation by combining land transportation with a sea link. So, for example instead of transporting a container from Toronto to Chicago by truck driving around the lakes, the container would be trucked to a port in Canada and loaded onto a ship for Chicago, where it would be picked up by a truck for final delivery.

1.6.2.1 Tomchick et al., 2003.

This report was prepared by E. A. Tomchick, et al. of the Pennsylvania Transportation Institute for Save the River and Great Lakes United.[22] The report is an independent examination of a 2003 study by the Army Corps of Engineers with regard to expansion of the Great Lakes waterway system that would allow winter navigation. The authors examine various aspects of the ACE study in the context of a 1979 study of season expansion on the Great Lakes. They also examine the opportunities for container shipping on the Great Lakes, which would be encouraged by winter navigation.

The authors question several of the assumptions in a transportation savings analysis of container traffic on the Great Lakes performed by the Tennessee Valley Authority. First, they suggest that the use of a 6.25 percent interest rate to estimate the capital costs of in-transit inventory understates those inventory costs because that 6.25 percent is lower than the current (2003) cost of capital. Second, they note that the freight rates used in the analysis are based on ocean liner services; Great Lakes liner services may be higher due to the costs of using the locks and other system fees. Finally, they note there is a tradeoff between transportation cost savings and longer transit times. Longer transit times are associated with more uncertainty with regard to service reliability, which necessitates higher inventories, which leads to higher inventory costs. Finally, there are shipping chain costs that should be taken into account as well.

The authors also describe several conditions that would encourage container shipping on the Great Lakes and evaluate whether these conditions are feasible. Ocean port congestion could lead to the development of container shipping on the Great Lakes, through direct transportation to consumer areas on the lakes. However, the authors conclude there is no evidence to suggest that Atlantic ports have significant capacity constraints. They also note that while there is increasing congestion on highways connecting the Atlantic and Great Lakes areas, rail carriers have the capacity needed to absorb future traffic growth. With regard to shippers, studies from the 1970s report that ship operators gave several reasons for not operating on the Great Lakes. These include items such as "long voyages, averaging 25-30 days; too many ports of call, limits on ship size, and no commercial interest."[23] The authors note that ships coming directly from Europe would be faced with consolidating Great Lakes cargo in Europe, while shuttle service from East Coast ports would require consolidation in those ports. Finally, with regard to marine transportation users, it was stated that "three service criteria were consistently rated most important: cost of service, transit time, and on-time pickup and delivery." The authors noted that "a major question is whether container shipping companies … even with improvements to the system, can provide the level of service required by shippers."[24]

In conclusion, these authors note that "it is not clear that expanding the [Great Lakes/St. Lawrence Seaway] would induce container ship operators to offer container service on the system or what the optimum size vessel would be for offering such service. If the system were expanded to permit larger vessels … there might be some improvement in transit time reduction, but the long transit times and associated transit time unreliability problems would still exist. … System expansion will not eliminate the business problems associated with long transit times."[25]

1.6.2.2 U.S. Department of Transportation Maritime Administration, 2005.

This study is part of the U.S. Department of Transportation's Industry Survey Series and reports the results of a survey of U.S. carriers operating on the Great Lakes.[26] Seven carriers responded to the survey, representing 93 percent of Great Lakes domestic traffic in 2004.

While this study does not measure the likelihood of intermodal shift, it examines operators' opinions on such a shift. When asked how much of their existing cargo could be captured by rail or truck, all respondents answered less than 10 percent, with the exception of iron ore for which 4 respondents indicated from 10 to 30 percent could be captured. When asked how much of existing rail or truck cargo could be captured by marine, more respondents replied 10 to 30 percent for all commodities (iron ore, coal, and limestone).

1.6.2.3 U.S. Department of Transportation Maritime Administration, 2006.

This study was performed by Global Insight in association with Reeve & Associates for the U.S. Department of Transportation/MARAD.[27] It examines the potential for short-sea shipping to "absorb a significant part of the projected growth in highway and rail freight traffic."[28] The direction of the freight shift is from highway truck to intermodal truck-ship-truck. Cargoes examined were containers or truck trailers (RO-RO); bulk cargoes of iron ore, coal, crude oil, and minerals were not considered in the analysis because they "are not commonly containerized or carried in highway trailers but [move] by water in large bulk ships or barges."[29] The Great Lakes corridor examined is between Milwaukee, WI and Muskegon, MI. The analysis for this corridor suggests that "the short-sea mode is superior to trucking in terms of both time and costs."[30]

The study provides "important information on the perceived criteria for a successful mode shift from truck to an intermodal truck/ship combination for containerized or trailer cargo." These include:[S,31]

- The market in a traffic corridor has enough density to enable relatively large vessels that provide economies of scale in terms of operating and capital cost to be deployed with high enough service frequency to be competitive with trucking

- Vessel capital, crew costs, and marine terminal expenses must be set at "best in class" levels for U.S. operations for short-sea shipping to be price competitive with ground transport alternatives on a door-to-door basis

[S] One peer reviewer notes "… the fact that this shift has not happened, even as fuel price spikes make truck transport much more disadvantageous, suggests they may still have it wrong." This commenter suggests there will be mode shift from truck to rail before there is mode shift to ships. (Belzer)

- Short-sea shipping can be particularly competitive for heavy and/or hazardous shipments currently moving over roads, such as chemicals
- When short-sea shipping provides a more direct point-to-point routing and/or avoids areas of traffic bottlenecks and urban congestion, it can be highly competitive with ground transportation in terms of both cost and transit time – such as in the Great Lakes corridor.

With regard to operating costs, survey respondents mentioned labor costs, the Harbor Maintenance Tax, and new vessel construction costs as constraints for an intermodal approach. While highway truck fuel costs were one of the costs motivating interest in short-sea shipping, there was no separate analysis of fuel price impacts on the comparative advantages of short-sea shipping.

1.6.2.4 Transport Canada, U.S. Army Corps of Engineers, et al, Fall 2007.

The goal of this study was to examine "the current condition of the [Great Lakes/St. Lawrence Seaway] system, and how best [to] use and maintain the system, in its current physical configuration, in order to capitalize on the opportunities and face the challenges that will present themselves in the coming years."[32] This study provides background on the geography of the waterway, its economic significance and environmental conditions. The report also discusses the current status of the infrastructure and how it should be managed to take full advantage of future economic opportunities.

The study provides the results of an analysis of the competitiveness of the Great Lakes compared to other modes of transportation by the Army Corps of Engineers.[33] That study consists of a transportation rate analysis based on a sample of 857 shipping movements in 2002, covering over 40 commodities and representing about 90 percent of total cargo tonnage shipped that year on the Great Lakes. The analysis was used to estimate the cost savings associated with the Great Lakes/St. Lawrence Seaway system in comparison to the next least expensive mode.

The analysis shows that the Great Lakes/St. Lawrence Seaway system "offers shippers an average savings of $14.80/ton in transportation and handling charges compared to the next-best, all-land transportation…" The total savings to shippers in 2002 were estimated at "$2.7 billion in transportation and handling charges that they would otherwise have incurred had they used other modes of transportation."[34] The estimated transportation cost savings of ship transportation compared to the least cost alternative transportation are presented in Table 1-7.

Table 1-7 Transportation Savings Offered by the Great Lakes/St. Lawrence Seaway by Commodity

Commodity group	Sample size (tons)	Savings/Ton	Total Savings[a]
Aggregates and Slag	37,813,000	$16.03	$605,988,000
Metallic Minerals and Ores	62,395,000	$9.35	$583,464,000
Coal, Coke, Pet Code	40,784,000	$13.36	$544,961,000
Iron, Steel and Other Metals	12,872,000	$32.49	$418,219,000
Non-metallic Minerals	8,884,000	$19.50	$173,224,000
Wheat	8,046,500	$17.37	$139,776,000
Petroleum Products	3,932,500	$18.60	$73,137,000
Other Grains and Feed Ingredients	1,819,000	$28.20	$51,330,000
Soybeans	1,692,000	$22.26	$37,667,000
Corn	1,169,000	$23.61	$27,614,000
Total	179,407,000	$14.80	$2,665,360,000

[a] In descending order of total shipper savings, numbers rounded to nearest 1,000
Source: Great Lakes St. Lawrence Seaway Study, Final Report, Fall 2007, available here: http://www.marad.dot.gov/documents/GLSLs_finalreport_Fall_2007.pdf

EPA's present economic study estimates the ECA fuel price increase at about $193/tonne of fuel, or $0.48/gallon (see Section 2.5.1.3). Given this relatively small increase, it is unlikely that compliance with the ECA fuel requirements on the Great Lakes would result in a large transportation mode shift, especially since rail and truck transportation will be required to use the more expensive 15 ppm ULSD in the same time frame.

Using the ECA fuel price from EPA's present study and comparing to the 2007 Transport Canada/ACE study, these fuel impacts reduce the savings per ton reported in Table 1-7 by less than 15 percent, and by 5 percent or less for the four commodities examined by EPA, for most scenarios analyzed.[T] The range of fuel cost increases reported in Chapter 2 of this EPA report for the sixteen scenarios examined range from $0.24 and $1.13 per cargo ton for coal, from $0.35 and $2.67 per cargo ton for iron ore, from $0.84 and $2.10 for wheat, and from $0.23 and $0.34 for crushed stone, with the largest cost increases occurring in the scenarios with the longest marine links.

[T] Coal, iron ore, grain, and crushed stone (see Chapter 2).

1.6.3 Studies Related to the Impacts of Fuel Prices on Shipping

1.6.3.1 U.S. Department of Transportation Maritime Administration, 2008.

This study was performed to estimate "the impact of oil prices on markets and their logistic chains [and] to evaluate the potential of [higher] oil prices on U.S. domestic freight transportation" as a response to sharp increases in crude oil prices that were experienced in 2008.[35] The authors note that the current distribution of cargo between truck, rail, and marine transportation is largely an artifact of several decades of low fuel prices which allowed trucking to obtain a large share of the market based on their shipment time advantages. This study projects future oil prices and "assesses how such prices would impact the transportation logistics chains and evaluate(s) likely changes." [36] The authors particularly want to explore how short-sea shipping may benefit from increased fuel prices:

> For water, the market position is similar to that of rail as it can provide an alternative to truck because of water's lower operating costs. The major issue is that because the water mode is so much slower than truck or rail it has not been able to move into the higher value container or intermodal business, and has typically only substituted for truck or rail in bulk and neobulk markets. However, as both truck and rail have capacity problems while water has considerable capacity, the opportunity may now exist for water to move up market from bulk traffic, first into neobulks (steel coil) and then into containerized freight, particularly where market conditions provide additional advantage for water (e.g., shorter water distance, easier port transfers, etc.).[37]

The analysis relies on the GOODS model, which is a generalized cost (GC) model based on a supply and demand analysis. On the supply side, the GC "incorporates all of the critical factors that motivate shippers and carriers to use a particular route, mode, and shipment type," and is a function of transit time, shipping cost, frequency, and reliability. The generalized cost of shipping is reported in hours rather than dollars. Generalized costs are developed for each origin-destination pair in a corridor. The demand side of the model considers the aggregate impacts of increased oil prices on the economy and what these impacts mean in terms of the demand for transportation services. The pertinent demand factors are economic growth, induced demand as a result of increased volumes, and competition effects leading to shifts in demand from one mode to another based on increased costs. The economic growth projections are based on the Freight Analysis Framework traffic levels, although the study does not specify what this growth rate is or how it was estimated.

For a defined set of transportation corridors (West Coast, Gulf Coast, East Coast, Great Lakes, Mississippi), demand and supply factors are defined. The model is then used to examine the impacts of increased fuel prices on costs, and whether short-sea shipping can be competitive with truck or rail service. The analysis was performed for three years (2002, 2005, and 2020), with three fuel price scenarios for 2020 (low, medium, high).

The results show that "fuel efficient rail and water modes … are far less affected by fuel price increases than trucking [and] shippers will be able to realize significant savings by diverting to rail and water." One limiting factor not included in the analysis is drayage[U] costs, which may reduce some of the potential intermodal shift. The authors note that "drayage charges are very high as there is frequently no back haul and trips involve extra time for pickups and delivery, both at ports and at the customer's loading dock … [increasing drayage costs] will encourage firms that make use of intermodal services to locate even closer to ports and rail terminals to minimize drayage costs."[38] It is not clear, however, if such relocation costs are included in the analysis. The authors also note an additional constraint for rail: capacity constraints that limit their ability to absorb additional shipping and the relatively long distance they require to break even on costs because they bear the costs of maintaining the rail system.

The results of this study indicate that as fuel prices increases there is a projected increase in the number of loaded containers carried on the Great Lakes, with forecast potential traffic increasing up to 200 percent for a fuel increase from $2 to $7 per gallon. The Mississippi and Gulf Coast corridors would see similar increases. While there was only a negligible increase in container traffic for the East and West coasts, there may be a potential for port feeder services (e.g. transferring containers from large ocean-going ships arriving at coastal ports to smaller ships for transportation to ports closer to the areas where the goods will be consumed, instead of transporting those containers by rail or truck). With regard to bulk cargo, "where in recent years, rail productivity improvement has flattened water traffic growth … the prospect of rising fuel prices is likely to shift the cost advantage back to water."[39] The results suggest that grain shipments on the Great Lakes are projected to increase substantially as fuel prices increase, although petroleum shipments are projected remain about the same.

The significant point to note about this study is that it explores the impact of fuel increases on the transportation system as a whole, including demand for transportation and the supply of transportation services (i.e., as fuel prices increases across the economy, what will be the impacts on the distribution of cargo across different transportation modes). In other words, there is a synergy in this model between expected economic growth and increases in fuel costs for the truck, rail, and marine sectors. As fuel price goes up, there is an expected increase in the cargo volumes handled by ship due to those synergies, and the study concludes an increase in fuel prices across the economy is expected to lead to more containerized and bulk traffic on the Great Lakes. However, this study does not provide a tool to analyze the impact of an increase in fuel costs on the Great Lakes associated with application of ECA fuel requirements, holding all other aspects of the economy, including all other fuel prices, constant.

1.6.3.2 Canadian Shipowners' Association Study, 2009.

This study was submitted to EPA in support of the Canadian Shipowners' Association (CSA) comments on EPA's Category 3 marine proposal.[40] The study consists of two parts. A quantitative analysis estimates the impacts of increased fuel costs on freight rates and transportation mode shift generally, and is performed for the grain and petroleum markets. These markets appear to have been chosen based on data availability. There is also a qualitative analysis that considers the impacts of increased fuel costs on a set of specified markets including the grain, salt, stone, petroleum, and steel markets.

[U] "Drayage" refers to movement of goods, by land, to and from a port.

With regard to the quantitative analysis, the study estimates operating cost increases for the fleet on average. These costs are used to adjust the freight rates. These adjusted freight rates are used to estimate potential mode shift using a mode shift factor derived from the 2008 MARAD study described above. The year of analysis is 2012, based on the assumption that heavy fuels meeting the 10,000 ppm 2012 standard will not be available and all vessels operating on the Great Lakes will be required to use distillate fuel by that date.[V]

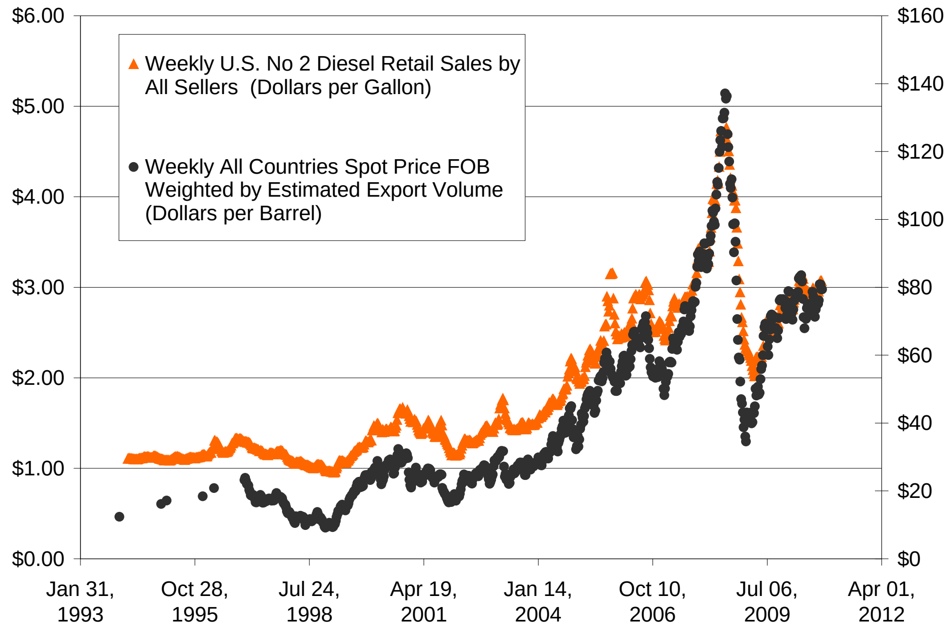
The fuel prices used in the analysis are the prices reported at Sarnia in Ontario, Canada. Three price cases are examined: the 2008 average price, the price at June 7, 2008 (reflecting a peak in fuel prices generally) and the price at July 10, 2009 (current to when the analysis was performed for the study). The 2008 average prices are $523 for HFO180, $906 for MDO, and $1,010 so-called premium MDO ($100/MT price premium). Not surprisingly, the choice of fuel price has an impact on the results. As illustrated in Table 1-8 and Figure 1-6, the oil and fuel prices for 2008 and early 2009 were particularly high due to various market factors, and they subsequently fell. In comparison, the prices used in EPA's analysis are $424 for HFO and $848 for MDO, which are the 2007 prices reported by U.S. Energy Information Administration / Annual Energy Outlook 2010, adjusted by 10% to reflect higher fuel prices on the Great Lakes.

Table 1-8 Europe Bren Spot Price FOB (Dollars per Barrel)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2007	53.68	57.56	62.05	67.49	67.21	71.05	76.93	70.76	77.17	82.34	92.41	90.93
2008	92.18	94.99	103.64	109.07	122.8	132.32	132.72	113.24	97.23	71.58	52.45	39.95
2009	43.44	43.32	46.54	50.18	57.3	68.61	64.44	72.51	67.65	72.77	76.66	74.46
Source: U.S. Energy Information Administration, available here: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rbrte&f=m												
Release Date: 10/27/2010												

[V] It should be noted that EPA's final rule contains a fuel availability waiver if 10,000 ppm fuel is not available on the lakes that would allow operators to use fuel with a higher sulfur content (see 40 CFR 1043.95).

Figure 1-6 Weekly Price Comparison No. 2 Diesel vs. FOB Crude



Source: Energy Information Administration (**http://www.eia.gov/dnav/pet/pet_pri_wco_k_w.htm**), World Crude Oil Prices, Release Date 11/3/2010. Excel file name pet_pri_wco_k_w.xls

Depending on the reference fuel price (2008 average, June 7, 2008, and July 10, 2009) this study estimates switching to 100 percent MDO would increase fleet fuel costs by 28 to 63 percent in 2012, based on the 2008 average price, and 47 to 76 percent, based on the $100/MT price premium. It is difficult to evaluate these results because the study does not provide the underlying data, even for the most basic inputs such as industry fuel volumes by fuel type.[W,X]

The adjusted freight rates were obtained by "applying the various fuel costs to the 2008 average daily fuel consumption, and using an estimated average daily time charter cost of vessels with a 10% increment for trade costs."[41] The estimated freight rate increases range from 6 to 17 percent, in the base case, and 9 to 21 percent in the premium case. Again, there is not enough information to evaluate the impact of fuel cost increases on freight rates as freight rata data is not provided. However, in this analysis fuel costs appear to be about 50 percent of the industry average freight rates.

To estimate mode shift, the analysis applies a modal shift factor to the fuel cost increase. The result is an estimate in the percentage of cargo that will shift to a different transportation mode. The modal shift factor was derived from the MARAD 2008 study described above. This was done by "scal[ing] from the reported mode-shift plot from grain" and then adjusting this for energy intensity.[42] The estimated modal shift factor is 0.243 for grain traffic and 0.225 for

[W] "While the consultant has used the data provided to offer some conclusions about the potential consequences of the proposed fuel regulations the confidentiality agreements precluded disclosing all the calculations by which they have been developed."

[X] For example, there appears to be an error in CSA's Table 1, as the proportion of consumption does not add up to 100 percent.

petroleum traffic, resulting in an estimated mode shift of 7 to 12 percent of cargo for grain and 6 to 14 percent of cargo for petroleum. It is not clear, however, how the mode-shift plot was scaled, or how it was adjusted, and no details are provided. Without a greater detail of how these modal shift factors were derived, it is not possible to understand whether they are appropriate. The derivation of the modal shift factors is important because the CSA factors do not seem to be consistent with the graphics in the MARAD 2008 study. Specifically, the MARAD 2008 study shows a negligible positive relationship between fuel price and increased cargo for petroleum. For grain the relationship is steeper, especially at a price increase of about $2.50 per gallon, but this may be due to an actual difference in cargo volumes for 2002 and 2005 versus projected volumes for later years (i.e., there is a kink in the graph that may be due to data differences).

In any case, as noted elsewhere in this section, the MARAD 2008 study was not intended to evaluate the impacts of a limited price increase on a specific market. It was intended to examine the impacts of systemic fuel increases across the economy due to rising oil prices. It uses a generalized cost approach that models the economy as a whole. In the MARAD 2008 study there are at least two sources of mode shift: fuel price increases for competitive modes (truck, rail, marine) and impacts on the demand for transportation services. In general, as fuel prices increase for all sources, it becomes more attractive to use intermodal transportation chains to take advantage of low cost marine services to reduce total transportation costs. Thus, instead of finding that as marine fuel prices go up demand for marine transportation services goes down, and the marine transportation market experiences loss of cargo, the MARAD 2008 study finds that as oil prices go up across the economy the marine transportation market can be expected to increase cargo carried as it becomes less expensive compared to other transportation options, and as truck/ship intermodal options become more attractive.

The CSA study also includes a qualitative discussion of the impacts of marine fuel price increases on specific markets: grain (Thunder Bay to Quebec City and Montreal); salt (Goderick/Windsor to Toronto); stone/aggregate (Manitoulin to Cleveland); petroleum products; and steel. The authors specify that iron ore and coal were not examined because for infrastructure and other reasons they are not vulnerable to shift, although iron ore was examined in the context of a discussion of potential production shift for steel. These discussions also include estimates of mode shift in terms of percent of cargo diverted, although these estimate are not explicitly calculated; instead the discussions extend the results for grain and petroleum described above.

The discussion of the grain market highlights the features of this market that support the earlier estimate of a 12 percent mode shift. The discussion of the salt market concludes that "even with increased ECA costs, rail and truck would not compete for this trade."[43] For the stone market, the CSA study included a competitive radius analysis for stone delivered to markets in Cleveland and Akron, OH. The study then applied qualitative arguments to conclude the nature of the market suggests an estimated shift of 20 percent based on a "reasonable" expectation of a shift twice that of grain. With regard to petroleum the discussion notes that while the marine mode is expected to recover some of the market from railroads, that recovery would not occur as a result of increased marine fuel costs; this opportunity cost is estimated to be about 11.3 percent. With regard to the steel market, the study notes that transportation costs of iron ore and coal to steel mills are not significant components of the cost of manufacturing steel. Transportation costs are not large components in the price of either coal or iron ore, and the steel mills examined do not have rail alternatives. Nevertheless, the study concludes that a rate increase of 10 percent or more could lead steel manufacturers to relocate production to a lower cost facility.[44]

While this study provides important insight on the questions that should be investigated with regard to the impacts of increased fuel costs on Great Lakes trade, for the reasons outlined above, the results should be considered with caution.

1.7 European Studies of the Potential Impacts of the 2008 Amendments to MARPOL Annex VI

Since the 2008 adoption of amendments to MARPOL Annex VI setting more stringent NO_X and fuel sulfur limits, several studies have been performed by government and industry groups in Europe that examine the impacts of those new standards on their shipping industry. These studies are briefly described in this section. In addition, two summaries have been prepared, one by Entec (July 2010), commissioned by the shipowner associations of Belgium, Finland, Germany, Holland, Sweden and UK[45] and one by the European Maritime Safety Agency (October 2010).[46] Note that most of these studies refer to marine diesel fuel meeting the ECA 1,000 sulfur limit as "MGO."[Y]

1.7.1 European Cost Studies

1.7.1.1 Ministry of Transport and Communications, Finland Study, 2009.

Each of the studies discussed below contain an analysis of the costs of complying with the more stringent 2015 ECA fuel sulfur limits, either on a national basis, a European basis, or a ship basis. The Finnish study is notable because it is the first such study.

Using a range of fuel prices for MGO (0.1% sulfur), this study estimates the maximum additional cost for ships operating in Finland and Finnish ships, given the difference in price between MGO and HFO (1.5% sulfur) that is currently used by ships operating in the Baltic and North Sea ECAs.[47] Estimated additional costs are developed by estimating fuel consumption costs at each of the HFO and MGO prices and calculating the difference between them. This information is used to create a linear relationship between the price differential and additional costs, which are then applied to price differentials that may occur in the future. These costs are then allocated among economic sectors based on the contribution of that sector to Finnish imports and exports, suggesting that the forest, construction, and chemical industries will be most affected. While the authors suggest that rising fuel prices will be incorporated into freight rates over time and that excessively high fuel prices might lead to a modal shift,[48] they provide no analysis to support these outcomes.

[Y] While there are small differences in the fuel characteristics of MDO and MGO, these are both distillate fuel and are functionally the same. The price difference between MGO and MDO is small, averaging about +/1 percent.

1.7.2 European Cost/Benefit Studies

1.7.2.1 UK Maritime and Coastguard Agency and AEA Studies, 2009.

These reports, performed by Entec[49] for the UK Maritime and Coastguard Agency and by AEA[50] for the European Commission, are cost and benefit studies that analyze the effects of the revised MARPOL Annex VI regulations on different parts of Europe. Both of these studies state that emissions from ships make significant contributions to air pollution, that these emissions are expected to increase over time, and marine emissions could surpass land-based emission sources over time if further action is not taken. The main difference between these two reports is that the UK report estimates the total costs in 2020 are greater than the estimated benefits in 2020, while the AEA study estimates that the benefits far outweigh the costs in 2015 and 2020. There are a number of variables that lead to these different results, including geographic area and traffic, baseline scenario, compliance strategies, models used, monetized benefits included, fuel prices, and abatement costs.

With respect to geographic area and traffic, the UK study looked at an area 200 nautical miles from the coastline, extended further East to ensure a more complete coverage of the North Sea. This study did not look at benefits to any other country, nor did the SO_X Emission Control Area (ECA) change throughout different scenarios as it focused on the North Sea and English Channel ECAs. The AEA study, on the other hand, looked at most of Europe and presented different cost and benefit scenarios based on both existing and hypothetical future ECAs. This study did model benefits to countries other than those adjacent to an ECA. The UK study also looked at emissions benefits for different groups of vessels including: all vessels traveling within the study area, vessels within the study area calling at UK ports, and vessels traveling within the study area with a UK flag. The AEA study did not separate vessels by flag or port, rather it looked only at all traffic in the study area.

With respect to the scenarios modeled, the UK study presents the cost and benefit estimates for 2020 for two policy options. The "Do nothing" option represents a business as usual case that includes the existing MARPOL Annex VI Regulations and the Sulfur Content of Liquid Fuels Direction (1999/32/EC), which are already in place in the UK. The "Full implementation" option implements the 2008 Annex VI amendments and focuses on three different compliance strategies with respect to the portion of the fleet that would use alternative abatement technologies. The AEA study examined the cost and benefits of a suite of scenarios reflecting reductions resulting from both the 2008 amendments to Annex VI and the potential addition of emission control areas. Scenarios were modeled for both 2015 and 2020. Table 1-8 below presents the scenarios analyzed.

A notable difference between the two studies is the baseline that was used to determine emission reductions and therefore benefits. The UK study baseline is the "Do nothing" scenario which includes an ECA fuel sulfur limit of 1.5% (i.e. Annex VI requirements prior to the 2008 amendments) the AEA study does not include these ECA fuel sulfur limits from the 1997 IMO protocol, nor does it include Tier I or Tier II NO_X controls, the latter of which suggests a larger reduction in emissions than would likely occur.

The two studies also use different models. The impacts of the revised MARPOL Annex VI regulations on baseline UK concentrations were estimated using the FRAME model. The FRAME model was also used to investigate impacts on the ecosystems based on deposition and critical load modeling. AEA used the LOTOS-EUROS model to estimate atmospheric dispersion of ship emissions, and their effect on the European distribution of sulfur-and nitrogen deposition, and on ground-level ozone and particulate matter concentrations. Background concentrations (from other parts of the world) are provided by a global model, TMf, and anthropogenic emissions are based on Gains Europe.

The largest difference between the UK and AEA studies are related to which benefits are monetized in the total benefits estimate. While the AEA study quantifies fifteen different health impacts, the UK study only looks at three health benefits – which results in substantially lower monetized benefits presented in the UK study. Although neither study presents monetized ecosystem impacts, the UK study did monetize benefits from reduced building and material damage and presented a value of £6.3 million in benefits (£2009 prices and present value). The AEA study did not expand the analysis to cover building or crop damage.

The two studies also use different fuel prices. The AEA study fuel prices are adapted from the 2009 Purvin and Gertz study. The UK fuel prices are derived from IEA historic data. As fuel prices comprise a majority of the cost of compliance with the revised Annex VI, the larger fuel differential prices used by the UK study could contribute to costs being higher than benefits.

Finally, each study discusses the estimated costs of abatement technology for both NO_X and SO_X. However, the UK study states that "there are currently no defined NO_X ECAs and thus the Tier III standards do not apply. Therefore, end of the pipe technology, such as selective catalytic reduction, is not considered likely to be necessary unless a NO_X ECA is designated." For this reason, Tier III NO_X abatement costs are not discussed in the UK study. Further, the UK study assumes that Tier I and II technologies are negligible when compared to the costs associated with complying with the sulfur requirements and these costs are not considered. The AEA study does present costs for Tier I, Tier II, Tier III, and Tier I retrofit technologies on a per vessel basis. Both studies present estimated scrubber costs on a per kilowatt basis.

With regard to results, the AEA study presents benefits that exceed the costs in all scenarios, while the UK study presents costs that exceed the benefits. However, the UK study presents costs that are annualized (indicating the present value of a stream of costs) while the benefits are annual. It is not generally considered appropriate to compare annual and annualized values. This makes it difficult to make a direct comparison of the UK costs and benefits presented in the study. The total costs and benefits presented in each study are shown in Table 1-9 below.

Table 1-9 Cost and Benefit Totals Presented in Each Study for 2020

	UK - IMPACTS ON THE UK FROM ALL VESSELS IN THE STUDY AREA (£MILLION)	AEA: BALTIC SEA, NORTH SEA AND THE ENGLISH CHANNEL AS SECA (€MILLION)	AEA: INCLUSION OF MEDITERRANEAN AND THE BLACK SEA IN THE SECA
Annualized costs	800 to 3,600	----	----
Annual costs	----	900 to 4,600	2,000 to 12,000
Annual health benefits	300 to 700	10,000 to 23,000	14,000 to 32,000

The UK study states that it underestimates the benefits, however, review of the study and the fact that Tier III costs are not presented indicate it likely also understates the costs. However, the UK study only presents benefits to the UK while the AEA study presents benefits to numerous countries surrounding the study area. The UK study appears to focus more on the fuel price impacts of the global standards changing from 0.5% sulfur to 0.1%, while the AEA study is focused on presenting a complete cost and benefit analysis for most of Europe.

1.7.3 European Modal Shift Studies

The five studies included in this section each examine the impacts of the new 0.1 percent ECA fuel sulfur requirement on marine transportation in Europe and whether the increase in costs is likely to result in a transportation mode shift away from marine. Two of the studies were performed for the European Commission (COMPASS, SKEMA), one was performed by a government (Swedish Maritime Administration), and two were performed for industry organizations (ESCA, ISL).

The primary focus of each of these studies is on short-sea shipping, although the Swedish Maritime Administration Study also includes "other" ships in their analysis.[Z] Short-sea shipping refers to transportation by container or truck trailer through a combination of land and marine transportation links, with the water link on RoRo, LoLo, or container feeder vessels, or ferries. This is an important distinction because the Great Lakes analysis contained in this report focuses on bulk shipping: coal, iron ore, grain, crushed stone, which are not as easy to switch to land-based transportation as are containers or truck trailers. Consequently, the results of these studies may not be directly transferrable to the Great Lakes situation. In addition, while each of the European studies examines the impacts of the 0.1% fuel sulfur requirement in the Baltic and North Sea ECAs, the geographic scope of the studies differs, as do the types of transportation studied. These differences, along with their use of different methodologies and fuel prices, make it difficult to compare results across studies and draw any general conclusions.

1.7.3.1 Swedish Maritime Administration Study, 2009.

The Swedish Maritime Administration was charged by the Swedish government to study the consequence of the Annex VI fuel sulfur limits.[51] They prepared this report in consultation

[Z] In contrast to Europe, where as much as 40 percent of all freight moved is through short-sea shipping, the United States does not have a strong short-sea sector, especially on the Great Lakes (see 1.7.2 for studies of the benefits of short-sea shipping in the United States).

with 18 organizations representing other Swedish government agencies and a variety of industry and public-interest groups.

The transportation mode shift analysis is performed using a freight model developed by SIKA (Swedish Institute for Transport and Communications Analysis) and the four Swedish transport administration agencies. The model is a type of geospatial model that "minimizes the aggregated logistics costs … for all freight transported during one year" and "focuses solely on selection of route and transport chain."[52] The analysis is performed for freight transported by ship to and from Sweden, with demand held constant in terms of O/Ds and volumes transported.[53] Baseline fuel prices are the average value of prices during October/November 2008 in Rotterdam ($365 for 1.5% sulfur); fuel prices are weighted by ship category for the baseline scenario to reflect the range of fuel sulfur limits currently experienced (some vessels use low sulfur fuel in response to the Swedish Fairway Dues program). The control cases are based on the October/November 2008 Rotterdam price for 0.1% sulfur fuel (Scenario 1; $662), 75 percent higher (Scenario 2; $1,158) and 150 percent higher (Scenario 3; $1,650).

With regard to results, the analysis suggests that switching to 0.1% sulfur fuel in the Baltic and North Sea ECAs can be expected to decrease ship cargo volumes. The estimated decrease ranges from 2 percent (Scenario 1) to 10 percent (Scenario 3). The lost marine cargo volumes are expected to switch to truck or rail transportation.

There are several aspects of this study that suggest the results for Scenarios 2 and 3 may be overstated. Specifically, while the price of distillate in both of these scenarios is increased to reflect increases in the prices of a barrel of oil by 75 percent and 150 percent, respectively, the baseline residual fuel price does not appear to be adjusted. This would result in an exaggerated price differential between residual and ECA-compliant fuel. In addition, the fuel prices for trucks and rail are not adjusted, making them relatively less expensive. As stated in the report, "the price of fuel for trucks has been kept the same in all scenarios." The given reason for doing this is to avoid price impacts from "increased competition for fuel between truck and shipping," but it is not clear how keeping truck fuel prices constant addresses that concern. This would also tend to increase the potential transportation mode shift impacts in Scenarios 2 and 3 since truck fuel prices are not adjusted as marine fuel prices are increased.

Finally, the model does not take road and rail infrastructure constraints into account, particularly with regard to transportation across key bridges, which may make transportation modal shift to rail and truck less practical ("… a part of the transported freight (e.g. metal products) is transferred from routes via the Port of Gothenburg to routes via the Öresund Bridge, which in reality must be seen as less likely since traffic already at present on the bridge is very significant. As previously mentioned, capacity shortages of the rail network have not been taken into account in the model." These constraints, however, can affect outcomes in all scenarios, potentially lessening the likelihood of transportation mode shift.

Scenario 1 is roughly comparable to the study contained in Chapter 2 of this report in that it is based on current fuel prices for marine and land sources and reflects a $297 price differential between current ECA fuel and distillate fuel that meets the 1,000 ppm sulfur limit. The results of Scenario 1 are consistent with the study contained in Chapter 2 of this report, in that a shift to ECA fuel expected to result in a 2 percent decrease in marine cargo volumes and a 1 percent increase in truck cargo volumes; this transportation mode shift in actuality may be offset by capacity constraints not considered in the Swedish modeling.

The report concludes: "The difference in costs demonstrates the need, at a high level, to pursue the issue of instituting new control areas outside SECA and the proposed Emission Control Areas (ECA) since this is no longer merely an environmental question but a question of finding a balance between environmental measures and fair competition for Swedish industry primarily within Europe but also globally." [AA,54]

1.7.3.2 ESCA Study, 2010.

This study was performed by the Universiteit Antwerpen and Transport & Mobility Leuven for the European Community Shipowners' Associations (ESCA), which represents shipowners' associations from twenty-one European countries.[55]

The study uses a cost approach to evaluate the impact of 0.1% sulfur ECA fuel for specified O/D pairs. An initial analysis is performed to examine the impacts on ship operating costs; this is compared to the results of a stated-preference analysis based on a survey of ship operators. The main focus of the study is a second approach that uses a cost analysis similar to that presented in Chapter 2 of this report to examine the likelihood of transport mode shift for a set of thirty O/D pairs. The analysis is performed for several fuel price scenarios, with the price differential between residual and ECA-compliant fuel ranging from $222 to $444 per ton.

For the low fuel differential case, the study estimates an average increase in total ship costs of 19.1 percent, on average, leading to an estimated average 11.5 percent increase in freight rates, across 16 O/D pairs. For the high price scenario, the results are a 30.6 percent in operating costs and 19.7 percent increase in freight rates.

With regard to transport mode shift, the study examines 30 O/D pairs for four areas (Germany/Denmark to Sweden; English Channel; West Europe – Baltic States; West Europe – Scandinavia). There are up to three transportation alternatives for each O/D pair, and all three fuel price estimates are examined. The analysis compares the adjusted marine freight rates to land-based freight rates to determine if transport mode shift is likely. The methodology uses a cost function approach. Cost functions are developed for both marine and road haulage to estimate freight rates based on distance at various fuel prices (marine) or geographic areas (road). The estimated freight rates for a given marine fuel price are then compared for each O/D pair; a transport mode shift is expected if the difference between marine and truck freight rates is greater than ten percent; between zero and ten percent the market is deemed to be "competitive."

With regard to cost changes, the authors conclude that "the use of MGO is expected to increase the transport prices particularly on the origin-destination relations with medium or long short-sea section. Such a price development might eventually trigger a shift from medium and long short-sea routes to shorter short-sea routes or a "truck only" alternative without any short-sea section." These results are distance sensitive: the longer the sea link, the larger the impact. As a result, the impacts of a fuel switch are expected to vary by region. The authors also note

[AA] A SECA is a Sulfur Emission Control Areas, in which only the more stringent fuel sulfur limits, and not the more stringent Tier III NO_X limits, apply. The Baltic and North Sea areas are SECAs.

that "the observed shifts in price differences incurred when introducing MGO as a base fuel in the ECA would undoubtedly lead to changes in the modal split at the expense of short-sea services" and that '[t]raffic losses for short-sea services force short-sea operators to reduce capacity, to downsize vessels deployed … [which could] trigger a vicious cycle of capacity reduction and lower frequencies ultimately leading to a poorer position for short-sea services…"[56] but the analysis does not support these broad conclusions.

With regard to the specific results of the study, the study does not appear to adjust truck fuel prices to reflect the higher distillate fuel prices in the medium and high marine fuel price scenarios. Therefore, the focus here is on the low price scenario, which reflects fuel prices and a fuel price differential more similar to those used in this study and the Swedish study (HFO 1.5% \$278; MGO 0.1% \$500; price differential \$222/ton). For this low price scenario, short-sea shipping is favored to truck transportation or remains competitive for all but two routes. For one of these, Scenario 3.2, Dieppe-Kaunas, short-sea shipping was not favored in the baseline HFO case. For the other, Scenario 3.6 Amsterdam-Kaunas, short-sea shipping changes from being competitive in the HFO case to favoring truck transportation in the MGO case.

1.7.3.3 SKEMA Study, 2010.

This study was performed by SKEMA for the European Commission, Directorate-General for Energy and Transport.[57] SKEMA is the Sustainable Knowledge Platform for the European Maritime and Logistics Industry.

This study uses two models, TAPAS (a supply chain model) and NECL (a cost model) to estimate the impacts of switching from residual to distillate fuel on two type of shipping, LoLo (for containers) and RoRo (for trailers) shipping. The analysis was performed for four sets of O/D pairs, with some overlap between the two methodologies.

Both of these models predict a transfer of cargo to land-based transportation. The TAPAS model, which was used to examine cargo going from Klaipeda to Harwich using five different routes, predicts that by 2015 most cargo movements will occur on the route through Rotterdam which has the shortest marine leg (less than 10 percent share of the total route). The NECL model, which was used to examine cargo going from Gothenburg to Dortmund, Dortmund to Manchester, and Vilnius to Dortmund as well as Klaipeda to Harwich, also predicts a loss of cargo to truck transportation; this transportation mode shift would be mitigated if scrubbers become an alternative. This analysis also examines a scenario in which the ECA fuel sulfur limit is changed to 0.5 percent, which predicts a much smaller transportation mode shift.

This study is based on the Purvin and Gertz fuel prices (see Section 1.7.4, below). However, it does not supply much information on the models themselves. Truck fuel prices do not appear to be adjusted to reflect higher oil prices, again giving truck transportation a cost advantage over marine freight prices. Trucks are also given an advantage with respect to capacity (75 percent, as opposed to 50 percent for marine); without a study of the industry, it is not possible to determine if this difference is reasonable.

1.7.3.4 COMPASS Study, 2010.

This study was performed for the European Commission DG Environment by Transport & Mobility Leuven and Nautical Enterprise.[58] It examines the impacts of a set of five policy scenarios to improve environmental performance for European short-sea shipping, on four vessel types (RoRo, RoPax small, RoPax large, LoLo).[BB] The policy initiatives include reducing the sulfur content of fuel used in the European ECAs, the EU eMaritime initiative,[CC] and greenhouse gas (GHG) requirements. Impacts are examined by vessel type and length of voyage for European routes covering the North Sea, Baltic Sea, Atlantic Coast and Mediterranean Sea. Both trucking and rail are considered as alternatives to marine transportation. The study used the Purvin & Gertz fuel prices also used in the SKEMA study.

The methodology is based on a business operation model, the goal of which is to determine the least cost method to ship goods. It is a closed loop model in which demand for transportation services is not driven by economic activity. Instead, demand is determined outside the model and is held constant. The model assumes that the amount of resources spent on transport is fixed and is the same for all policies. In this model, an increase in transportation costs results in a reduction in transportation services provided given the fixed transportation services budget.

This study finds that the largest policy impact comes from the ECA 1,000 ppm fuel limit. This requirement is estimated to increase total costs from 6 percent for RoPax small to 29 percent for LoLos. The resulting decreases in cargo volumes range from 1 percent for RoPax small to 10 percent for LoLo routes. The results also indicate that cargo volumes for truck transportation will also decline. The analysis concludes that a combination of all policy options considered will result in decreases in the modal share of short-sea shipping between 1 percent and 7 percent. Finally, the results suggest that the decrease in cargo tends to increase as the distance travelled increases, although this is not true in all cases.

These results of this study should be treated with caution. The impacts of the model may be overstated due to the closed nature of the model, which artificially restricts spending in the transportation sector. In fact, the amount of transportation services provided is driven by demand and not by a fixed transportation budget. In addition, a small increase in transportation costs may not result in a significant reduction in transportation services. This is because transportation services are only a small part of the total costs of goods produced, and manufacturers may be able to pass on a portion or all of an increase in transportation prices. These impacts cannot be assessed in a closed model such as the one used in this study.

1.7.3.5 ISL Study, 2010.

The study performed by the Institut fur Seeverkehrswirtschaft and Logistik (ISL) was originally commissioned by the Federal Ministry of Transport, Building and Urban Development

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[BB] RoPax are RoRo vessels that also transport passengers.
[CC] According to the study, "the EU eMaritime initiative is aimed at fostering the use of advanced information technologies for working and doing business in the maritime sector. It is expected that this initiative will reduced delays in ports through more efficient documentation submission and review processes, and, improved coordination of inspections by authorities." (p. 13)

(BMVMS) and the German Shipowners' Association (VDR) and was completed by VDR and the Association of German Seaport Operators (ZDS).[59] Like the other European study, this study examines the impact of the ECA 0.1% fuel sulfur requirement on short-sea shipping in the North Sea and Baltic Sea, focusing on truck trailers transported by RoRo vessels and containers transported by LoLo vessels.

The analysis is performed separately for RoRo and LoLo markets. For each market, the main shipping corridors are defined and a set of O/D pairs are specified. Then, for each corridor, the impacts of higher fuel prices on shipping costs are estimated based on the contribution of fuel costs to total shipping costs for that corridor. Finally, the risk of transportation mode shifts is estimated for each corridor using a logit function approach. The analysis is performed for two sets of future fuel prices representing a high price case (HFO: $709/tonne; MGO $1,182/tonne) and a low price case (HFO $514/tonne; MGO $773/tonne); current fuel prices are taken as being $450 and $650/tonne for HFO and MGO, respectively.

With respect to RoRo shipping, the study estimates marine cost increases of 14 to 37 percent in the high fuel price case and 8 to 21 percent in the low fuel price case. The estimated mode shift risk for these corridors ranges from 14 to 46 percent, with an average of 22 percent for the high fuel price scenario; no transport mode risk estimates are reported for the low fuel price alternative. With respect to short-sea container shipping, the study estimates marine cost increases of 21 to 28 percent in the high fuel price case and 13 to 18 percent in the low fuel price case. With regard to short-sea shipping, the estimated mode shift risk for these corridors ranges from 25 to 35 percent with an average of 27 percent in the high fuel price scenario, and from 16 to 23 percent with an average of 17 percent in the low fuel price scenario. Results are also presented for the feeder ship case.

These results are significantly different from the results of other studies discussed in this section. However, these results are problematic due to the way in which truck fuel costs were handled. First, while the authors report that truck fuel prices are adjusted to reflect future fuel prices, they state that the adjustment was small. They note that "[t]he forecast rise in the market-dependent proportion of the fuel costs is only slightly above the inflation rate, at least for the lower limit of the corridor up to 2015. This means that only a small proportion of the rise remains after discounting to 2010 prices."[60] This is surprising given assumed increase in the price of distillate fuel of 82 percent in the high price case and 19 percent in the low price case. Alternatively, the authors may be assuming that the price of marine distillate fuel (MGO) is very different from the price of land distillate fuel; if this is the case, it is not explained. In either case, the negligible adjustment for truck fuel prices gives road transportation a large advantage over marine transportation in the analysis. Second, the analysis does not consider that, all things being equal, higher fuel prices for both modes would result in marine transportation becoming more advantageous compared to land transportation, all other things remaining equal. This is because as fuel prices increase, the more efficient mode of transportation on a ton-mile basis becomes more advantageous, not less.[DD] However, because results are not provided on a ton-

[DD] See for example the MARAD report described in Section 1.6.2.2, above. One peer reviewer notes that "the tradeoff between [marine and land transportation] may not be linear. As the price of oil goes up, the greater efficiency of using the marine mode might provoke a shift of freight to marine over rail; this would happen at the extremes of price when the cost of fuel is so great that it begins to trump the cost of intermodal handling needed to shift as much to marine as possible." (Belzer) mile basis, it is hard to evaluate the results of this study's methodology with respect to efficiency.

Finally, the analysis adjusts the percent contribution of fuel costs to total costs, for each of the future fuel price scenarios, although this is not explained. Nor do the authors explain whether the assumption that labor costs, capital costs, and other variable and fixed costs will not change as fuel prices increase by 20 percent to 80 percent is reasonable. By assuming all other costs are constant, marine transportation is again disadvantaged compared to truck costs with respect to increasing fuel prices, since it means that marine operating costs are adjusted a significant amount while truck operating costs are adjusted minimally if at all.

The final section of the report discusses policy options that may reduce the estimated impacts of the ECA fuel controls. Ship-based measures include the use of scrubbers, measures to reduce fuel consumption, and the use of alternative fuels. Other measures include increasing the cost of land transportation and subsidizing sea transportation, and applying the 0.5 percent 2020 global sulfur limit in the Baltic and North Sea ECAs instead of the revised ECA fuel sulfur limit. According to the results presented in this section, such a change in the fuel sulfur content would decrease the risk of transport mode shift to 2 percent, on average, for the RoRo markets and to 3 percent, on average, for the short-sea container markets. This analysis is performed for 2008, however, and may not be comparable to the analysis for 2015 performed for 0.1 percent fuel sulfur described above. In addition, the analysis relies on a fuel price of about $515/tonne in the high price case, which is very similar to the HFO price used in the low price analysis for the 1,000 ppm fuel sulfur limit. This price for HFO suggests that the authors assume fuel meeting such a limit would be residual fuel. Even assuming that an inexpensive 0.5% sulfur residual fuel can be produced in the quantities needed for the Baltic and North Sea ECAs, which is by no means certain, Purvin and Gertz (below) estimate that the cost increase of 0.5% sulfur fuel would be significantly higher than assumed by ISL. If, alternatively, 0.5 percent sulfur fuel is a distillate fuel, the advantages of applying the global fuel sulfur limit instead of the new ECA fuel limits would be reduced.

With regard to the mode shift analysis, it is difficult to evaluate the methodology used without a more detailed explanation of how these results were obtained. Specifically, it is not clear how to evaluate the risk of shift without a better understanding of how the logit model was constructed and the data inputs used to obtain those results, particularly the cost for the truck alternatives and how the routes were evaluated (on a route basis or some other metric).

1.7.4 Purvin & Gertz Fuel Study, 2009.

Purvin & Gertz (PGI) performed a study for the European Commission on the impacts of the Annex VI fuel sulfur limits on the European refining industry.[61] In determining the refinery investment and product pricing impacts, this study considered a number of scenarios for producing 0.5% sulfur fuel to meet the global requirement and 0.1% sulfur fuel to meet the SECA requirement in the Baltic and North Sea.

PGI estimates that the price of 0.1% sulfur marine fuel will be in the range of $250 to $300/tonne more than 1.5% sulfur HFO, which until recently, was used in the Baltic and North Sea SECAs. PGI presents scenarios where 0.1% sulfur fuel could be produced as a residual or distillate fuel. PGI states that most cases result in prices similar to MGO (distillate), even when a 0.1% sulfur HFO is produced.

PGI also estimates that the 0.5% sulfur fuel will be in the range of $120 to $170/tonne more expensive than heavy fuel oil meeting the global 3.5% fuel sulfur limit. The difference between 0.5% sulfur fuel and HFO meeting the current 1.0% fuel sulfur limit in SECAs is estimated to be in the range of $80 to $140/tonne. This range based on scenarios where HFO is produced that meets the 0.5% sulfur limit. Although one scenario was modeled for the production of a 0.5% sulfur distillate fuel, this scenario showed higher prices than current MGO and was not considered in the range presented by PGI.

PGI bases its costs primarily on the desulfurization of residual fuel oil. However, this report makes no assessment of the availability of low sulfur crude or low sulfur refinery feedstocks that would be needed for this approach. Note that these crudes and feedstocks are of high value to modern refineries. PGI's cost assessment assumes that these components are available at the volumes needed to produce the projected amounts of low sulfur marine fuel. This cost assessment also assumes that refiners would invest in residual fuel desulfurization equipment rather than in equipment that would increase the distillate production. Given the similar capital costs of the associated equipment and the much higher value of distillate products, it is not clear that this would be the case.

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[16] See Chapters 2, 3, 5, 6, and 7 of the Regulatory Impact Analysis prepared for the rule, available at http://www.epa.gov/otaq/regs/nonroad/marine/ci/420r09019.pdf

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[51] Swedish Maritime Administration. Consequences of the IMO's New Marine Fuel Sulphur Regulations. May 2009. A copy of this report can be found at: http://anchortime.com/portal/images/stories/PDF/Consequences%20of%20the%20IMOs%20New%20Marine%20Fuel%20Sulphur%20Regulations.pdf

[52] Ibid., 34.

[53] Ibid, p. 34.

[54] Ibid, p. 5.

[55] European Community Shipowners Associations (ESCA). Analysis of the Consequences of Low Sulphur Fuel Requirements. January, 2010. A copy of this study can be found at: http://www.ecsa.be/newsletters/itmmastudy.pdf

[56] Ibid, p. 7.

[57] SKEMA. Impact Study of the future requirements of Annex VI of the MARPOL Convention on Short-sea Shippping" Project supported by the European Commission, Directorate- General for Energy and Transportation. June 2010. A copy of this study can be downloaded from: http://www.eskema.eu/defaultinfo.aspx?topicid=189&index=1 (download document 1)

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[59] Institut fur Seeverkehrswirtschaft and Logistic, ISL. Reducing the sulphur content of shipping fuels further to 0.1% in the North Sea and Baltic Sea in 2015: Consequences for shipping in this shipping area. Final Report. September 2010. A copy of this report can be found at: http://www.reederverband.de/files/images/GermanISLStudyonSECAimpacts.PDF

[60] Ibid, pp. 4-17.

[61] Purvin & Gertz, Inc. Impacts on the EU Refining Industry & Markets of IMO Specification Changes & Other Measures to Reduce the Sulphur Content of Certain Fuels. Prepared for Directorate General Environment. June, 2009. A copy of this report can be found at http://ec.europa.eu/environment/air/transport/pdf/impacts_refineries.pdf

CHAPTER 2: Transportation Shift Analysis

Transportation mode shift refers to users of a particular method of transportation changing to a different method in response to a change in the market. In the context of the Great Lakes, industry stakeholders commented that the application to the Great Lakes of certain provisions of the Category 3 marine rule, and the long-term ECA fuel sulfur limits in particularly, could lead to higher freight rates, which would make rail transportation more attractive to shippers.

This chapter examines the impacts of the Category 3 marine rule on Great Lakes shipping with respect to transportation mode shift. This study was carried out consistent with Congressional recommendation[1] and in response to specific Great Lakes stakeholder concerns. We engaged with these stakeholders throughout the development of the analysis, particularly with respect to the choice of scenarios studied, the methodology used, and important data inputs. Appendix 2A contains a chronology of stakeholder outreach. Appendix 2A also contains information about EPA's June 10, 2010 stakeholder workshop and a list of stakeholders who attended the workshop. Appendix 2B contains the presentation used at that workshop.

This analysis is based on modeling performed for EPA by ICF International and its subcontractor, Energy and Environmental Research Associates (EERA). [A] This chapter summarizes the results of that modeling and describes key data inputs. The final contractor report is contained in Appendix 2C. The analysis shows that compliance with the ECA fuel sulfur requirements is unlikely to lead to transportation mode shift on the at-risk routes studied.

2.1 Summary and Results

This study examines the economic impacts of applying the Category 3 marine rule to Great Lakes shipping. Consistent with stakeholder comments, the study focuses on the impacts of increased fuel costs associated with the use of reduced sulfur ECA fuel. Section 2.2 contains a description of the scope of the analysis with respect to the standards included, geographic area, and ship types.

The analysis uses a route-based approach in which the impacts of applying the Category 3 marine program are estimated for a discrete number of trade routes that were identified by stakeholders as being at-risk for transportation mode shift, source shift, or production shift due to increases in fuel costs associated with the requirement to use ECA fuel on the Great Lakes. It should be noted that the results of this analysis are specific to the O/D pairs examined, and are not estimates of average freight rate increases across the fleet or estimates of average mode shift impacts. However, if fuel cost increases of the magnitude expected from switching to ECA-compliant fuel on the Great Lakes do not indicate a transportation mode shift on these at-risk routes, where the price difference between marine transportation and the all-rail alternative is close enough to be of concern to stakeholders, then transportation mode shift on other routes without such price pressures would not likely be indicated. Section 2.3 explains the route-based

[A] Final Report: Analysis of Impacts of Category 3 Marine Rule on Great Lakes Shipping, September 2010. EPA Contract No. EP-C-06-094, Work Assignment 3-16. See also Bibliography provided by the contractor, provided in Appendix D.

approach and Section 2.4 describes the sixteen scenarios that form the basis of this analysis and how they were selected. Finally, Section 2.5 describes key data used in the analysis.

Transportation mode shift analysis was performed for twelve Great Lakes trade routes identified: four each for coal, iron ore, and grain (the four crushed stone scenarios are the subject of source shift analysis; see Chapter 3). Transportation mode shift is assessed by estimating the impacts of an increase in operating costs associated with the marine control program on a scenario-specific freight rate and comparing the adjusted freight rate to an all-rail alternative for that scenario. To perform this analysis, the optimal transportation route that contains a marine link was identified for each scenario. This route is intended to maximize the use of the Great Lakes across the overall route. It should be noted that nearly all of the Base Case scenarios contain both a marine and a rail link, since each commodity must be transported from the origination site to a Great Lakes departure port and from the arrival port to the end user. Next, the total freight rate was estimated for each scenario that incorporates the combined marine and rail segments. This freight rate is then adjusted to reflect the increased costs associated with the control program. An activity-based fuel consumption and cost model is used that accounts for vessel operation "at sea" and "in port." Then, an All-Rail Alternative route was identified for each scenario. Next, a route-based freight rate was estimated for each scenario. This Base Case freight rate incorporates the combined marine and rail segments. To determine if transportation mode shift is indicated, the Base Case freight rate was then adjusted to reflect the use of ECA-compliant fuel on the marine link. The incremental change in fuel costs associated with using ECA-compliant MDO fuel was estimated using an activity-based fuel consumption and cost model that accounts for vessel operation "at sea" and "in port." This adjusted freight rate is called the ECA MDO Case freight rate. Finally, the ECA MDO Case freight rate was then compared to the All-Rail Alternative Route freight rate for that scenario to determine which route has the higher freight rate. If the freight rate for the ECA MDO Case is less than that of the All-Rail Alternative Route, then no transportation mode shift to rail is indicated for these at-risk routes. Appendix 2C contains more information about the transportation mode shift modeling.

The results of the analysis are set out in Table 2-1. In addition to the twelve transportation mode shift cases, freight rate impacts are also presented for the four gravel cases.

Table 2-1 Detailed Scenario Results

	Origin/Destination	Base Case Total Freight Rate[a]	ECA (MDO) Case Total Freight Rate[b]	Base to ECA[c] (% Diff)	All-Rail Scenario Total Freight Rate	ECA to All-Rail (% Diff)
1	Coal from Rosebud Mine, MT to Bayfront Power Plant, Ashland, WI	$19.99	$20.23	1.2%	$21.71	-7.3%
2	Coal from Elk Creek Mine, CO to Georgia Pacific West Mill, Green Bay, WI	--[d]	--[d]	--[d]	--[d]	--[d]
3	Coal from Rosebud Mine, MT to DTE Power Plants, St. Clair and Monroe, MI	$21.19	$22.00	3.8%	$27.44	-24.7%
4	Coal from Rosebud Mine, MT to Weadock & Kam Generating Plants, Essexville, MI	$25.28	$26.41	4.5%	$28.12	-6.5%
5	Iron Ore from Empire and Tilden Mines, Palmer, MI to Algoma Steel Algoma, ON	$4.12	$4.47	8.5%	$5.22	-16.8%
6	Iron Ore from Quebec Cartier Mining Co., QC to ArcelorMittal, Burns Harbor, IN	$16.10	$18.77	16.6%	--	N/A
7	Iron Ore from Hull Rust Mine, Hibbing, MN to U.S. Steel, Gary, IN	$6.21	$7.14	15.0%	$11.99	-67.9%
8	Iron Ore from Northshore Mining, Babbit, MN to Severstal Steel, Warren, OH	$6.83	$7.73	13.2%	$18.37	-137.6%
9	Grain from Lake Calumet, IL to Baie Comeau, QC	$22.00	$24.11	9.6%	$46.75	-93.9%
10	Grain from Duluth, MN to Baie Comeau, QC	$19.78	$21.82	10.3%	$59.57	-173.0%
11	Grain from Duluth, MN to WNY Energy Ethanol Plant, Medina, NY	$22.43	$23.93	6.7%	$36.62	-53.0%
12	Grain from Goderich, ON to Nabisco Flour Mill, Toledo, OH	$9.12	$9.95	9.1%	$11.80	-18.6%
13	Stone from Port Dolomite, MI to J.M. Stuart Power Plant, Aberdeen, OH	$10.89	$11.15	2.4%	--	N/A
14	Stone from Calcite, MI to J.M. Stuart Power Plant, Aberdeen, OH	$8.91	$9.14	2.6%	--	N/A
15	Stone from Calcite, MI to American Crystal Sugar Co., Crookstone, MN	$12.04	$12.39	2.9%	--	N/A
16	Stone from Quarry at Calcite, MI to Bruce Mansfield Power Station, Shippingport, PA	$6.51	$6.82	4.8%	--	N/A

[a] Modeled baseline freight rates ($/ton) using 2007 fuel prices adjusted for the Great Lakes market (2008$): HFO at $424/MT
[b] Adjusted control freight rates ($/ton) using 2007 fuel prices adjusted for the Great Lakes market (2008$); MDO at $617/MT
[c] 45.5% fuel price increase
[d] Results are inconclusive due to mis-specification of the scenario. See discussion in text.

With regard to the impacts of the cost of complying with the 1,000 ppm ECA marine fuel sulfur limit on total route freight rates, these results show an estimated increase in the Base Case freight rate from about 1.2 percent to 16.6 percent, depending on the route. When considered by commodity, the estimated freight rate increases reflect, in part, the share of the marine portion to the total route. The stone and coal cases generally have a shorter marine link, and the estimated percent increase in the freight rate for these scenarios is less than 5 percent. The coal and iron ore cases have a longer marine link, with the freight moved by ship from the mine directly to the using facility, and the estimated percent increase in the freight rate is about 17 percent and 11 percent respectively. In all cases, given that transportation is only one part of the cost of these raw materials, which are only one input for final goods produced using them, these small freight rate increases are unlikely to have a significant economic impact overall.[B]

With regard to transportation mode shift, the results contained in Table 2-1 show that the ECA Case freight rate for the marine transportation mode is expected to remain well below the All-Rail Alternative freight rate for ten of the twelve scenarios examined, with the difference ranging from 6.5 percent to as much as 173 percent. Therefore, no transportation mode shift is indicated.

Scenario 2 consists of coal transported from the Elk Creek Mine in Colorado through South Chicago to the Georgia Pacific paper mill in Green Bay, Wisconsin. The initial results for this scenario, reported in Appendix C to this chapter, suggest that the route-based freight rate for the All-Rail Alternative ($24.43) is less than both the Base Case and the ECA Case freight rates ($26.03 and $26.64, respectively). This contrary result led EPA to perform additional research with regard to this facility. The information obtained by EPA indicates that, due to quality specifications for the coal used by this facility, the western bituminous coal used in this paper mill is blended with other coal to obtain the product needed.[2,3] The blended coal is obtained from a source in South Chicago, where the KCBX Terminal can store up to 1 million net tons of coal on site and can blend up to three coals for a customer. Consequently, this case was mis-specified. However, it is unclear whether the transportation costs for this case should be based solely on the cost of transporting coal from the terminal in Chicago to the facility in Green Bay, or whether some portion of the transportation cost from the mine head(s) should be included. This question could be important because this facility also receives coal by ship from Sandusky and Ashtabula, Ohio, and vessels operating from those facilities are also required to use ECA-compliant fuel.[4] For these reasons, and because freight rates for a revised scenario are not readily available, it is not possible to determine the potential for transportation mode shift impacts for this route.

[B] One peer reviewer noted "[r]esearchers are correct to conclude that the increment of higher cost due to the fuel change is so small that it is lost in the noise of price changes. Indeed, the cost of some of these raw materials, most notably iron ore, coal, and grain, have increased dramatically just in the last year because of global demand for raw materials such as iron ore and coal, and weather-related pressure on grain prices due to the drought and fires in Russia in 2010. U.S. public policy that subsidizes corn production for ethanol has driven up grain prices even further. The additional fraction of a percent of cost for cleaner fuel is a very small increment – one that by itself would not be noticed in fuel price because other factors, such as the foregoing, put much greater pressure on price. The recent flooding in Queensland may have a greater impact on commodity prices than the cost of lower sulfur more refined fuel." (Belzer)

Scenario 6 consists of iron ore transported from Quebec Cartier Mining Co., in Quebec, to ArcelorMittal, in Burns Harbor, Indiana. Transportation mode shift to rail is impractical for this scenario because there is no access to a national highway or rail line at the mine in Quebec. However, this scenario is similar to Scenario 9, which also involves transportation of cargo (grain) the length of the St. Lawrence Seaway, and the All-Rail Alternative route for that scenario can be used to estimate the likelihood of transportation mode shift for Scenario 6. As indicated in Table ES-1, the All-Rail Alternative freight rate for Scenario 9 exceeds the ECA Case freight rate and no transportation mode shift is indicated. The use of this rail alternative would likely be even less favorable for Scenario 6 because it would require transportation by ship to the rail port on the opposite shore of the Gulf of St. Lawrence, with associated cargo transfers.

2.2 Scope of Analysis

This section describes specific characteristics of the Category 3 program and the Great Lakes shipping industry that are included in the analysis, with respect to the year of analysis, the geographic scope, the standards modeled, and the vessels included. In general, the application of the long-term ECA standards to the captive fleet of Great Lakes Category 3 ships operating in to all areas of the Great Lakes.

2.2.1 Year of Analysis

The long-term international ECA fuel sulfur limits will go into effect in 2015, pursuant to Regulation 14 of MARPOL Annex VI. As a result, the year of analysis for this study ideally would be 2015. Using 2015 as the year of analysis, however, would require estimated projected values of several key inputs, one of the most important of which is estimated freight rates. Freight rates reflect all costs associated with shipping, including fuel, insurance, repairs and maintenance, crew, capital, overhead, dock fees and taxes. Because of the lack of publically-available freight rates, this analysis relies on estimated rates (see below and Chapter 4 of the study included in Appendix 2C). While it may be possible to project some freight rate inputs (e.g., projected fuel prices using widely accepted data from a reliable source such as the Energy Information Agency), it is not possible to project the future prices of other inputs, such as labor or capital costs. Similarly, some other costs important to the analyses contained in Chapter 3 are not easily projected, including the price of crushed stone or electrical generating and steel sector revenues.

As a result, the year of analysis for this study is 2007. The analysis estimates the impacts of switching from unregulated fuel to ECA compliant fuel on the Great Lakes based on 2007 freight rates, fuel prices, and other conditions, and assumes the estimated results are indicative of the expected impacts in 2015, all other conditions not affected by the program held constant. This approach is appropriate because this is a route-based study that considers the impacts of the program on freight rates for at-risk routes, as opposed to a longitudinal study like the analysis performed for our Category 3 rule that compares aggregated estimated compliance costs to monetized benefits for several future years.

2.2.2 Geographic Area

The broad geographic area included in this analysis includes the five Great Lakes and the St. Lawrence Seaway. It should be noted, however, that the actual area of shipping activity is scenario specific. In some scenarios activity may be limited to specified portions of one of the Great Lakes; for others, activity may reach from the western edges of the Great Lakes to the eastern edge of the St. Lawrence Seaway.

Although the Canadian program to implement the ECA standards is still under development, this analysis assumes uniform application of the ECA fuel sulfur requirements across the entire marine leg of each route, on both the U.S. and Canadian portions of the Great Lakes/St. Lawrence Seaway system. This approach is therefore conservative in that it applies the higher price ECA fuel to the entire marine segment. Chapter 1 explains the legal application of the ECA standards to non-U.S. vessels on the U.S. portions of the Great Lakes.

2.2.3 Standards Included in the Analysis

Consistent with the concerns raised by Great Lakes stakeholder commenters on our Category 3 rule, this analysis examines the impacts of complying with the 1,000 ppm ECA fuel sulfur limit on the Great Lakes.

We do not consider the international interim 10,000 ppm fuel sulfur limit in this analysis. That standard began to apply to the European ECAs in July 2010 and that will begin to apply to the North American ECA in August, 2012. The application of this interim standard is not expected to have a significant impact on Great Lakes shipping due to inclusion of a fuel availability waiver provision for that fuel in the Category 3 rule (see Section 1.5.2.1). We also do not consider the new tiers of global fuel sulfur limits that will apply outside areas that are not designated ECAs. As noted above, the analysis assumes uniform application of the ECA fuel sulfur requirements across the Great Lakes and therefore the global fuel sulfur limits are not relevant.

We also do not consider the impacts of the engine NO_X standards contained in EPA's Category 3 program and in MARPOL Annex VI (see Table 1-5 and associated text). The Tier 3 engine NO_X emissions standards apply to a ship operating in a designated ECA only if the ship was constructed on or after January 1, 2016. Great Lakes vessels operate in fresh water and therefore they have long service lives; new vessels are only rarely built and no new vessels have been introduced into the U.S. fleet since the early 1980s. As a result it is difficult to anticipate how that standard would affect the Great Lakes fleet beginning in 2016. The application of the Tier 2 engine NO_X limits and the standards for certain existing Category 3 engines[C] is not dependent on ECA designation for the Great Lakes and therefore are also not included in the analysis.

[C] The MARPOL Annex VI Category 3 existing engine standards apply to marine diesel engines with a power output of more than 5,000 kW and a per cylinder displacement at or above 90 liters installed on a ship constructed on or after 1 January 1990 but prior to 1 January 2000 (Regulation 13.7.1). Note that this requirement depends on the availability of a certified approved method (i.e., remanufacture system).

We do not consider the impacts of engine retrofitting in our analysis. Neither the Clean Air Act requirements nor MARPOL Annex VI contain a mandatory requirement for a ship owner to retrofit an existing vessel with cleaner, more efficient engines. Retrofitting Great Lakes ships would be done in response to individual company concerns, for fuel efficiency, maintenance, or environmental reasons. If a ship owner decides to retrofit, however, the owner may be required to use an engine that meets the emission standards in effect at that time. We include an estimate of the cost of engine retrofitting U.S. Category 3 ships in Chapter 7 in response to stakeholder questions.

2.2.4 Vessels

With regard to the vessels modeled, we consider the impacts of the ECA fuel limits on only vessels with Category 3 marine diesel engines. Category 3 engines are defined as engines with a per cylinder displacement at or above 30 liters (40 CFR 94.2; 40 CFR 1042.901). These are high power, low speed (rpm) engines that are typically designed to use HFO, although they can be operated on distillate fuel.[D] Ships with smaller, Category 2, propulsion engines are not included in this analysis because they do not generally operate on HFO. While these vessels may often be indistinguishable from and perform the same function as vessels with Category 3 propulsion engines, vessels with Category 2 marine diesel propulsion engines are not typically equipped with the fuel handling systems and storage tanks that are necessary to use HFO. In the United States, marine distillate fuel used in vessels with Category 2 and smaller propulsion engines is already subject to stringent fuel sulfur controls that are unaffected by ECA fuel controls (see Chapter 1). Steamships that operate on the Great Lakes are also not included in this analysis. While they also use HFO, they are exempt from the ECA fuel requirements due to technical and safety issues (40 CFR 1043.95).

The St. Clair, John J. Boland, and the Hon. James L. Oberstar (formerly named the Charles M. Beeghly) in layup for the winter of 2002 in Sturgeon Bay. Source: Taken by and used with permission from Dick Lund, available at: http://www.dlund.20m.com/custom.html#A.

[D] Chapter 6 discusses equipment changes that may be necessary for these vessels to operate on distillate fuel.

The analysis focuses on ships that operate solely on the Great Lakes and none of the scenarios specifically address the impacts on "salties" (ocean-going ships that operate only sporadically in the Great Lakes). As noted in Chapter 1, salties carry only a small share of cargo on the Great Lakes, mainly grain for export. These salties will be required to use ECA compliant fuel while operating within the North American ECA boundaries, the outer boundary of which is about 200 nautical miles from the U.S. and Canadian coasts. While salties bring containers as far down the seaway as Montreal we did not think it appropriate to include these ships in this analysis because the purpose of the analysis is to evaluate the impacts of EPA's Category 3 rule on Great Lakes shipping. In addition, container shipping has not caught on in the Great Lakes. While several studies over the past 25 years have investigated the potential for Europe-to-Great Lakes direct container shipping or feeder shipping links with East Coast Ports,[E] this market continues to be undeveloped, in part because infrastructure (port facilities; draft restrictions) and scheduling constraints make it difficult for short-sea shipping on the Great Lakes to compete with the preferred rail alternative.[F]

2.2.5 Flag Neutral

This analysis is flag neutral. It is based on the fuel and vessel characteristics described in this chapter and not on the characteristics for particular vessels operating under particular flags in particular ways. As explained in Chapter 1, the application of the ECA fuel requirements on the U.S. portions of the Great Lakes and St. Lawrence Seaway will apply to all ships, U.S., Canadian, and foreign, while operating in the regulated areas.

2.3 A Route-Based Approach

In choosing an analytic methodology used to perform this analysis, EPA considered several approaches including general equilibrium modeling, a fleet average approach, and a route-based approach.

The broadest type of economic modeling, general equilibrium modeling, examines the impact of a program by modeling all of its submarkets simultaneously.[G] This type of model can be used to estimate the impact of a cost change across an entire economic system. However, this type of broad-based modeling is not appropriate for this study. Available general equilibrium models typically estimate impacts across an economy as a whole and are not constructed in a way that would allow analysis of specific transportation links or examination of the extent to which the raw materials and goods currently transported by one mode (ship) would shift to

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[E] See Chapter 1 for a discussion of a few of these studies.

[F] While one peer reviewer included detailed comments about the future potential for container shipping on the Great Lakes (Hull), other comments from industry representatives at a meeting sponsored by the Maritime Administration in Cleveland, Ohio on February 15, 2011 suggested they do not expect growth in this sector. One industry representative noted that it is not possible to establish this type of container service without customers but the customer is reluctant to use ships because there is no service. Lack of port infrastructure for handing containers, draft restrictions, and ballast water restrictions were also noted as barriers to short-sea shipping. Finally, it was noted that railroads are not subject to seasonality constraints.

[G] One peer reviewer noted that "the broadest type of economic model, a macroeconomic model such as that incorporated in REMI and IMPLAN, would be the best to do a full benefit/cost analysis. This was not required for this particular study, and thus it was not necessary to incur the additional cost, as mode, production, and source shifts were in question in this case." (Belzer) another (rail or truck). It would also not be feasible to construct a model for the purpose of this analysis as these models also require a great deal of data and information for potentially hundreds of submarkets.

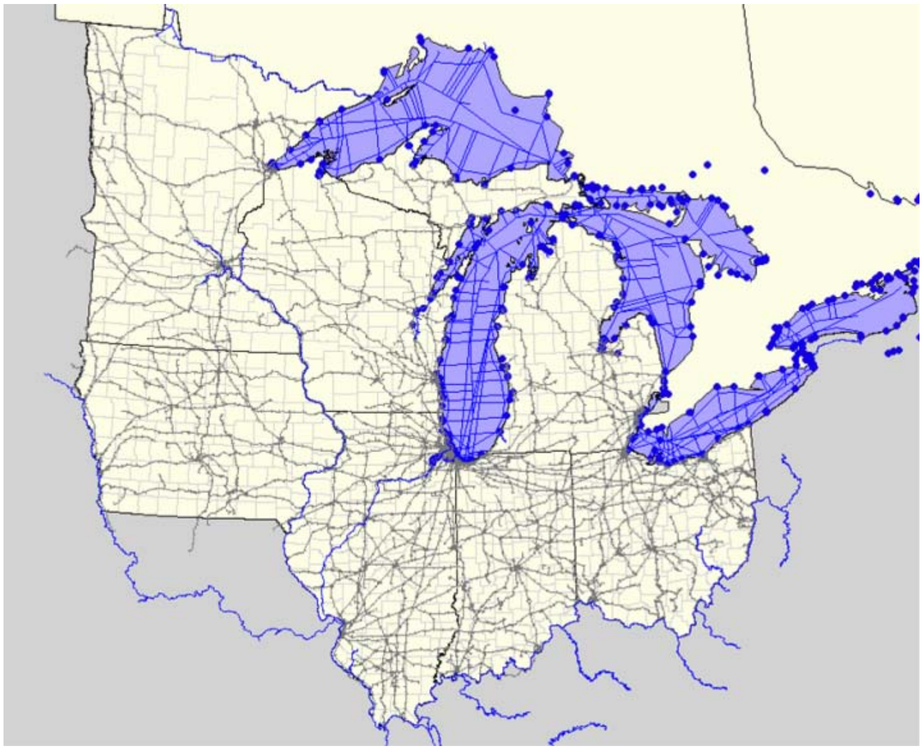
Similarly, while a fleet average approach like that used in the 2009 Canadian Shipowners' Association study (see Section 1.6.3.2) would permit focusing on Great Lakes transportation and reduces the data needs, it would also require a significant amount of information, much of it considered to be confidential by the affected industry. Also, this approach requires creating an average vessel and average route which may not be useful to model the impacts of a fuel cost increase on a transportation market with as much variation as the Great Lakes. This approach would also require development of a more robust estimation of a modal shift factor for each type of cargo, which would still require a more thorough market-based analysis.

The method used in this analysis is a route-based approach. Developed by ICF International and their subcontractor, EERA, it is based on combination of geospatial and cost modeling. In this approach, a shipping route is identified for each O/D pair using the Intermodal Freight Transport (GIFT) model they developed with funding from the United States Maritime Administration (MARAD). Then, freight rates are adjusted to account for an increase in fuel costs and compared with the least cost land-based alternative. A route-based approach allows us to take advantage of available information while recognizing the complexity of the Great Lakes transportation system. It also allows us to tailor the research to those routes that are of most interest to stakeholders: those that are at risk for transportation mode shift. This general approach was shared with stakeholders at a workshop on June 10, 2010 and received general support.

2.4 Selection of Origin/Destination Pairs and Shipping Routes

It would not be feasible to look at the impact of the ECA fuel sulfur limits on every potential O/D pair for Great Lakes cargo using a route-based approach. As illustrated in Figure 2-1, there are thousands of potential combinations and the data requirements and modeling for such an effort would be enormous, with respect to the types of ships, cargoes carried, and frequency with which the routes are used. As a result, a more manageable approach was taken for this study in which analysis is performed for a small number of specified O/D pairs believed to be most at risk for transportation mode shift. This section describes the selection of O/D pairs and shipping routes.

Figure 2-1 Great Lakes Maritime Docks, Waterways and Railroads



Source: Department of Geography and Planning: Center for Geographic Information Sciences and Applied Geographics (GISAG), 2007

2.4.1 Selection of Origin/Destination Pairs

To ensure that the study responds to the Great Lakes stakeholder concerns, we requested industry assistance to identify the routes to be examined. Specifically, we asked stakeholders to identify Great Lakes trade routes they believe are most at risk of transportation mode shift due to an increase in operating costs (i.e., the price difference between marine transportation and the all-rail alternative is close enough to be of concern to stakeholders).

Several stakeholders responded to EPA's request, resulting in a list of about fifty at-risk trade routes for several commodities (e.g., iron ore/Duluth to Conneaut).[H] EPA selected 16 of these routes, representing each of the four main cargoes carried on the Great Lakes (coal, iron ore, grain, and stone)[I] and a variety of geographic locations extending from Duluth, Minnesota, to Baie Comeau, Quebec, to define the sixteen O/D pairs used in this analysis. These sixteen O/D pairs were selected to include routes that were contained on more than one stakeholder list, where possible.

We forwarded the 16 O/D pairs to the primary industry trade organizations, asking them to share the list with their members and to let us know if they would like to replace any of the

[H] Because the respondents indicated their suggested routes were confidential business information (CBI), the entire list is not replicated in this report.

[I] The importance of grain as a Great Lakes cargo has been declining in recent years; see http://www.lcaships.com/08SR%20dry-bulk%20commerce%20-%20text.pdf

O/D pairs with a different route.[5] This method was chosen to ensure that a maximum of Great Lakes shipping company representatives, and not simply those that had participated in the EPA public meeting, had a chance to review the list. We received no adverse comment on this list.

We then proceeded to develop the final list of O/D pairs with respect to actual location of mines/silo and the production facility that uses the commodity. We did this using information furnished by stakeholders and public resources. We did not call the production facilities or the mines for detailed information about their shipments and transportation routes. Instead, we assume that at least a portion of these routes contains a ship segment, since all O/D pairs were suggested by Great Lakes stakeholders. Note that we do not assume that all shipments from or to these facilities are by ship; we only assume that at least some are. The final list of O/D pairs is set out in Table 2-2.

Table 2-2 Summary of Scenario Routes and Cargo Types

SCENARIO	ORIGIN & PORT USED	DESTINATION & PORT USED	CARGO TYPE
1	Rosebud Mine - Superior	Bayfront Power Plant – Ashland, WI	Coal
2	Elk Creek Mine – South Chicago	GP West Mill – Green Bay	Coal
3	Rosebud Mine - Superior	DTE Power Plants – Port Huron	Coal
4	Rosebud Mine - Superior	Weadock & Karn Generating Plants - Essexville	Coal
5	Empire and Tilden Mines - Marquette	Algoma Steel - Algoma	Iron Ore
6	Quebec Cartier Mining Co. – Port Cartier	ArcelorMittal – Chicago/Burns Harbor	Iron Ore
7	Hull Rust Mine - Duluth	U.S. Steel - Gary	Iron Ore
8	Northshore Mining – Silver Bay	Severstal - Ashtabula	Iron Ore
9	Lake Calumet Grain Elevators - Chicago	Export to Rest of World (RoW) – Baie Comeau	Grain
10	Duluth Port Grain Elevators	Export to RoW – Baie Comeau	Grain
11	Duluth Port Grain Elevators	WNY Ethanol Plant - Buffalo	Grain
12	Goderich Port Grain Elevators	Nabisco Flour Mill - Toledo	Grain
13	Port Dolomite	J.M. Stuart Power Plant - Toledo	Stone
14	Calcite Quarry and Port	J.M. Stuart Power Plant - Toledo	Stone
15	Calcite Quarry and Port	American Crystal Sugar Co. - Duluth	Stone
16	Calcite Quarry and Port	Bruce Mansfield Power Station - Ashtabula	Stone

It should be emphasized that these 16 O/D pairs were not randomly selected from the combined list of potential pairs provided by stakeholders, nor was the original list a random selection of possible Great Lakes shipping routes. As a result, this list of 16 at-risk O/D pairs is not meant to be representative of all Great Lakes cargo traffic, nor are these meant to be "typical" routes that could be used to the estimate the economic impacts of the Category 3 rule on all Great Lakes shipping and a general analysis of transportation mode shift. Instead, the original set of 50 O/D trade routes was identified by stakeholders as being at risk of transportation mode shift and the final set of 16 O/D pairs was purposefully selected based on cargo type and geographic factors. This is important to keep in mind especially because these at-risk O/D pairs may not be typical and the amount of cargo shipped to these destinations may be only a small portion of total Great Lakes cargo in any one year. However, if fuel cost increases of the magnitude expected from switching to ECA-compliant fuel on the Great Lakes do not indicate a transportation mode shift on these at-risk routes, where the price difference between marine transportation and the all-rail alternative is close enough to be of concern to stakeholders, then transportation mode shift on other routes without such price pressures would not likely be indicated.[J]

2.4.2 Development of Shipping Routes

Shipping routes were constructed for each of the selected O/D pairs using the Geospatial Intermodal Freight Transport (GIFT) model developed by EERA with funding from the United States Maritime Administration. These routes include all transportation links from the source of the cargo (e.g., mine head, grain silo, and quarry) to the using facility. This is an important feature of the analysis because it allows consideration of the impacts of the cost of ECA fuel on the freight rate (in $/ton) for the entire trip and it allows identification of a reasonable all-land alternative route that would be used if there were transportation mode shift.

The **Default Scenario Route** for each of the 16 O/D pairs is modeled to represent the current transportation route between the originating producer of the material being transported and the using facility. The Default Scenario Route either makes use of the Great Lakes for a portion of the overall route when the source or destination of the commodity is inland, or represents a port-to-port route when the source and destination of the commodity are both at a port. We assume that the marine segment for each of the routes is currently serviced or can be serviced by Category 3 vessels that would be required to comply with the ECA fuel sulfur limits.

The Default Scenario Route is intended to maximize the use of the Great Lakes across the overall route, and may include legs of overland travel, where the specified origin and/or destination of the commodity are inland. In some scenarios (coal and grain, Scenarios 1, 2, 3, 4, 13, 14, 15, 16), there is a large rail component; for the other scenarios (iron ore and stone, Scenarios 5, 6, 7, 8, 9, 10, 11, 12), the rail component is small or the entire route is by ship. None of these scenarios includes a highway truck transportation link. This is not surprising as rail transportation is less expensive that truck transportation, especially for the types of commodities under consideration.

The Default Scenario Route is used in both the <u>Base Case</u>, which models the use of HFO for the main engine and MDO for the auxiliary engine of the vessel; and the <u>MDO Case</u>, which models the use of MDO for both the main and auxiliary engine of the vessel.

[J] One peer reviewer considers EPA's selection of the sixteen O/D pairs in detail and concludes that a random selection among the possible 50 cases would be unlikely to yield much different results given that one third of the possible cases were used. This peer reviewer also notes that while "[o]ne might also be concerned [ ] that the EPA selected these cases systematically to identify O/D pairs that would be least likely to trigger the shifts … it is a thin reed because the results so strongly refute the contention that transportation mode shift, source shift, and production shift would occur from the higher fuel cost. (Belzer)

The **All-Rail Alternative Route** is modeled to represent an all-rail route from origin to destination.[K] An All-Rail Alternative Route was developed for eleven of the twelve iron ore, coal, and grain scenarios; during this phase of the analysis it was discovered that the mine in Scenario 6 has no access to a national rail line or highway (see discussion in Section 2.4.2.2 below). No All-Rail Alternative Route was developed for the crushed stone scenarios; instead, the alternative for these scenarios is to source the crushed stone from a quarry located closer to the using facility (see Section 2.4.2.4 below; Chapter 3 contains the source shift analysis for these scenarios).

The method used to create the Default Scenario and All-Rail Alternative routes is described in Appendix 2C to this chapter, as well as in Appendix 8B. An example transportation route is illustrated in Figure 2-2, for Scenario 7 (iron ore from Duluth, MN to Gary, IN).

Figure 2-2 Example of Route Mapping, Scenario 7

2.4.2.1 Coal Routes

For each coal O/D pair, this analysis assumes that the coal user purchases the coal from the originating mine. Therefore, the Default Scenario Route extends from the mine head to the

[K] An all-rail alternative was identified for eleven scenarios. An all-rail alternative was not identified for Scenario 6, nor for the four stone scenarios.

final user facility. Scenario 1 is coal from Montana, transported through Duluth/Superior to a power plant in Wisconsin; Scenario 2 is western bituminous coal from Colorado transported through South Chicago to a paper mill in Green Bay;[L] Scenario 3 is coal from Montana transported through Duluth/Superior to a pair of power plants in southern Michigan, and Scenario 4 is coal from Montana transported through Duluth/Superior to another power plant in Northern Michigan. These cases all involve an extensive rail link from a mine located fairly far inland to a Great Lakes port. In each case, the marine link is shorter than the rail link.

2.4.2.2 Iron Ore Routes

For each iron ore O/D pair, the Default Scenario Route also extends from the mine to the final user, although in these cases the mine is located much closer to the Great Lakes and therefore the rail segment in the base case is small compared to the marine link. The destination facilities are all steel mills, in Ontario (Scenario 5), Illinois (Scenario 6), Indiana (Scenario 7), and Ohio (Scenario 8). Scenario 8 is different from the other three in that the destination is located inland. This approach is reasonable given the amount of iron ore used by these facilities and given the fact that there are not many alternative uses for iron ore.[M]

For Scenario 6 there was no All-Rail Alternative Route identified. Scenario 6 consists of iron ore transported from Quebec Cartier Mining Co., Quebec, to ArcelorMittal in Burns Harbor, Indiana. There is no access to a national highway or rail line at the mine in Quebec. Because the analysis is based on the optimal route between this origin and destination using a ship/rail transportation mode, a more advantageous ship/rail alternative was not examined (any ship/rail combination would be less attractive than the all-ship method in the Default Scenario Route). However, this scenario was retained because it was identified by stakeholders as at-risk for transportation mode shift, and it is used in the production shift analysis included in Chapter 3.

2.4.2.3 Grain Routes

For each grain O/D pair, the Default Scenario Route extends from a grain silo complex located at a port to the final user. A silo origin was used for two reasons. First, it would not be feasible to track the transport of grain from individual farms origin points. Second, silos are regional gathering points for regional grain shipments for the least-cost land alternative transportation (rail) as well. In Scenarios 9 and 10, the destination is the export port in Baie Comeau, where the grain is transferred to ocean vessels. The destination in Scenario 11 is an ethanol plant in Buffalo, while the destination in Scenario 12 is a food processing plant in Toledo. All of these facilities are located at or close to port.

[L] Subsequent to completing the transportation mode shift analysis, EPA learned that while this facility uses Western bituminous coal, that coal is blended with other coal to meet the quality specifications for the coal used by this facility. This blending may occur in Chicago. See discussion in Section 2.1, above.

[M] One peer reviewer noted that in the 2009 Canadian Shipowners' study, the authors state: Marine transportation costs are a significant but not a majority component of the delivered cost of iron ore. … Transportation costs while an important factor in determining ore sourcing are often subordinate to considerations of ore quality, mine ownership, long term contracts, and overall corporate benefit. With respect to the latter point, the Ontario mills may at times source from a higher transportation cost origin in order to satisfy an overall corporate contract commitment. (Kruse)

For each of the Default Scenario Routes, because the route begins at a grain silo at the port, there is no rail component or it is very short. The All-Rail Alternative Route begins at the same grain silo as the Default Scenario Route.

2.4.2.4 Crushed Stone Routes

For each crushed stone O/D pair, the Default Scenario Route extends from the quarry, located in Michigan, to the final user facility. The Default Scenario Route was developed in a similar manner as for the other three commodities. The marine leg was maximized and rail was presumed to be used for the other cargo-laden leg(s) of the journey. However, instead of designing an alternate mode route originating at the given quarry in Michigan, the alternate stone case is one in which a competing quarry provides the stone to the customer. The methodology for this source shift analysis is described more in Section 3.1.

This different treatment of the stone trade in this study was suggested to EPA by the stakeholders, who expressed concerns that some other local quarry may offer limestone of sufficient quality to compete with Michigan quarries for utility customers who have need of lime for emissions scrubbing. This source-shift rather than mode-shift concept was reinforced when our contractor ascertained that there is no rail service available at the specified quarries in Michigan (see Scenarios 13-16, pages 53-59 of Appendix 2C), thus development of an all-rail mode-shift alternative would not be feasible.

The peer reviewers suggested that EPA evaluate competing routes from specific quarries that could offer comparable quality stone to that from Michigan. While this study did not attempt to verify transport routes from specific quarries with confirmed high-calcium scrubber stone products, we believe there is evidence that some quarries in states including Pennsylvania, Kentucky, Ohio and Iowa, may offer such products. Given the complexities of this approach, EPA chose to follow the competitive radius methodology used in the 2009 CSA study (see Section 1.6.3.2 of Chapter 1). EPA's analysis also assumes, for simplicity, that the stone travels solely by truck in the alternate case. EPA's research indicates that the American Crystal Sugar plant in MN (Scenario 15) and the Bruce Mansfield generating station in PA (Scenario 16) both have rail service, though the JM Stuart generating station in OH (Scenarios 13-14) may not have rail service.[6,7] EPA's research also indicates that both of the power plants in Scenarios 13, 14 and 16 periodically receive their limestone via river barges (*See* Note 7). Given the variables in designing a multi-mode route from a competing quarry, such as a rail/truck, truck/barge or rail/barge route, such an analysis may not provide meaningful results for comparison with the Default Scenario Route.

2.5 Data Inputs

The data inputs used to carry out the modeling for this analysis are described in detail in Appendix 2C to this chapter and summarized below. The fuel prices used in the analysis were supplied to the contractors by EPA and are also described below.

2.5.1 Scenario Characteristics - Marine

Many of the data used to represent the marine link in each of the routes included in this analysis are unique to that Default Scenario Route. These include the length of the route, port depth restrictions (which have an impact on the amount of cargo carried), and route restrictions (e.g., locks and canals which may limit the length of vessels that can be used on a route). These are all described in the report contained in Appendix 2C to this Chapter.

Data describing vessel and engine characteristics are common across groups of scenarios and are summarized in Table 2-3. It should be noted that these vessel and engine characteristics are not meant to represent the actual vessels that service these routes. The identities of those vessels are not easily available and likely to change from shipment to shipment and from year to year. In addition, there may be times when the route is serviced by a vessel with a Category 2 main propulsion engine. However, based on stakeholder input, we assume that there are Category 3 vessels that actually service each of these routes at least some of the time. These assumed characteristics are meant to describe a hypothetical vessel with a Category 3 main propulsion engine that could service each route given route restrictions (port depth, canal length, etc.) for that O/D pair.

Table 2-3 General Vessel Characteristics

Scenario	Vessel Length	Maximum Draft	Cargo Capacity	Main Engine Power	Operating Speed
Coal (1,2)	635 ft	28 ft	18,150 net tons	7,200 hp	12 knots / 14 mph
Coal (3,4)	1,000 ft	29 ft	57,200 net tons*	16,000 hp	14 knots / 16 mph
Iron Ore (5, 6)	635 ft	28 ft	18,150 net tons	7,200 hp	14 knots / 16 mph
Iron Ore (7, 8)	1,000 ft	29 ft	57,200 net tons	16,000 hp	14 knots / 16 mph
Grain (9, 10, 11, 12)	635 ft	28 ft	18,150 net tons	7,200 hp	12 knots / 14 mph
Stone (13, 14, 15, 16)	770 ft	29 ft	49,300 net tons	11,000 hp	14 knots / 16 mph
*Scenario 3 only; Scenario 4 has a lighter cargo capacity due to port restrictions					

Table 2-3 shows that two general vessel types are used for the coal, iron ore, and grain scenarios. One vessel has a length of 635 ft, main engine power of 7,200 hp, and has a cargo capacity of 18,150 net tons. This vessel has a draft of 28 ft and travels at 12 knots (14 mph) at cruise, although the iron ore ships are assumed to travel faster (14 knots or 16 mph). The other is a longer vessel, at 1,000 ft, powered by a 16,000 hp main engine and has a cargo capacity of 57,200 net tons. It has a draft of 29 feet and travels at 14 knots (16 mph) at cruise. The stone vessels are assumed to have a length of 770 ft, with main engine power of 11,000 hp and a cargo capacity of 49,300 net tons. The stone vessels travel at 14 knots (16 mph) and have a draft of 29 feet.

With regard to the main propulsion engine, these are assumed to be operated on HFO in the Base Case and distillate fuel in the ECA case. The engine specific fuel oil consumption is 196 to 236 g/kW-hr, depending on assumptions about vessel age. Total propulsion power is assumed to be 7,200 hp, 11,000 hp, or 16,000, depending on cargo (see Table 2-3). The load factor at sea is dependent on vessel speed; the load factor at port is assumed to be zero (the engines are assumed to not be operated at port).

With regard to auxiliary engines, these are assumed to be operated on distillate fuel (no auxiliary boilers). The engine specific fuel oil consumption is 221 g/kW-hr. Total auxiliary power for each vessel is equivalent to 3 percent of main engine power, and the auxiliary engine load factor in port and underway is 80 percent.

The analysis includes the fuel costs for a round trip on the marine segment of a scenario route but assumes that ships have empty backhauls. This approach was used both because not all routes have backhauls and not all ships on a route with backhauls (e.g., iron ore) will have a backhaul. As a result, the analysis is conservative because it assumes that no revenue is generated on the backhaul and all fuel costs are included in the one-way freight rate.

2.5.2 Scenario Characteristics - Rail

The methodology in this analysis included minimizing rail distances between cargo transfer points. Further information about the design and selection of rail services used in each scenario may be found in Appendix 2C and Chapter 8. The rail freight rates used in the analysis reflect a diesel fuel price equivalent to the MDO price described in Section 2.6.3. The analysis also assumes a rail energy intensity of 328 BTU/ton-mile for all rail links, in accordance with the national average forecast for 2015, published by the U.S. Energy Information Administration (EIA), in its Annual Energy Outlook (AEO). See Chapter 3 for a discussion of EPA's analysis of emissions from locomotives.

2.5.3 Marine Fuel Prices

The fuel prices used in this analysis were provided by EPA to the contractors and are summarized in Table 2-4.

These fuel prices are different from the fuel prices we used in the analysis supporting our Category 3 marine rule. The fuel prices used in that earlier economic analysis were projected fuel prices for 2020 obtained through refinery modeling, based on a price of oil at $52/barrel. In that analysis, the year 2020 was used instead of the compliance year of 2015 due to constraints associated with the air quality modeling performed for that rule. The projected fuel prices used in that rule were $322/MT for HFO and $468/MT for MDO (2006$).

As explained in Section 2.1.1, this analysis uses 2007 as the year of analysis. As a result, rather than using projected fuel prices the analysis is based on prices reported by the EIA for 2007. This approach responds to the recommendation of Great Lakes stakeholders that EPA should consider a different approach for estimating fuel prices, one that reflects changes in the oil market since the Category 3 rule analysis was performed. As a result, the fuel prices used in this Great Lakes analysis are based on 2007 fuel price for residual diesel fuel reported by the U.S. EIA in the 2010 AEO: $1.375/gal, or $385/tonne (based on a density of 280 gal/MT; 2008$).[N]

Stakeholders also informed EPA that fuel prices on the Great Lakes are higher than fuel prices at coastal ports. An analysis of confidential fuel data provided to EPA by several

[N] The prices for 2008 were not used due to the perturbations in the global fuel market that occurred in that year, and data for 2009 were not available.

stakeholders suggests that fuel prices on the Great Lakes are approximately ten percent higher than fuel prices on the U.S. coasts and in other major global ports (Singapore, and Rotterdam). Therefore, the 2007 HFO price was adjusted by ten percent, to $424/tonne.

Table 2-4 Fuel Prices Used in the Analysis
(2007 Prices reported by EIA, adjusted for Great Lakes Market; 2008$)

FUEL TYPE	PRICE: $/MT	PRICE: $/GAL
Marine HFO – Great Lakes	$424	$1.51
Marine MDO – Great Lakes	$617	$1.99

To obtain the MDO price used in the analysis, we applied the EIA 2015 projected fuel price differential for HFO and MDO to the adjusted 2007 HFO fuel price of $424/tonne. This differential, 45.5%, was calculated and applied as follows.

- The 2015 HFO projected price of $2.033 was adjusted by 10 percent to reflect fuel prices on the Great Lakes, yielding $2.24/gal or $626/MT.
- The 2015 MDO price was adjusted to remove the fuel taxes ($0.47) and to reflect the fuel prices on the Great Lakes, yielding $2.94/gal or $911/MT (based on a density of 310 gal/MT). Thus the 2015 differential is 1.455 ($911/$626), meaning MDO is expected to be 45.5 percent more expensive than residual fuel.
- When that differential is applied to the 2007 HFO price of $424/MT for the Great Lakes, this yields an MDO price of $617/MT.

This approach was taken because the price differential in 2007 reported by EIA was about 100%, meaning the price of distillate was about twice the price of HFO, due to heavy worldwide demand for distillate fuel at that time. Such a large differential is not representative of the normal MDO/HFO price differential that has been experienced in past years. During the development of this transportation mode shift analysis, some Great Lakes industry stakeholders suggested that the analysis be run using various prices for marine distillate fuel. While this type of sensitivity analysis could be run, the overall results regarding the occurrence of transportation mode shift would not change. This is because MDO and distillate fuel used in land-based transportation (rail and highway truck) are essentially the same fuel and have essentially the same price, and therefore a price increase in one would be associated with a price increase in the other.[O] While changing the distillate fuel price would affect the absolute value of freight rates for both marine and the all-rail alternative, the relationship between the two would not change.[P]

[O] Note that the refinery model focuses on fuel cost impacts, where the historic fuel prices can be affected by external market impacts. An example of external market impacts that can drive pricing was during the tight distillate market of 2008. During this time period, diesel prices in the U.S. were higher than gasoline prices, even though further refining (more expensive processing) is necessary to produce gasoline than diesel fuel. This occurred because of high distillate demand in India and China outstripping existing distillate refining capacity.

[P] One peer reviewer notes that "though the tradeoffs in fuel prices between marine and land-based distillate probably would remain constant … the tradeoff between the two might not be linear. As the price of oil goes up, the greater efficiency of using the marine mode might provoke shift of freight to marine over rail; this would happen at the extremes of price when the cost of fuel is so great that it begins to trump the cost of intermodal handling needed to

While oil prices are currently increasing, what is important in this analysis is the price ratio of the price of HFO and MDO and not their absolute prices. This is because as oil prices increase the prices of both residual fuel and distillate fuel will increase, and distillate fuel prices will be higher for both marine and for land-based transportation alternatives. The relationship between the HFO and MDO prices used in this study is consistent with historic prices for HFO and MDO. Data for Singapore and Fujairah for the years 2000 through 2007, reported in a 2007 Experts Group study prepared for the IMO and reproduced in Table 2-5, show that the price of HFO ranged between 50 to 72 percent of the price of MDO over that 7-year period.[8] For this analysis, the price of HFO is 69 percent of the price of MDO ($424/$617). The refinery modeling we performed in support of the North American ECA package and our Category 3 rule also estimates the price of HFO to be 69 percent of the price of MDO ($322/$468).[9]

Table 2-5 Price Difference Between HFO and Distillate Fuel, 2000-2007 ($US)

Year	Average price MDO (USD)	Average price HFO (USD)	Annual price increase/decrease MDO (USD)	Annual price increase/decrease HFO (USD)	HFO/MDO
2000	273	156			57%
2001	202	127	-26.1%	-18.3%	63%
2002	203	146	0.5%	14.8%	72%
2003	239	166	17.5%	13.9%	70%
2004	343	176	43.8%	5.8%	51%
2005	503	258	46.5%	46.4%	51%
2006	617	311	22.7%	20.7%	50%
2007	655	365	6.2%	17.2%	56%

Source: Bunkerworld (based on prices in Singapore and Fujairah)

2.5.4 Equipment Costs

The ECA-related fuel costs used in this mode shift analysis do not include equipment costs associated with fuel switching, such as distillate fuel tanks, fuel coolers, pumps, filters, and piping. These estimated equipment costs are one-time costs and are relatively small, averaging about $60,000 per vessel, with the costs for no vessel expected to exceed $71,000. Including these one-time costs would not change the results of the transportation mode shift analysis. A discussion of the equipment costs is included in Chapter 6.

2.5.5 Freight Rates

The freight rates used in this analysis were obtained by the contractor and are summarized in Table 2-6. These freight rates were estimated as described in Chapter 4 of the

shift as much to marine as possible. This, however, would not change the conclusions of the analysis because it would drive freight toward, not away from the marine mode; it would not favor truck or rail." (Belzer) See also various MARAD reports cited in Chapter 1.

study contained in Appendix 2C of this chapter and are based on the fuel prices described in Section 2.5.1.3.

Table 2-6 Marine and Rail Freight Rates ($/cargo ton)[a]

SCENARIO	DEFAULT SCENARIO ROUTE		ALL-RAIL ALTERNATIVE ROUTE
	Marine Freight Rate	Rail Freight Rate	Rail Freight Rate
1	$1.81	$16.62	$20.21
2	$3.50	$20.98	$22.93
3	$3.02	$16.62	$25.94
4	$7.11	$16.62	$26.62
5	$2.45	$0.32	$3.97
6	$10.98	$3.76	N/A
7	$3.34	$1.52	$10.74
8	$3.66	$1.82	$17.12
9	$18.50	N/A	$43.08
10	$16.28	N/A	$55.90
11	$17.40	$1.53	$32.95
12	$5.52	$0.10	$8.13
13	$4.73	$4.96	N/A
14	$2.75	$4.96	N/A
15	$6.15	$4.69	N/A
16	$3.30	$2.01	N/A

[a] Freight rates based on 2007 fuel prices, presented in 2008$

The basis for comparison is freight rates in terms of $/cargo ton, not $/ton-mile. In other words, the analysis estimates how much it would cost to move a ton of cargo (e.g., iron ore) from Point A (e.g., Hull Rust Mine in Minnesota) to Point B (e.g., U.S. Steel in Gary, Indiana), instead of estimating a freight rate that could be applied to any route based on distance. While this approach does not allow for comparisons across scenarios, it does allow comparison of the marine and all-rail modes for the same cargo tonnage between the same O/D pairs.

With respect to the Default Scenario Route, the total freight rate for each scenario is the sum of the marine rate, the rail rate, and the cargo transfer costs. This is estimated for both the Base Case (HFO fuel) and MDO Case (ECA fuel). With respect to the All-Rail Alternative Route, the total freight rate is the sum of the all-rail route rates and the all-rail route transfer costs.

A sensitivity analysis was performed to incorporate routing constraints that would increase the cost of transporting goods by rail for the Default Scenario Route and All-Rail Alternative Route. In this analysis, rail freight rates increase for all cases except Scenarios 1 and 2. In all cases, no mode shift is indicated.

2.6 Conclusion

This transportation mode shift analysis shows that the additional fuel costs associated with complying with the 1,000 ppm ECA fuel sulfur limit on the Great Lakes are not expected to result in transportation mode shift. For ten of the twelve scenarios examined, ECA-adjusted marine freight rates are expected to remain well below the next least expensive shipping mode, all-rail. For one of the two remaining scenarios, an All-Rail Alternative route could not be identified, although the results for a similar case suggest that no transportation mode shift would be indicated. For the other scenario, the results of the analysis are inconclusive due to mis-specification of the scenario.

These results are specific to the O/D pairs examined. However, the routes studied were identified by stakeholders as being at-risk of transportation mode shift due to increases in fuel costs associated with the requirement to use ECA fuel on the Great Lakes. If fuel cost increases of the magnitude expected from switching to ECA-compliant fuel on the Great Lakes do not indicate a transportation mode shift on these at-risk routes, where the price difference between marine transportation and the all-rail alternative is close enough to be of concern to stakeholders, then transportation mode shift on other routes without such price pressures would not likely be indicated.

Appendices

Appendix 2A

Stakeholder Interactions

EPA performed the analysis contained in this report in response to comments received from Great Lakes stakeholders during our Category 3 rulemaking process. As a result, we solicited industry stakeholder input during all phases of the analysis, especially with respect to the routes studied, the study methodology used, and key data inputs such as cargo types, vessel characteristics, and cargo transfers.

EPA engaged with various Great Lakes industry stakeholders throughout the development of this analysis. Our first outreach with stakeholders was through a presentation to industry members at Marine Community Day on February 11, 2010. At this conference, EPA explained to stakeholders that we were developing a research strategy and evaluating existing modeling tools and various ways to assess the economic impacts of our rule on Great Lakes shipping. The goal of the analysis, we noted, would be to see if a transportation cost increase of the order we expected as a result of applying the ECA fuel requirements to the Great Lakes, in combination with the dynamics of transportation in the Great Lakes region, would potentially lead shippers to shift away from marine transportation to one of the land-based alternatives, rail or truck. We also indicated we were developing ways to engage stakeholders to obtain input on the methods we would be using and the data we would need to carry out the study.

During the spring of 2010, we evaluated existing models and methodologies that could be used to perform this analysis. We also engaged a contractor who began to develop the analytic tools and carry out test modeling for several example cargo/route combinations.

We hosted a workshop in Ann Arbor on June 10, 2010, to present our proposed transportation mode shift methodology and to solicit data inputs from industry stakeholders. The invitation to the workshop was sent by email to the full list of stakeholders to whom we had been making announcements throughout the rulemaking process, including those who had submitted comments, attended hearings, and those whose interest was made known to us. A remote attendance option was provided for connecting via phone and web link for those who could not travel to Ann Arbor on that day. An attempt was made to be inclusive of a wide range of stakeholders, so that we had the best chance possible of receiving valid data for our study. Exhibit 1, below, documents EPA's external correspondence during this study. The invitation, final agenda and attendance list are provided as Exhibits 2, 3, and 4 of this Appendix, respectively.

At the workshop, EPA's contractors, James Winebrake of the University of Rochester and James Corbett of the University of Delaware described their Geospatial Intermodal Freight Transport (GIFT) model they developed with funding from the United States Maritime Administration (MARAD) and presented the results of draft scenarios examining the cost impacts of the ECA fuel program for two fairly typical transportation scenarios: coal shipped from Montana to Monroe and St. Clair, Michigan, and iron ore shipped from Minnesota to Gary, Indiana (slides of the presentation given at this workshop are included as Appendix 2B to this report). This methodology was well-received by the workshop participants. At the close of that workshop we indicated that the next step in EPA's study would be to define the shipping scenarios that would be included in the analysis, and we requested industry input for the cargo/route combinations that should be included in the analysis. Specifically, we asked the industry to identify routes most likely to see direct competition leading to a potential mode shift. We noted it would be helpful if suggested scenarios represented cargo and O/D combinations that are at risk for transportation mode shift due to competition from landside alternatives.

At the request of attendees, EPA followed up the on Ann Arbor workshop with an e-mail, dated June 16, 2010, that provided additional details about the methodology we intended to use for the transportation mode shift analysis and contained a list of the data inputs that would be needed. The e-mail was sent to workshop attendees as well as the two primary trade associations for Great Lakes carriers: Lake Carriers' Association and the Canadian Shipowners' Association. In that e-mail, EPA again requested stakeholders assistance in identifying sensitive routes that may be at risk for transportation mode shift.

We again presented a summary of our analytic approach and results for the two initial scenarios at the 74th International Joint Conferences of the Canadian Shipowners' Association and Lake Carriers' Association in Niagara-on-the-Lake, Ontario, on June 21, 2010, and requested stakeholder input.

Several stakeholders responded directly to EPA with confidential information about the trade routes they believe might be at risk for transportation mode shift as a result of increased fuel costs. Using this information, EPA prepared a list of 16 routes to be included in the analysis. After obtaining the agreement of those stakeholders who had shared their recommendations, on July 12, 2010 we forwarded our draft list of at-risk routes to the primary industry trade organizations for dissemination to their members and requested comments or revisions. We received no adverse comment on this list of routes. The specific data needed to perform the analysis for each route were then gathered by EPA's contractor. We forwarded draft data sheets along with associated route maps to the trade associations on August 13, 2010, again with a request that they forward the information to their members for review and comment. The final data inputs used in this analysis are based on the comments we received on these data sheets.

In addition, EPA exchanged e-mails and had telephone conversations with various stakeholders with regard to their questions and concerns about the study.

In summary, stakeholder input was solicited during all phases of this project with regard to the study methodology, the choice of at-risk routes to be analyzed, and the data used to characterize these routes in the analysis. The assistance provided by stakeholders was highly valuable and allowed us to focus this analysis on those routes identified by shipping interests as being most likely to be adversely affected by the application of the ECA fuel requirements to the Great Lakes

Exhibit 2A-1: Index of External Communication

DATE	DOCUMENT TYPE	SUBJECT	DESCRIPTION
April 14, 2010	Log of telephone call	Scenario Inputs - CBI	Telephone conversation between Jean Marie Revelt of EPA and Glenn Nekvasil of Lake Carriers' Association regarding loads of iron ore to Gary and coal to ports in Michigan
April 30, 2010	Log of telephone call	Scenario building	Telephone conversation between JM Revelt of EPA and Glenn Nekvasil of LCA, regarding privileged nature of competitive route information
May 26, 2010	Electronic mail	Scheduling public workshop	Email from Byron Bunker of EPA to James Weakley of LCA, suggesting possible dates for public workshop
May 26, 2010	Electronic mail	Scheduling public workshop	Email from James Weakley of LCA to B Bunker of EPA, commenting on possible dates for public workshop
May 28, 2010	Electronic mail	Invitation to public workshop	Email from Lauren Steele of EPA to large list of stakeholders, with invitation to public workshop
May 28, 2010	Electronic mail	Public workshop	Email from Paul Billings of ALA to L Steele of EPA, commenting on invitation to public workshop
May 28, 2010	Electronic mail	Invitation to public workshop	Email from L Steele of EPA to Julie Gedeon, with invitation to public workshop
May 28, 2010	Electronic mail	Public workshop	Email from Craig McKim of Testo Ink to L Steele of EPA, regarding public workshop
May 28, 2010	Electronic mail	Public workshop	Email from G. Bowler of GR Bowler to L Steele of EPA, regarding public workshop
May 28, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Craig McKim of Testo Ink, regarding public workshop
May 28, 2010	Electronic mail	Public workshop	Email from Karl Briers of Herbert Engineering to L Steele of EPA, regarding public workshop
May 28, 2010	Electronic mail	Public workshop	Email from Gregg Ruhl of Great Lakes Fleet to L Steele of EPA, regarding public workshop
May 28, 2010	Electronic mail	Public workshop	Email from Craig McKim of Testo Ink to L Steele of EPA, regarding public workshop
May 28, 2010	Electronic mail	Public workshop	Email from Mark Mather of PM Shipping to L Steele of EPA, regarding public workshop
May 29, 2010	Electronic mail	Public workshop	Email from Raymond Johnston of CMC to L Steele of EPA, regarding public workshop
May 31, 2010	Electronic mail	Public workshop	Email from Azin Moradhassel of CSA to L Steele of EPA, regarding public workshop

DATE	DOCUMENT TYPE	SUBJECT	DESCRIPTION
June 1, 2010	Electronic mail	Public workshop	Email from Daniel Yuska of MARAD to L Steele of EPA, regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from Adrian Mitterhuber of Provmar Fuels to L Steele of EPA, regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from Chris Tsang of DTE to L Steele of EPA, regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Adrian Mitterhuber of Provmar Fuels, regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from Cliff Hill of TOTE to L Steele of EPA, regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Craig McKim, regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from Brian Harney of Exxonmobile to L Steele of EPA, regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from Caroline Gravel of Shipping Federation of Canada to L Steele of EPA regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from Gordon Gerber of Caterpillar to L Steele of EPA regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Lynn Nadon of Environment Canada, regarding public workshop
June 1, 2010	Electronic mail	Public workshop	Email from Bill Hart of Toromont to L Steele of EPA regarding public workshop
June 2, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to 13 stakeholders, confirming information for public workshop
June 2, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to 2 invitees at CATF, regarding public workshop
June 2, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to S. Kiser of ALA, regarding public workshop
June 2, 2010	Electronic mail	Public workshop	Email from Lynn Nadon of Environment Canada to L Steele of EPA, regarding public workshop
June 3, 2010	Electronic mail	Public workshop	Email from Mike Elliott of NOVA Chemicals to L Steele of EPA regarding public workshop
June 3, 2010	Electronic mail	Public workshop	Email from John Kaltenstein of FOE to L Steele of EPA regarding public workshop
June 3, 2010	Electronic mail	Public workshop	Email from John Kaltenstein of FOE to L Steele of EPA regarding call-in for public workshop

DATE	DOCUMENT TYPE	SUBJECT	DESCRIPTION
June 4, 2010	Electronic mail	Public workshop	Email from Adrian Mitterhuber of Provmar Fuels to L Steele of EPA regarding public workshop
June 4, 2010	Electronic mail	Public workshop	Email from Ted Thompson of CLIA to L Steele of EPA regarding public workshop
June 4, 2010	Electronic mail	Public workshop	Email from Patrice Cote of Transport Canada to L Steele of EPA regarding public workshop
June 4, 2010	Electronic mail	Public workshop	Email from Peter Kelly of Sterling Marine Fuels to L Steele of EPA regarding public workshop
June 4, 2010	Electronic mail	Public workshop	Email from Nancy Kruger of NACAA to L Steele of EPA regarding web option for public workshop
June 4, 2010	Electronic mail	Public workshop	Email from L Steele to Nancy Kruger of NACAA regarding web option for public workshop
June 4, 2010	Electronic mail	Public workshop	Email from Paul Topping of Transport Canada to L Steele of EPA regarding public workshop
June 4, 2010	Electronic mail	Public workshop	Email from Andrew Green of Environment Canada to L Steele of EPA regarding public workshop
June 4, 2010	Electronic mail	Public workshop	Email from Daniel Yuska of MARAD to L Steele of EPA regarding public workshop
June 5, 2010	Electronic mail	Public workshop	Email from David Celebrezze of Ohio Environmental Council to L Steele of EPA regarding web option for public workshop
June 7, 2010	Electronic mail	Public workshop	Email from Mike Elliott of NOVA Chemicals to L Steele of EPA regarding public workshop
June 7, 2010	Electronic mail	Public workshop	Email from Adrian Mitterhuber of Provmar Fuels to L Steele of EPA regarding web option for public workshop
June 7, 2010	Electronic mail	Public workshop	Email from Mark Barker of Interlake Steamship to L Steele of EPA regarding public workshop
June 7, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Adrian Mitterhuber of Provmar Fuels regarding web option for public workshop
June 7, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to 6 stakeholders, confirming attendance at the public workshop
June 7, 2010	Electronic mail	Public workshop	Email from Adrian Mitterhuber of Provmar Fuels to L Steele of EPA regarding web option for public workshop

DATE	DOCUMENT TYPE	SUBJECT	DESCRIPTION
June 7, 2010	Electronic mail	Public workshop	Email from Ted Thompson of CLIA to L Steele of EPA regarding web option for public workshop
June 7, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to 12 stakeholders with invitation to participate via the web option
June 7, 2010	Electronic mail	Public workshop	Email from Mark Mather of PM Shipping to L Steele of EPA regarding web option for public workshop
June 7, 2010	Electronic mail	Public workshop	Email from Mike Elliott of NOVA Chemicals to L Steele of EPA regarding web option for public workshop
June 7, 2010	Electronic mail	Public workshop	Email from Lawrence Dorr of DTE Energy to L Steele of EPA regarding public workshop
June 7, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Lawrence Dorr of DTE Energy regarding public workshop
June 8, 2010	Electronic mail	Public workshop	Email from Raymond Johnston of CMC to L Steele of EPA regarding public workshop
June 8, 2010	Electronic mail	Public workshop	Email from Mark Lathrop of American Steamship to L Steele of EPA regarding public workshop
June 8, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to S. Bridgewater of American Iron and Steel Institute inviting to public workshop
June 8, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to David Knight of Great Lakes Commission confirming attendance at public workshop
June 8, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to M. Lathrop and D Hutchinson of American Steamship confirming attendance at public workshop
June 9, 2010	Electronic mail	Public workshop	Email from Peter Kelly of Sterling Marine Fuels to L Steele of EPA regarding web option for public workshop
June 9, 2010	Electronic mail	Public workshop	Email from Fred Walas of Marathon Oil to L Steele of EPA regarding public workshop
June 9, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Fred Walas of Marathon Oil regarding public workshop
June 10, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Eric McKenzie of Seaway Marine Transport regarding public workshop
June 10, 2010	Electronic mail	Public workshop	Email from Eric McKenzie of Seaway Marine Transport to L Steele of EPA regarding public workshop

DATE	DOCUMENT TYPE	SUBJECT	DESCRIPTION
June 10, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to 49 stakeholders with presentation from public workshop
June 10, 2010	Electronic mail	Applicability	Email from John Medley of ExxonMobil to L Steele of EPA regarding applicability of C3 and IMO standards
June 10, 2010	Electronic mail	Public Workshop	Email from Jim Weakley of LCA to L Steele, B Bunker and JM Revelt of EPA with thanks for an outstanding workshop
June 11, 2010	Electronic mail	Scenario building	Email from L Steele of EPA to 43 stakeholders conveying request (given verbally at workshop) for information on routes to include in the study
June 16, 2010	Electronic mail	Vessel Info	Email from JM Revelt of EPA to 43 stakeholders sharing list of C3 vessels to be included in the study
June 16, 2010	Electronic mail	Study Inputs	Email from JM Revelt of EPA to 43 stakeholders sharing description of input data and assumptions, and reiterating request for routes to study
June 17, 2010	Electronic mail	Vessel Info	Email from Glen Nekvasil of LCA to JM Revelt of EPA with additions to list of C3 vessels to be included in the study
June 18, 2010	Electronic mail	Scenario Inputs	Email from Mark Barker of Interlake Steamship to JM Revelt of EPA, providing CBI on routes to study
June 18, 2010	Electronic mail	Scenario Inputs	Email from Gregg Ruhl of CN Supply Chain Solutions to JM Revelt of EPA, providing CBI on routes to study
June 21, 2010	Electronic mail	Scenario building	Email from William Strauss of the Federal Reserve Bank of Chicago to JM Revelt of EPA, providing CBI on rail congestion
June 25, 2010	Electronic mail	Scenario inputs	Email from Azin Moradhassel of CSA to JM Revelt of EPA, providing CBI comments on fuel costs
June 28, 2010	Electronic mail	Scenario building	Email from Mira Hube of Seaway Marine Transport to JM Revelt of EPA, providing CBI comments on routes and fuel costs
June 30, 2010	Electronic mail	Scenario building	Email from Azin Moradhassel of CSA to JM Revelt of EPA, providing CBI comments on routes and fuel costs
July 12, 2010	Electronic mail	Scenario building	Email from Mark Barker of Interlake Steamship to JM Revelt of EPA with CBI comments on routes

DATE	DOCUMENT TYPE	SUBJECT	DESCRIPTION
July 12, 2010	Electronic mail	Scenario building	Email from JM Revelt of EPA to B Bowie of CSA and J Weakley of LCA sharing 16 suggested O/D pairs to be modeled in the study, and asking for comment
July 12, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to David Roth of Holland & Knight with presentation from public workshop
July 12, 2010	Facsimile	Public workshop	Fax from L Steele of EPA to David Roth of Holland & Knight with attendee list from public workshop
July 13, 2010	Electronic mail	Scenario building	Email from J Weakley of LCA to JM Revelt of EPA and B Bowie of CSA confirming that EPA's message of July 12 with 16 O/D pairs was forwarded to LCA members
July 14, 2010	Electronic mail	Scenario building	Email from Gregg Ruhl of Great Lakes Fleet to JM Revelt o f EPA, providing comments including CBI on stone scenario development
July 19, 2010	Log of telephone call	Scenario Inputs	Telephone conversation between Jean Marie Revelt of EPA and Glen Nekvasil of LCA, regarding final destinations of loads of ore unloaded at 2 ports in Ohio
July 19, 2010	Electronic mail	Scenario building	Email from Gregg Ruhl of Great Lakes Fleet to JM Revelt of EPA, providing CBI on fuel costs
August 2, 2010	Electronic mail	Scenario Inputs	Email from L Steele of EPA to B Bowie of CSA and J Weakley of LCA sharing additional data inputs and assumptions for the study, plus an annotated list of the 16 O/D pairs, asking for comment
August 10, 2010	Electronic mail	Scenario Inputs	Email from Azin Moradhassel of CSA to Lauren Steele of EPA, providing comments on inputs, assumptions and O/D pairs
August 13, 2010	Electronic mail	Scenario Inputs	Email from JM Revelt of EPA to LCA, CSA and other stakeholders, sharing detailed input data and constraints for each of 16 O/D pairs to be modeled in the study, and asking for comment
August 18, 2010	Electronic mail	Scenario Inputs	Email from Dave Anderson of Interlake Steamship to JM Revelt of EPA, providing comments including CBI on scenario inputs
August 18, 2010	Electronic mail	Scenario Inputs	Email from Azin Moradhassel of CSA to JM Revelt of EPA, providing comments including CBI on scenario inputs

DATE	DOCUMENT TYPE	SUBJECT	DESCRIPTION
August 20, 2010	Electronic mail	Scenario Inputs	Email from Kate Ferguson of Great Lakes Fleet to JM Revelt o f EPA, providing comments including CBI on scenario inputs
August 20, 2010	Electronic mail	Scenario Inputs	Email from Azin Moradhassel of CSA to JM Revelt of EPA, providing comments including CBI on scenario inputs for cargo handling
August 30, 2010	Electronic mail	Public workshop	Email from L Steele of EPA to Donald Gregory of EGCSA with presentation from public workshop
September 2, 2010	Electronic mail	Scenario Inputs	Email from Wesley Walker of U.S. Army Corps of Engineers to JM Revelt of EPA, clarifying role of ACE consultant in scenario development

Exhibit 2A-2: Stakeholder Meeting Invitation

Invitation to Participate

Presentation of Methodology for Study of Economic Impacts of Category 3 Marine Diesel Rule on the Great Lakes Shipping Industry

The United States Environmental Protection Agency (US EPA) is hosting a workshop to discuss the proposed methodology for studying economic impacts on the Great Lakes shipping industry, due to the Category 3 Marine Diesel Engine Rule, published April 30, 2010. The workshop will be held from 9:30 a.m. to 1:00 p.m. on Thursday, June 10, 2010, at the US EPA's National Vehicle and Fuel Emissions Laboratory, 2000 Traverwood Drive, Ann Arbor, MI 48105, as well as through a Web conferencing portal for remote participants. A draft agenda is attached below.

US EPA is pleased to invite maritime and transportation experts representing all organizations interested in this subject, including producers and shippers, to participate in this workshop. Others are welcome to observe the discussions. Those wishing to connect via the Web conferencing portal should follow the instructions below.

Results of preliminary trials using the Geographic Intermodal Freight Transportation (GIFT) model will be presented by experts from Energy and Environmental Research Associates, LLC (EERA). In addition to the general sharing of information, US EPA and EERA will use these discussions to consider modifications to the current research plan to study the potential for modal shift on the Great Lakes due to enactment of stringent marine fuel standards. All attendees are invited to share technical information they have that may be relevant to the subject of the meeting. US EPA will use this information to augment its data inputs and improve the modeling methodology, as it proceeds with its economic study.

We ask that those traveling to Ann Arbor register for this workshop by sending an e-mail to Ms. Lauren Steele of US EPA at steele.lauren@epa.gov no later than Monday June 7, 2010. Remote participants will be able to log in 15 minutes prior to the start time.

EPA

Web Conference

Web conference invitation : Great Lakes Workshop

Those wishing to participate in the workshop remotely should go to the URL provided and enter the conference ID, the conference key, and your name where requested. The dial-in telephone number is also provided for the audio connection.

http://hawkeye.epa.gov/imtapp/app/prelogin.uix?siteID=0

Conference Details

Conference Title	**Great Lakes Workshop**
Conference ID	**84817**
Conference Key	**2144788**
Date and Time	**10-Jun-2010 9:30 AM**
Duration	**3 Hours, 30 Mins**
Timezone	**(UTC-05:00) US Eastern Time**
Dial-In Number	**866-299-3188 code 7342144117**

Exhibit 2A-3: Stakeholder Meeting Final Agenda

Presentation of Methodology for Study of Economic Impacts of Category 3 Marine Diesel Rule on the Great Lakes Shipping Industry

Public Workshop

EPA National Vehicle and Fuel Emissions Laboratory

Ann Arbor, Michigan

June 10, 2010

9:30 am to 1:00 pm

AGENDA

Welcome and introductions

Opening remarks

Overview of Great Lakes economic study to date

- The research question
- The modeling framework
- Analysis of initial scenarios

Break (15 minutes)

Next steps

- Data used in modeling
- Additional modeling scenarios

Open discussion

Conclusion

Exhibit 2A-4: Stakeholder Meeting Attendance List

Last Name	First Name	Affiliation
Barker	Mark	Interlake Steamship
Bowie	Bruce	Canadian Shipowners
Bowler	Gary	GR Bowler Inc
Briers	Karl	Herbert Engineering
Browning	Lou	ICF International, EPA Contractor
Cameron	Susan	Sarasota County, Florida
Celebrezze	David	Ohio Env Council
Corbett	Jim	EERA, EPA Sub Contractor
Cote	Patrice	Transport Canada
Elliott	Mike	NOVA Chemicals
Gerber	Gordon	Caterpillar
Harkins	Rick	Keystone Shipping
Hart	Bill	Toromont Power Systems
Hill	Cliff	Totem Ocean Trailer Express
Hopkins	John	Interlake Steamship
Kelly	Patrice	State of Connecticut
Kelly	Peter	Sterling Fuels
Knight	Dave	Great Lakes Commission
Koman	Trish	EPA
Kopin	Amy	EPA
Kubsh	Joseph	MECA
Lathrop	Mark	American Steamship
Lewis	Paula	Lafarge North America
Lindhjem	Chris	Environ, Inc.
Mather	Mark	PM Shipping
McKenzie	Eric	Seaway Marine Transport
Medley	John	ExxonMobil
Mitterhuber	Adrian	Provmar Fuels Inc
Moar	Brian	Environment Canada
Moradhassel	Azin	Canadian Shipowners
Muehling	Brian	EPA
Nadon	Lynn	Environment Canada
Nekvasil	Glen	Lake Carriers Association

Otterson	Brenda	American Maritime Operators Plans
Ruhl	Greg	Great Lakes Fleet
Samulski	Mike	EPA
Sharrow	James	Duluth Seaway Port Authority
Thompson	Ted	CLIA
Topping	Paul	Transport Canada
Trent	Mireille	Transport Canada
Tsang	Chris	DTE Energy
Walas	Fred	Marathon Oil
Waterhouse	Alex	EPA
Weakley	Jim	Lake Carriers Association
Winebrake	James	EERA, EPA Sub Contractor
Yuska	Daniel	MARAD

Appendix 2B

Economic Impacts of Category 3 Rule on Great Lakes Shipping: Modeling Fuel Price Impacts on Potential Modal Diversion

Presentation from June 10, 2010 Stakeholder Workshop

Economic Impacts of C3 Rule on Great Lakes Shipping:

Modeling fuel price impacts on potential modal diversion

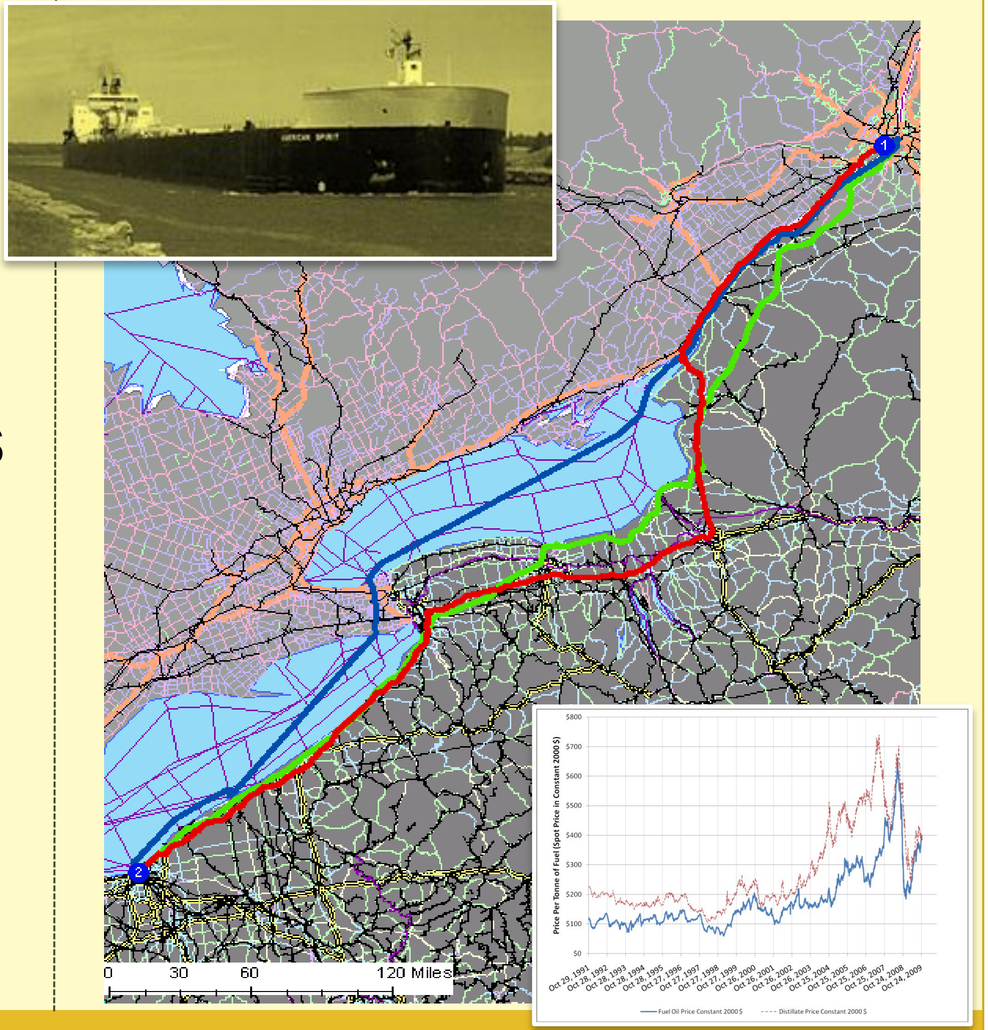
U.S. ENVIRONMENTAL PROTECTION AGENCY STAKEHOLDER MEETING

ANN ARBOR, MICHIGAN
JUNE 10, 2010

JAMES J. CORBETT, PHD, PE
JAMES J. WINEBRAKE, PHD

Overview of Work So Far

- The research question
- The modeling framework
- Analysis of initial scenarios
- Discussion



The Research Question

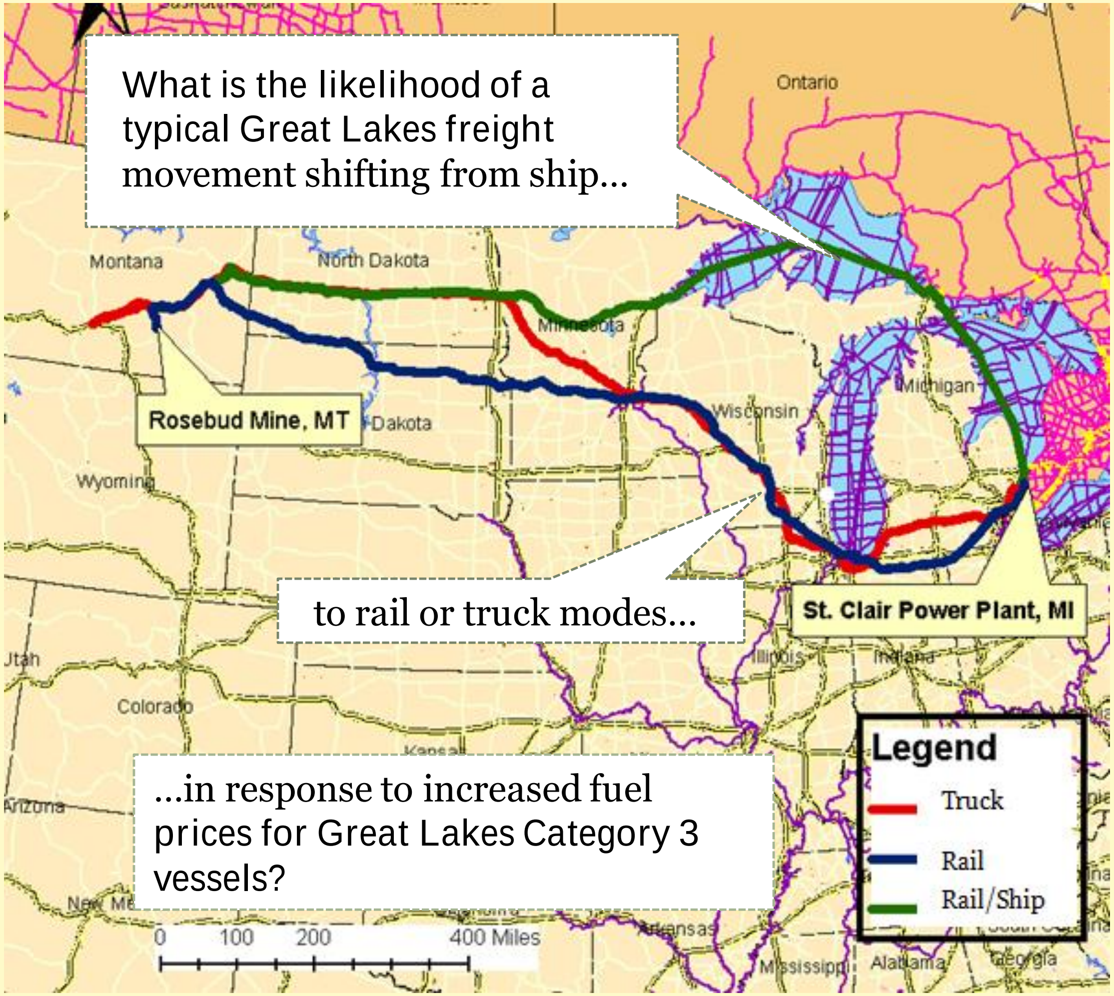
Background

Given the expected increase in fuel prices associated with the C3 Rule, as estimated by EPA:

Q: What is the likelihood of an intermodal shift from vessel to rail or truck modes?

We use cost functions, scenario data, and modeling tools to frame and examine this question

Understanding the Question



The Modeling Framework

Framing the Question

- Understanding impacts of fuel prices on Great Lakes goods movement requires estimating:
  - Costs involved in Great Lakes shipping
  - Cost component due to fuel expenditures
  - Anticipated changes in costs due to increased fuel prices
  - Comparison of costs and other factors with alternative modes of transport

Analytical Approach

- Characterize Great Lakes Category 3 vessels
- Develop cost functions for Great Lakes shipping
- Estimate fuel cost component for vessels and increased costs due to fuel switching
- Estimate freight costs for shipping and alternative modes (for base fuel price and estimated new price)
- Examine scenarios with the increased shipping freight rates to determine if diversion may occur

Category 3 Great Lakes Vessel Characteristics

USA Flag

Vessel type (Fuel type)	Category 3 Vessels
USA	**8**
Bulk Carrier	**8**
IFO / HFO	1
IFO 280	4
IFO 320	3

Canada Flag

Vessel type (Fuel type)	Category 3 Vessels
CAN	**57**
Bulk Carrier	**42**
IFO (various)	42
General Cargo	**3**
IFO 180	2
MDO	1
Tanker	**12**
HFO	2
IFO (various)	9
MDO	1

Data from Greenwood's Guide (2009) and Lloyd's (provided by ICF Consulting).

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Great Lakes C3 Bulk Vessel Characterization

	Fleet C3	US Flag C3
Averages Horsepower	10,430	15,780
Average Service Speed (kts)	13.9	14.2
Average Age (years)	36	37
Fuel Type	IFO (var)	IFO (var)
Coal Cargo Capacity (Net tons)	33,310	47,900
Iron Ore Capacity (Gross tons)	37,530	59,400

The Modeling Approach

- The proposed analysis is comprised of three components, each of which employ best available data:
  - Great Lakes Shipping Cost model
  - Fuel consumption model
  - Geospatial Intermodal Freight Transport (GIFT) Model

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Great Lakes Shipping Cost Model: Modeling Approach

- Purpose:
  - Estimate costs of Great Lakes shipping for a range of routes and vessels and compare estimates with published freight rates for validation
  - Estimate the fraction of costs that are fuel-based
  - Estimate the additional shipping costs due to fuel price increase
- Approach:
  - Identify key variables involved in Great Lakes shipping costs through cost function analysis
  - Collect and process data on Great Lakes in order to identify "typical" vessels and routes
  - Conduct case analyses to estimate costs for certain routes

Elements included in Great Lakes Shipping Cost Model

Voyage costs are the variable costs of a vessel trip:

- Fuel costs for main (*FM*) and auxiliary engine (*F*A)
- Port fees (*P*)
- Canal dues and lock fees (C*D*)
- Tug fees (*T*)

Operational costs are ongoing costs of vessel operation

- Personnel/labor (*L*)
- Repairs (*R*)
- Stores (consumable supplies) (*S*)
- Maintenance (*M*)
- Insurance (*I*)

Capital costs of financing vessel equipment

- Capital payments(*CP*)
- Interest payments (*IP*)

Cargo handling costs (CS) are charges including:

- Cargo loading charges (LC)
- Cargo discharge costs (DC)
- Cargo claims (*CL*)

Periodic maintenance (PM) is required every several years by federal and international regulations

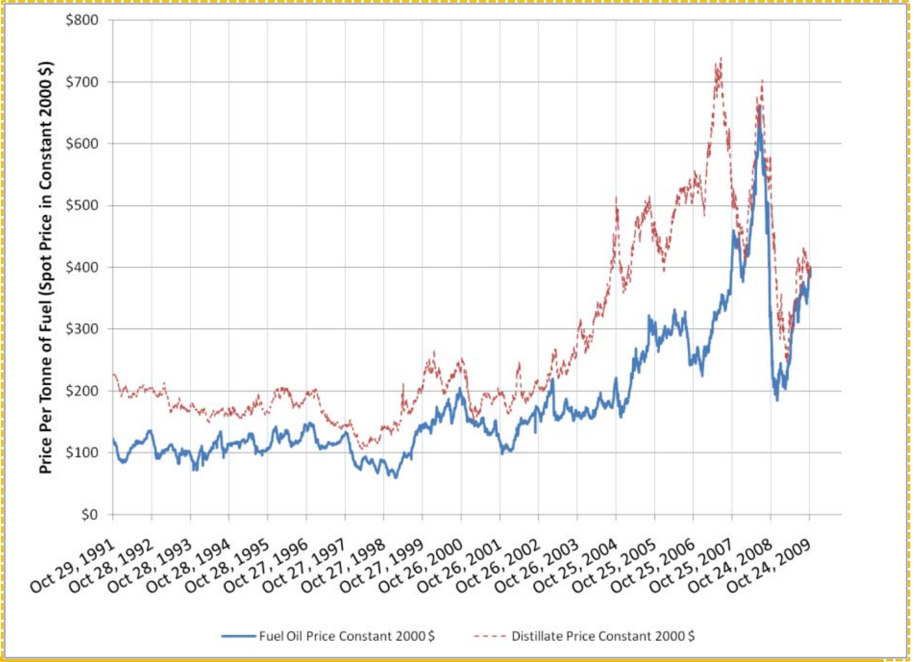
Stopford, M., *Maritime Economics: Second Edition*. 2009, New York, NY: Routledge, Taylor and Francis Group.

Great Lakes Shipping Cost Model

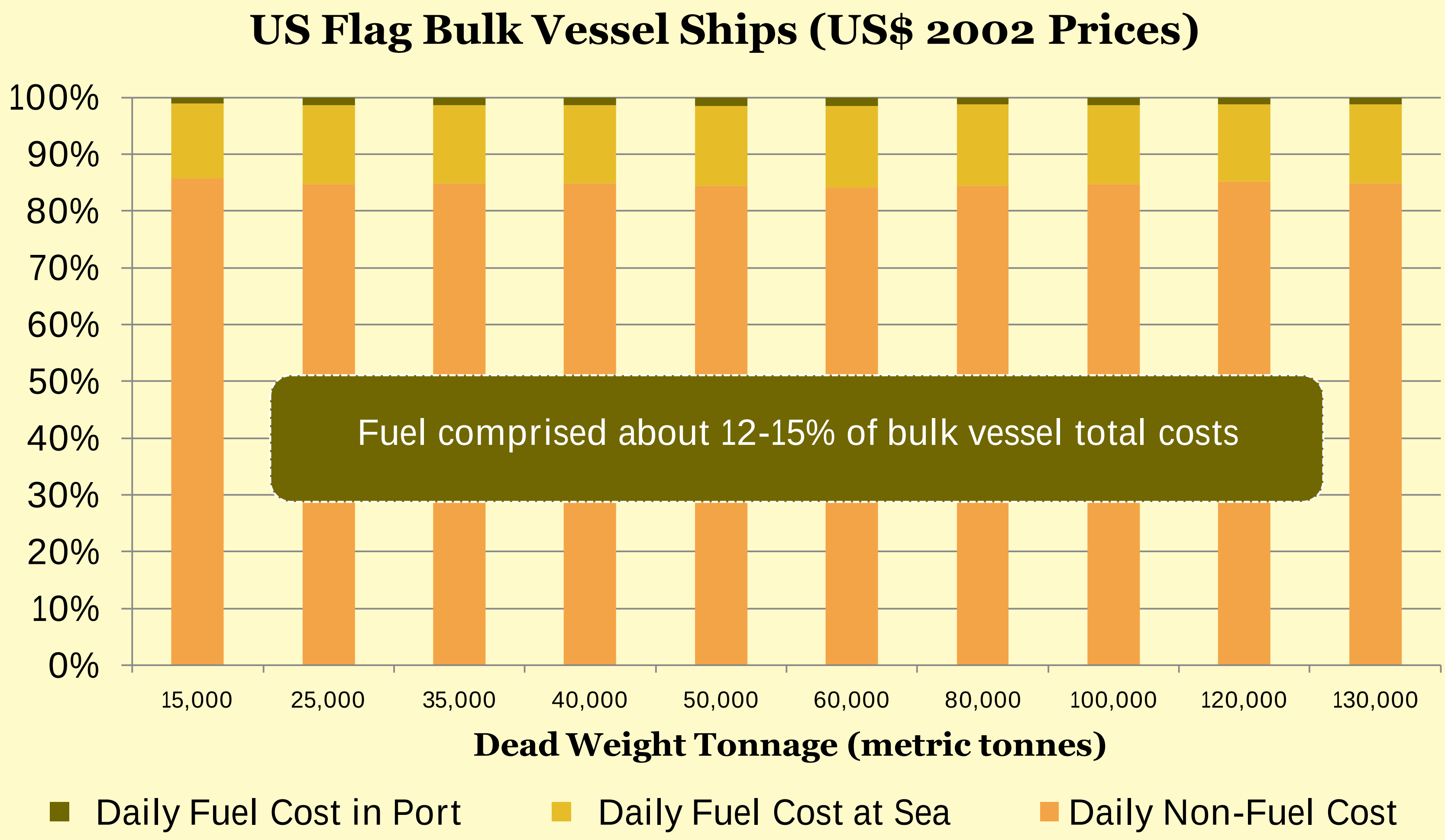
- EERA's Great Lakes Shipping Cost Model also incorporates:
  - Data specific to Great Lakes region
    - Lock fees and traversing time
      - Montreal-Ontario Locks, Welland Canal, Soo Locks
    - Harbor Maintenance Tax
    - Port and cargo-handling fees
    - Shipping season
  - Data representative of Great Lakes Category 3 vessels
    - Engine size, service speed, cargo capacity, age, unloading time
    - Ability to include/exclude capital costs

Great Lakes Shipping Cost Model: Fuel Consumption

- Fuel consumption model incorporates:
  - Specific fuel oil consumption (g/kWh)
    - Main engine and auxiliary engine
    - Age
    - Engine power and load
    - Engine type (SSD, MSD, Steam)
  - Speed and voyage duration
    - Hours at sea and at port
  - Cargo moved
    - Fuel consumption per ton-mile
  - Range of fuel prices
    - 10-year average
    - Individual years 2000 – 2009
    - EPA estimates for ECA rule



Great Lakes Shipping Cost Model Validation: US ACE Data



US Army Corps of Engineers, *Economic Guidance Memo #02-06: FY 2002 Deep Draft Vessel Operating Costs*. 2002: Washington, DC.

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Great Lakes Shipping Cost Model: Summary

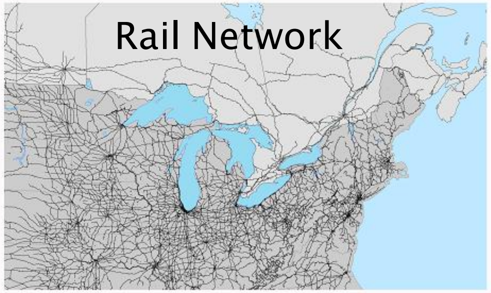
Model cost results appear valid:

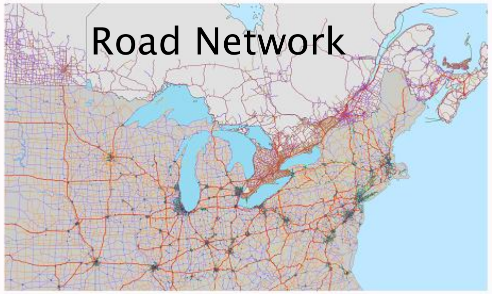
- Expected differences when cost of capital is included or not
- Realistic fractions of cost components (13-18% fuel cost contributions based on recent fuel prices)
- Good agreement with published freight rate data from current and historic sources

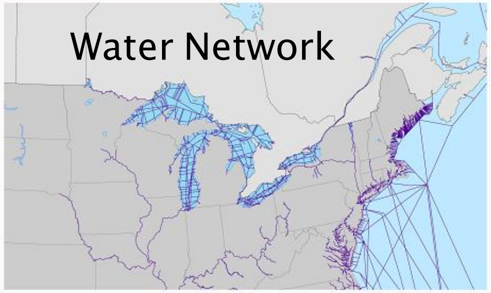
Geospatial Intermodal Freight Transport (GIFT) Model

- GIFT is jointly developed by the Rochester Institute of Technology and the University of Delaware
  - Support from US DOT/MARAD, Great Lakes Maritime Research Institute, ARB and others
- GIFT is an ArcGIS based tool that:
  - Evaluates the *economic, energy, and environmental* costs of freight transport
  - Analyzes tradeoffs across multi-modal freight transport routes
  - Examines impacts of freight transport policies
- GIFT calculates optimal routing of freight between origin and destination points
  - GIFT can solve for least-cost , least-time, least emissions objectives

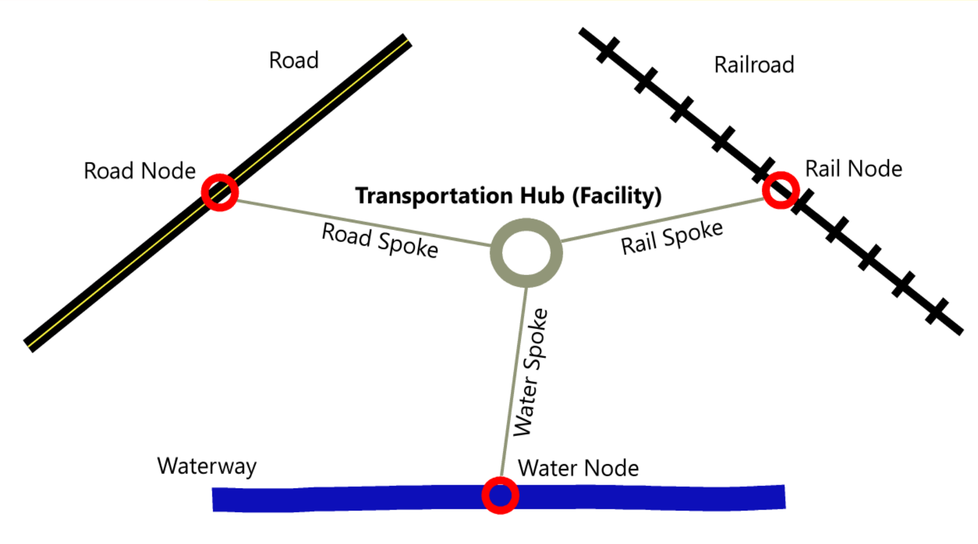
GIFT Integrates Three Independent Networks





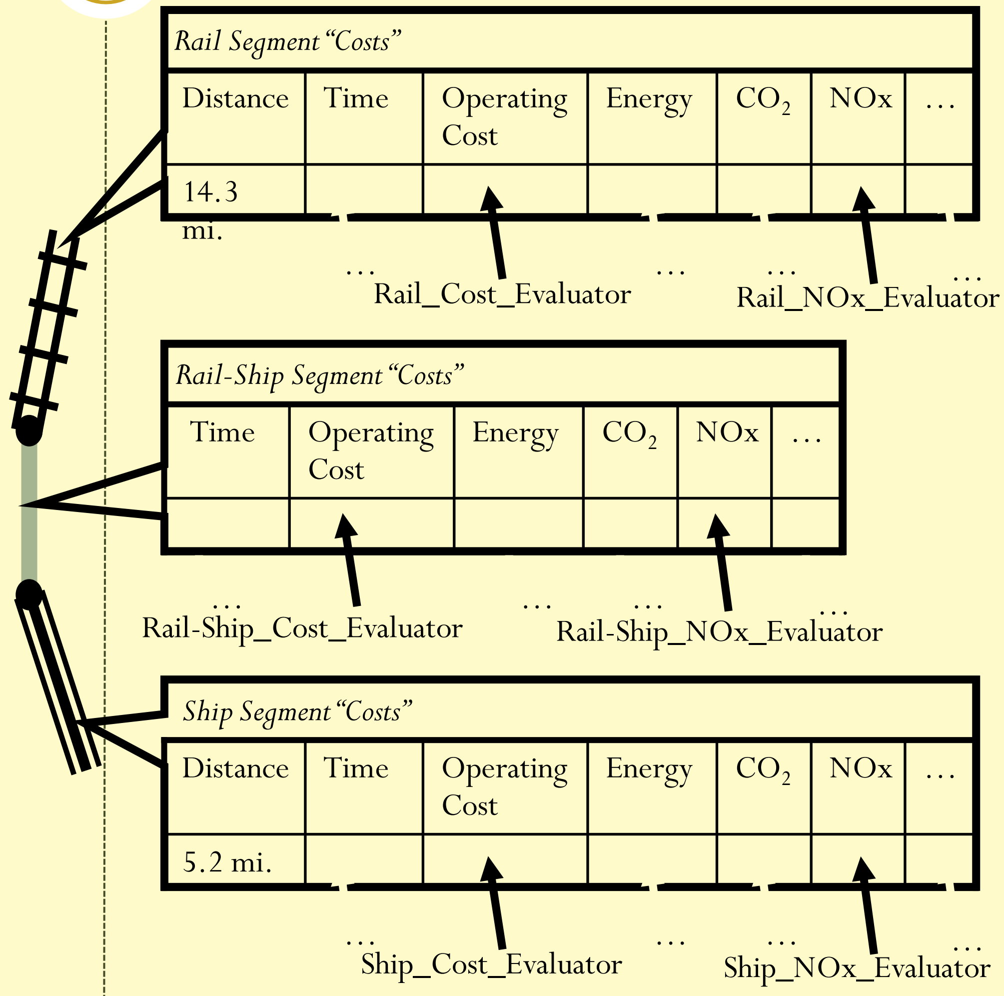


Hub-and-Spoke Construct



GIFT Methodology: Attributes and Evaluators

- GIFT includes the time, distance and costs associated with each modal network feature (water, rail and road segments)
- Time and costs are also associated with intermodal transfer facilities to provide accurate route optimization for multi-modal routes



Recap/Summary of Methodology

- Cost Model Methodology:
  - Estimate the portion of total voyage costs devoted to fuel (from Great Lakes Shipping Cost Model)
  - Calculate the impact of new fuel prices on total costs per ton-mile and per voyage
- GIFT Methodology:
  - Run a scenario based on published freight rates for ship and for rail
  - Adjust the ship freight rates to include higher fuel costs
  - Run a scenario with the new ship freight rate
  - Observe whether GIFT assigns a diversion

Initial Scenario Construction

Selection Criteria for Initial Scenarios

- Criteria included identifying routes with
  - Dominant cargo types in Great Lakes shipping
  - Large volumes of goods movement
  - Multimodal opportunities
  - Commodity-specific origins and destinations
- Two that met these criteria were selected

Commodity	Commodity Origin-Destination	Voyage Origin-Destination	Dominant Cargo	Large Flow	MultiModal Option	Commodity O-D
Iron Ore	Hull Rust, MN to Gary, IN	Duluth, MN - Gary, IN	X	X	X	X
Coal	Rosebud, MT to Monroe, MI	Superior, WI - Monroe, MI	X	X	X	X

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Category 3Vessels Identified as Traveling Scenario Routes

Coal: Superior, WI to Monroe, MI

	Average	Scenario Vessel
HP	16,560	16,560
Service Speed (kts)	13.5	13.5
Build Date	1979	--
Capacity	64,230 (net tons)	65,000 (tons) @ 85% load (55,250 tons)
Fuel	IFO	--

Iron Ore: Duluth, MN to Gary, IN

	Average	Scenario Vessel
HP	17,650	16,560
Service Speed (kts)	14.6	13.5
Build Date	1977	--
Capacity	63,870 (gross tons)	65,000 (tons)@ 85% load (55,250 tons)
Fuel	IFO	--

Note: 1 net ton = 1 short ton; 1 gross ton = 1.12 short tons

Analysis of Initial Scenarios

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Scenario Inputs: Coal Shipment Rosebud Mine to Monroe, MI

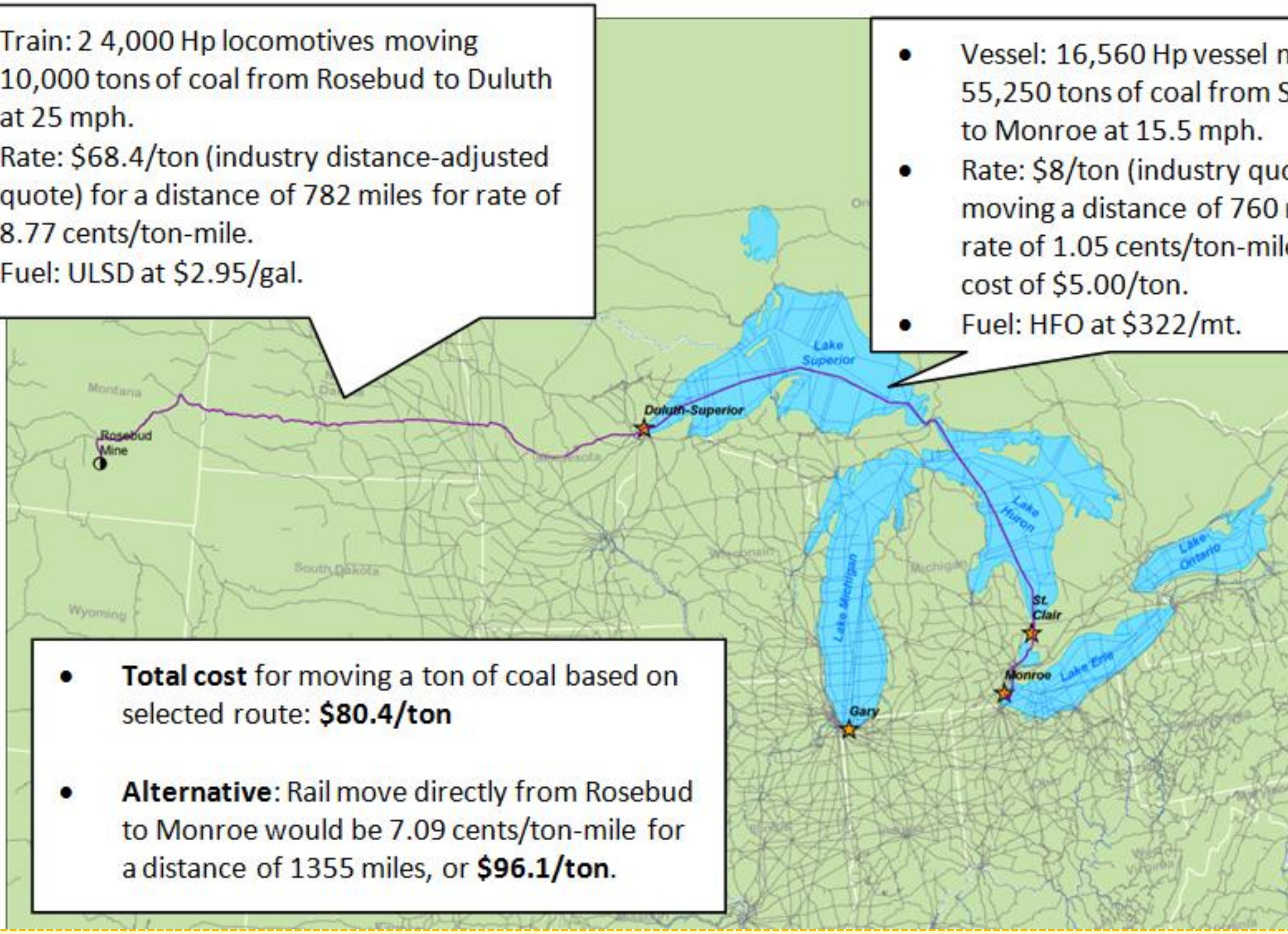
Scenario 1	Intermodal Rosebud to Monroe	Unimodal Rosebud to Monroe
Locomotive Inputs	2 4,000 Hp Locomotives moving 10,000 tons of coal at 25 mph	2 4,000 Hp Locomotives moving 10,000 tons of coal at 25 mph
Rail Freight Rates	Rate: $68.4/ton (industry distance-adjusted quote) for a distance of 782 miles for rate of 8.77 cents/ton-mile.	Rate: $96.1/ton (industry distance-adjusted quote) for a distance of 1355 miles for rate of 7.09 cents/ton-mile.
Rail Fuel Price	Fuel: ULSD at $2.95/gal	Fuel: ULSD at $2.95/gal.
Vessel Inputs	Vessel: 16,560 Hp vessel moving 55,250 tons of coal from Superior to Monroe at 15.5 mph.	Not used in an all-rail route
Vessel Freight Rate	Rate: $8/ton (industry quote) moving a distance of 760 miles for rate of 1.05 cents/ton-mile; transfer cost of $5.00/ton.	Not used in an all-rail route
Vessel Fuel Prices	Fuel: HFO at $322/mt and MDO at $444/mt.	Not used in an all-rail route
Cargo Transfer Inputs	Cost of $5.00 per ton to load from rail to vessel	Not used in an all-rail route

EE RA

Results for Coal – Rosebud to Monroe MI HFO

- Train: 2 4,000 Hp locomotives moving 10,000 tons of coal from Rosebud to Duluth at 25 mph.
- Rate: $68.4/ton (industry distance-adjusted quote) for a distance of 782 miles for rate of 8.77 cents/ton-mile.
- Fuel: ULSD at $2.95/gal.

- Vessel: 16,560 Hp vessel moving 55,250 tons of coal from Superior to Monroe at 15.5 mph.
- Rate: $8/ton (industry quote) moving a distance of 760 miles for rate of 1.05 cents/ton-mile; transfer cost of $5.00/ton.
- Fuel: HFO at $322/mt.



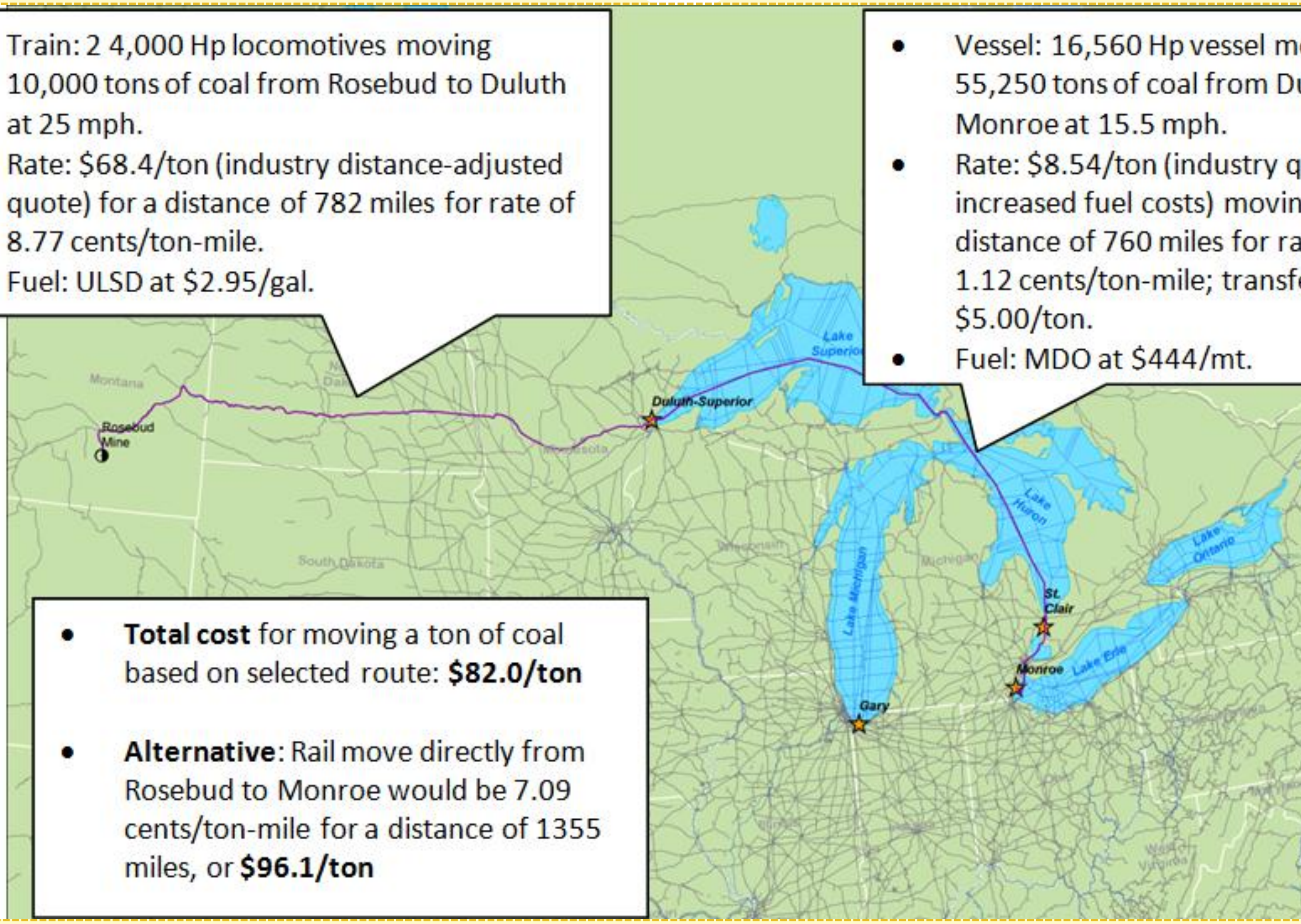
- **Total cost** for moving a ton of coal based on selected route: **$80.4/ton**
- **Alternative**: Rail move directly from Rosebud to Monroe would be 7.09 cents/ton-mile for a distance of 1355 miles, or **$96.1/ton**.

Alternative Unimodal Rail Route

Results for Coal – Rosebud to Monroe MI MDO

- Train: 2 4,000 Hp locomotives moving 10,000 tons of coal from Rosebud to Duluth at 25 mph.
- Rate: $68.4/ton (industry distance-adjusted quote) for a distance of 782 miles for rate of 8.77 cents/ton-mile.
- Fuel: ULSD at $2.95/gal.

- Vessel: 16,560 Hp vessel moving 55,250 tons of coal from Duluth to Monroe at 15.5 mph.
- Rate: $8.54/ton (industry quote+ increased fuel costs) moving a distance of 760 miles for rate of 1.12 cents/ton-mile; transfer cost of $5.00/ton.
- Fuel: MDO at $444/mt.



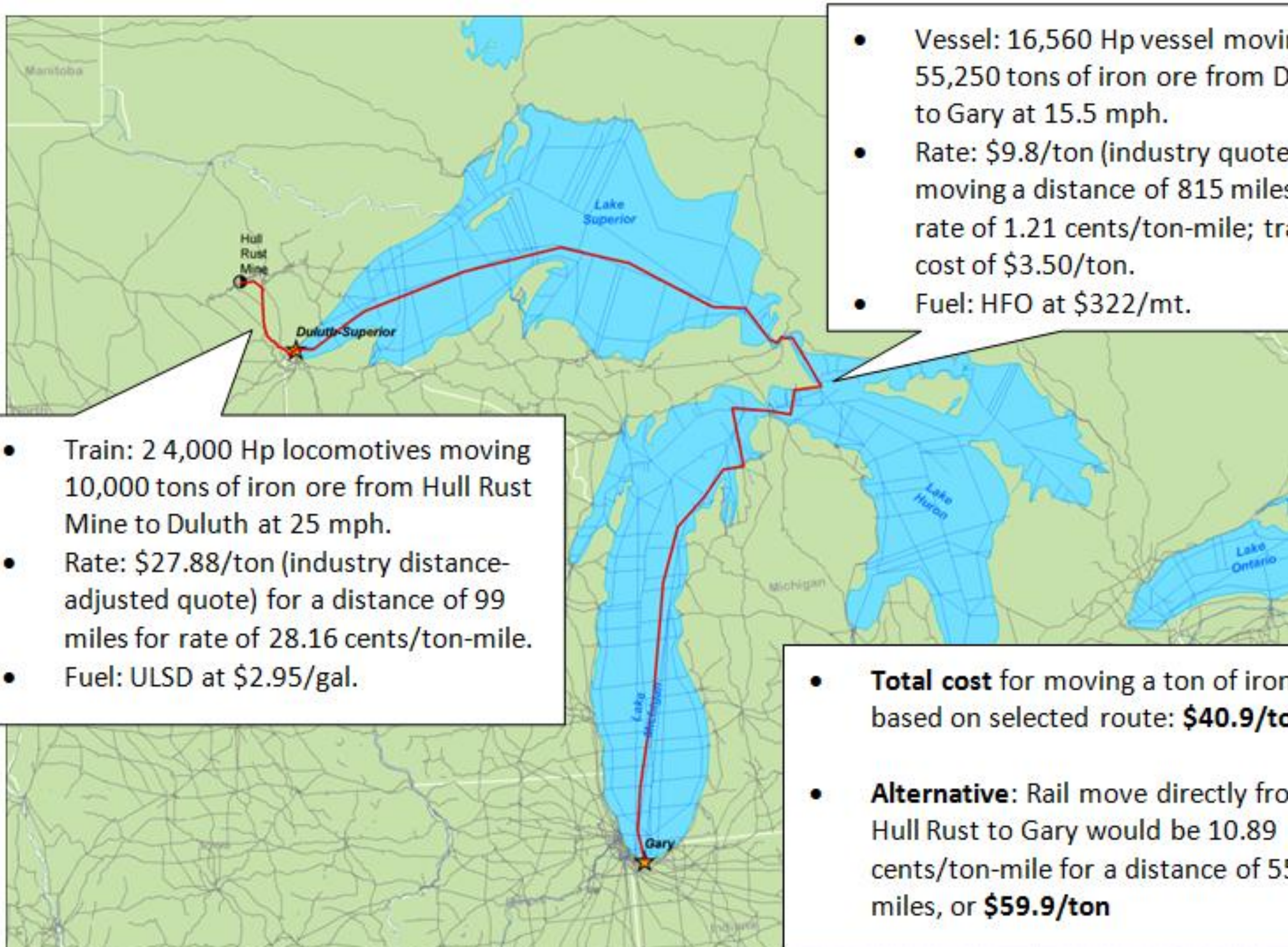
- **Total cost** for moving a ton of coal based on selected route: **$82.0/ton**
- **Alternative**: Rail move directly from Rosebud to Monroe would be 7.09 cents/ton-mile for a distance of 1355 miles, or **$96.1/ton**

EE RA

Data Inputs: Iron Ore Shipment from Hull Rust to Gary, IN

Scenario 2	Intermodal Hull Rust to Gary	Unimodal Hull Rust to Gary
Locomotive Inputs	2 4,000 Hp Locomotives moving 10,000 tons of iron ore at 25 mph	2 4,000 Hp Locomotives moving 10,000 tons of iron ore at 25 mph
Rail Freight Rates	Rate: $27.88/ton (industry distance-adjusted quote) for a distance of 99 miles for rate of 28.16 cents/ton-mile.	Rate: $59.9/ton (industry distance-adjusted quote) for a distance of 550 miles for rate of $10.89 cents/ton-mile.
Rail Fuel Price	Fuel: ULSD at $2.95/gal.	Fuel: ULSD at $2.95/gal.
Vessel Inputs	Vessel: 16,560 Hp vessel moving 55,250 tons of iron ore from Duluth to Gary at 15.5 mph.	Not used in an all-rail route
Vessel Freight Rate	Rate: $9.8/ton ($11/gross ton--industry quote) moving a distance of 815 miles for rate of 1.21 cents/ton-mile; transfer cost of $3.50/ton.	Not used in an all-rail route
Vessel Fuel Prices	Fuel: HFO at $322/mt and MDO at $444/mt.	Not used in an all-rail route
Cargo Transfer Inputs	Cost of $3.50 per ton to load from rail to vessel	Not used in an all-rail route

Results for Iron Ore – Hull Rust Mine to Gary, IN HFO

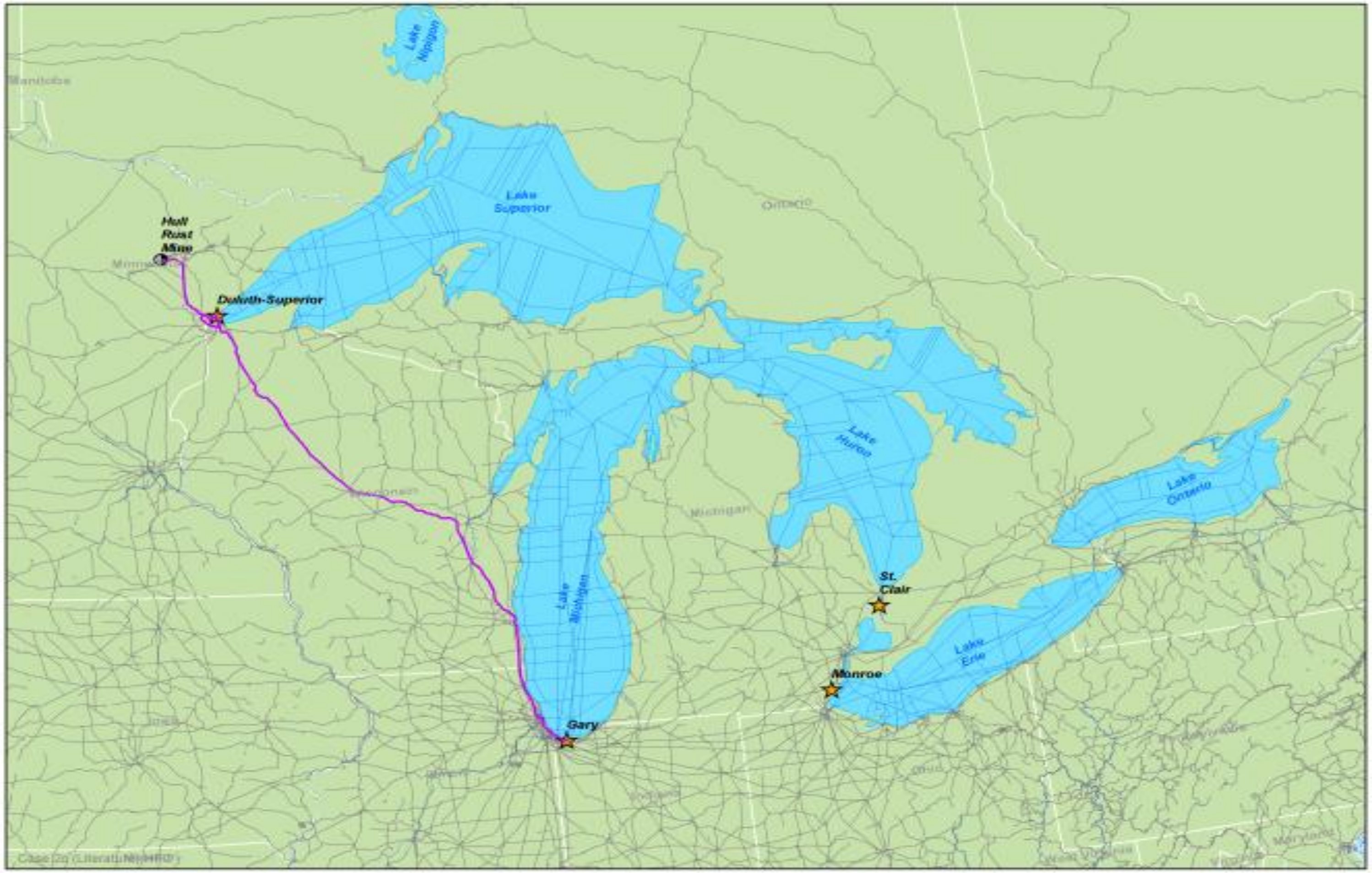


- Vessel: 16,560 Hp vessel moving 55,250 tons of iron ore from Duluth to Gary at 15.5 mph.
- Rate: $9.8/ton (industry quote) moving a distance of 815 miles for rate of 1.21 cents/ton-mile; transfer cost of $3.50/ton.
- Fuel: HFO at $322/mt.

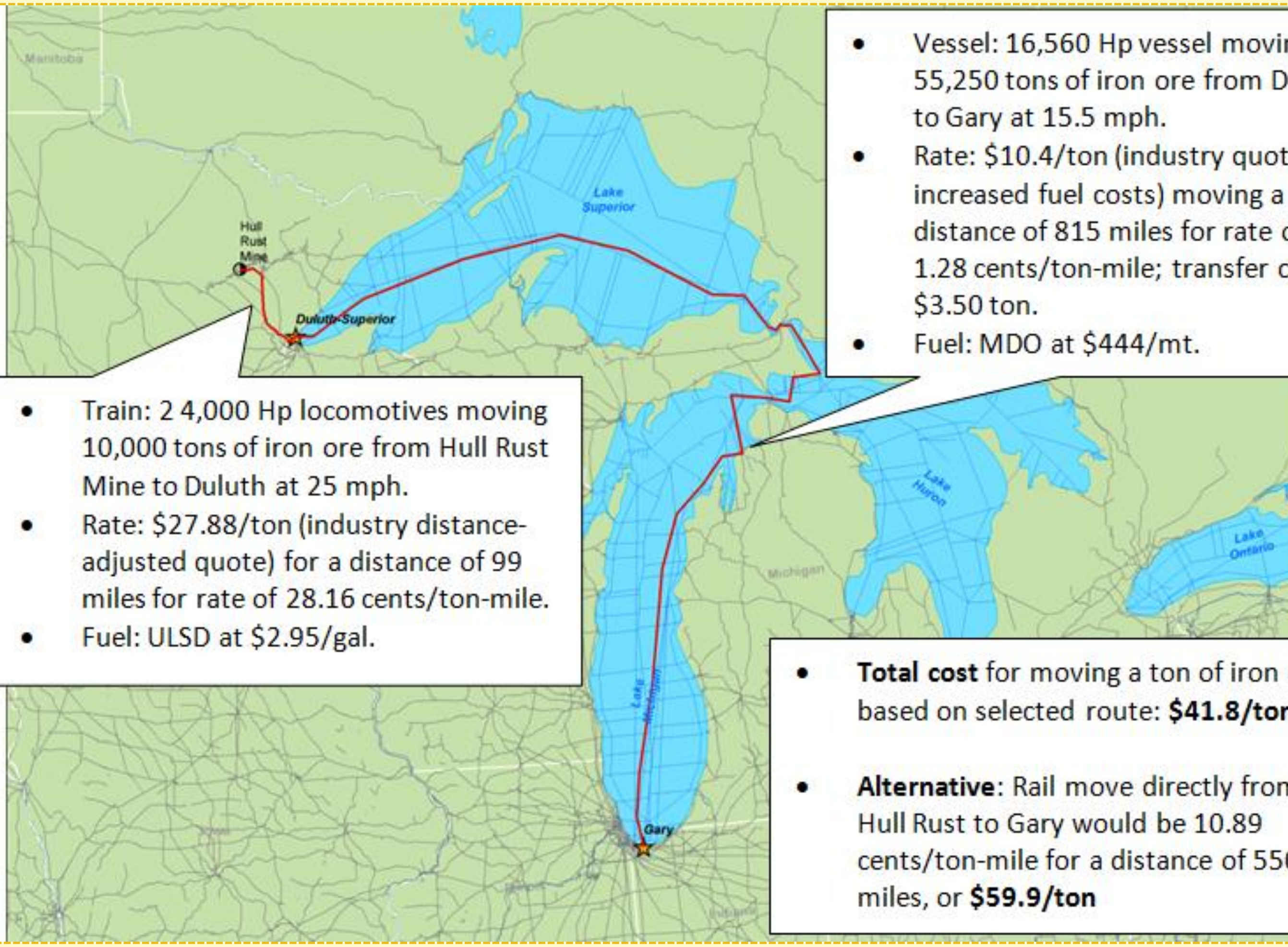
- Train: 2 4,000 Hp locomotives moving 10,000 tons of iron ore from Hull Rust Mine to Duluth at 25 mph.
- Rate: $27.88/ton (industry distance-adjusted quote) for a distance of 99 miles for rate of 28.16 cents/ton-mile.
- Fuel: ULSD at $2.95/gal.

- **Total cost** for moving a ton of iron ore based on selected route: **$40.9/ton**
- **Alternative**: Rail move directly from Hull Rust to Gary would be 10.89 cents/ton-mile for a distance of 550 miles, or **$59.9/ton**

Alternative Unimodal Rail Route



Results for Iron Ore – Hull Rust Mine to Gary, IN MDO



- Train: 2 4,000 Hp locomotives moving 10,000 tons of iron ore from Hull Rust Mine to Duluth at 25 mph.
- Rate: $27.88/ton (industry distance-adjusted quote) for a distance of 99 miles for rate of 28.16 cents/ton-mile.
- Fuel: ULSD at $2.95/gal.

- Vessel: 16,560 Hp vessel moving 55,250 tons of iron ore from Duluth to Gary at 15.5 mph.
- Rate: $10.4/ton (industry quote+ increased fuel costs) moving a distance of 815 miles for rate of 1.28 cents/ton-mile; transfer cost of $3.50 ton.
- Fuel: MDO at $444/mt.

- **Total cost** for moving a ton of iron ore based on selected route: **$41.8/ton**

- **Alternative**: Rail move directly from Hull Rust to Gary would be 10.89 cents/ton-mile for a distance of 550 miles, or **$59.9/ton**

Initial Scenario Result Summary

- Increase in fuel price due to HFO-to-MDO shift ($122/mt) increases total voyage costs by 6-9%

- Increase in fuel price is relatively small fraction of price differential between vessel and rail freight rates
  - Increases vessel costs by less than $1/ton vs. incremental cost of rail routes of ~$15/ton

Other Factors to Consider

- Additional factors are involved in modal selection that are not addressed when considering costs of freight transportation only:
  - Infrastructure
    - Ports/terminals with required cargo-handling equipment (iron, grain)
    - Locations where labor, factory, or other activities may transform these resources
    - Dock accessibility and rail yard capacity
  - Level of service
  - Time
  - Other performance factors
  - Capacity of mode
  - Value of commodity
  - Market characteristics

Break

AFTER BREAK:
OUR PLANNED WORK
OPEN DISCUSSION

Next Steps

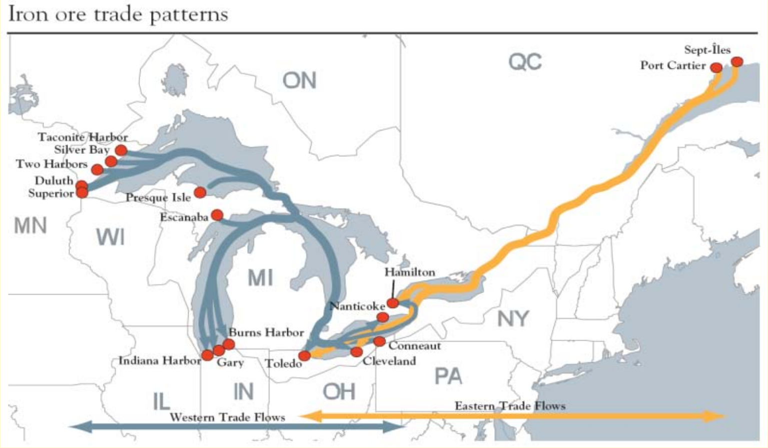
INPUT FROM INDUSTRY AND EPA

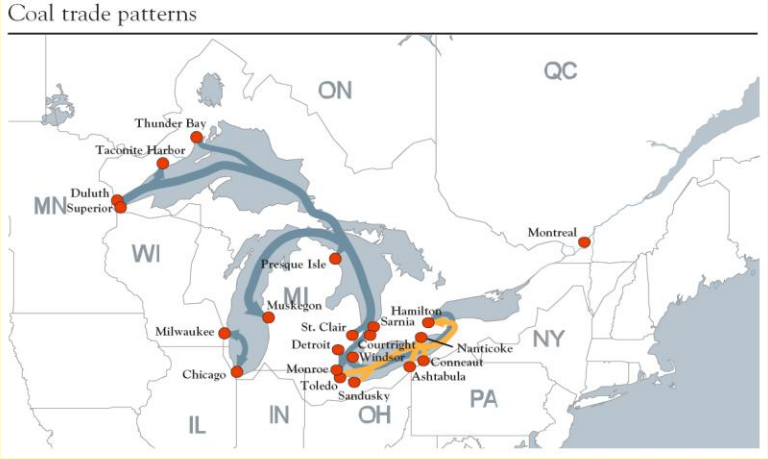
CONSTRUCTION OF ADDITIONAL SCENARIOS FOR ANALYSIS

Scenario Construction

- Scenario Construction involves:
  - Typical trade patterns and routes on the Great Lakes
  - Dominant commodities and cargo
  - Typical origin points for port origin-destination pairs
  - Characteristics of vessels identified as traveling key routes with examined cargo
  - Other factors that the industry sees as important and relevant

Commodity Flows in Great Lakes





Introduction for Discussion

- We would like to engage you on these topics:
  - Comments and questions on our methods
  - Suggestions for improved or substitute data
  - Discussion of initial scenario results
  - Ideas for additional scenario selection

Discussion Welcome

Appendix 2C

Analysis of Impacts of Category 3

Marine Rule on Great Lakes Shipping

Final Report

This Appendix 2C contains the report prepared by EPA's contractor, ICF International and their subcontractor, Energy and Environmental Research Associates (EERA), documenting the Base Case conditions for the sixteen trade route scenarios that are the subject of this economic impact analysis and describing the transport mode shift modeling and results for twelve of those scenarios. This appendix includes transportation mode shift results for Scenario 2 that suggest that the route-based freight rate for the All-Rail Alternative is less than both the Base Case and the ECA freight rates. Subsequent to acceptance of this final contractor report, EPA performed additional research with regard to Scenario 2 that led the Agency to believe this scenario was mis-specified. Therefore, although the results of the contractor's modeling are included in the attached report, these results are not included in EPA's summary of the results of this study (see Section 2.1 and 8A.6) and are not considered to be applicable for the purpose of this study.

Analysis of Impacts of Category 3 Marine Rule on Great Lakes Shipping

Final Report

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4/13/2011

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Abstract

Energy and Environmental Research Associates (EERA) performed analysis on the potential for a modal shift from ship to rail in Great Lakes freight transportation due to a switch from heavy fuel oil (HFO) to marine diesel oil (MDO) in Category 3 marine diesel engines. The analysis supports the US Environmental Protection Agency's (EPA) study on the economic impact of the Category 3 Marine Rule on Great Lakes shipping.

EPA established a set of sixteen (16) scenarios consisting of origin and destination (O/D) pairs representing the flow of coal, iron ore, grain, and stone in the Great Lakes region. For each Default Scenario Route, two cases are run. The first case is called the *Base Case* and models a ship operating on HFO for the main engine and MDO for the auxiliary engine. The second case is called the *MDO Case* and models that same ship operating on MDO for both the main engine and the auxiliary engines. A second route called the All-Rail Alternative Route was developed which models an all-rail route from origin to destination, except where no all-rail route could be identified. We were able to identify all-rail alternative routes for 11 of the 16 scenarios.

Total operating costs for transporting the commodity in the Default Scenario Route using MDO fuel for both the main and auxiliary engines (the *MDO Case*) are calculated and compared to the total operating costs of transporting the same commodity in the All-Rail Alternative Route. The goal of the analysis was to determine if an increase in fuel prices associated with a switch from HFO to MDO for main engine fuel-use in Great Lakes marine vessels would result in the potential for a mode shift from ship to rail for the transportation of bulk commodities.

For 10 of 11 scenarios where an all-rail route was modeled, the All-Rail Alternative Route was more expensive than the Default Scenario Route's *MDO Case*. One scenario (Scenario 2) showed that the All-Rail Route is less expensive than the *Base Case* route even before adding an additional cost to the route to account for a switch to MDO fuel use. Figure 1 shows all 16 O/D pairs. The 11 O/D pairs that are colored yellow represent the routes where an all-rail alternative was confirmed. The five O/D pairs that are colored gray represent routes where no all-rail alternative was identified.

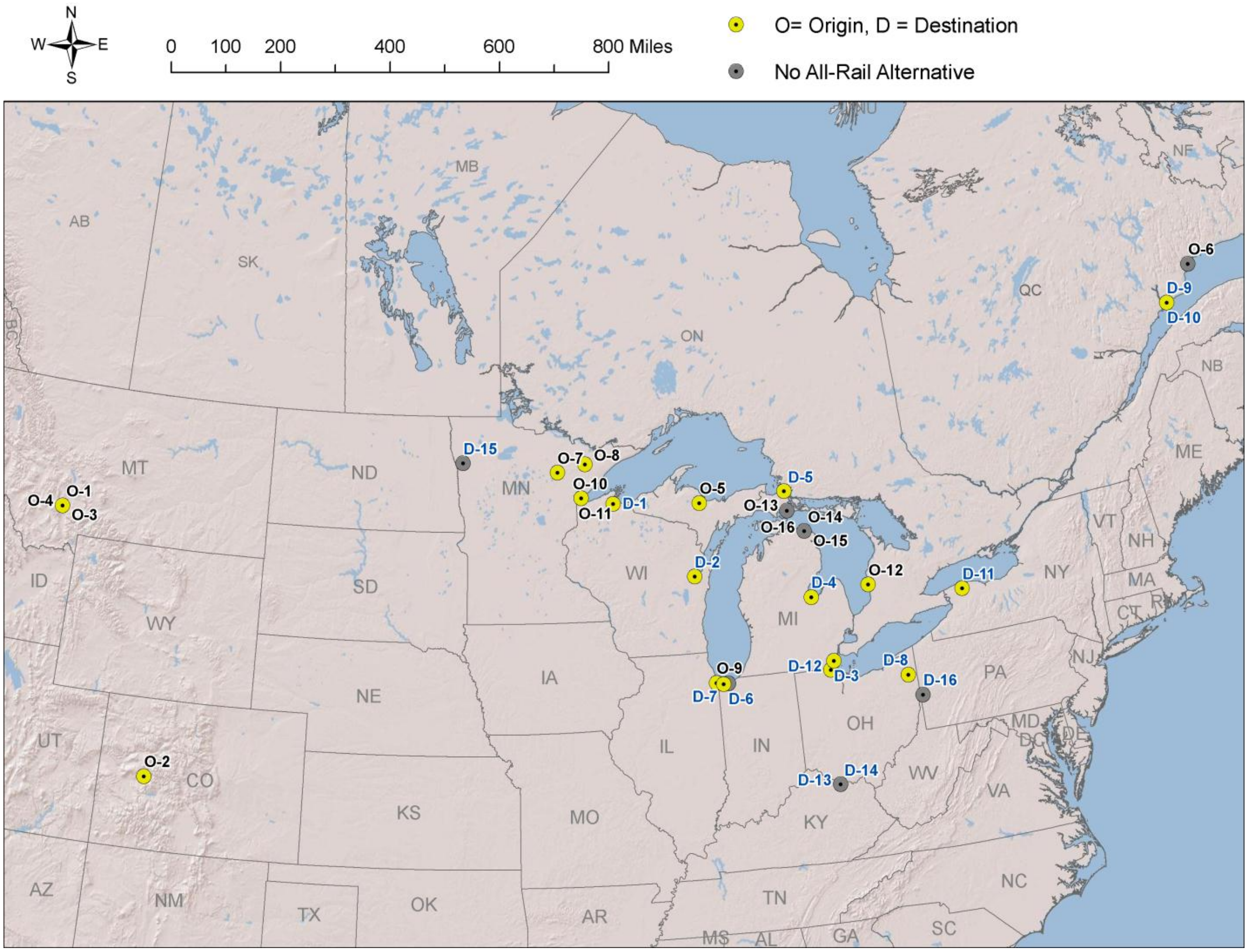

Figure 1: Overview map of origin-destination pairs for each scenario

Chapter 1: Introduction

Energy and Environmental Research Associates (EERA) performed analysis in support of the US Environmental Protection Agency's (EPA) study on the economic impact of the Category 3 Marine Rule on Great Lakes shipping. The analysis evaluated the potential for a modal shift from ships to rail in the Great Lakes region due to the switch from heavy fuel oil (HFO) to marine diesel oil (MDO) by US-flagged Category 3 vessels.

The EPA selected a set of sixteen (16) scenarios consisting of origin and destination (O/D) pairs representing the flow of particular commodities in the Great Lakes region. For this study, "Great Lakes region" includes all the navigable streams, rivers, lakes, and other bodies of water that are within the drainage basin of the St. Lawrence River, west of Anticosti Island, including US and Canadian waters. The commodities represented include: coal, iron ore, grain, and stone.

Each of the 16 scenarios includes a Default Scenario Route that either makes use of the Great Lakes for a portion of the overall route when the source or destination of the commodity is inland, or represents a port-to-port route when the source and destination of the commodity are both at the port. The Default Scenario Route is comprised of: (1) the *Base Case* which models the use of HFO for the main engine and MDO for the auxiliary engine of the vessel; and (2) the *MDO Case* which models the use of MDO for both the main and auxiliary engines on the vessel. Eleven of the scenarios include a second route called the All-Rail Alternative Route, representing a confirmed all-rail route from origin to destination.

In each scenario, the cost of transporting the commodity via the *MDO Case* of the Default Scenario Route is compared with the cost of transporting the same commodity via the All-Rail Alternative Route (where available). We report whether the cost of transporting the commodity is more expensive in the *MDO Case* or the All-Rail Alternative Route.

This study uses the Geospatial Intermodal Freight Transport (GIFT) model, discussed in detail in Winebrake et al. (2008) and Comer et al. (2010), to display maps of the Default Scenario Route and All-Rail Alternative Route. Additionally, the GIFT model is used to calculate the distance (in miles) from origin to destination for the All-Rail Alternative Route as well as the distance traveled by rail for the rail portion of the Default Scenario Route, if any, by solving for the "least-distance" route along active rail lines. The GIFT model is a GIS-based tool developed by the Rochester Institute of Technology and the University of Delaware that combines the US and Canadian road, rail, and water transportation networks through intermodal transfer facilities to create an intermodal network. The GIFT model can solve a route from origin to destination based on user-defined objectives including least-time, least distance, least-economic cost, least-energy, and least-emissions (including carbon dioxide [CO_2], carbon monoxide [CO], oxides of nitrogen [NO_x], sulfur oxides [SO_x], particulate matter [PM_{10}], and volatile organic compounds [VOCs]). For this study, we utilize GIFT's visualization and least-distance optimization capabilities.

This report is comprised of six chapters. Chapter 2 is a characterization of the Great Lakes fleet; Chapter 3 provides the methodology for the analysis; Chapter 4 describes the inputs used in the analysis and the sources of those inputs; Chapter 5 summarizes the results of the analysis; and Chapter 6 analyzes the results and includes a sensitivity analysis.

Chapter 2: Great Lakes Vessel Fleet Characterization

Vessels

Great Lakes vessels using diesel marine engines were identified according to EPA engine category. Category 3 engines have per cylinder displacements equal to or greater than 30 liters; Category 2 engines have per cylinder displacements between 7 and 30 liters (U.S. Environmental Protection Agency, 2009). In Great Lakes freight transportation, heavy fuel oil (HFO) is only used by ships with Category 3 engines or by steam-powered vessels not considered in this study. Category 3 vessels are Great Lakes ships that carry bulk cargo and are typically large in size (dead weight tonnage, length, and draft). Table 1 shows the distribution of Great Lakes bulk carriers by EPA engine category and flag. The Great Lakes bulk carrier fleet (US-flag and Canadian-flag combined) is split about 50/50 between Category 3 and other engine sizes. There are a total of 69 Category 3 marine vessels operating on the Great Lakes; however, only 12 Category 3 marine vessels are US-flag. There are 21 US-flag Category 2 vessels and 15 US-flag steamships operating on the Great Lakes.

Table 1: Great Lakes bulk carriers by EPA engine category and flag, 2008

EPA engine category	Number of Vessels (US Flag)	Number of Vessels (Canadian Flag)	Total
Category 3	12	57	69
Category 2	21	19	40
Steamship	15	8	22
Total	**48**	**84**	**132**

Source: Harbor House Publishers (2009).

Fuels

Marine fuels, or *bunkers*, can be generally classified into two categories: residual fuels and distillate fuels. Residual fuels, also known as HFO or intermediate fuel oil (IFO), are a blend of various oils obtained from the highly viscous residue of distillation or cracking after the lighter (and more valuable) hydrocarbon fractions have been removed. Since the 1973 fuel crisis, refineries adopted secondary refining technologies (known as thermal cracking) to extract the maximum quantity of refined products (distillates) from crude oil. As a consequence, the concentration of contaminants such as sulfur, ash, asphaltenes, and metals has increased in residual fuels (Corbett & Winebrake, 2008a).

Petroleum fractions of crude oil that are separated in a refinery by a boiling process are known as distillate fuels. Distillate marine fuels are more similar to nonroad and onroad diesel fuels, except with differing specification limits for sulfur, viscosity, cetane and other properties. Marine distillate grade A (Distillate Marine A or DMA) currently has an International Organization for Standardization (ISO) (2005) specification limit of 1.5% sulfur (15,000 parts per million, or ppm) although the global average is closer to 3,900 ppm (California Air Resources Board, 2007; Corbett & Winebrake, 2008b); for US-sold DMA, more than 90% sampled by Det Norske Veritas (DNV) contains less than 500 ppm sulfur (California Air Resources Board, 2007). Marine distillate grade B (Distillate Marine B or DMB) must meet ISO specification limits of 2% sulfur, although the global average sulfur content is less than 4,000 ppm and ~70% of US-sold DMB contains less than 800 ppm sulfur (Corbett & Winebrake, 2008b). The current IMO Annex VI fuel sulfur standards are 4.5% globally (including the US) and 1% in the North and Baltic Sea emission control areas (ECAs). Generally, EPA and other environmental regulations have motivated stricter standards for onroad and nonroad distillate fuels, including requirements that rail locomotives use an ultra-low-sulfur diesel (ULSD) fuel with less than 15 ppm sulfur (U.S. Environmental Protection

Agency, 2010). For this study, marine diesel oils (MDO) represent a range of distillate fuels used by ships that also meet EPA standards.

While residual fuels can be blended to meet low-sulfur standards, this essentially requires mixing high-value distillates into low-value residuals. Refinery and market conditions make this less economically desirable for fuel suppliers than offering marine distillates that immediately comply with sulfur regulations and are currently fueling ships with Category 2 and Category 1 engines for auxiliary engines and/or main engines.

The vessels operating on the Great Lakes use a variety of different marine fuel types as indicated in Table 2. Table 3 shows that the majority of vessels are not using MDO, rather, they are using other marine fuels. Under the Category 3 Marine Rule, these vessels may eventually have to switch to a marine fuel oil with a sulfur content of less than 1,000 ppm. Low-sulfur fuel meeting EPA standards is likely to be a marine distillate fuel, unless a low-sulfur residual fuel is introduced into the Great Lakes market as a new product; current understanding suggests the demand for such a new product is insufficient and vessels will comply with a switch to MDO.

Table 2: Marine fuel distribution by type and vessel flag for all engine categories shown as number of vessels operating on the Great Lakes, 2008

Flag	HFO	IFO / HFO	IFO 120	IFO 150	IFO 180	IFO 280	IFO 320	IFO 350	IFO 380	IFO 40	IFO 60	IFO	MDO
Canada	9	0	2	2	33	0	0	2	6	4	4	2	20
United States	15	3	0	0	1	4	4	0	0	0	0	0	21
Grand Total	**24**	**3**	**2**	**2**	**34**	**4**	**4**	**2**	**6**	**4**	**4**	**2**	**41**

Table 3: Residual Fuel Blends vs. MDO fuel distribution by flag for all engine categories shown as number of vessels operating on the Great Lakes, 2008

Flag	Residual Fuel Blends	MDO Fuel
Canada	64	20
United States	27	21
Grand Total	**91**	**41**

Table 4 presents the distribution of marine fuel types for Category 3 engines. Most Category 3 engines are operating on IF 180 fuel.

Table 5 shows that the majority of Category 3 engines are using residual fuel blends. Category 2 vessels operating on the Great Lakes mainly use MDO as presented in Table 6 and Table 7.

Table 4: Marine fuel distribution by type and vessel flag for Category 3 engines shown as number of vessels operating on the Great Lakes, 2008

Flag	HFO	IFO / HFO	IFO 120	IFO 150	IFO 180	IFO 280	IFO 320	IFO 350	IFO 380	IFO 40	IFO 60	IFO	MDO
Canada	2	0	1	2	32	0	0	2	5	4	4	2	3
United States	0	3	0	0	1	4	4	0	0	0	0	0	0
Grand Total	**2**	**3**	**1**	**2**	**33**	**4**	**4**	**2**	**5**	**4**	**4**	**2**	**3**

Table 5: Residual Fuel Blends vs. MDO fuel distribution by flag for Category 3 engines shown as number of vessels operating on the Great Lakes, 2008

Flag	Residual Fuel Blends	MDO Fuel
Canada	54	3
United States	12	0
Grand Total	**66**	**3**

Table 6: Marine fuel distribution by type and vessel flag for Category 2 engines shown as number of vessels operating on the Great Lakes, 2008

Flag	IFO 120	IF 180	MDO
Canada	1	1	17
United States	0	0	21
Grand Total	**1**	**1**	**38**

Table 7: Residual Fuel Blends vs. MDO fuel distribution by flag for Category 2 engines shown as number of vessels operating on the Great Lakes, 2008

Flag	Residual Fuel Blends	MDO Fuel
Canada	2	17
United States	0	21
Grand Total	**2**	**38**

Service Speeds

Service speeds of Great Lakes bulk carriers range from 9-17 knots (kts) with an average speed of 13.6 kts as presented in Table 8. The average service speed does not vary much among engine categories.

Table 8: Service speeds by flag and EPA engine category, 2008

	Canadian		United States	
	Cat 2	**Cat 3**	**Cat 2**	**Cat 3**
Max of Service Speed (kts)	16.3	17.0	16.0	15.0
Min of Service Speed (kts)	9.0	10.0	10.0	13.5
Average of Service Speed (kts)	**12.7**	**13.7**	**13.8**	**14.2**

Bulk Cargo Capacity

Great Lakes vessels carry a variety of different cargoes. Table 9 provides a reference for the number of vessels capable of carrying iron ore, coal, and grain by flag and EPA engine category. Relatively few vessels carry grain and all are Canadian-flagged. Typically, vessels can be used to carry more than one commodity; for example, all of the vessels that carry iron ore can also carry coal and stone, and some grain vessels will backhaul iron ore (currently only Canadian-flagged). Table 10 gives statistics on the cargo capacities for iron ore, coal, and grain by flag and EPA engine category.

Table 9: Number of vessels capable of carrying iron ore, coal, and grain by flag and EPA engine category, 2008

	Canadian			United States			Total
Commodity	**Cat 2**	**Cat 3**	**Steamship**	**Cat 2**	**Cat 3**	**Steamship**	
Iron Ore	11	33	8	21	12	13	98
Coal	11	33	8	21	12	13	98
Grain	5	12	4	0	0	2	23

Table 10: Cargo capacities for iron ore, coal, and grain by flag and EPA engine category, 2008

		Canadian		United States	
Commodity	**Capacity**	**Cat 2**	**Cat 3**	**Cat 2**	**Cat 3**
Iron Ore (gross tons)*	Maximum	32,700	38,200	78,850	74,000
	Minimum	5,880	4,550	14,900	12,650
	Average	**17,873**	**29,699**	**42,908**	**52,395**
Coal (net tons)	Maximum	31,100	39,500	71,300	71,250
	Minimum	6,880	5,050	7,850	12,450
	Average	**16,424**	**27,695**	**34,636**	**41,807**
Grain (metric tons)	Maximum	26,159	35,760	N/A	N/A
	Minimum	5,974	4,582	N/A	N/A
	Average	**12,557**	**24,766**	**N/A**	**N/A**

*Note: All analyses in this report use net tons, converting gross or metric as needed, per notes here.

1. Gross ton: 2,240 pounds of a given material. This measure is used mostly for iron ore by mining companies. Also referred to as a long ton. To convert a gross ton to a net ton, multiply the gross ton total by 1.12.
2. Net ton: 2,000 pounds of a given material. Also referred to as a short ton. To convert a net ton to a gross ton (see previous entry), multiply the net ton by .89286.

Horsepower

Table 11 gives a summary of the range and average horsepower of Great Lakes bulk carriers by flag and EPA engine category. Table 12 gives horsepower range and average by commodity carried. Since the same ships carry both iron ore and coal, the horsepower values are the same.

Table 11: Installed horsepower (Hp) by flag and EPA engine category, 2008

	Canadian		United States	
Values	**Cat 2**	**Cat 3**	**Cat 2**	**Cat 3**
Max of Installed Hp	9,408	12,000	14,400	19,500
Min of Installed Hp	1,880	1,120	850	3,240
Average of Installed Hp	**5,705**	**8,384**	**8,428**	**13,465**

Table 12: Installed horsepower by commodity, flag, and EPA engine category, 2008

Flag	Commodity	Max Installed Hp		Min Installed Hp		Avg. Installed Hp		Total Average
		Cat 2	Cat 3	Cat 2	Cat 3	Cat 2	Cat 3	
Canadian	Iron Ore (and Stone)	9,378	11,094	1,880	1,860	5,372	**8,965**	8,067
	Coal	9,378	11,094	1,880	1,860	5,372	**8,965**	8,067
	Grain	8,000	10,881	1,880	1,860	4,642	**8,128**	7,102
United States	Iron Ore (and Stone)	14,400	19,500	2,150	3,240	8,807	**13,465**	11,136
	Coal	14,400	19,500	2,150	3,240	8,807	**13,465**	11,136
	Grain	N/A	N/A	N/A	N/A	N/A	**N/A**	N/A

Value of Goods Transported on the Great Lakes

Many different commodities are transported in the Great Lakes region. The top four bulk commodities traded on the Great Lakes are iron ore, coal, limestone, and grain (Lake Carriers' Association, 2007a; U.S. Army Corps of Engineers, 2008). In 2007, iron ore and steel products where the number one commodity imported to the Great Lakes and grain was the number one commodity exported from the Great Lakes (U.S. Army Corps of Engineers, 2009). Table 13 presents the value of iron ore, coal, stone, and grain shipped and received in the Great Lakes. These commodities can be transported by various modes including ship, rail, and truck. This study models several scenarios for the transport of the following bulk commodities: coal, iron ore, grain, and stone.

Table 13: Quantity and value of iron ore, coal, aggregates, and grain trade on the Great Lakes, 2008

Commodity	Thousands of Net Tons				Value (Millions of 2007$)
	Shipped	Received	Within[1]	Total	
Iron ore/Steel Products	541	1,184	58,454	60,179	$3,318
Coal	54	361	39,157	39,572	$1,553
Aggregates (including limestone)	147	754	31,299	32,199	$2,266
Grain	2,302	22	2,773	5,097	$680

Source: (U.S. Army Corps of Engineers, 2009). [1]Quantity shipped between and within US ports located on waterways on the Great Lakes system.

Nature of Backhauls in Great Lakes Freight Transportation

Backhaul refers to the practice of carrying cargo on both legs of a round-trip delivery; the "backhaul" is the cargo carried on the return trip. Owners arrange backhauls to generate revenue on the return trip to cover labor and other expenses. There are two types of backhauls on the Great Lakes. The first type of backhaul involves ocean-going vessels ("Salties"). Often, a Salty will unload its iron ore cargo at its destination within the Great Lakes (e.g., Gary, IN) and take on grain for export out of the Great Lakes overseas to Europe or Africa (SLSDC & Saint Lawrence Seaway Development Corporation, 2002; Transportation Research Board, 2008). The second type of backhaul involves U.S. and Canadian vessels operating solely on the Great Lakes. For example, an ore carrier may take iron ore from mines in

Quebec to Gary, IN and backhaul grain. In another example, an ore carrier may take iron ore or coal from the Head of Lakes to Lake Erie destinations and backhaul fluxing stone, sugar stone, or construction stone from Michigan quarries back to Head of Lakes. There are two important points about backhauls on the Great Lakes. First, not all trips have backhauls. Second, a backhaul may cover only a portion of the return trip, and may or may not be a full load. For example, it would be rare that all trips from Duluth, MN to Ashtabula, OH would be associated with equal return hauls of some other cargo. More likely the ship would pick up salt in Cleveland and take it to Michigan. Because of the uncertainty of backhauls, this study estimates fuel costs and freight rates without considering backhaul in its analysis. It is therefore a conservative analysis because it applies the fuel price increase associated with a switch from HFO to MDO to the fuel used for a round-trip journey without accounting for potential backhaul revenue generation.

Seasonality of Goods Movement

The Great Lakes/St. Lawrence Seaway (GLSLS) is typically open for navigation from late March to late December (SLSMC and SLSDC, St. Lawrence Seaway Management Corp, & St. Lawrence Seaway Development Corp, 2010). Ice begins forming on the Great Lakes in December and can form up to three to four feet thick. Slabs of floating ice piled on top of each other, called windrows, can reach 10 to 15 feet thick (Lake Carriers' Association, 2007c).

The U.S. Coast Guard is charged with keeping shipping lanes on the Great Lakes open during ice season to ensure that industry can continue to operate year round. Approximately 16 percent of American dry-bulk cargo is transported during periods of ice cover (Lake Carriers' Association, 2007c).

Figure 2 shows the average monthly carriage of dry-bulk cargo on the Great Lakes based on a five-year average between 2004 and 2009. The shipments of each commodity remain fairly constant throughout the year but then significantly decrease during the winter months. However, shipments of various commodities, including iron ore and coal, occur during ice-covered months. Little dry-bulk cargo is transported on the lakes during January, and less is transported during February.

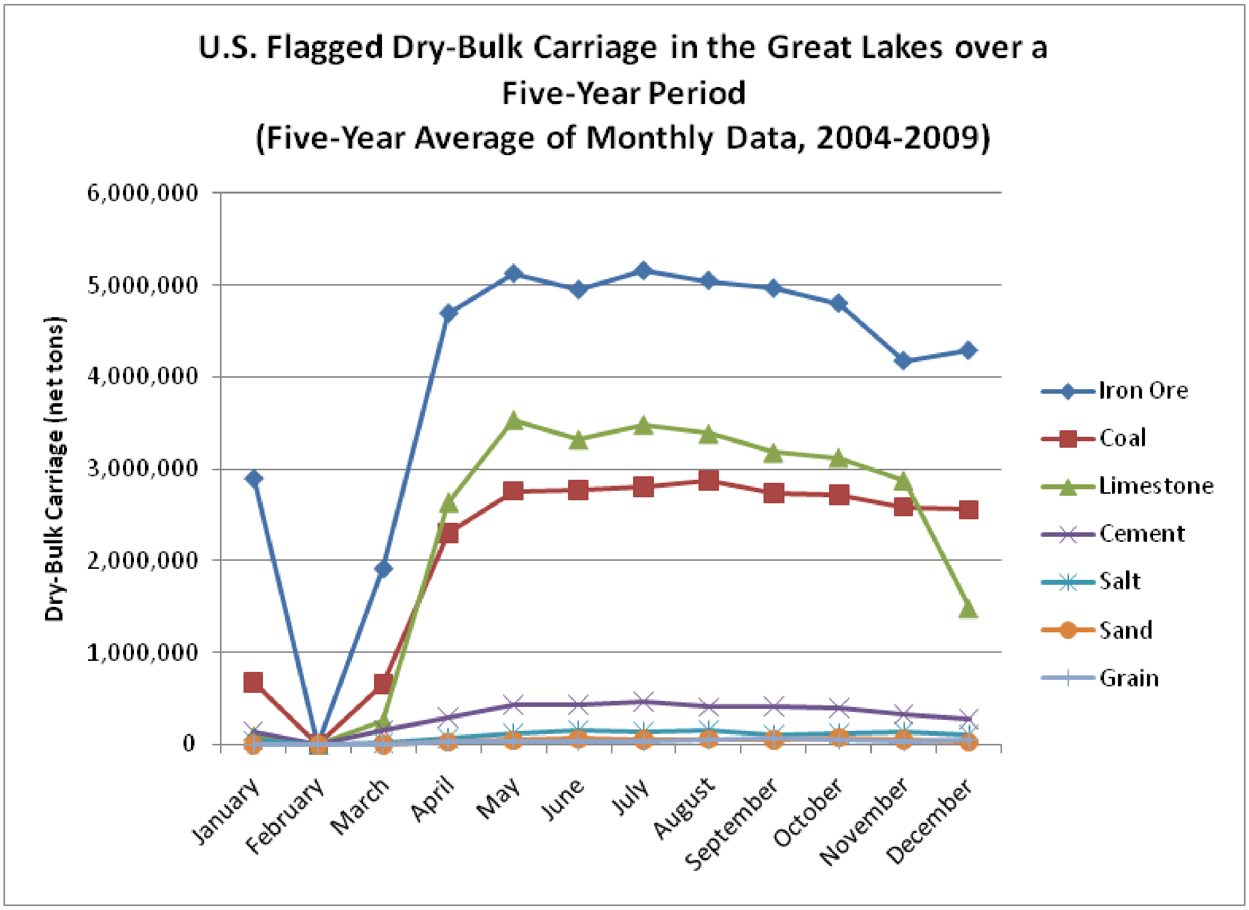

Figure 2: U.S. Flagged Dry-Bulk Carriage in the Great Lakes over a Five-Year Period (Five-Year Average of Monthly Data, 2004-2009)

Companies Involved in Great Lakes Shipping

There are a number of companies involved in Great Lakes shipping, including both American and Canadian firms. Table 14 summarizes the companies involved in Great Lakes shipping and their annual corporate revenues, if publicly available. The table does not include companies that only own Category 1 vessels, car ferries, barges, or tankers.

Table 14: Companies involved in Great Lakes shipping and their annual corporate revenues

Company	Flag	Number of C3 Vessels	Number of C2 Vessels	C3 + C2 Vessels	Annual Corp. Revenue (if available)	Company Website
Algoma Central Corp.	CAN	19	3	22	$520M (2009)[1]	http://www.algonet.com/
CSL Group Inc.	CAN	16	0	16	Unknown	http://www.csl.ca/
American Steamship Co.	USA	1	14	15	$272M (2008)[2]	http://www.americansteamship.com/
Upper Lakes Group Inc.	CAN	9	2	11	Unknown	http://www.upperlakes.com/
Transport Desgagnes Inc.	CAN	4	2	6	$200M (year unknown)[3]	http://www.groupedesgagnes.com/en/home/1.cfm
Interlake Steamship Co.	USA	5	1	6	Unknown	http://www.interlake-steamship.com/
Grand River Navigation Co.	USA	1	4	4	$85M (2009)[4]	http://www.randlogisticsinc.com/
Lower Lakes Towing Ltd.	CAN	1	4	4		http://www.lowerlakes.com/ http://www.randlogisticsinc.com/
Great Lakes Fleet Inc.	USA	3	0	3	Unknown	N/A
Central Marine Logistics	USA	0	1	1	Unknown	N/A
GLF Great Lakes	USA	1	0	1	Unknown	N/A
Gravel and Lake Services	CAN	0	1	1	Unknown	N/A
Inland Lakes Transportation	USA	0	1	1	Unknown	N/A
Purvis Marine Ltd.	CAN	1	0	1	Unknown	http://www.purvismarine.com/
Transport Igloolik Inc.	CAN	0	1	1	Unknown	N/A
Vanguard Shipping	CAN	0	1	1	Unknown	N/A
Voyager Maritime Inc	CAN	0	1	1	Unknown	N/A
KK Integrated Logistics	USA	1	0	1	Unknown	http://www.kkil.net

[1]Algoma Central Corporation (2010); [2]GATX Corporation (2009); [3]Ryan (2010); [4]Grand River Navigation Co. and Lower Lakes Towing Ltd. are owned by Rand Logistics, Inc. The FY 2009 annual revenue for Rand Logistics, Inc. as a whole was approximately $85M (Rand Logistics Incorporated, 2010)

Chapter 3: Methodology

Each scenario includes a Default Scenario Route that either makes use of the Great Lakes for a portion of the overall route when the source or destination of the commodity is inland, or represents a port-to-port route when the source and destination of the commodity are both at the port. Except where no all-rail route could be identified, a second route called the All-Rail Alternative Route is included and represents an all-rail route from origin to destination.

In the Default Scenario Route, two cases are evaluated. The first case (*Base Case*) models a ship operating on HFO for the main engine and MDO for the auxiliary engine. The second case (*MDO Case*) models that same ship operating on MDO for both the main engine and the auxiliary engines. An activity-based fuel cost model is used to calculate the incremental freight rate increase from the Base Case to the MDO Case due to a switch from HFO to MDO fuel. The MDO Case freight rate increase is the sum of the Base Case Voyage Rate along with any rail freight rate plus cargo transfer costs accumulated along the route. Our analysis compares the MDO Case freight rate to the All-Rail Alternative Route freight rate to determine whether the freight rate increases due to MDO fuel use are sufficiently high to cause a potential "switchover" to rail. Details of the methodology are presented in the following sections.

Calculating Default Scenario Route Freight Rates

Fuel costs associated with vessel operation for the Default Scenario Routes are calculated using an activity-based fuel consumption model that accounts for vessel operation "at sea" and "in port." Incremental fuel costs for the voyage can be determined by comparing the *Base Case* fuel costs (using HFO prices) with the *MDO Case* fuel costs (using MDO prices). This incremental fuel cost is then added to the voyage freight rates to estimate new (*MDO Case*) freight rates under the Category 3 Rule. The voyage freight rates were obtained through communication with Chrisman Dager (2010) who provided EERA with appropriate values on a scenario-by-scenario basis. Key equations for this analysis are shown below.

Equation 1: Calculating "at sea" *Base Case* fuel costs

$$VFC_{sea\ bc} = (P_{HFO} * C_{ME} * L_{ME\ sea} * W_{ME} + P_{MDO} * C_{AE} * L_{AE\ at\ sea} * W_{AE}) * D_{ptp} \div S_a \div 10^6$$

where,

$VFC_{sea\ bc}$ = Voyage fuel costs at sea for the *Base Case* in dollars
P_{HFO} = Price of HFO fuel in dollars per metric ton
C_{ME} = Specific Fuel Oil Consumption for the main engine in grams per kilowatt-hour
$L_{ME\ sea}$ = Main engine load factor at sea as a percent (see Equation 2)
W_{ME} = Rated power of the main engine in kilowatts
P_{MDO} = Price of MDO fuel in dollars per metric ton
C_{AE} = Specific Fuel Oil Consumption for the auxiliary engine in grams per kilowatt-hour
$L_{AE\ sea}$ = Auxiliary engine load factor at sea as a percent
W_{AE} = Rated power of the auxiliary engine in kilowatts
D_{ptp} = Port-to-port distance in miles
S_a = Vessel operating speed in miles per hour

Main engine load ($L_{ME\ sea}$) can be estimated using the cubic propeller law for fixed-pitched propellers and displacement hulls as shown in Equation 2.

Equation 2: At-sea load-factor adjustment

$$L_{ME\ sea} = \left(\frac{S_a}{S_m}\right)^3$$

where,

$L_{ME\ sea}$ = Main engine load factor at sea as a percent
S_m = The vessel's maximum operating speed in miles per hour

Equation 3: Calculating "in port" *Base Case* fuel costs

$$VFC_{port\ bc} = \left(P_{HFO} * C_{ME} * L_{ME\ port} * W_{ME} + P_{MDO} * C_{AE} * L_{AE\ port} * W_{AE}\right) * H_{port} \div 10^6$$

where,

$VFC_{port\ bc}$ = Voyage fuel costs for the *Base Case* in port in dollars
P_{HFO} = Price of HFO fuel in dollars per metric ton
C_{ME} = Specific Fuel Oil Consumption for the main engine in grams per kilowatt-hour
$L_{ME\ port}$ = Main engine load factor in port as a percent (zero load assumed in port)
W_{ME} = Rated power of the main engine in kilowatts
P_{MDO} = Price of MDO fuel in dollars per metric ton
C_{AE} = Specific Fuel Oil Consumption for the auxiliary engine in grams per kilowatt-hour
$L_{AE\ port}$ = Auxiliary engine load factor in port as a percent
W_{AE} = Rated power of the auxiliary engine in kilowatts
H_{port} = Hours in port

Equation 4: Calculating total *Base Case* fuel costs

$$VFC_{total\ bc} = VFC_{sea\ bc} + VFC_{port\ bc}$$

where,

$VFC_{total\ bc}$ = Total voyage fuel cost for the *Base Case* in dollars
$VFC_{sea\ bc}$ = Voyage fuel costs for the *Base Case* at sea in dollars
$VFC_{port\ bc}$ = Voyage fuel costs for the *Base Case* in port in dollars

Equation 5: Calculating total *Base Case* fuel costs per cargo ton

$$VFC_{per\ ton\ bc} = VFC_{total\ bc}\ \div\ T * 2$$

where,

$VFC_{per\ ton\ bc}$ = Voyage fuel costs for the *Base Case* in dollars per ton
$VFC_{total\ bc}$ = Total voyage fuel cost for the *Base Case* in dollars
T = Cargo load in net tons
We multiply by "2" in order to account for fuel costs associated with making an empty return trip to the port of origin.

The above equations for the *Base Case* are repeated for the *MDO Case*, but using MDO fuel prices specified by EPA. The "incremental fuel cost increase" due to the shift from HFO to MDO fuel is given as the difference between the VFC for the *Base Case* and the VFC for the *MDO Case*. This incremental cost increase (in $/cargo ton) is added to the freight rate for the vessel leg of each Default Scenario Route to obtain a vessel freight rate under the *MDO Case*, as shown in Equation 6.

Equation 6: Calculating the new vessel freight rate for the *MDO Case*

$$FR_{MDO} = FR_{BC} + (VFC_{per\ ton\ MDO} - VFC_{per\ ton\ BC})$$

where,

FR_{MDO} = the new (calculated) freight rate ($/cargo ton) using MDO
FR_{BC} = the freight rate ($/cargo ton) using HFO

The freight rates for the vessel leg of each Default Scenario Route are added to the rail leg of each Default Scenario Route (if applicable) to obtain a total freight rate ($/cargo ton). Rail rates ($FR_{dsr\ rail}$) are calculated by multiplying rates ($/cargo ton-mile) by rail distance as shown below. In addition, any transfer costs are included ($/cargo ton) to determine an overall (total) freight rate for the origin-destination pair.

Equation 7: Calculating rail freight rate for the Default Scenario Route

$$FR_{dsr\ rail} =\ DTM_{dsr\ rail} * D_{dsr\ rail}$$

where,

$FR_{\ dsr\ rail}$ = Rail freight rate in dollars per cargo ton
$DTM_{dsr\ rail}$ = Rail freight rate in dollars per cargo ton-mile
$D_{dsr\ rail}$ = Rail distance in miles

Equation 8: Calculating total route freight rate for the *Base Case*

$$TRC_{BC} = FR_{BC} + FR_{dsr\ rail} + TC_{dsr}$$

where,

TRC_{BC} = Total route freight rate for the *Base Case* in $/cargo ton
FR_{BC} = Vessel freight rate for the *Base Case* in $/cargo ton
$FR_{\ dsr\ rail}$ = Rail freight rate (used in both the *Base Case* and the *MDO Case*) in $/cargo ton
TC_{dsr} = Total transfer costs (used in both the *Base Case* and the *MDO Case*) in $/cargo ton

Equation 9: Calculating total route freight rate for the *MDO Case*

$$TRC_{MDO} = FR_{MDO} + FR_{dsr\ rail} + TC_{dsr}$$

where,

TRC_{MDO} = Total route freight rate for the *Base Case* in $/cargo ton
FR_{MDO} = Vessel freight rate for the *Base Case* in $/cargo ton
$FR_{dsr\ rail}$ = Rail freight rate (used in both the *Base Case* and the *MDO Case*) in $/cargo ton
TC_{dsr} = Total transfer costs (used in both the *Base Case* and the *MDO Case*) in $/cargo ton

Calculating the Total Route Freight Rate for the All-Rail Alternative Route

The All-Rail Alternative Route also has an associated freight rate; this is compared to the *MDO Case* freight rate in order compare freight rates between Great Lakes routes and all-rail alternatives. The equation for calculating the rail freight rate in the All-Rail Alternative Route is shown below, along with the equation for calculating total freight rates that include any associated transfer costs with the All-Rail Alternative Route.

Equation 10: Calculating rail freight rate for the Default Scenario Route

$$FR_{all\ rail} = DTM_{all\ rail} * D_{all\ rail}$$

where,

$FR_{all\ rail}$ = Rail freight rate in dollars per cargo ton
$DTM_{all\ rail}$ = Rail freight rate in dollars per cargo ton-mile
$D_{all\ rail}$ = Rail distance in miles

Equation 11: Calculating total route freight rate for the All-Rail Alternative Route

$$TRC_{all\ rail} = FR_{all\ rail} + TC_{all\ rail}$$

where,

$TRC_{all\ rail}$ = Total route freight rate for the all-rail scenario in dollars per ton
$FR_{all\ rail}$ = Rail freight rate used in the all-rail scenario in dollars per ton
$TC_{all\ rail}$ = Total transfer costs used in the all-rail scenario in dollars per ton

Chapter 4: Scenario Description and Input Assumptions

This chapter provides an overview of each of the scenarios evaluated in the report, as well as key input assumptions for each of these scenarios. Table 15 summarizes the origin and destination (O/D) pairs and the cargo transported for the sixteen (16) scenario routes. These scenarios were provided by EPA and more information is available in Chapter 2 and Section 8A.5 of Chapter 8 in EPA's *Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping* (2011). Table 16 provides a description of the general inputs used in each scenario.

Table 15: Summary of scenario routes and cargo types

Scenario #	Origin (Port Used)	Destination (Port Used)	Cargo Type
1	Rosebud Mine, MT (Port of Superior, WI)	Bayfront Power Plant, WI (Port of Ashland, WI)	Coal
2	Elk Creek Mine, CO (Port of South Chicago, IL)	Georgia Pacific West Mill, WI (Port of Green Bay, WI)	Coal
3	Rosebud Mine, MT (Port of Superior, WI)	St. Clair & Monroe Power Plants, MI (St. Clair and Monroe Ports, MI)	Coal
4	Rosebud Mine, MT (Port of Superior, WI)	Weadock & Karn Generating Plants, MI (Port of Essexville, MI)	Coal
5	Empire and Tilden Mines, MI (Port of Marquette, MI)	Algoma Steel, ON (Port of Algoma, Sault Ste. Marie, ON)	Iron Ore
6	Quebec Cartier Mining Co., QC (Port Cartier, QC)	ArcelorMittal, IL (Port of Chicago-Burns Harbor)	Iron Ore
7	Hull Rust Mine, MN (Port of Duluth, MN)	U.S. Steel, IN (Port of Gary, IN)	Iron Ore
8	Northshore Mining, MN (Port of Silver Bay, MN)	Severstal, OH (Port of Ashtabula, OH)	Iron Ore
9	Lake Calumet Grain Elevators, IL (Port of Chicago, IL)	Export to Rest of World (RoW) (Port of Baie Comeau, QC)	Grain
10	Duluth Port Grain Elevators, MN (Port of Duluth, MN)	Export to RoW (Port of Baie Comeau, QC)	Grain
11	Duluth Port Grain Elevators, MN (Port of Duluth, MN)	WNY Ethanol Plant , NY (Port of Buffalo, NY)	Grain
12	Goderich Port Grain Elevators, ON (Port of Goderich, ON)	Nabisco Flour Mill, OH (Port of Toledo, OH)	Grain
13	Port Dolomite, MI (Port Dolomite, MI)	J.M. Stuart Power Plant, OH (Port of Toledo, OH)	Stone
14	Calcite Quarry, MI (Calcite Quarry Port, MI)	J.M. Stuart Power Plant, OH (Port of Toledo, OH)	Stone
15	Calcite Quarry, MI (Calcite Quarry Port, MI)	American Crystal Sugar Co., MN (Port of Duluth, MN)	Stone
16	Calcite Quarry, MI (Calcite Quarry Port, MI)	Bruce Mansfield Power Station, PA (Port of Ashtabula, OH)	Stone

Table 16: General inputs for each scenario

Data description	General or Scenario-specific	Value	Units
Vessel Fuel Type (defined under baseline and control conditions)	General	HFO or MDO	Categorical
EPA Specified Fuel Prices	General	$ 424/MT HFO $ 617/MT MDO	$/metric ton (MT)
Main Engine Load Factor at Sea	General	Varied using Equation 2.	Percent of rated power
Auxiliary Engine Power[1]	General	3% of main engine power	kW
Auxiliary Engine Specific Fuel Oil Consumption	General	221	g/kWh
Auxiliary Engine Load Factor in Port[1]	General	80	Percent
Main Engine Load Factor in Port	General	0	Percent
Rail Fuel Type	General	Ultra-Low Sulfur Diesel (ULSD)	Categorical
Rail Fuel Price	General	$617/MT	$/metric ton
Rail Energy Intensity	General	328[2]	BTU/ton-mile

[1]See Auxiliary Engine Horsepower and Load Factor section below. [2]U.S. Energy Information Administration, Annual Energy Outlook, Freight Transportation Energy Use. The
average value of 328 Btu/ton-mile is calculated using the 2015 forecasts published in the 2009 and 2010 AEO reports. See Table 67 of the Supplemental Demand Sector Data Tables, available at http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html, and http://www.eia.doe.gov/oiaf/aeo/supplement/stimulus/suparra.htm

Description of Input Assumption Sources

In addition to the general input assumptions above, the analysis requires scenario-specific input assumptions that relate to the vessels, routes, and port characteristics for each scenario. This section describes the sources of each scenario-specific input assumption used in the analysis. The following headings correlate to the rows found in each scenario's input summary table.

Origin-Destination Pairs

The origin-destination pairs for each scenario used in the analysis were specified by the US Environmental Protection Agency (EPA) following discussions with EERA and after receiving input from stakeholders.

Origin and Destination Ports

The origin and destination ports are those ports that are used in the Default Scenario Route for each scenario. The Default Scenario Route either makes use of the Great Lakes for a portion of the overall route when the source or destination of the commodity is inland, or represents a port-to-port route when the source and destination of the commodity are both at the port (e.g. Scenarios 9 and 10). Origin and destination port characteristics were selected based on the characteristics of each scenario and EPA consultation with stakeholders and EERA discussion with topical experts (Dager, 2010). For example, Figure 3 shows the origin port selected for Scenario 4 as the Port of Duluth, MN and the destination port as the Port of Essexville, MI.

Vessel Type

Each vessel modeled is assumed to be a bulk carrier equipped with a self-unloader. Vessels with a self-unloader have a conveyor system that allows the vessel to discharge its cargo into a pile on land after arriving at the dock. Self-unloaders make it possible for a vessel to unload its cargo without shore-side assistance. Greenwood's Guide to Great Lakes Shipping (2009) indicates that every Category 3 vessel operating on the Great Lakes is equipped with a self-unloader; therefore, bulk carriers with self-unloaders are modeled for each scenario.

Figure 3: Example of origin and destination port selection.

Cargo Transported

The EPA specified the cargoes that would be modeled for each scenario. The analysis models the transportation of four bulk commodities: coal, iron ore, grain, and stone.   Scenarios 1 through 4 model coal transportation; Scenarios 5 through 8 model iron ore transportation; Scenarios 9 through 12 model grain transportation; and Scenarios 13-16 model stone transportation.

Vessel Length

In choosing vessels to model, the analysis considered scenario characteristics that limit the length of the vessel. For example, any route that transits the Welland Canal would be limited to a maximum vessel length of 740 feet. However, in most cases, the limitation on vessel length came from the length of the dock that the vessel would use at port. Based on length restrictions, the maximum length vessel that could transit the route completely was chosen. In all, three different vessels are modeled with lengths of 1,000 feet (Scenarios 3, 4, 7, and 8), 770 feet (Scenarios 13, 14, 15, and 16), and 635 feet (Scenarios 1, 2, 5, 6, 9, 10, 11, and 12). The study applies representative characteristics for each vessel based on the bulk carriers/self-unloaders found in the Greenwood Great Lakes Shipping Guide (2009). All vessels are assumed to be Category 3 vessels because the purpose of the study is to evaluate the economic impacts of the Category 3 Marine Rule. It should be noted that this study does not model particular vessels; rather we are modeling representative vessels that are the appropriate length, cargo capacity, and power that could realistically transport the specified commodity along each route examined in this report.

Vessel Main Engine Horsepower

The main engine horsepower is dependent on the vessel being modeled. Horsepower data were determined by consulting Greenwood's Great Lakes Shipping Guide (2009) and Lloyds Register data provided by ICF Consulting (Browning, 2010). The following horsepower (Hp) values are used in this analysis: 16,000 Hp for 1,000 foot vessels; 11,000 Hp for 770 foot vessels; and 7,200 Hp for 635 foot vessels. Main engine horsepower values were chosen after analyzing power ratings for Great Lakes vessels with these lengths and are appropriate according to stakeholder input and expert judgment for vessels carrying the cargoes (i.e. coal, grain, iron ore, and stone) presented in each scenario.

Vessel Main Engine Specific Fuel Oil Consumption

Data for diesel engine specific fuel oil consumption is included in EPA's Regulatory Impact Analysis for the Category 3 Marine Rule (2009). The main engine specific fuel oil consumption varies depending on the age of the vessel's engine being modeled; the newer the engine, the lower the specific fuel oil consumption. We model three different vessels with lengths of 635, 770, and 1000 feet. We assumed a fuel oil consumption of 236 grams per kilowatt-hour (g/kWh) for 635 foot vessels (1950 to 1960 engine build date), 196 g/kWh for 770 foot vessels (1980 or 1981 engine build date), and 231 g/kWh for 1000 foot vessels (1961 to 1965 engine build date). These assumptions are reported in best practices for preparing port emission inventories (Browning & Bailey, 2006) and consistent with bulk vessel calculations in the Second IMO Greenhouse Gas Study (Buhaug et al., 2009).

Auxiliary Engine Horsepower and Load Factor

As stated in the EPA's *Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping* report (Chapter 4, Section 4.4.1.3) (2011), we do not have data for the number or type of auxiliary units installed on Great Lakes vessels. Thus, we apply general and uniform assumptions about the fraction of energy used by auxiliaries at sea and in port. At sea, we assume that the auxiliary engine represents approximately 3% of main engine horsepower. An assumption that auxiliary engine in-use power during our scenario analysis is small may be reasonable given that only one (or at most two) of several auxiliary generator sets are operating at sea. While in port, the auxiliary systems may be operating with more engines, especially during cargo offloading operations. We acknowledge that specific auxiliary engine data could be determined in future studies; however, given the focus on main engine fuel switching, this was out of scope for this work. Similar assumptions to those used here are reported in best practices for preparing port emission inventories (Browning & Bailey, 2006) and consistent with bulk vessel calculations in the Second IMO Greenhouse Gas Study (Buhaug et al., 2009).

Vessel Operating Speed

The typical maxi*mum* operating speed for the vessels modeled was 14 knots (~16 mph) (Harbor House Publishers, 2009). Through stakeholder input, solicited and distributed to EERA from EPA, the operating speed on the lakes was adjusted as follows: 12 knots (~14 mph) for Scenarios 1, 2, 9, 10, 11 and 12; and 14 knots (~16 mph) for Scenarios 3, 4, 5, 6, 7, 8, 13, 14, 15, and 16.

Vessel Cargo Capacity

The vessel cargo capacity was chosen by examining the Greenwood's Guide to Great Lakes Shipping (2009) to find appropriate cargo capacities for the modeled vessels. Additionally, EPA solicited input from stakeholders on this issue. The following vessel cargo capacities were used in the analysis:

57,200 net tons for Scenarios 3, 7, and 8; 49,300 net tons for Scenarios 13, 14, 15, and 16; 47,510 net tons for Scenario 4; and 18,150 net tons for Scenarios 1, 2, 5, 6, 9, 10, 11, and 12.

Assumed Cargo Load

The assumed cargo load is the amount of the commodity in net tons that is transported along the route. The analysis assumes that the cargo load is 85% of the vessel cargo capacity provided that the maximum allowable vessel draft at the loading or unloading dock does not require the load to be less than 85%. If the load needs to be less than 85% of the vessel cargo capacity, Equation 12 is applied.

Equation 12. Calculating assumed scenario cargo load

$$Assumed\ Cargo\ Load = C_{vessel} - TL * (D_{max} - D_{assumed})$$

where

C_{vessel} = Vessel cargo capacity in net tons, using adjustments described in Table 10
D_{max} = Vessel draft at maximum cargo load in feet
$D_{assumed}$ = Vessel draft considering constrained port or channel conditions in feet
TL = Tons of vessel cargo capacity lost per foot of draft reduction in net tons per foot

The term, tons of vessel cargo capacity lost per foot of draft reduction (*TL*), is a function of vessel size and was obtained from the Lake Carriers' Association (2007b). The values for *TL* are: 1,284 for Scenarios 1, 2, 5, 9, 11, and 12; and 3,204 for Scenario 4. Scenarios 3, 6, 7, 8, 10, 13, 14, 15, and 16 used an assumed cargo load of 85% of the vessel cargo capacity because there were no restrictions requiring a lighter load. Selecting an assumed cargo load of 85% reflects our understanding of actual cargo moves in the Great Lakes following discussion with experts and also creates a more conservative estimate of marine vessel freight rates in $/cargo ton for the purposes of this study. The results of our analysis would not change had we selected an assumed cargo load greater than 85%.

Vessel Draft at Maximum Cargo Load

The vessel draft at maximum cargo load is assumed to be 29 feet for the 1,000 foot and 770 foot vessels, and 28 feet for the 625 foot vessels modeled. These drafts were chosen after researching the range of typical drafts for 1,000 foot, 770 foot, and 635 foot vessels (Harbor House Publishers, 2009).

Vessel Draft at Assumed Cargo Load

The default assumption is that the assumed cargo load is 85% of the vessel's cargo capacity. Using Equation 12, we can solve for $D_{assumed}$ (which in this case equals the vessel draft at assumed cargo load) using a tons of vessel cargo capacity lost per foot of draft reduction (*TL)* value of 1,284 for Scenarios 6 and 10 (635 foot vessel); 1,524 for Scenarios 13, 14, 15, and 16 (770 foot vessel); and 3,204 for Scenarios 3, 7, and 8 (1000 foot vessel) (Lake Carriers' Association, 2007b). For scenarios that had port or channel restrictions (Scenarios 1, 2, 4, 5, 9, 11, and 12), the vessel draft at assumed cargo load was set to equal the "Port Depth Limit" described next.

Port Depth Limit

The port depth limit equals the maximum allowable vessel draft that can be accepted at the load dock or unload dock at the port (whichever is shallower). This value was obtained by researching the various dock depth limits at the ports for loading and unloading the commodity being modeled in each scenario. Dock depth limits for US ports were available from the US Army Corps of Engineers (USACE, 2010). These draft limits are modified by observed vessel drafts from the USACE Waterborne Commerce Statistical Center 2008 data. Dock depth limits for Canadian ports were obtained from

Greenwood's Guide to Great Lakes Shipping (2009). In some cases, port depth limit actually refers to a restriction elsewhere along the route, such as a maximum channel depth.

Default Scenario Route Port-to-Port Distance

The Default Scenario Route port-to-port distance refers to the distance traveled by the water-leg of the Default Scenario Route. This distance was calculated using the Network Analyst extension of ArcGIS as applied to the US ACE waterway network database. Input was also received from stakeholders (via EPA) that gave alternate, though similar, port-to-port distances. When the US ACE distance disagreed with the stakeholder distance, the longer distance was used. A longer port-to-port distance would result in higher costs for the Default Scenario Route and increase the potential for a mode shift.

Default Scenario Route Rail Distance

The Default Scenario Route rail distance refers to the distance traveled by the rail-leg of the Default Scenario Route (if applicable). This distance was calculated in the GIFT model (discussed in Chapter 1) using the Network Analyst extension of ArcGIS as applied to the railway network of the National Transportation Atlas Database (NTAD).

All-Rail Alternative Route Distance

The All-Rail Alternative Route distance is the total miles traveled by rail along the All-Rail Alternative Route. This value was calculated in the GIFT model using the Network Analyst extension of ArcGIS as applied to the railway network of the NTAD. Input from stakeholders was also received (via EPA) that give alternate all-rail distances for some routes. These alternate distances were very similar to those calculated in ArcGIS; however, the values presented by stakeholders were chosen when available.

Marine Vessel Freight Rate

The Base Case freight rates for marine vessels used in the analysis were estimated using the Great Lakes Vessel Costing Model developed by Chrisman Dager while at the Tennessee Valley Authority and implemented in studies for the Great Lakes for USACE. The model has been used for rate analysis in 22 USACE projects since 1999 and uses data collected from 226 Great Lakes dock facilities. The Great Lakes Vessel Costing Model estimates vessel rates on the Great Lakes by class of vessel using reported operating costs, depreciated replacement vessel construction costs, return on investment and vessel operating characteristics such as vessel speed, empty return, and vessel capacity. In addition, the loading and unloading time is calculated from reported handling speeds at the specific docks, and the reported draft at the dock or lock is used to develop vessel capacity. For those vessels traversing locks, the average processing and delay time and tolls (if applicable) are added to the rate estimation. The marine vessel freight rates are referred to as "Base Case Voyage Rates" in this report. The model assumed fuel prices of $424/MT of HFO for the main engines and $617/MT of MDO for the auxiliary engines. The difference in fuel costs in dollars per cargo ton resulting from a switch from HFO to MDO fuel for main engines is added to the Base Case Voyage Rate to calculate the "MDO Case Voyage Rate."

Rail Freight Rate

The rail freight rates are reported based upon revenue per mile. The source of the railroad data is the Surface Transportation Board Public Waybill Sample for 2007 (2009). In addition to the Public Waybill Sample, the Association of American Railroads (AAR) 2007 fourth quarter base, productivity-adjusted Rail Cost Adjustment Factor (2007) was used to arrive at an index to correct to the second quarter of 2010. The index indicated that second quarter 2010 rates were 1% greater than the fourth quarter 2007 rail rates. The attributes used from the AAR to calculate the rail freight rate include carload revenue, average distance, and average weight per car. The rail freight rate is referred to as the "Base Case Rail Rate" later in the report.

Total Cargo Transfer Cost for Default Scenario Route

The total cargo transfer cost for the Default Scenario Routes includes all of the costs associated with transferring one net ton of cargo from origin to destination for the Default Scenario Route. This value includes all transfer costs that are not captured in the rail and ship freight rates. Representative transfer costs were obtained through communication with Chrisman Dager (2010) and derived from data included in the Great Lakes Vessels Costing model described in the *Marine Vessel Freight Rate* section. These rates vary depending on the commodity transferred. The analysis assumes the following total cargo transfer costs for the Default Scenario Routes: $1.55/cargo ton for coal; $1.35/cargo ton for iron ore; $3.50/cargo ton for grain; and $1.20/cargo ton for stone. These values include transferring from rail to ship and unloading from ship to the dock (or into rail cars for further transport if the destination is not at the dock).

Total Cargo Transfer Cost for All-Rail Alternative Route

The total cargo transfer cost for the All-Rail Alternative Route includes all of the costs associated with transferring one net ton of cargo from origin to destination for the All-Rail Alternative Route. This value includes all transfer costs that are not captured in the rail freight rates. Representative transfer costs were obtained through communication with Chrisman Dager (2010). These rates vary depending on the commodity transferred. The analysis assumes the following total cargo transfer costs for the All-Rail Alternative Routes: $1.50/cargo ton for coal; $1.25/cargo ton for iron ore; $3.67/cargo ton for grain; and stone is not considered in our All-Rail Alternative Routes. These values include loading the commodity into rail cars and unloading them at the destination.

Scenario 1: Coal from Rosebud Mine, MT to Bayfront Power Plant, WI

This scenario represents the transport of coal from the Rosebud Mine in Montana to the Bayfront Power Plant in Ashland, Wisconsin. The Bayfront Power Plant is an end-user. The Bayfront Power Plant is a 76 megawatt (MW) power plant that burns coal, biomass, and other fuels.

Input Assumptions

The assumptions for this case can be found in Table 17. A 635 foot long vessel is modeled due to dock restrictions at Ashland which limit vessel draft to 22 feet and length to approximately 700 feet. Due to draft restrictions, we assume that the vessel will not be fully loaded and apply a loss of 1,284 tons per foot of draft reduction.

Figure 4: Scenario 1 map – Rosebud Mine, MT to Bayfront Power Plant, Ashland, WI

Table 17: Summary of Scenario 1 inputs

Data description	Value	Units
Origin-Destination Pair	Rosebud Mine to Bayfront Power Plant	Categorical
Origin and Destination Ports	Superior, WI to Ashland, WI	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Coal	Categorical
Vessel Length (ft.)	635	feet
Vessel Main Engine Horsepower (Hp)	7,200	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	236	g/kWh
Vessel Operating Speed (knots)	12	knots
Vessel Operating Speed (mph)	14	mph
Vessel Cargo Capacity (net tons)	18,150	Net tons
Assumed Cargo Load (net tons)	10,450	Net tons
Vessel Draft at Maximum Cargo Load	28	feet
Vessel Draft at Assumed Cargo Load	22	feet
Port Depth Limit	22	feet
Default Scenario Route Port-to-Port Distance (miles)	140	miles
Default Scenario Route Rail Distance (miles)	1,040	miles
All-Rail Alternative Route Distance (miles)	1,260	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.55	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$1.50	$/cargo ton

Scenario 2: Coal from Elk Creek Mine, CO to Georgia Pacific West Mill in Green Bay, WI

This scenario represents the transport of coal from the Elk Creek Mine in Colorado to the Georgia Pacific West Mill in Green Bay, WI. The Georgia Pacific West Mill is an end-user.

Input Assumptions

The assumptions for this case can be found in Table 18. This scenario is based on a 635 foot vessel due to vessel length restrictions for vessels traveling under the bridges at the Green Bay port and draft restriction at the dock in Green Bay (23 feet). Due to the vessel size restrictions, this scenario is based on a cargo load that assumes a loss of 1,284 tons per foot of draft reduction.

Figure 5: Scenario 2 map - Elk Creek Mine, CO to Georgia Pacific West Mill, Green Bay, WI

Table 18: Summary of Scenario 2 inputs

Data description	Value	Units
Origin-Destination Pair	Elk Creek Mine, CO to Georgia Pacific West Mill in Green Bay, WI	Categorical
Origin and Destination Ports	South Chicago to Green Bay	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Coal	Categorical
Vessel Length (ft.)	635	feet
Vessel Main Engine Horsepower (Hp)	7,200	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	236	g/kWh
Vessel Operating Speed (knots)	12	knots
Vessel Operating Speed (mph)	14	mph
Vessel Cargo Capacity (net tons)	18,150	Net tons
Assumed Cargo Load (net tons)	11,730	Net tons
Vessel Draft at Maximum Cargo Load	28	feet
Vessel Draft at Assumed Cargo Load	23	feet
Port Depth Limit	23	feet
Default Scenario Route Port-to-Port Distance (miles)	390	miles
Default Scenario Route Rail Distance (miles)	1,310	miles
All-Rail Alternative Route Distance (miles)	1,430	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.55	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$1.50	$/cargo ton

Scenario 3: Coal from Rosebud Mine, MT to St. Clair and Monroe Power Plants, MI

This scenario represents the transport of coal from the Rosebud Mine in Montana to the St. Clair and Monroe Power Plants in Michigan. The power plants are end-users.

Input Assumptions

The assumptions for this case can be found in Table 19. This scenario consists of three port calls total. It is assumed that a sufficient amount of coal is unloaded at St. Clair in order to reduce the vessel's draft so that it can unload the remaining coal in Monroe. The Detroit Edison coal dock in Monroe has a maximum draft limit of 21 feet. Due to the synergies between the two ports, no reduction in vessel cargo load is assumed due to the restrictions in Monroe.

Figure 6: Scenario 3 map - Rosebud Mine, MT to St. Clair and Monroe Power Plants, MI

Table 19: Summary of Scenario 3 inputs

Data description	Value	Units
Origin-Destination Pair	Rosebud Mine, MT to St. Clair and Monroe Power Plants, MI	Categorical
Origin and Destination Ports	Superior to St. Clair and onto Monroe, MI	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Coal	Categorical
Vessel Length (ft.)	1,000	feet
Vessel Main Engine Horsepower (Hp)	16,000	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	231	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	57,200	Net tons
Assumed Cargo Load (net tons)	48,620	Net tons
Vessel Draft at Maximum Cargo Load	29	feet
Vessel Draft at Assumed Cargo Load	26.5	feet
Port Depth Limit	Unknown limit at St. Clair but 21 foot limit at the DTE dock in Monroe	feet
Default Scenario Route Port-to-Port Distance (miles)	760	miles
Default Scenario Route Rail Distance (miles)	1,040	miles
All-Rail Alternative Route Distance (miles)	1,620	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.55	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$1.50	$/cargo ton

Scenario 4: Coal from Rosebud Mine, MT to Weadock and Karn Generating Plants, MI

This scenario represents the transport of coal from the Rosebud Mine in Montana to the Weadock and Karn Generating Plants in Michigan. The generating plants are end-users.

Input Assumptions

The assumptions for this case can be found in Table 20. This scenario is based on two port calls, with each of two generating plants receiving coal from the port in Essexville, MI. While this scenario is based on a large vessel (1,000 foot), there are port draft restrictions at Essexville (23 feet). Due to the vessel size restrictions, this scenario is based on a cargo load that assumes a loss of 3,204 tons per foot of draft reduction.

Figure 7: Scenario 4 map - Rosebud Mine, MT to Weadock/Karn Generating Plants, Essexville, MI

Table 20: Summary of Scenario 4 inputs

Data description	Value	Units
Origin-Destination Pair	Rosebud Mine, MT to Weadock and Karn Generating Plants, MI	Categorical
Origin and Destination Ports	Superior to Essexville	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Coal	Categorical
Vessel Length (ft.)	1,000	feet
Vessel Main Engine Horsepower (Hp)	16,000	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	231	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	47,510	Net tons
Assumed Cargo Load (net tons)	28,290	Net tons
Vessel Draft at Maximum Cargo Load	29	feet
Vessel Draft at Assumed Cargo Load	23	feet
Port Depth Limit	23	feet
Default Scenario Route Port-to-Port Distance (miles)	620	miles
Default Scenario Route Rail Distance (miles)	1,040	miles
All-Rail Alternative Route Distance (miles)	1,660	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.55	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$1.50	$/cargo ton

Scenario 5: Iron ore from Empire and Tilden Mines, MI to Algoma Steel, ON

This scenario represents the transport of iron ore from the Empire and Tilden Mines in Michigan to Algoma Steel in Ontario, Canada. Algoma Steel is an end-user.

Input Assumptions

The assumptions for this case can be found in Table 21. This scenario is based on a 635 foot vessel due to dock restrictions at the Sault St. Marine, Ontario (Algoma) port which limit vessel draft (23 feet). Due to the vessel size restrictions, this scenario is based on a cargo load that assumes a loss of 1,284 tons per foot of draft reduction.

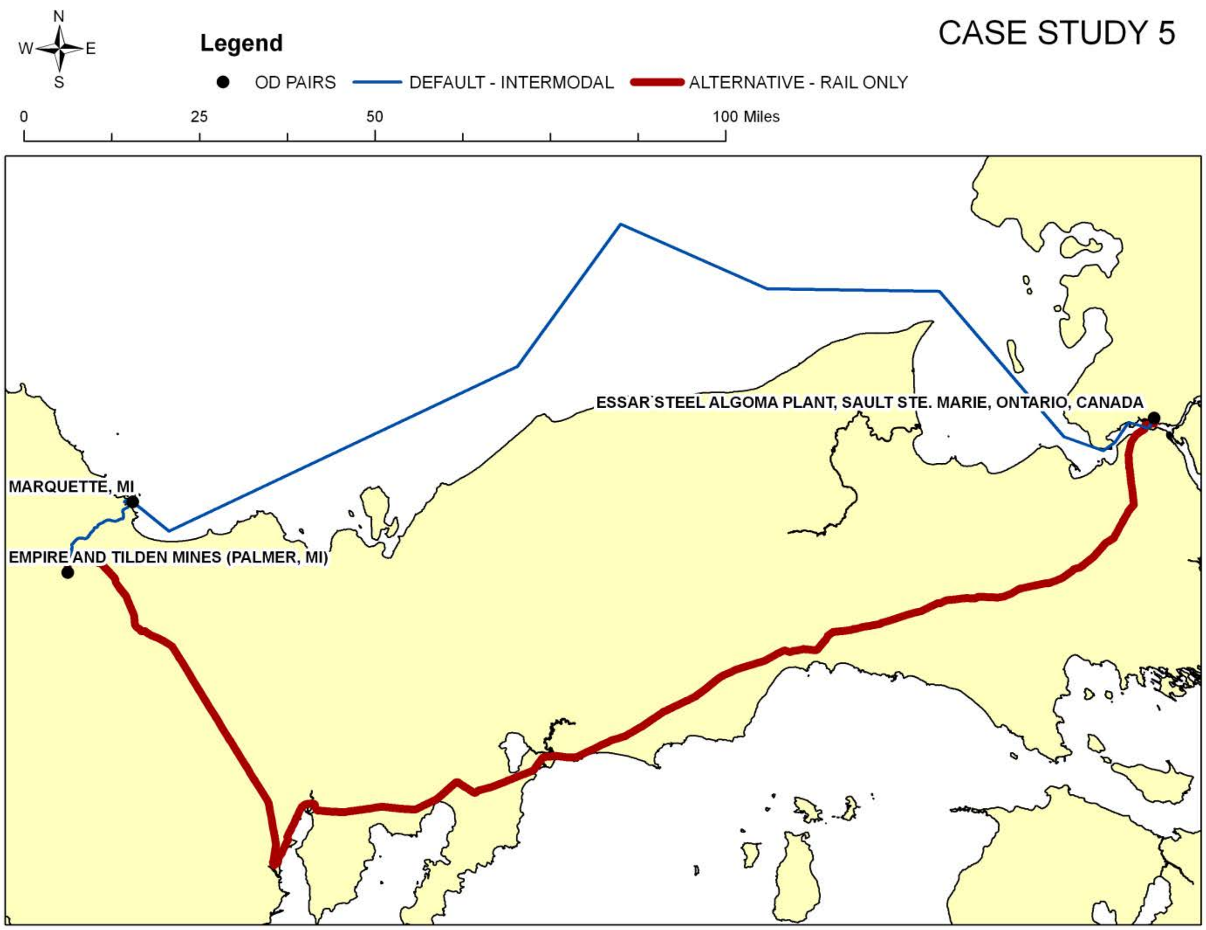

Figure 8: Scenario 5 map - Empire and Tilden Mines, Palmer, MI to Essar Steel Algoma Plant, Sault Ste. Marie, ON

Table 21: Summary of Scenario 5 inputs

Data description	Value	Units
Origin-Destination Pair	Empire and Tilden Mines, MI to Algoma Steel, ON	Categorical
Origin and Destination Ports	Marquette to Algoma	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Iron Ore	Categorical
Vessel Length (ft.)	635	feet
Vessel Main Engine Horsepower (Hp)	7,200	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	236	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	18,150	Net tons
Assumed Cargo Load (net tons)	11,730	Net tons
Vessel Draft at Maximum Cargo Load	28	feet
Vessel Draft at Assumed Cargo Load	23	feet
Port Depth Limit	23	feet
Default Scenario Route Port-to-Port Distance (miles)	170	miles
Default Scenario Route Rail Distance (miles)	20	miles
All-Rail Alternative Route Distance (miles)	210	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.35	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$1.25	$/cargo ton

Scenario 6: Iron ore from Quebec Cartier Mining Company, QC to ArcelorMittal, IL

This scenario represents the transport of iron ore from the Quebec Cartier Mining Company in Quebec, Canada to ArcelorMittal in Illinois. ArcelorMittal is an end-user. After reviewing the rail network in the GIFT model and through discussions with stakeholders and experts, it was determined that Port Cartier, QC is not serviceable by rail; therefore an All-Rail Alternative Route does not exist.

Input Assumptions

The assumptions for this case can be found in Table 22. This scenario is based on a 635 foot vessel because this route traverses the Montreal-Lake Ontario Locks and the Welland Canal which has a maximum allowable draft of 26.5 feet and a maximum vessel length of 740 feet. When the vessel is loaded at 85% capacity, the resulting draft becomes 26 feet due to a one foot draft reduction per 1,284 net tons of cargo reduction (Lake Carriers' Association, 2007b).

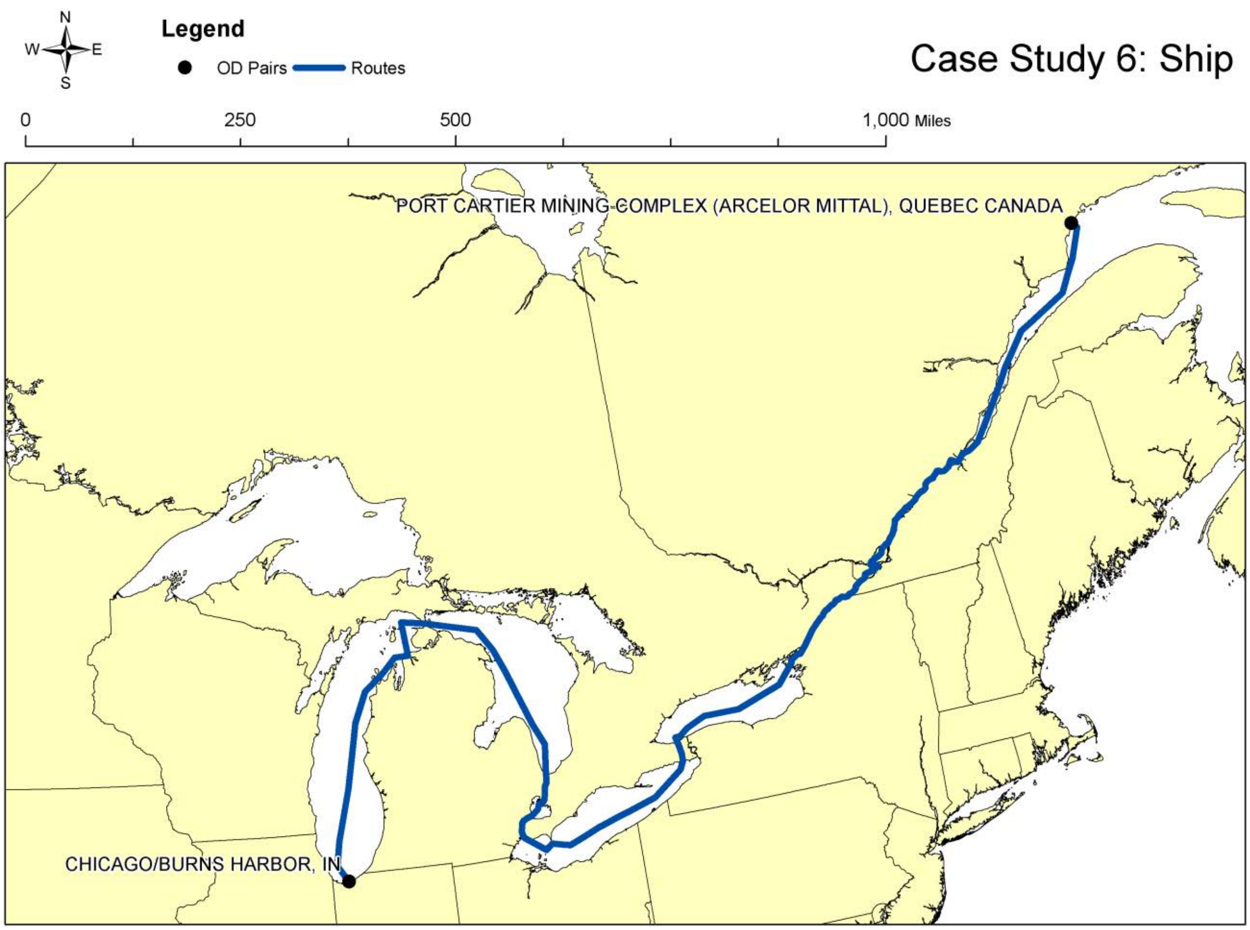

Figure 9: Scenario 6 map - Quebec Cartier Mining Company, Port Cartier, QC to ArcelorMittal, Chicago, IL

Table 22: Summary of Scenario 6 inputs

Data description	Value	Units
Origin-Destination Pair	Quebec Cartier Mining Company, QC to ArcelorMittal, IL	Categorical
Origin and Destination Ports	Port Cartier to Chicago	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Iron Ore	Categorical
Vessel Length (ft.)	635	feet
Vessel Main Engine Horsepower (Hp)	7,200	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	236	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	18,150	Net tons
Assumed Cargo Load (net tons)	15,430	Net tons
Vessel Draft at Maximum Cargo Load	28	feet
Vessel Draft at Assumed Cargo Load	26	feet
Port Depth Limit	28	feet
Default Scenario Route Port-to-Port Distance (miles)	1,730	miles
Default Scenario Route Rail Distance (miles)	200	miles
All-Rail Alternative Route Distance (miles)	No All-Rail Alternative	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.35	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	No All-Rail Alternative	$/cargo ton

Scenario 7: Iron ore from the Hull Rust Mine, MN to US Steel, IN

This scenario represents the transport of iron ore from the Hull Rust Mine in Minnesota to US Steel in Indiana. US Steel is an end-user.

Input Assumptions

The assumptions for this case can be found in Table 23. This scenario is based on a 1,000 foot vessel. Despite a port depth limit of 26.5 feet, we assume that the vessel's draft is 26 feet at 85% capacity due to a loss of one foot per 3,204 net tons of cargo reduction (Lake Carriers' Association, 2007b).

Figure 10: Scenario 7 map - Hull Rust Mine, Hibbing, MN to US Steel, Gary, IN

Table 23: Summary of Scenario 7 inputs

Data description	Value	Units
Origin-Destination Pair	Hull Rust Mine, MN to US Steel, IN	Categorical
Origin and Destination Ports	Superior to Gary	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Iron Ore	Categorical
Vessel Length (ft.)	1,000	feet
Vessel Main Engine Horsepower (Hp)	16,000	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	231	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	57,200	Net tons
Assumed Cargo Load (net tons)	48,620	Net tons
Vessel Draft at Maximum Cargo Load	29	feet
Vessel Draft at Assumed Cargo Load	26	feet
Port Depth Limit	26.5	feet
Default Scenario Route Port-to-Port Distance (miles)	870	miles
Default Scenario Route Rail Distance (miles)	80	miles
All-Rail Alternative Route Distance (miles)	570	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.35	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$1.25	$/cargo ton

Scenario 8: Iron ore from Northshore Mining, MN to Severstal, OH

This scenario represents the transport of iron ore from Northshore Mining in Minnesota to Severstal in Ohio. Severstal is an end-user.

Input Assumptions

The assumptions for this case can be found in Table 24. This scenario is based on a 1,000 foot vessel. Despite a port depth limit of 26.5 feet, we assume that the vessel's draft is 26 feet at 85% capacity due to a loss of one foot per 3,204 net tons of cargo reduction (Lake Carriers' Association, 2007b).

Figure 11: Scenario 8 map - Northshore Mining, Babbit, MN to Severstal, Warren, OH

Table 24: Summary of Scenario 8 inputs

Data description	Value	Units
Origin-Destination Pair	Northshore Mining, MN to Severstal, OH	Categorical
Origin and Destination Ports	Silver Bay to Ashtabula	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Iron Ore	Categorical
Vessel Length (ft.)	1,000	feet
Vessel Main Engine Horsepower (Hp)	16,000	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	231	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	57,200	Net tons
Assumed Cargo Load (net tons)	48,620	Net tons
Vessel Draft at Maximum Cargo Load	29	feet
Vessel Draft at Assumed Cargo Load	26	feet
Port Depth Limit	26.5	feet
Default Scenario Route Port-to-Port Distance (miles)	840	miles
Default Scenario Route Rail Distance (miles)	100	miles
All-Rail Alternative Route Distance (miles)	900	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.35	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$1.25	$/cargo ton

Scenario 9: Grain from Lake Calumet Grain Elevators, IL to Baie Comeau, QC

This scenario represents the transport of grain from the Lake Calumet Grain Elevators in Illinois to Baie Comeau in Quebec, Canada. Baie Comeau is a transportation hub.

Input Assumptions

The assumptions for this case can be found in Table 25. This scenario assumes a 635 foot vessel because this route traverses the Welland Canal. The maximum allowable vessel length for the Welland Canal is 740 feet and the next smallest vessel that we model is 770 feet long. The Calumet River depth is the limiting factor for the vessel draft in this scenario. The river can support a draft of 25.5 feet. Due to the vessel size restrictions, this scenario is based on a cargo load that assumes a loss of 1,284 tons per foot of draft reduction.

Figure 12: Scenario 9 map - Lake Calumet Grain Elevators, Chicago, IL to Baie Comeau, QC for export to the rest of the world

Table 25: Summary of Scenario 9 inputs

Data description	Value	Units
Origin-Destination Pair	Lake Calumet Grain Elevators, IL to Baie Comeau, QC for export to the rest of the world	Categorical
Origin and Destination Ports	Chicago to Baie Comeau	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Grain	Categorical
Vessel Length (ft.)	635	feet
Vessel Main Engine Horsepower (Hp)	7,200	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	236	g/kWh
Vessel Operating Speed (knots)	12	knots
Vessel Operating Speed (mph)	14	mph
Vessel Cargo Capacity (net tons)	18,150	Net tons
Assumed Cargo Load (net tons)	14,940	Net tons
Vessel Draft at Maximum Cargo Load	28	feet
Vessel Draft at Assumed Cargo Load	25.5	feet
Port Depth Limit	25.5 (Calumet River)	feet
Default Scenario Route Port-to-Port Distance (miles)	1,720	miles
Default Scenario Route Rail Distance (miles)	0	miles
All-Rail Alternative Route Distance (miles)	1,270	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$3.50	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$3.67	$/cargo ton

Scenario 10: Grain from Duluth Port Grain Elevators, MN to Baie Comeau, QC

This scenario represents the transport of grain from the Duluth Port Grain Elevators in Minnesota to Baie Comeau in Quebec, Canada. Baie Comeau is a transportation hub.

Input Assumptions

The assumptions for this case can be found in Table 26. This scenario assumes a 635 foot vessel because this route traverses the Welland Canal. The maximum allowable vessel length for the Welland Canal is 740 feet and the next smallest vessel that we model is 770 feet long. At an 85% cargo load, the assumed vessel draft is 26 feet, less than the Seaway limit of 26.5 feet.

Figure 13: Scenario 10 map - Duluth Port Grain Elevators, Duluth, MN to Baie Comeau, QC for export to the rest of the world

Table 26: Summary of Scenario 10 inputs

Data description	Value	Units
Origin-Destination Pair	Duluth Port Grain Elevators, MN to Baie Comeau, QC for export to the rest of the world	Categorical
Origin and Destination Ports	Duluth to Baie Comeau	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Grain	Categorical
Vessel Length (ft.)	635	feet
Vessel Main Engine Horsepower (Hp)	7,200	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	236	g/kWh
Vessel Operating Speed (knots)	12	knots
Vessel Operating Speed (mph)	14	mph
Vessel Cargo Capacity (net tons)	18,150	Net tons
Assumed Cargo Load (net tons)	15,430	Net tons
Vessel Draft at Maximum Cargo Load	28	feet
Vessel Draft at Assumed Cargo Load	26	feet
Port Depth Limit	26.5 (St. Lawrence Seaway draft limit)	feet
Default Scenario Route Port-to-Port Distance (miles)	1,730	miles
Default Scenario Route Rail Distance (miles)	0	miles
All-Rail Alternative Route Distance (miles)	1,640	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$3.50	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$3.67	$/cargo ton

Scenario 11: Grain from Duluth Port Grain Elevators, MN to WNY Ethanol Plant, Medina, NY

This scenario represents the transport of grain from the Duluth Port Grain Elevators in Minnesota to the WNY Ethanol Plant in Medina, NY. The WNY Ethanol Plant is an end-user.

Input Assumptions

The assumptions for this case can be found in Table 27. This scenario is based on a 635 foot vessel because of port draft restrictions in Buffalo (23 feet). Due to the vessel size restrictions, this scenario is based on a cargo load that assumes a loss of 1,284 tons per foot of draft reduction (Lake Carriers' Association, 2007b).

Figure 14: Scenario 11 map - Duluth Port Grain Elevators, Duluth, MN to WNY Ethanol Plant, Medina, NY

Table 27: Summary of Scenario 11 inputs

Data description	Value	Units
Origin-Destination Pair	Duluth Port Grain Elevators, MN to WNY Ethanol Plant, Medina, NY	Categorical
Origin and Destination Ports	Duluth to Buffalo	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Grain	Categorical
Vessel Length (ft.)	635	feet
Vessel Main Engine Horsepower (Hp)	7,200	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	236	g/kWh
Vessel Operating Speed (knots)	12	knots
Vessel Operating Speed (mph)	14	mph
Vessel Cargo Capacity (net tons)	18,150	Net tons
Assumed Cargo Load (net tons)	11,730	Net tons
Vessel Draft at Maximum Cargo Load	28	feet
Vessel Draft at Assumed Cargo Load	23	feet
Port Depth Limit	23	feet
Default Scenario Route Port-to-Port Distance (miles)	960	miles
Default Scenario Route Rail Distance (miles)	50	miles
All-Rail Alternative Route Distance (miles)	970	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$3.50	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$3.67	$/cargo ton

Scenario 12: Grain from Goderich Port Grain Elevators, ON to Nabisco Flour Mill, OH

This scenario represents the transport of grain from the Goderich Port Grain Elevators in Ontario, Canada to the Nabisco Flour Mill in Ohio. The Nabisco Flour Mill is an end-user.

Input Assumptions

The assumptions for this case can be found in Table 28. This scenario is based on a 635 foot vessel because of port draft restrictions at the Nabisco Flour Dock in Toledo (17 feet). Due to the vessel size restrictions, this scenario is based on a cargo load that assumes a loss of 1,284 tons per foot of draft reduction (Lake Carriers' Association, 2007b).

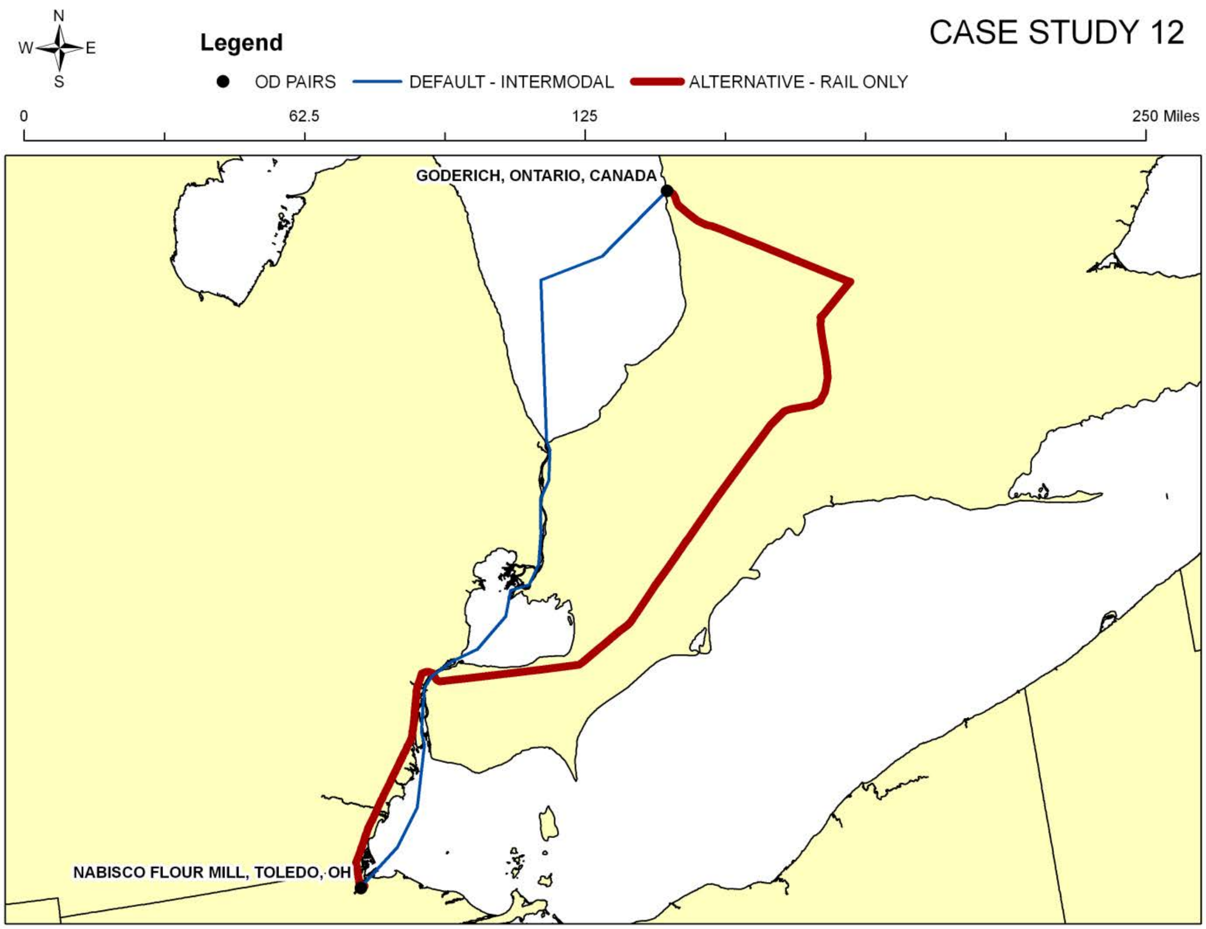

Figure 15: Scenario 12 map - Goderich Port Grain Elevators, Goderich, ON to Nabisco Flour Mill, Toledo, OH

Table 28: Summary of Scenario 12 inputs

Data description	Value	Units
Origin-Destination Pair	Goderich Port Grain Elevators, ON to Nabisco Flour Mill, OH	Categorical
Origin and Destination Ports	Goderich to Toledo	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Grain	Categorical
Vessel Length (ft.)	635	feet
Vessel Main Engine Horsepower (Hp)	7,200	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	236	g/kWh
Vessel Operating Speed (knots)	12	knots
Vessel Operating Speed (mph)	14	mph
Vessel Cargo Capacity (net tons)	18,150	Net tons
Assumed Cargo Load (net tons)	4,030	Net tons
Vessel Draft at Maximum Cargo Load	28	feet
Vessel Draft at Assumed Cargo Load	17	feet
Port Depth Limit	17	Feet
Default Scenario Route Port-to-Port Distance (miles)	185	miles
Default Scenario Route Rail Distance (miles)	5	miles
All-Rail Alternative Route Distance (miles)	240	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$3.50	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	$3.67	$/cargo ton

Scenario 13: Stone from Port Dolomite, MI to the J.M. Stuart Power Plant, OH

This scenario represents the transport of stone from Port Dolomite in Michigan to the J.M. Stuart Power Plant in Ohio. The power plant is an end-user. After reviewing the rail network in the GIFT model and through discussions with stakeholders and experts, it was determined that Port Dolomite, MI is not serviceable by rail; therefore, an All-Rail Alternative Route does not exist. Additionally, it appears that there is not a physical rail connection to the J.M. Stuart power plant. If stone were to be transported from the rail line to the power plant, it would need to be transferred to truck or barge (likely in Cincinnati). Though we understand that a real-world route would require extra transfer costs related to the movement of stone to the power plant, this portion of the route is not impacted by the Category 3 Marine Rule.

Input Assumptions

The assumptions for this case can be found in Table 29. We assume a vessel length of 770 feet based on stakeholder comment forwarded to EERA from EPA stating that 1,000 foot vessels do not frequent this route. Stakeholders indicated that vessel lengths are typically 800 feet or less for this route. At 85% cargo capacity, the vessel draft is assumed to be 24 feet due to a loss of one foot of draft per 1,524 net tons of cargo reduction (Lake Carriers' Association, 2007b). There is no All-Rail Alternative Route evaluated for this scenario.

Figure 16: Scenario 13 map - Port Dolomite to J. M. Stuart Power Plant, Aberdeen, OH

Table 29: Summary of Scenario 13 inputs

Data description	Value	Units
Origin-Destination Pair	Port Dolomite, MI to J.M. Stuart Power Plant, OH	Categorical
Origin and Destination Ports	Port Dolomite to Toledo	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Stone	Categorical
Vessel Length (ft.)	770	feet
Vessel Main Engine Horsepower (Hp)	11,000	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	196	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	49,300	Net tons
Assumed Cargo Load (net tons)	41,900	Net tons
Vessel Draft at Maximum Cargo Load	29	feet
Vessel Draft at Assumed Cargo Load	24	feet
Port Depth Limit	26.5	feet
Default Scenario Route Port-to-Port Distance (miles)	360	miles
Default Scenario Route Rail Distance (miles)	260	miles
All-Rail Alternative Route Distance (miles)	No All-Rail Alternative	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.20	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	No All-Rail Alternative	$/cargo ton

Scenario 14: Stone from Calcite Quarry, MI to the J.M. Stuart Power Plant, OH

This scenario represents the transport of stone from Calcite Quarry in Michigan to the J.M. Stuart Power Plant in Ohio. The power plant is an end-user. After reviewing the rail network in the GIFT model and through discussions with stakeholders and experts, it was determined that Calcite Quarry near Rodgers City, MI is not serviceable by rail; therefore, an All-Rail Alternative Route does not exist. As stated in the Scenario 13 description, it appears that there is no physical rail connection to the J.M. Stuart power plant. If stone were to be transported from the rail line to the power plant, it would need to be transferred to truck or barge (likely in Cincinnati). Though we understand that a real-world route would require extra transfer costs related to the movement of stone to the power plant, this portion of the route is not impacted by the Category 3 Marine Rule.

Input Assumptions

The assumptions for this case can be found in Table 30. We assume a vessel length of 770 feet based on stakeholder comment forwarded to EERA from EPA stating that 1,000 foot vessels do not frequent this route. Stakeholders indicated that vessel lengths are typically 800 feet or less for this route. At 85% cargo capacity, the vessel draft is assumed to be 24 feet due to a loss of one foot of draft per 1,524 net tons of cargo reduction (Lake Carriers' Association, 2007b). There is no All-Rail Alternative Route evaluated for this scenario.

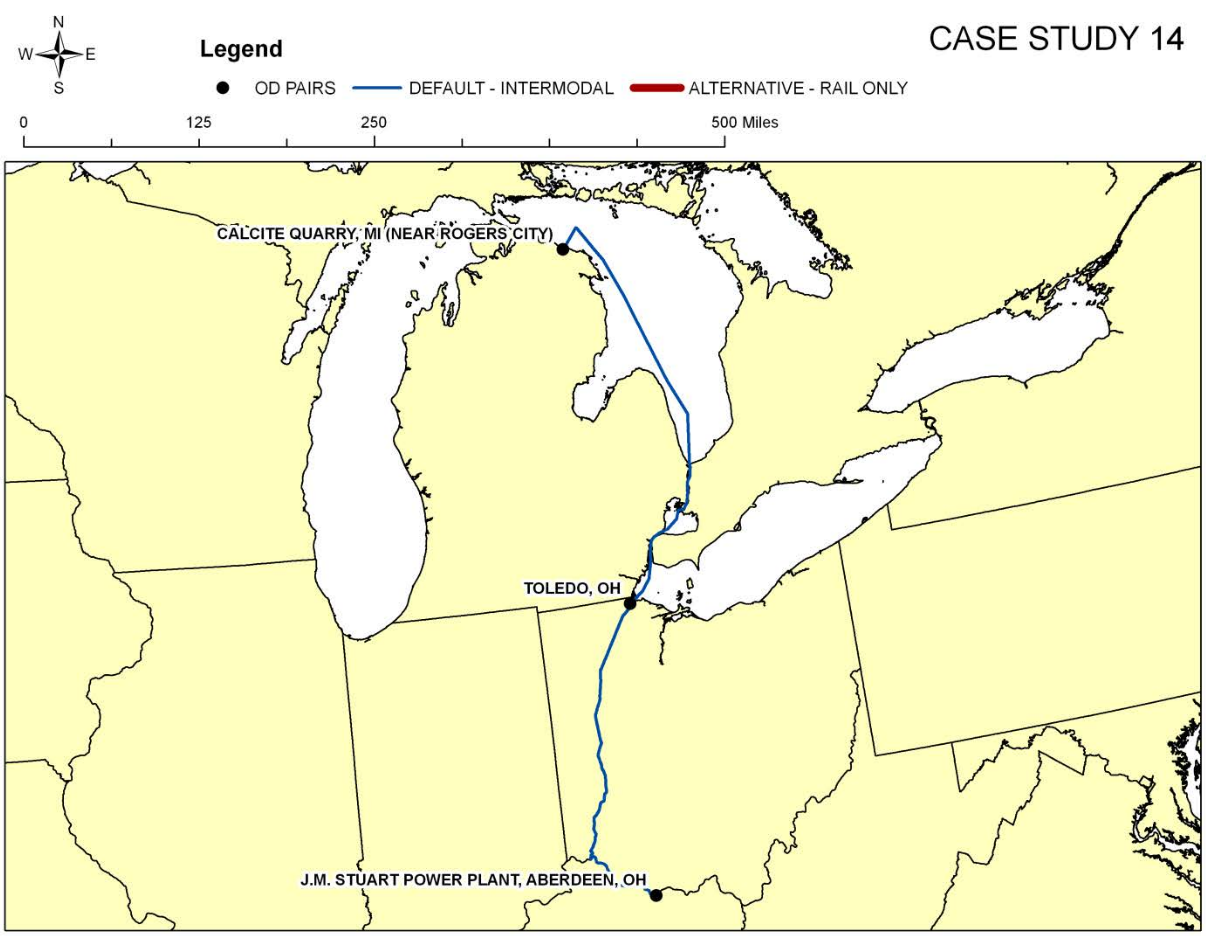

Figure 17: Scenario 14 map - Calcite Quarry, MI to J.M. Stuart Power Plant, Aberdeen, OH

Table 30: Summary of Scenario 14 inputs

Data description	Value	Units
Origin-Destination Pair	Calcite Quarry, MI to J.M Stuart Power Plant, OH	Categorical
Origin and Destination Ports	Calcite Quarry to Toledo	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Stone	Categorical
Vessel Length (ft.)	770	feet
Vessel Main Engine Horsepower (Hp)	11,000	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	196	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	49,300	Net tons
Assumed Cargo Load (net tons)	41,900	Net tons
Vessel Draft at Maximum Cargo Load	29	feet
Vessel Draft at Assumed Cargo Load	24	feet
Port Depth Limit	26.5	feet
Default Scenario Route Port-to-Port Distance (miles)	320	miles
Default Scenario Route Rail Distance (miles)	260	miles
All-Rail Alternative Route Distance (miles)	No All-Rail Alternative	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.20	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	No All-Rail Alternative	$/cargo ton

Scenario 15: Stone from Calcite Quarry, MI to American Crystal Sugar Company, MN

This scenario represents the transport of stone from Calcite Quarry in Michigan to the American Crystal Sugar Company in Minnesota. The sugar company is an end-user. After reviewing the rail network in the GIFT model and through discussions with stakeholders and experts, it was determined that Calcite Quarry near Rodgers City, MI is not serviceable by rail; therefore, an All-Rail Alternative Route does not exist.

Input Assumptions

The assumptions for this case can be found in Table 31. We assume a vessel length of 770 feet based on stakeholder comment forwarded to EERA from EPA stating that 1,000 foot vessels do not frequent this route. Stakeholders indicated that vessel lengths are typically 800 feet or less for this route. At 85% cargo capacity, the vessel draft is assumed to be 24 feet due to a loss of one foot of draft per 1,524 net tons of cargo reduction (Lake Carriers' Association, 2007b). There is no All-Rail Alternative Route evaluated for this scenario.

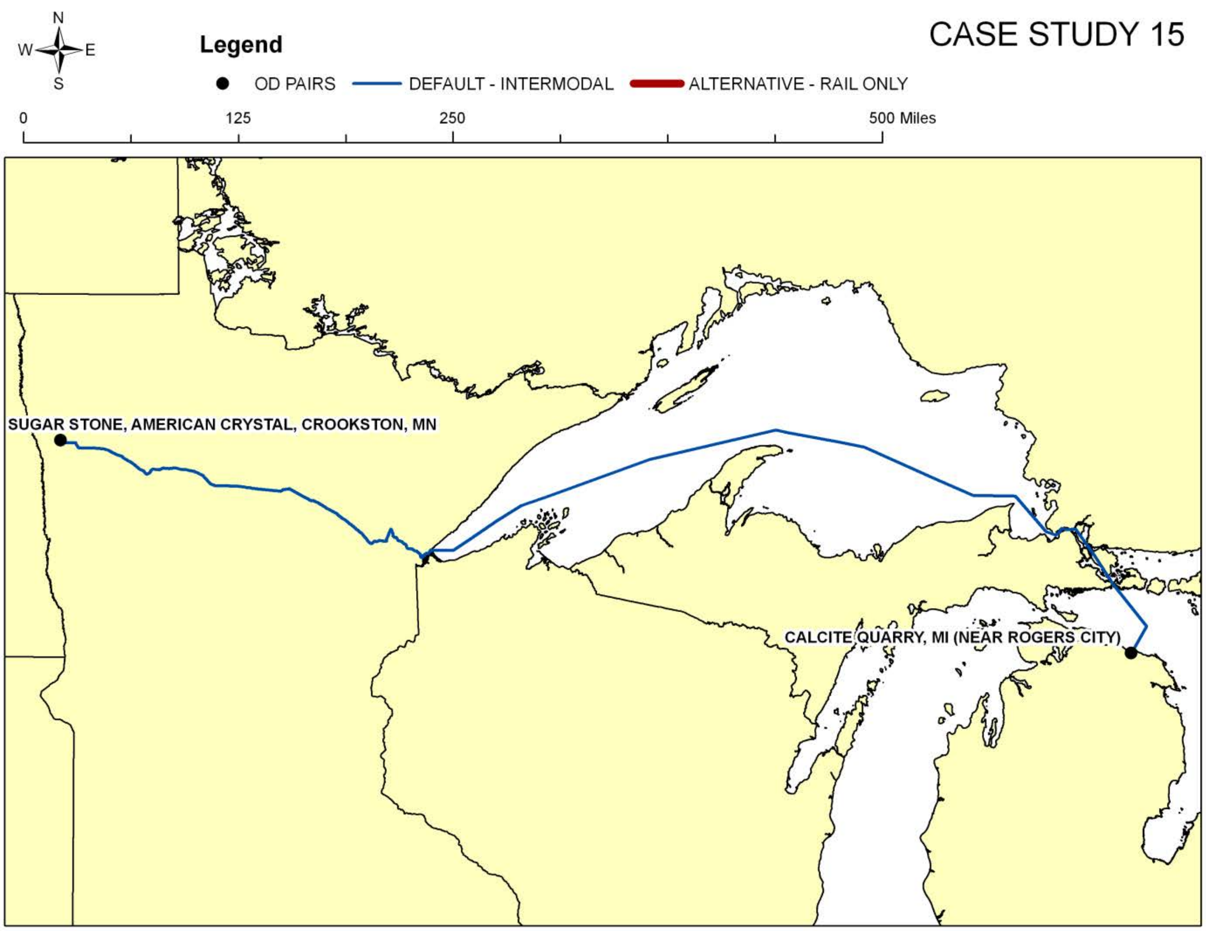

Figure 18: Scenario 15 map - Calcite Quarry, MI to American Crystal Sugar Company, Crookston, MN.

Table 31: Summary of Scenario 15 inputs

Data description	Value	Units
Origin-Destination Pair	Calcite Quarry, MI to American Crystal Sugar Company, MN	Categorical
Origin and Destination Ports	Calcite Quarry to Duluth	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Stone	Categorical
Vessel Length (ft.)	770	feet
Vessel Main Engine Horsepower (Hp)	11,000	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	196	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	49,300	Net tons
Assumed Cargo Load (net tons)	41,900	Net tons
Vessel Draft at Maximum Cargo Load	29	feet
Vessel Draft at Assumed Cargo Load	24	feet
Port Depth Limit	26.5	feet
Default Scenario Route Port-to-Port Distance (miles)	470	miles
Default Scenario Route Rail Distance (miles)	250	miles
All-Rail Alternative Route Distance (miles)	No All-Rail Alternative	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.20	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	No All-Rail Alternative	$/cargo ton

Scenario 16: Stone from Calcite Quarry, MI to Bruce Mansfield Power Station, OH

This scenario represents the transport of stone from Calcite Quarry in Michigan to the Bruce Mansfield Power Station in Ohio. The power plant is an end-user. After reviewing the rail network in the GIFT model and through discussions with stakeholders and experts, it was determined that Calcite Quarry near Rodgers City, MI is not serviceable by rail; therefore, an All-Rail Alternative Route does not exist.

Input Assumptions

The assumptions for this case can be found in Table 32. We assume a vessel length of 770 feet based on stakeholder comment forwarded to EERA from EPA stating that 1,000 foot vessels do not frequent this route. Stakeholders indicated that vessel lengths are typically 800 feet or less for this route. At 85% cargo capacity, the vessel draft is assumed to be 24 feet due to a loss of one foot of draft per 1,524 net tons of cargo reduction (Lake Carriers' Association, 2007b). There is no All-Rail Alternative Route evaluated for this scenario.

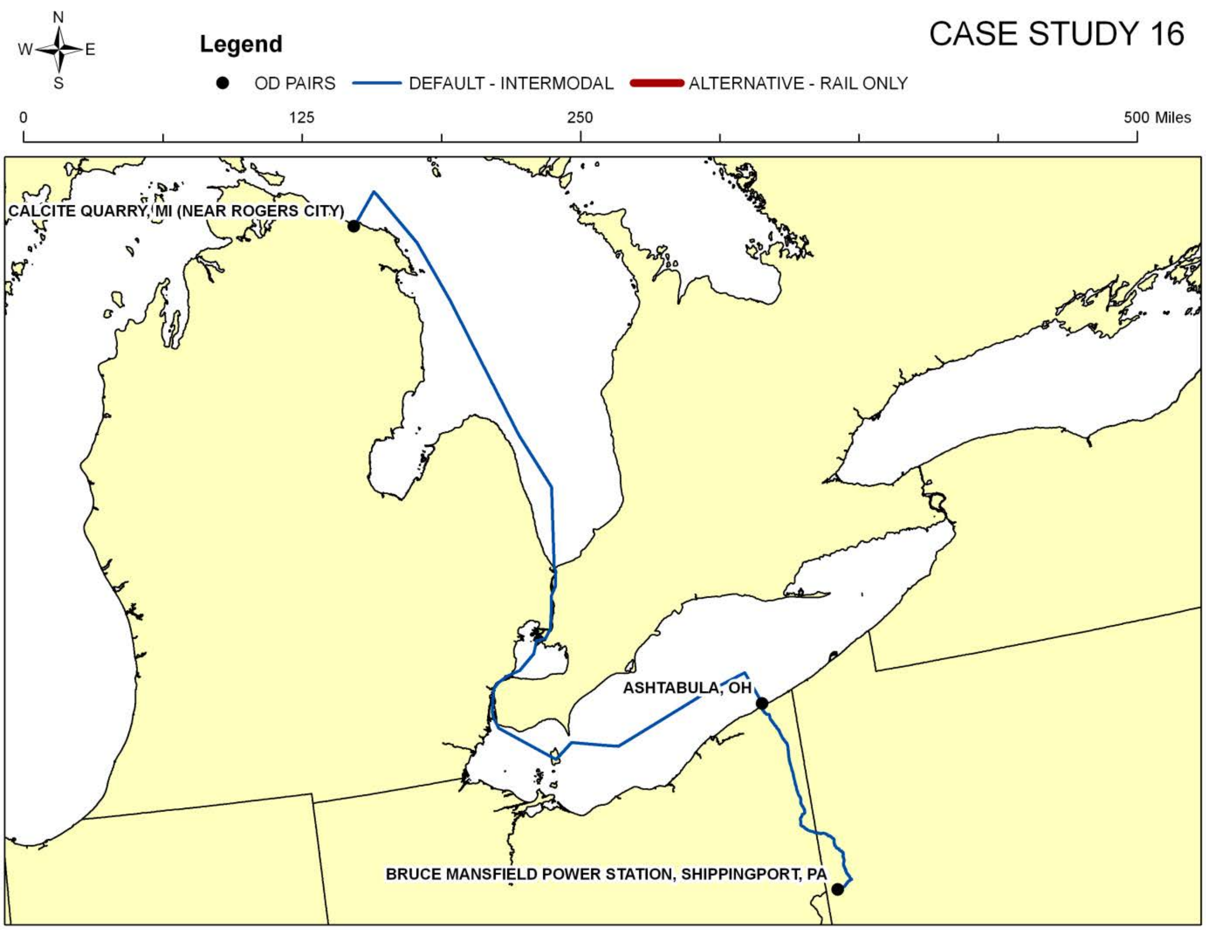

Figure 19: Scenario 16 map - Calcite Quarry, MI to Bruce Mansfield Power Station, Shippingport, PA

Table 32: Summary of Scenario 16 inputs

Data description	Value	Units
Origin-Destination Pair	Calcite Quarry, MI to Bruce Mansfield Power Station, OH	Categorical
Origin and Destination Ports	Calcite Quarry to Ashtabula	Categorical
Vessel Type	Bulk/Self-unloader	Categorical
Cargo Transported	Stone	Categorical
Vessel Length (ft.)	770	feet
Vessel Main Engine Horsepower (Hp)	11,000	Horsepower
Vessel Main Engine Specific Fuel Oil Consumption	196	g/kWh
Vessel Operating Speed (knots)	14	knots
Vessel Operating Speed (mph)	16	mph
Vessel Cargo Capacity (net tons)	49,300	Net tons
Assumed Cargo Load (net tons)	41,900	Net tons
Vessel Draft at Maximum Cargo Load	29	feet
Vessel Draft at Assumed Cargo Load	24	feet
Port Depth Limit	26.5	feet
Default Scenario Route Port-to-Port Distance (miles)	430	miles
Default Scenario Route Rail Distance (miles)	110	miles
All-Rail Alternative Route Distance (miles)	No All-Rail Alternative	miles
Total Cargo Transfer Cost for Default Scenario Route ($/ton)	$1.20	$/cargo ton
Total Cargo Transfer Cost for All-Rail Alternative Route ($/ton)	No All-Rail Alternative	$/cargo ton

Chapter 5: Results

This chapter presents results for each scenario. Results include a map, tables, and a brief discussion for each scenario.

Scenario 1: Coal from Rosebud Mine, MT to Bayfront Power Plant, WI

Table 33 summarizes the results of Scenario 1. The All-Rail Alternative Route is more expensive than the Default Scenario Route in dollars per cargo ton. Table 34 presents a summary of the Default Scenario Route characteristics; Table 35 presents the All-Rail Alternative Route.

Figure 20: Scenario 1 map – Rosebud Mine, MT to Bayfront Power Plant, Ashland, WI

Table 33: Scenario 1 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$20.23	$21.71
Total Route Distance (miles)	1,180	1,260

Table 34: Scenario 1 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	140
Total Rail Distance (miles)	1,040
Total Route Distance (miles)	1,180
Tons Transported (net ton)	10,450
Base Scenario Fuel Costs ($/cargo ton)	$0.80
MDO Scenario Fuel Costs ($/cargo ton)	$1.04
Change in Fuel Costs ($/cargo ton)	$0.24
Total Transfer Cost ($/cargo ton)	$1.55
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$1.81
Total Rail Portion of Freight Rate ($/cargo ton)	$16.62
Total Freight Rate for *Base Case* ($/cargo ton)	$19.99
Total Freight Rate for *MDO Case* ($/cargo ton)	**$20.23**

Table 35: Scenario 1 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	1,260
Tons Transported (net ton)	10,450
Total Transfer Cost ($/cargo ton)	$1.50
Total Rail Portion of Freight Rate ($/cargo ton)	$20.21
Total Freight Rate ($/cargo ton)	**$21.71**

Scenario 2: Coal from Elk Creek Mine, CO to Georgia Pacific West Mill in Green Bay, WI

Table 36 summarizes the results of Scenario 2 and shows that an existing rail-water route may have higher freight rates under the *MDO Case* than an All-Rail Alternative. The All-Rail Alternative Route is less expensive than the Default Scenario Route in dollars per cargo ton. However, in this case, even the *Base Case* shows freight rates that are higher than the All-Rail Alternative. Therefore, it is possible that other factors not considered in this analysis support the movement of this commodity via ship given prevailing freight rates. Table 37 presents a summary of the Default Scenario Route characteristics; Table 38 presents the All-Rail Alternative Route.

Figure 21: Scenario 2 map - Elk Creek Mine, CO to Georgia Pacific West Mill, Green Bay, WI

Table 36: Scenario 2 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$26.64	$24.43
Total Route Distance (miles)	1,700	1,430

Table 37: Scenario 2 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	390
Total Rail Distance (miles)	1,310
Total Route Distance (miles)	1,700
Tons Transported (net ton)	11,730
Base Scenario Fuel Costs ($/cargo ton)	$1.64
MDO Scenario Fuel Costs ($/cargo ton)	$2.25
Change in Fuel Costs ($/cargo ton)	$0.61
Total Transfer Cost ($/cargo ton)	$1.55
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$3.50
Total Rail Portion of Freight Rate ($/cargo ton)	$20.98
Total Freight Rate for *Base Case* ($/cargo ton)	$26.03
Total Freight Rate for *MDO Case* ($/cargo ton)	**$26.64**

Table 38: Scenario 2 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	1,430
Tons Transported (net ton)	11,730
Total Transfer Cost ($/cargo ton)	$1.50
Total Rail Portion of Freight Rate ($/cargo ton)	$22.93
Total Freight Rate ($/cargo ton)	**$24.43**

Scenario 3: Coal from Rosebud Mine, MT to St. Clair and Monroe Power Plants, MI

Table 39 summarizes the results of Scenario. Table 40 presents a summary of the Default Scenario Route characteristics; Table 41 presents the All-Rail Alternative Route.

Figure 22: Scenario 3 map - Rosebud Mine, MT to St. Clair and Monroe Power Plants, MI

Table 39: Scenario 3 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$22.00	$27.44
Total Route Distance (miles)	1,800	1,620

Table 40: Scenario 3 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	760
Total Rail Distance (miles)	1,040
Total Route Distance (miles)	1,800
Tons Transported (net ton)	48,620
Base Scenario Fuel Costs ($/cargo ton)	$1.97
MDO Scenario Fuel Costs ($/cargo ton)	$2.78
Change in Fuel Costs ($/cargo ton)	$0.81
Total Transfer Cost ($/cargo ton)	$1.55
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$3.02
Total Rail Portion of Freight Rate ($/cargo ton)	$16.62
Total Freight Rate for *Base Case* ($/cargo ton)	$21.19
Total Freight Rate for *MDO Case* ($/cargo ton)	**$22.00**

Table 41: Scenario 3 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	1,620
Tons Transported (net ton)	48,620
Total Transfer Cost ($/cargo ton)	$1.50
Total Rail Portion of Freight Rate ($/cargo ton)	$22.94
Total Freight Rate ($/cargo ton)	**$27.44**

Scenario 4: Coal from Rosebud Mine, MT to Weadock and Karn Generating Plants, MI

Table 42 summarizes the results of Scenario 4. Table 43 presents a summary of the Default Scenario Route characteristics; Table 44 presents the All-Rail Alternative Route.

Figure 23: Scenario 4 map - Rosebud Mine, MT to Weadock/Karn Generating Plants, Essexville, MI

Table 42: Scenario 4 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$26.41	$28.12
Total Route Distance (miles)	1,660	1,660

Table 43: Scenario 4 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	620
Total Rail Distance (miles)	1,040
Total Route Distance (miles)	1,660
Tons Transported (net ton)	28,290
Base Scenario Fuel Costs ($/cargo ton)	$2.78
MDO Scenario Fuel Costs ($/cargo ton)	$3.91
Change in Fuel Costs ($/cargo ton)	$1.13
Total Transfer Cost ($/cargo ton)	$1.55
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$7.11
Total Rail Portion of Freight Rate ($/cargo ton)	$16.62
Total Freight Rate for *Base Case* ($/cargo ton)	$25.28
Total Freight Rate for *MDO Case* ($/cargo ton)	**$26.41**

Table 44: Scenario 4 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	1,660
Tons Transported (net ton)	28,290
Total Transfer Cost ($/cargo ton)	$1.50
Total Rail Portion of Freight Rate ($/cargo ton)	$26.62
Total Freight Rate ($/cargo ton)	**$28.12**

Scenario 5: Iron ore from Empire and Tilden Mines, MI to Algoma Steel, ON

Table 45 summarizes the results of Scenario 5. The All-Rail Alternative Route is less than $1.00 more expensive than the Default Scenario Route in dollars per cargo ton. Table 46 presents a summary of the Default Scenario Route characteristics; Table 47 presents the All-Rail Alternative Route.

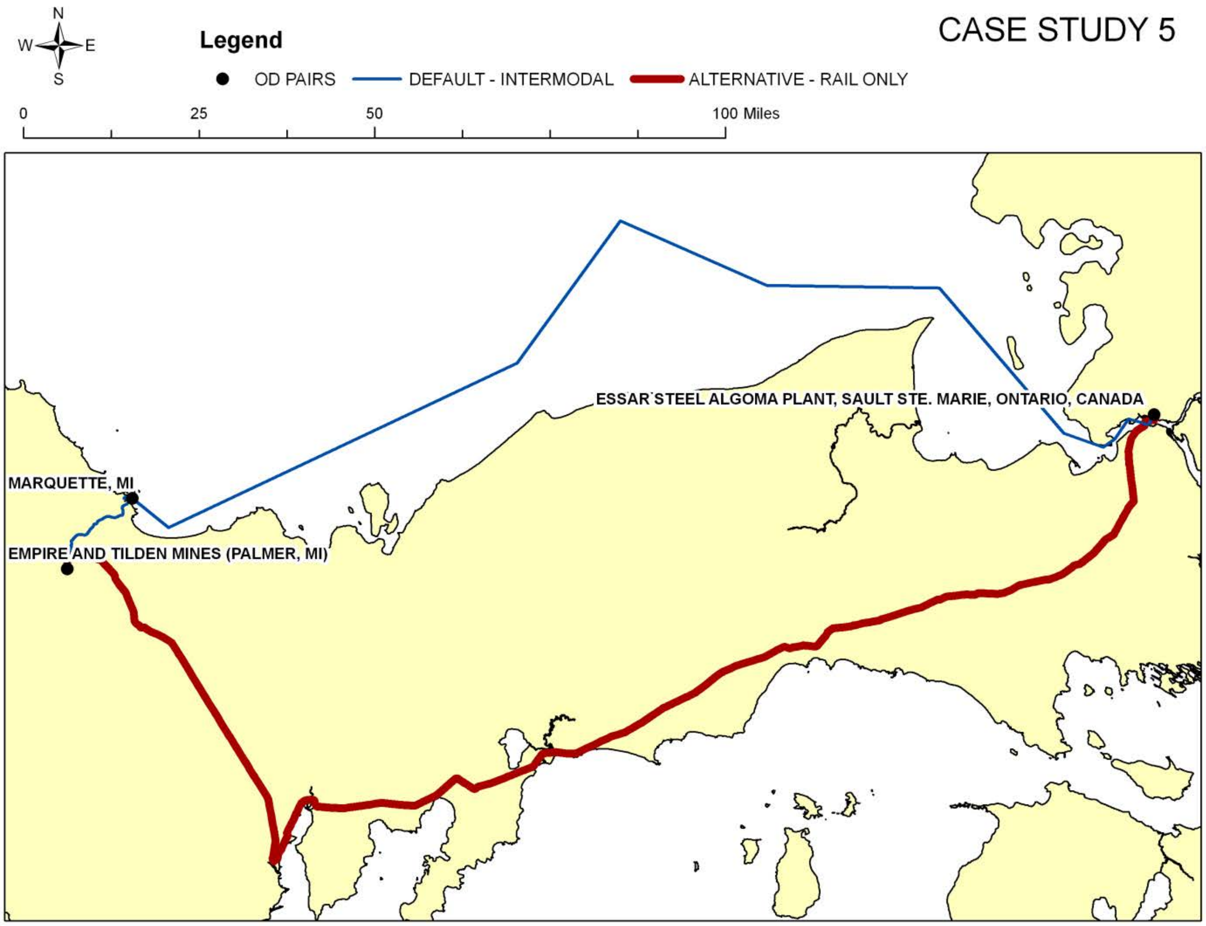

Figure 24: Scenario 5 map - Empire and Tilden Mines, Palmer, MI to Essar Steel Algoma Plant, Sault Ste. Marie, ON

Table 45: Scenario 5 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$4.47	$5.22
Total Route Distance (miles)	190	210

Table 46: Scenario 5 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	170
Total Rail Distance (miles)	20
Total Route Distance (miles)	190
Tons Transported (net ton)	11,730
Base Scenario Fuel Costs ($/cargo ton)	$1.01
MDO Scenario Fuel Costs ($/cargo ton)	$1.35
Change in Fuel Costs ($/cargo ton)	$0.35
Total Transfer Cost ($/cargo ton)	$1.35
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$2.45
Total Rail Portion of Freight Rate ($/cargo ton)	$0.32
Total Freight Rate for *Base Case* ($/cargo ton)	$4.12
Total Freight Rate for *MDO Case* ($/cargo ton)	**$4.47**

Table 47: Scenario 5 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	210
Tons Transported (net ton)	11,730
Total Transfer Cost ($/cargo ton)	$1.25
Total Rail Portion of Freight Rate ($/cargo ton)	$3.97
Total Freight Rate ($/cargo ton)	**$5.22**

Scenario 6: Iron ore from Quebec Cartier Mining Company, QC to ArcelorMittal, IL

Table 48 summarizes the results of Scenario 6. It was determined that Port Cartier, QC is not serviceable by rail. Therefore an All-Rail Alternative Route does not exist. This scenario is useful for comparing the increase in the total Freight Rate of the *Base Case* to the *MDO Case* which can be found in the last two rows of Table 49.

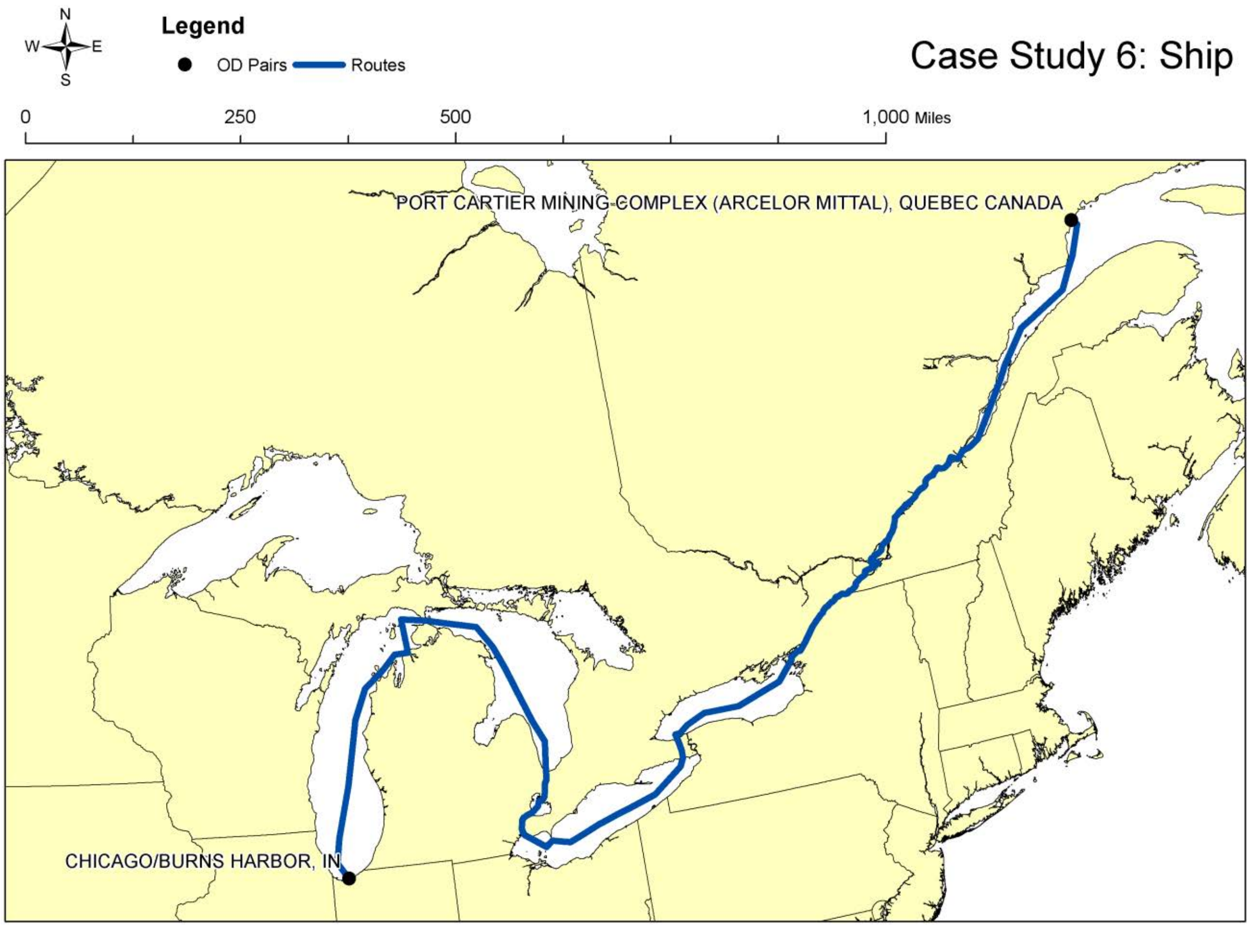

Figure 25: Scenario 6 map - Quebec Cartier Mining Company, Port Cartier, QC to ArcelorMittal, Chicago, IL

Table 48: Scenario 6 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$18.77	N/A
Total Route Distance (miles)	1,930	N/A

Table 49: Scenario 6 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	1730
Total Rail Distance (miles)	200
Total Route Distance (miles)	1,930
Tons Transported (net ton)	15,430
Base Scenario Fuel Costs ($/cargo ton)	$6.27
MDO Scenario Fuel Costs ($/cargo ton)	$8.94
Change in Fuel Costs ($/cargo ton)	$2.67
Total Transfer Cost ($/cargo ton)	$1.35
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$10.98
Total Rail Portion of Freight Rate ($/cargo ton)	$3.76
Total Freight Rate for *Base Case* ($/cargo ton)	$16.10
Total Freight Rate for *MDO Case* ($/cargo ton)	**$18.77**

Scenario 7: Iron ore from the Hull Rust Mine, MN to US Steel, IN

Table 50 summarizes the results of Scenario 7. Table 51 presents a summary of the Default Scenario Route characteristics; Table 52 presents the All-Rail Alternative Route.

Figure 26: Scenario 7 map - Hull Rust Mine, Hibbing, MN to US Steel, Gary, IN

Table 50: Scenario 7 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$7.14	$11.99
Total Route Distance (miles)	950	570

Table 51: Scenario 7 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	870
Total Rail Distance (miles)	80
Total Route Distance (miles)	950
Tons Transported (net ton)	48,620
Base Scenario Fuel Costs ($/cargo ton)	$2.24
MDO Scenario Fuel Costs ($/cargo ton)	$3.16
Change in Fuel Costs ($/cargo ton)	$0.93
Total Transfer Cost ($/cargo ton)	$1.35
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$3.34
Total Rail Portion of Freight Rate ($/cargo ton)	$1.52
Total Freight Rate for *Base Case* ($/cargo ton)	$6.21
Total Freight Rate for *MDO Case* ($/cargo ton)	**$7.14**

Table 52: Scenario 7 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	570
Tons Transported (net ton)	48,620
Total Transfer Cost ($/cargo ton)	$1.25
Total Rail Portion of Freight Rate ($/cargo ton)	$10.74
Total Freight Rate ($/cargo ton)	**$11.99**

Scenario 8: Iron ore from Northshore Mining, MN to Severstal, OH

Table 53 summarizes the results of Scenario 8. The All-Rail Alternative Route is more than twice as expensive as the Default Scenario Route in dollars per cargo ton. Table 54 presents a summary of the Default Scenario Route characteristics; Table 55 presents the All-Rail Alternative Route.

Figure 27: Scenario 8 map - Northshore Mining, Babbit, MN to Severstal, Warren, OH

Table 53: Scenario 8 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$7.73	$18.37
Total Route Distance (miles)	940	900

Table 54: Scenario 8 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	840
Total Rail Distance (miles)	100
Total Route Distance (miles)	940
Tons Transported (net ton)	48,620
Base Scenario Fuel Costs ($/cargo ton)	$2.16
MDO Scenario Fuel Costs ($/cargo ton)	$3.05
Change in Fuel Costs ($/cargo ton)	$0.89
Total Transfer Cost ($/cargo ton)	$1.35
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$3.66
Total Rail Portion of Freight Rate ($/cargo ton)	$1.82
Total Freight Rate for *Base Case* ($/cargo ton)	$6.83
Total Freight Rate for *MDO Case* ($/cargo ton)	**$7.73**

Table 55: Scenario 8 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	900
Tons Transported (net ton)	48,620
Total Transfer Cost ($/cargo ton)	$1.25
Total Rail Portion of Freight Rate ($/cargo ton)	$17.12
Total Freight Rate ($/cargo ton)	**$18.37**

Scenario 9: Grain from Lake Calumet Grain Elevators, IL to Baie Comeau, QC

Table 56 summarizes the results of Scenario 9. The All-Rail Alternative Route is almost twice as expensive as the Default Scenario Route in dollars per cargo ton. Table 57 presents a summary of the Default Scenario Route characteristics; Table 58 presents the All-Rail Alternative Route.

Figure 28: Scenario 9 map - Lake Calumet Grain Elevators, Chicago, IL to Baie Comeau, QC for export to the rest of the world

Table 56: Scenario 9 Summary Results

	Default Scenario Route using MDO (blue)	**All-Rail Alternative Route (red)**
Total Freight Rate ($/cargo ton)	$24.11	$46.75
Total Route Distance (miles)	1,720	1,270

Table 57: Scenario 9 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	1,720
Total Rail Distance (miles)	0
Total Route Distance (miles)	1,720
Tons Transported (net ton)	14,940
Base Scenario Fuel Costs ($/cargo ton)	$5.07
MDO Scenario Fuel Costs ($/cargo ton)	$7.17
Change in Fuel Costs ($/cargo ton)	$2.10
Total Transfer Cost ($/cargo ton)	$3.50
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$18.50
Total Rail Portion of Freight Rate ($/cargo ton)	--
Total Freight Rate for *Base Case* ($/cargo ton)	$22.00
Total Freight Rate for *MDO Case* ($/cargo ton)	**$24.11**

Table 58: Scenario 9 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	1,270
Tons Transported (net ton)	14,940
Total Transfer Cost ($/cargo ton)	$3.67
Total Rail Portion of Freight Rate ($/cargo ton)	$43.08
Total Freight Rate ($/cargo ton)	**$46.75**

Scenario 10: Grain from Duluth Port Grain Elevators, MN to Baie Comeau, QC

Table 59 summarizes the results of Scenario 10. The All-Rail Alternative Route is almost three times as expensive as the Default Scenario Route in dollars per cargo ton. Table 60 presents a summary of the Default Scenario Route characteristics; Table 61 presents the All-Rail Alternative Route.

Figure 29: Scenario 10 map - Duluth Port Grain Elevators, Duluth, MN to Baie Comeau, QC for export to the rest of the world

Table 59: Scenario 10 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$21.82	$59.57
Total Route Distance (miles)	1,730	1,640

Table 60: Scenario 10 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	1,730
Total Rail Distance (miles)	0
Total Route Distance (miles)	1,730
Tons Transported (net ton)	15,430
Base Scenario Fuel Costs ($/cargo ton)	$4.93
MDO Scenario Fuel Costs ($/cargo ton)	$6.97
Change in Fuel Costs ($/cargo ton)	$2.04
Total Transfer Cost ($/cargo ton)	$3.50
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$16.28
Total Rail Portion of Freight Rate ($/cargo ton)	--
Total Freight Rate for *Base Case* ($/cargo ton)	$19.78
Total Freight Rate for *MDO Case* ($/cargo ton)	**$21.82**

Table 61: Scenario 10 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	1,640
Tons Transported (net ton)	15,430
Total Transfer Cost ($/cargo ton)	$3.67
Total Rail Portion of Freight Rate ($/cargo ton)	$55.90
Total Freight Rate ($/cargo ton)	**$59.57**

Scenario 11: Grain from Duluth Port Grain Elevators, MN to WNY Ethanol Plant, Medina, NY

Table 62 summarizes the results of Scenario 11. Table 63 presents a summary of the Default Scenario Route characteristics; Table 64 presents the All-Rail Alternative Route.

Figure 30: Scenario 11 map - Duluth Port Grain Elevators, Duluth, MN to WNY Ethanol Plant, Medina, NY

Table 62: Scenario 11 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$23.93	$36.62
Total Route Distance (miles)	1,010	970

Table 63: Scenario 11 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	960
Total Rail Distance (miles)	50
Total Route Distance (miles)	1,010
Tons Transported (net ton)	11,730
Base Scenario Fuel Costs ($/cargo ton)	$3.70
MDO Scenario Fuel Costs ($/cargo ton)	$5.20
Change in Fuel Costs ($/cargo ton)	$1.50
Total Transfer Cost ($/cargo ton)	$3.50
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$17.40
Total Rail Portion of Freight Rate ($/cargo ton)	$1.53
Total Freight Rate for *Base Case* ($/cargo ton)	$22.43
Total Freight Rate for *MDO Case* ($/cargo ton)	**$23.93**

Table 64: Scenario 11 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	970
Tons Transported (net ton)	11,730
Total Transfer Cost ($/cargo ton)	$3.67
Total Rail Portion of Freight Rate ($/cargo ton)	$32.95
Total Freight Rate ($/cargo ton)	**$36.62**

Scenario 12: Grain from Goderich Port Grain Elevators, ON to Nabisco Flour Mill, OH

Table 65 summarizes the results of Scenario 12. Table 66 presents a summary of the Default Scenario Route characteristics; Table 67 does the same for the All-Rail Alternative Route.

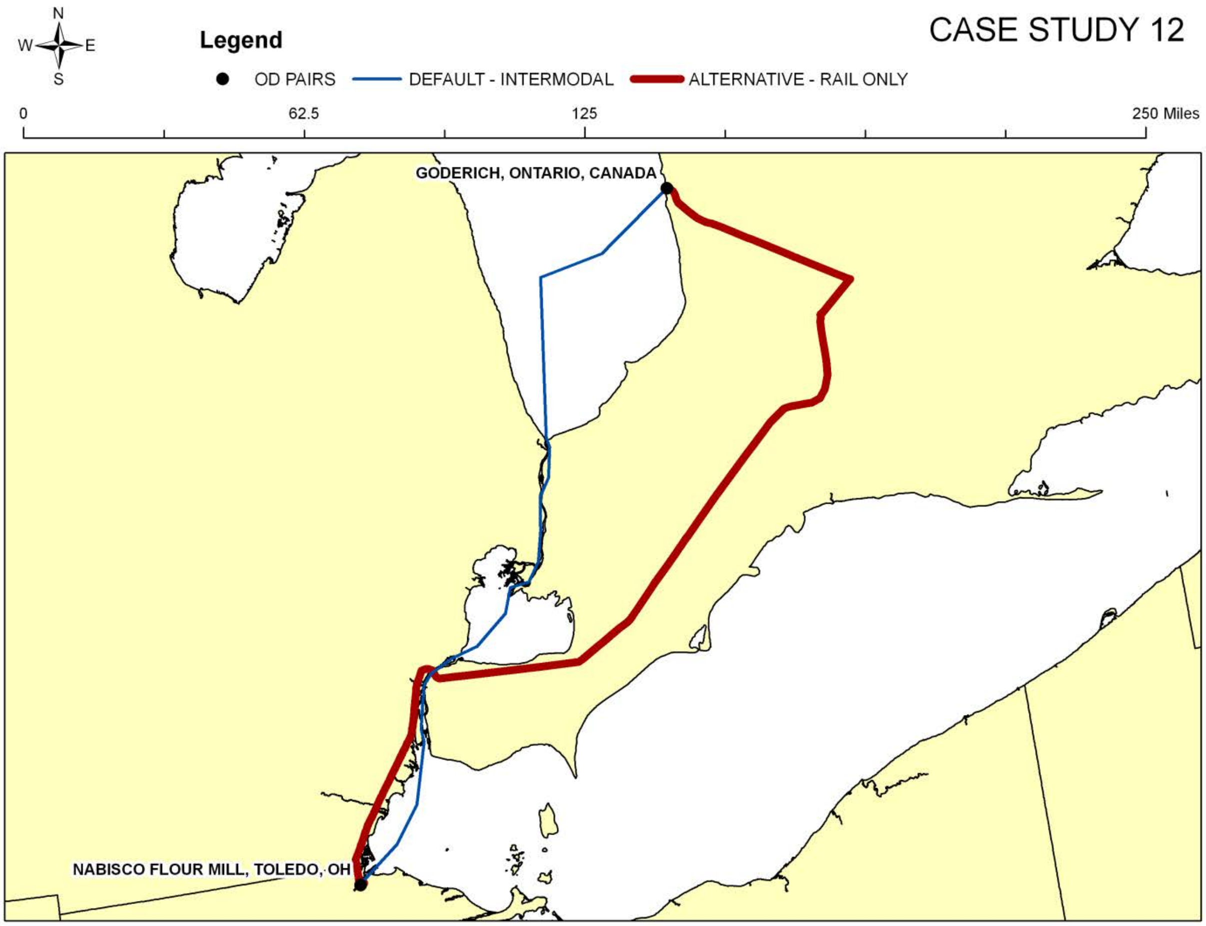

Figure 31: Scenario 12 map - Goderich Port Grain Elevators, Goderich, ON to Nabisco Flour Mill, Toledo, OH

Table 65: Scenario 12 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$9.95	$11.80
Total Route Distance (miles)	190	240

Table 66: Scenario 12 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	185
Total Rail Distance (miles)	5
Total Route Distance (miles)	190
Tons Transported (net ton)	4,030
Base Scenario Fuel Costs ($/cargo ton)	$2.58
MDO Scenario Fuel Costs ($/cargo ton)	$3.42
Change in Fuel Costs ($/cargo ton)	$0.84
Total Transfer Cost ($/cargo ton)	$3.50
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$5.52
Total Rail Portion of Freight Rate ($/cargo ton)	$0.10
Total Freight Rate for *Base Case* ($/cargo ton)	$9.12
Total Freight Rate for *MDO Case* ($/cargo ton)	**$9.95**

Table 67: Scenario 12 All-Rail Alternative Route Summary

	All-Rail Alternative Route
Total Route Distance (miles)	240
Tons Transported (net ton)	4,030
Total Transfer Cost ($/cargo ton)	$3.67
Total Rail Portion of Freight Rate ($/cargo ton)	$8.13
Total Freight Rate ($/cargo ton)	**$11.80**

Scenario 13: Stone from Port Dolomite, MI to the J.M. Stuart Power Plant, OH

Table 68 summarizes the results of Scenario 13. It was determined that Port Dolomite, MI is not serviceable by rail. Therefore an All-Rail Alternative Route does not exist. This scenario is useful for comparing the increase in the total Freight Rate of the *Base Case* to the *MDO Case* which can be found in the last two rows of Table 69.

Figure 32: Scenario 13 map - Port Dolomite to J. M. Stuart Power Plant, Toledo, OH

Table 68: Scenario 13 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$11.15	N/A
Total Route Distance (miles)	620	N/A

Table 69: Scenario 13 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	360
Total Rail Distance (miles)	260
Total Route Distance (miles)	620
Tons Transported (net ton)	41,900
Base Scenario Fuel Costs ($/cargo ton)	$0.68
MDO Scenario Fuel Costs ($/cargo ton)	$0.94
Change in Fuel Costs ($/cargo ton)	$0.26
Total Transfer Cost ($/cargo ton)	$1.20
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$4.73
Total Rail Portion of Freight Rate ($/cargo ton)	$4.96
Total Freight Rate for *Base Case* ($/cargo ton)	$10.89
Total Freight Rate for *MDO Case* ($/cargo ton)	**$11.15**

Scenario 14: Stone from Calcite Quarry, MI to the J.M. Stuart Power Plant, OH

Table 70 summarizes the results of Scenario 14. It was determined that Calcite Quarry near Rodgers City, MI is not serviceable by rail. Therefore an All-Rail Alternative Route does not exist. This scenario is useful for comparing the increase in the total Freight Rate of the *Base Case* to the *MDO Case* which can be found in the last two rows of Table 71.

Figure 33: Scenario 14 map - Calcite Quarry, MI to J.M. Stuart Power Plant, Aberdeen, OH

Table 70: Scenario 14 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$9.14	N/A
Total Route Distance (miles)	580	N/A

Table 71: Scenario 14 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	320
Total Rail Distance (miles)	260
Total Route Distance (miles)	580
Tons Transported (net ton)	41,900
Base Scenario Fuel Costs ($/cargo ton)	$0.61
MDO Scenario Fuel Costs ($/cargo ton)	$0.84
Change in Fuel Costs ($/cargo ton)	$0.23
Total Transfer Cost ($/cargo ton)	$1.20
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$2.75
Total Rail Portion of Freight Rate ($/cargo ton)	$4.96
Total Freight Rate for *Base Case* ($/cargo ton)	$8.91
Total Freight Rate for *MDO Case* ($/cargo ton)	**$9.14**

Scenario 15: Stone from Calcite Quarry, MI to American Crystal Sugar Company, MN

Table 72 summarizes the results of Scenario 15. It was determined that Calcite Quarry near Rodgers City, MI is not serviceable by rail. Therefore an All-Rail Alternative Route does not exist. This scenario is useful for comparing the increase in the total Freight Rate of the *Base Case* to the *MDO Case* which can be found in the last two rows of Table 73.

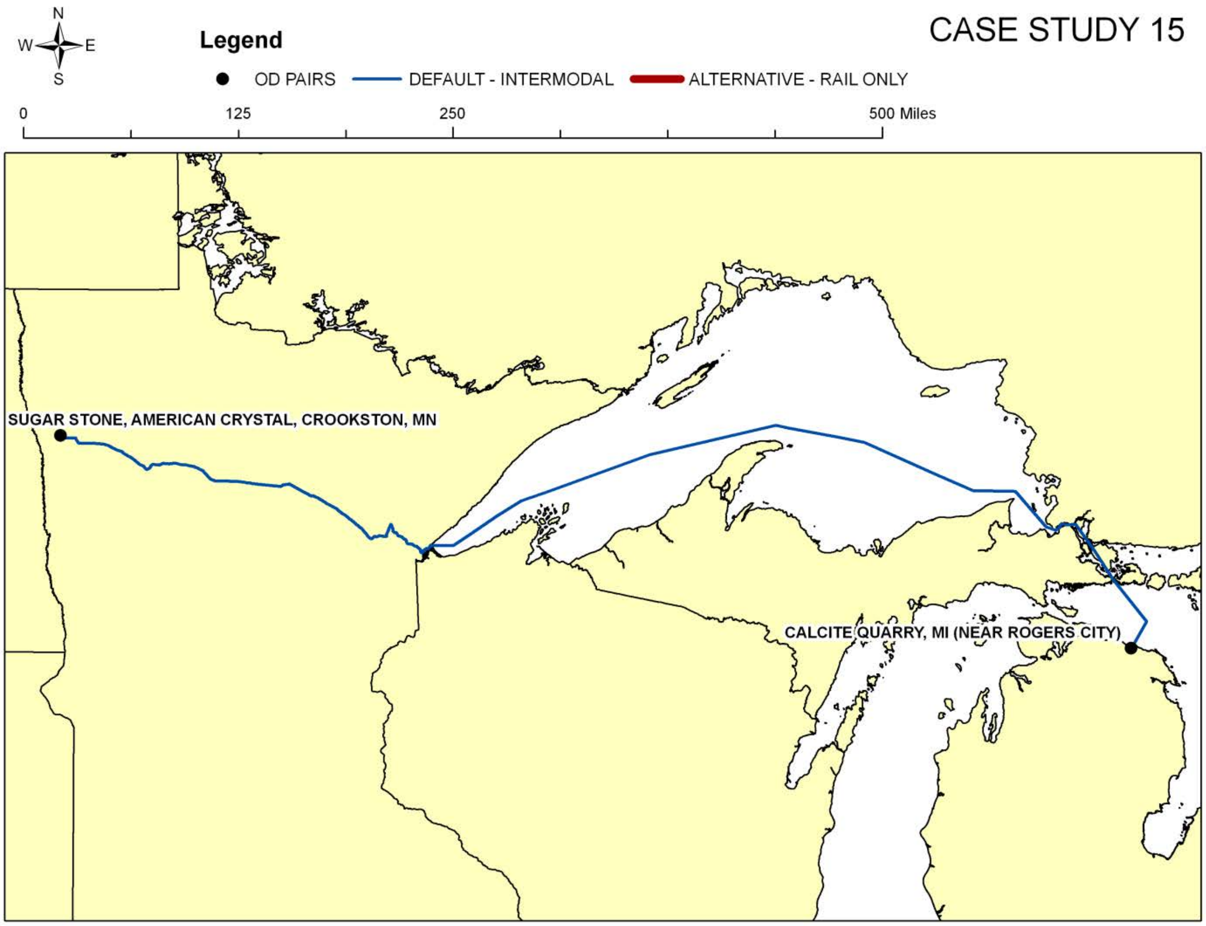

Figure 34: Scenario 15 map - Calcite Quarry, MI to American Crystal Sugar Company, Crookston, MN.

Table 72: Scenario 15 Summary Results

	Default Scenario Route using MDO (blue)	All-Rail Alternative Route (red)
Total Freight Rate ($/cargo ton)	$12.39	N/A
Total Route Distance (miles)	720	N/A

Table 73: Scenario 15 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	470
Total Rail Distance (miles)	250
Total Route Distance (miles)	720
Tons Transported (net ton)	41,900
Base Scenario Fuel Costs ($/cargo ton)	$0.88
MDO Scenario Fuel Costs ($/cargo ton)	$1.22
Change in Fuel Costs ($/cargo ton)	$0.34
Total Transfer Cost ($/cargo ton)	$1.20
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$6.15
Total Rail Portion of Freight Rate ($/cargo ton)	$4.69
Total Freight Rate for *Base Case* ($/cargo ton)	$12.04
Total Freight Rate for *MDO Case* ($/cargo ton)	**$12.39**

Scenario 16: Stone from Calcite Quarry, MI to Bruce Mansfield Power Station, OH

Table 74 summarizes the results of Scenario 16. It was determined that Calcite Quarry near Rodgers City, MI is not serviceable by rail. Therefore an All-Rail Alternative Route does not exist. This scenario is useful for comparing the increase in the total Freight Rate of the *Base Case* to the *MDO Case* which can be found in the last two rows of Table 75.

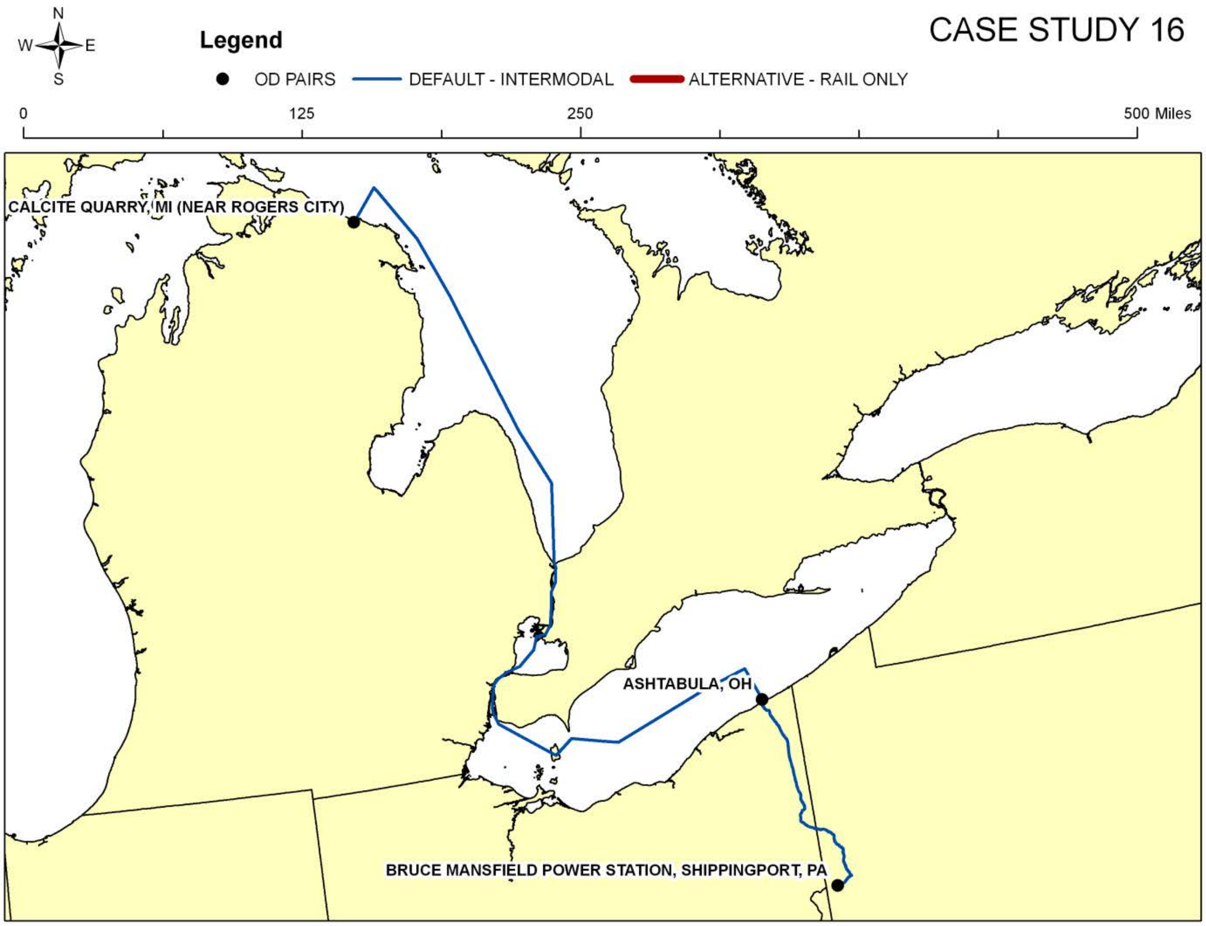

Figure 35: Scenario 16 map - Calcite Quarry, MI to Bruce Mansfield Power Station, Shippingport, PA

Table 74: Scenario 16 Summary Results

	Default Scenario Route using MDO (blue)	**All-Rail Alternative Route (red)**
Total Freight Rate ($/cargo ton)	$6.82	N/A
Total Route Distance (miles)	540	N/A

Table 75: Scenario 16 Default Scenario Route Summary

	Default Scenario Route
Total Vessel Distance (miles)	430
Total Rail Distance (miles)	110
Total Route Distance (miles)	540
Tons Transported (net ton)	41,900
Base Scenario Fuel Costs ($/cargo ton)	$0.81
MDO Scenario Fuel Costs ($/cargo ton)	$1.11
Change in Fuel Costs ($/cargo ton)	$0.31
Total Transfer Cost ($/cargo ton)	$1.20
Total Vessel Portion of Freight Rate for *Base Case* ($/cargo ton)	$3.30
Total Rail Portion of Freight Rate ($/cargo ton)	$2.01
Total Freight Rate for *Base Case* ($/cargo ton)	$6.51
Total Freight Rate for *MDO Case* ($/cargo ton)	**$6.82**

Chapter 6: Discussion of Results and Sensitivity Analysis

This chapter provides an interpretation of the results presented in Chapter 5 and discusses the sensitivity of the results. Table 76 presents a summary of each scenario's results. For each scenario, the All-Rail Alternative Route is more expensive than the *MDO Case* of the Default Scenario route with the exception of Scenario 2. For Scenario 2, the cost of the All-Rail Alternate Route is lower than the Default Scenario Route even before a switch to all-MDO fuel. This route has a couple of unique characteristics that make it likely to prefer an all-rail route. First, the overall distance for the Default Scenario Route is approximately 270 miles longer than the All-Rail Alternative Route. Second, the Default Scenario Route has a relatively short distance traveled by ship (390 miles) compared to the rail segment (1,310 miles). Therefore, the ship segment of the Default Scenario Route would have to be very inexpensive to overcome the obstacles of increased route length and costs incurred with an intermodal transfer from rail to ship (an extra transfer that the All-Rail Alternative Route does not have).

Table 76: Summary Results of Default Scenario Freight Rates compared to All-Rail Alternative Freight Rates, if available (all $/cargo ton)

	Scenario Number, Origin & Port Used, Destination & Port Used	Cargo	*Base Case* Voyage Rate	*Base Case* Transfer Costs	*Base Case* Rail Rate (if used)	*Base Case* Total Freight Rate	*MDO Case* Total Freight Rate	All-Rail Transfer Costs	All-Rail Scenario Rail Freight Rate	All-Rail Scenario Total Freight Rate
1	Rosebud Mine – Superior to Bayfront Power Plant – Ashland, WI	Coal	$1.81	$1.55	$16.62	$19.99	$20.23	$1.50	$20.21	**$21.71**
2	Elk Creek Mine – South Chicago to GP West Mill – Green Bay	Coal	$3.50	$1.55	$20.98	**$26.03**	**$26.64**	$1.50	$22.93	$24.43
3	Rosebud Mine – Superior to DTE Power Plants – Port Huron	Coal	$3.02	$1.55	$16.62	$21.19	$22.00	$1.50	$25.94	**$27.44**
4	Rosebud Mine – Superior to Weadock & Karn Generating Plants - Essexville	Coal	$7.11	$1.55	$16.62	$25.28	$26.41	$1.50	$26.62	**$28.12**
5	Empire and Tilden Mines – Marquette to Algoma Steel - Algoma	Iron Ore	$2.45	$1.35	$0.32	$4.12	$4.47	$1.25	$3.97	**$5.22**
6	Quebec Cartier Mining Co. – Port Cartier to ArcelorMittal – Chicago/ Burns Harbor	Iron Ore	$10.98	$1.35	$3.76	$16.10	$18.77	--	--	**--**
7	Hull Rust Mine – Duluth to U.S. Steel – Gary	Iron Ore	$3.34	$1.35	$1.52	$6.21	$7.14	$1.25	$10.74	**$11.99**
8	Northshore Mining – Silver Bay to Severstal – Ashtabula	Iron Ore	$3.66	$1.35	$1.82	$6.83	$7.73	$1.25	$17.12	**$18.37**
9	Lake Calumet Grain Elevators – Chicago to Baie Comeau	Grain	$18.50	$3.50	--	$22.00	$24.11	$3.67	$43.08	**$46.75**
10	Duluth Port Grain Elevators to Baie Comeau	Grain	$16.28	$3.50	--	$19.78	$21.82	$3.67	$55.90	**$59.57**
11	Duluth Port Grain Elevators to WNY Ethanol Plant - Buffalo	Grain	$17.40	$3.50	$1.53	$22.43	$23.93	$3.67	$32.95	**$36.62**
12	Goderich Port Grain Elevators to Nabisco Flour Mill – Toledo	Grain	$5.52	$3.50	$0.10	$9.12	$9.95	$3.67	$8.13	**$11.80**
13	Port Dolomite to J.M. Stuart Power Plant – Toledo	Stone	$4.73	$1.20	$4.96	$10.89	$11.15	--	--	**--**
14	Calcite Quarry and Port to J.M. Stuart Power Plant – Toledo	Stone	$2.75	$1.20	$4.96	$8.91	$9.14	--	--	**--**
15	Calcite Quarry and Port to American Crystal Sugar Co. - Duluth	Stone	$6.15	$1.20	$4.69	$12.04	$12.39	--	--	**--**
16	Calcite Quarry and Port to Bruce Mansfield Power Station - Ashtabula	Stone	$3.30	$1.20	$2.01	$6.51	$6.82	--	--	**--**

BOLD and shaded cells represent highest cost

Validation of Fuel Costs Compared to Freight Rates

In order to validate the activity-based fuel consumption and costing model discussed in Chapter 3, a calculation was performed to determine the percentage of vessel-based freight rates that are due to fuel costs. Results of this validation exercise are shown in Table 77. To determine the percentage of the port-to-port *Base Case* freight rate attributable to fuel costs, we divide Column C by Column A and get a range of 14%-67% (Column E) with eight scenarios above 40%. This is consistent with information obtained from an EPA stakeholder meeting held in June 2010. Moreover, Column I in the table shows that waterborne fuel cost as a percentage of origin-destination freight rates for the *Base Case* may range from 4% to 12% in Scenarios 1 through 4 and 13 through 16 where a significant rail-connected movement is included. In Scenarios 5 through 12, where waterborne transport is the dominant service, fuel accounts for 21% to 67% of the origin-destination freight rate for the *Base Case*. When a switch to MDO is considered, the percentage of the port-to-port *MDO Case* freight rate attributable to fuel is determined by dividing Column D by Column B and is found to be between 19%-74% (Column F) with nine scenarios above 40%. After a switch to MDO, fuel accounts for 5% to 16% of the origin-destination *MDO Case* freight rate for Scenarios 1 through 4 and 13 through 16 and 22% to 48% for Scenarios 5 through 12 (Column J).

Table 77: Summary of impact of fuel price on port-to-port freight rates compared to total route freight rates

Scenario	(A) *Base Case* Marine Vessel Freight Rate ($/cargo ton)	(B) *MDO Case* Marine Vessel Freight Rate ($/cargo ton)	Port-to-Port Voyage Considering both Main Engines and Auxiliaries: (C) Portion of *Base Case* Freight Rate Attributable to Fuel ($/cargo ton)	(D) Portion of *MDO Case* Freight Rate Attributable to Fuel ($/cargo ton)	(E) % of P-to-P *Base Case* Freight Rate Attributable to Fuel	(F) % of P-to-P *MDO Case* Freight Rate Attributable to Fuel	Scenario Origin to Destination Considering both Main Engines and Auxiliaries: (G) Total *Base Case* Freight Rate ($/cargo ton)	(H) Total *MDO Case* Freight Rate ($/cargo ton)	(I) *% of O-D Base Case* Freight Rate Attributable to Fuel	(J) % of O-D *MDO Case* Freight Rate Attributable to Fuel
1	$1.81	$2.05	$0.80	$1.04	44%	51%	$19.99	$20.23	4%	5%
2	$3.50	$4.11	$1.64	$2.25	47%	55%	$26.03	$26.64	6%	8%
3	$3.02	$3.83	$1.97	$2.78	65%	73%	$21.19	$22.00	9%	13%
4	$7.11	$8.24	$2.78	$3.91	39%	47%	$25.28	$26.41	11%	15%
5	$2.45	$2.79	$1.01	$1.35	41%	48%	$4.12	$4.47	24%	30%
6	$10.98	$13.65	$6.27	$8.94	57%	66%	$16.10	$18.77	39%	48%
7	$3.34	$4.27	$2.24	$3.16	67%	74%	$6.21	$7.14	36%	44%
8	$3.66	$4.55	$2.16	$3.05	59%	67%	$6.83	$7.73	32%	39%
9	$18.50	$20.61	$5.07	$7.17	27%	35%	$22.00	$24.11	23%	30%
10	$16.28	$18.32	$4.93	$6.97	30%	38%	$19.78	$21.82	25%	32%
11	$17.40	$18.90	$3.70	$5.20	21%	28%	$22.43	$23.93	17%	22%
12	$5.52	$6.35	$2.58	$3.42	47%	54%	$9.12	$9.95	28%	34%
13	$4.73	$4.99	$0.68	$0.94	14%	19%	$10.89	$11.15	6%	8%
14	$2.75	$2.98	$0.61	$0.84	22%	28%	$8.91	$9.14	7%	9%
15	$6.15	$6.49	$0.88	$1.22	14%	19%	$12.04	$12.39	7%	10%
16	$3.30	$3.61	$0.81	$1.11	24%	31%	$6.51	$6.82	12%	16%

Note: Columns G and H include vessel freight rates, rail freight rates (if used), and transfer costs.

Sensitivity of Results to Scenario-Specific Routing Constraints

Finally, a sensitivity analysis was conducted that explored the use of freight rates that addressed specific constraints that exist in the Great Lakes transportation system (Dager, 2010). For example, these constraints can include the necessary use of smaller trains (i.e. less cars) to deliver the commodity to the destination due to track restrictions or the use of rail ferries across water segments (such as in Scenarios 9 and 10). These constraints serve to increase the cost of transporting goods by rail for the Default Scenario Route and All-Rail Alternative Route except for the *Base Case* and *MDO Case* in Scenarios 1 and 2. Table 78 summarizes the results of the analysis assuming scenario-specific routing constraints. Scenarios 6, 12, 13, 14, 15, and 16 could not be evaluated in the sensitivity analysis, and so are not included in this table. In discussions with Chrisman Dager (2010), we learned that scenario-specific routing constraints precluded the use of rail for these routes. Limitations that prevented the use of rail for these routes included a lack of Class 1 rail lines near the origin or destination. Scenarios 12 through 16 are not included here, because we understand that they use truck rather than rail as part of intermodal goods movements.

Table 78: Sensitivity Results using Route-Specific constraints (all $/cargo ton)

Scenario Number, Origin & Port Used, Destination & Port Used		Cargo	Default Scenario Route					All-Rail Alternative Route		
			***Base Case* Voyage Rate**	***Base Case* Transfer Costs**	***Base Case* Rail Rate (updated)**	***Base Case* Total Freight Rate**	***MDO Case* Total Freight Rate**	**All-Rail Route Transfer Costs**	**All-Rail Route Rail Freight Rate**	**All-Rail Route Total Freight Rate**
1	Rosebud Mine – Superior to Bayfront Power Plant – Ashland, WI	Coal	$1.81	$1.55	$17.98	$21.34	$21.58	$1.50	$43.49	**$44.99**
2	Elk Creek Mine – South Chicago to GP West Mill – Green Bay	Coal	$3.50	$1.55	$18.35	$23.41	$24.01	$1.50	$36.01	**$37.51**
3	Rosebud Mine – Superior to DTE Power Plants – Port Huron	Coal	$3.02	$1.55	$17.98	$22.55	$23.36	$1.50	$29.74	**$31.24**
4	Rosebud Mine – Superior to Weadock & Karn Generating Plants - Essexville	Coal	$7.11	$1.55	$20.68	$29.34	$30.46	$1.50	$83.53	**$85.03**
5	Empire and Tilden Mines – Marquette to Algoma Steel - Algoma	Iron Ore	$2.45	$1.35	$2.29	$6.09	$6.43	$1.25	$11.62	**$12.87**
7	Hull Rust Mine – Duluth to U.S. Steel - Gary	Iron Ore	$3.34	$1.35	$5.69	$10.38	$11.31	$1.25	$18.14	**$19.39**
8	Northshore Mining – Silver Bay to Severstal - Ashtabula	Iron Ore	$3.66	$1.35	$5.65	$10.66	$11.56	$1.25	$21.71	**$22.96**
9	Lake Calumet Grain Elevators – Chicago to Baie Comeau	Grain	$18.50	$3.50	--	$22.00	$24.11	$3.67	$46.88	**$50.55**
10	Duluth Port Grain Elevators to Baie Comeau	Grain	$16.28	$3.50	--	$19.78	$21.82	$3.67	$61.28	**$64.95**
11	Duluth Port Grain Elevators to WNY Ethanol Plant - Buffalo	Grain	$17.40	$3.50	$2.27	$23.17	$24.66	$3.67	$52.15	**$55.82**

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Appendix 2D

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Chapter 2 References

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[9] See Summary and Analysis of Comments: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder. EPA-420-R-09-015, December 2009. Response 6.2. A copy of this document is available at www.epa.gov/otaq/oceanvessels.htm

CHAPTER 3: Potential for Other Shifts in Transport of Goods, and Emissions Impacts

In addition to the transportation mode shift analysis described in Chapter 2, we also examined the impacts of the application of ECA fuel requirements to Great Lakes shipping with respect to source shift and production shift. We also estimated the air emissions impacts of potential transportation mode shift, source shift, and production shift. These analyses are described in this chapter.

Source shift refers to users of a particular commodity changing to a different supply network. In the context of the Great Lakes, stakeholders indicated that there is a risk of source shift with respect to crushed stone markets: the additional fuel costs associated with applying the ECA fuel requirements to Great Lakes shipping would make stone from local quarries delivered by truck more cost competitive, leading users to shift their purchases to those local sources. Our analysis of four O/D pairs at risk for source shift suggests no source shift is indicated for those scenarios.

Production shift refers to producers of a particular good changing the location of the production of that good. In the context of the Great Lakes, stakeholders indicated that there is a risk of production shift with respect to the steel and electrical markets: the additional fuel costs associated with applying the ECA fuel requirements to Great Lakes shipping would lead producers to relocate production to facilities outside the region, with presumably lower coal and iron ore transportation costs. Our analysis of the steel and electric markets in the United States suggests that no production shift is indicated.

3.1 Source Shift Analysis: Crushed Stone

3.1.1 Background

In the course of developing and carrying out this economic impact analysis, several stakeholders told EPA that the transportation market for stone is different from that for coal, iron ore, or grain, and that rather than a transportation mode shift, the likely impact of the application of ECA fuel requirements on the Great Lakes would be a source shift. Specifically, the increased costs of transporting stone mined in Michigan to various inland facilities would lead these users to switch to locally-mined stone. In that case, the stone would be transported from the local quarries by truck rather than ship, resulting in increased emissions – the opposite of what EPA intends.

The U.S. Geological Survey (USGS) Crushed Stone Compendium contains a description of several important features of the crushed stone market.[1] Crushed stone is a low value commodity that is used in large quantities. Production costs are mining-related, dominated by labor, equipment, energy and water, although safety and environmental regulatory compliance costs are also relevant. While the price of crushed stone varies based on location, the difficulty of the deposit and the type of stone being mined, the market price of crushed stone has been relatively constant. USGC notes that “despite having one of the lowest average-per-ton values of all mineral commodities, the constant dollar price of crushed stone has changed relatively little” and notes price fluctuation of only $0.43 during the period1970 to 1990 ($3.48 and $3.91 per metric ton, in constant 1982 dollars). They note that the stability in prices occurs because cost increases due to increases in labor, energy, and mining and processing equipment were offset by productivity increases.

Not surprisingly, "transportation is a major factor in the delivered price of crushed stone" and that, due to its low price, transportation costs "often equals or exceeds the sale price of the product at the plant."[2] USGS notes that "because of the high cost of transportation and the large quantities of bulk material that have to be shipped, crushed stone is usually marketed locally."[3] The transportation method is typically by truck; according to the USGS 2008 Minerals Yearbook, nearly 81 percent of stone mined nationwide is transported from the quarry by truck and only 5 percent and 3 percent is transported by rail and waterway, respectively; the remainder is used on site.[4]

According to the 2008 Minerals Yearbook, an important change in the industry is a significant increase in the number of sales and distribution yards. Those "located near metropolitan areas significantly reduce the distance most trucks must travel to pick up and deliver crushed stone. Therefore, the transportation costs are reduced, as is the impact on heavy traffic on the infrastructure and the environment."[5]

Crushed stone from Michigan makes up an important part of stone that is transported long-distance in the Great Lakes region. According to the Great Lakes Maritime Task Force (GLMT) comments on the Category 3 marine rule, this stone is attractive to power plants and manufacturers far inland because it "has the chemical properties ideal for use in scrubbers in coal fired power plants. Its high calcium carbonate (>97 percent) and low bond work index make it easier and less expensive to grind in mills. The high $CaCO_3$ scrubs more SO_2 with less stone." GLMT notes that at least one Great Lakes power company was concerned that the potential impacts of the ECA fuel requirements on Great Lakes shipping carrying capacity would adversely affect the ability of this transportation sector to supply Michigan and Ohio power plants with stone for scrubbers. The annual need of that particular facility is more than 400,000 tons.[6]

3.1.2 Methodology

To examine the economic impacts of applying the ECA fuel requirements on the stone sector, EPA chose to follow the competitive radius methodology used in the 2009 Canadian Shipowners' Association study, which examines stone deliveries to two cities in Ohio (see Section 1.6.3.2 of Chapter 1).[7] Rather than performing an in-depth study of the nature of local quarries for a particular stone user and assessing the extent to which such quarries could replace stone from long-distance sources, both in terms of quality and quantity of stone, the CSA methodology instead looks at the extent to which higher transportation costs for ship would increase the competitive radius around purchasing facilities, resulting in an increase in the number of local quarries that could service the facility and thus a change in the competitive dynamics of that market.

In the CSA approach, a geographic area is created around a purchasing facility within which the facility would be indifferent between using stone from a distant quarry transported by ship or stone from a local quarry transported by truck, given identical stone characteristics. In other words, the total transportation costs would be the same. This competitive radius is estimated based on the distance a fleet of trucks can operate from the using facility location carrying the same quantity of stone for the same total transportation cost as that of the base case ship/rail scenario. Once the geographic area is identified, it is superimposed on a map identifying the using facility and the local quarries. The analysis is then repeated using total freight rate for ship/rail transportation adjusted to account for the ECA fuel costs. This expanded competitive radius indicates that additional local quarries may become competitive as a result of the increase in ship operating costs. There are two ways to evaluate the impact of the increase in competitive radius. The first is to consider the absolute number of additional quarries that are included in the expanded radius. The second is to consider the size of the increase in radius. If either the number of additional quarries or the size of the increase in radius is small, then no change in the competitive structure of the market is indicated and no source shift would be indicated.

Consistent with the methodology used in the CSA study, this analysis does not examine the reasons why the purchasing facility uses stone originating at a much longer distance, requiring ship transportation, when stone from local quarries may be available.

The analysis does not assume that substitution of local crushed stone is impossible; that assumption would be to say that only Michigan crushed stone has the properties required by the using facility and therefore there would be no source shift. [A] At the same time, however, the analysis does not examine the extent to which such additional quarries *could* supply the purchasing facility in terms of quantity or quality of stone. Such an analysis would require detailed information about the using facility and each of the quarries within the competitive radius of that facility. Instead, the analysis is based on the assumption that the using facility is making an economically sound decision in purchasing the stone from Michigan and that the dynamics of the crushed stone market are such that the using facility purchases at least some stone from Michigan quarries. The analysis examines whether an increase in competitive radius around the using facilities corresponding to an increase in the freight rate for crushed stone from Michigan is large enough that it is likely to result in a change in the competitive dynamics of the crushed stone market for that facility.

3.1.3 Data Inputs

This analysis was performed for Scenarios 13-16, identified in Chapter 2. Table 3-1 repeats the estimated total freight rates for the stone scenarios, for the primary (Base) case and the ECA (MDO) fuel case, used in this source shift analysis. The increase in freight rates is estimated using the methodology described in Chapter 2.

[A] One peer reviewer noted that "if the higher cost of fuel causes customers to source their products more nearby, the products must be close enough substitutes that they should not travel such distances in the first place. In other words, if close substitutes do not shift closer then society must be subsidizing excessive freight transport distance … Especially whether the product is iron ore or Michigan stone that is high in calcium carbonate, the product is sufficiently unique that it does not provoke a shift" (Belzer)

Table 3-1 Estimated Freight Rate Increases Associated with ECA Fuel - Stone Scenarios[a]

Scenario	Base Scenario Route	Base Case Total Freight Rate	ECA (MDO) Case Total Freight Rate	Base to ECA (% Diff)
13	Stone from Port Dolomite, MI to J.M. Stuart Power Plant, Aberdeen, OH	$10.89	$11.15	2.4%
14	Stone from Calcite, MI to J.M. Stuart Power Plant, Aberdeen, OH	$8.91	$9.14	2.6%
15	Stone from Calcite, MI to American Crystal Sugar Co., Crookston, MN	$12.04	$12.39	2.9%
16	Stone from Quarry at Calcite, MI to Bruce Mansfield Power Station, Shippingport, PA	$6.51	$6.82	4.8%

[a] Data from Table 2-1

Consistent with the CSA study, this analysis is based on trucks with a delivery of a load of 39 metric tonnes (43 short tons) of stone by a tandem tractor and quad dump semi-trailer.[8] A delivery load of this size provides a conservative analysis of the impacts, as a smaller delivery load would require more trucks to deliver the same amount of crushed stone as one shipload. Because the CSA study does not give details with respect to truck operation, we assume fuel consumption to be 5 mpg. This analysis uses the same fuel price, $2.00/gallon, as the transportation mode shift study in Chapter 2 (see discussion in Section 2.5.1.3)[B] and assumes the share of fuel to total operating costs to be about 40.2 percent.[9]

The analysis uses state-level prices for crushed stone as reported in the USGS 2008 Mineral Yearbook (Table 4; 2007; nominal prices) for Minnesota ($9.68/short ton), Ohio ($5.98/short ton) and Michigan ($4.40/short ton).[10]

This approach assumes that the freight rate on a dollar per ton basis is the same for trucks as for the ship/rail case (i.e., stone can be transported from a local quarry to the purchasing facility at the same price per ton as the ship/rail method). However, anecdotal evidence suggests that truck rates may be higher, at $20 per short ton or more. In this case, the competitive radius from the using facility, and the increase in that radius due to the increase in ship fuel costs, would be smaller.

To simplify the analysis, this approach does not take into account the sometimes spidery nature of road networks but instead assumes the truck routes are straight lines from the local quarries to the using facility. As a result, the true competitive radius around a using facility may be shorter than a simple wheel-and-spokes approach suggests. Therefore, the results of the analysis are conservative in that the approach maximizes the competitive radius around a using facility.

[B] One peer reviewer notes "The current cost of diesel fuel is around $3/gallon. … as long as fuel prices rise, systematic shifts likely will favor maritime over rail and rail over truck, so a low price probably leaves a very conservative result in this case." (Belzer)

This analysis does not consider constraints such as whether the number of trucks needed to transport the equivalent of a shipload of stone (41,900 short tons, or about 974 truckloads) would be available, or whether local roads can absorb the additional traffic on a constant basis. These constraints would ultimately be relevant, however, in terms of environmental and other social costs associated with the high number of additional trucks on the road in a given area as well as the ability of localities to absorb the additional traffic due to road capacity and other infrastructure constraints.

3.1.4 Detailed Results

Table 3-2 presents the results of the competitive distance analysis for Scenarios 13 through 16. We estimated the impacts two ways: one in which using facility is indifferent with regard to the freight rate (the freight rates are equivalent for trucks and marine/rail intermodal) and one in which the using facility is indifferent with regard to the total cost of the delivered stone (freight rate plus cost of stone are equivalent for trucks and marine/rail). From either perspective, this analysis shows that the increase in fuel costs for Great Lakes ships is expected to increase the competitive radius around using facilities by only about five to eight miles for the four stone scenarios analyzed.

Table 3-2 Stone Scenarios Competitive Radius Analysis

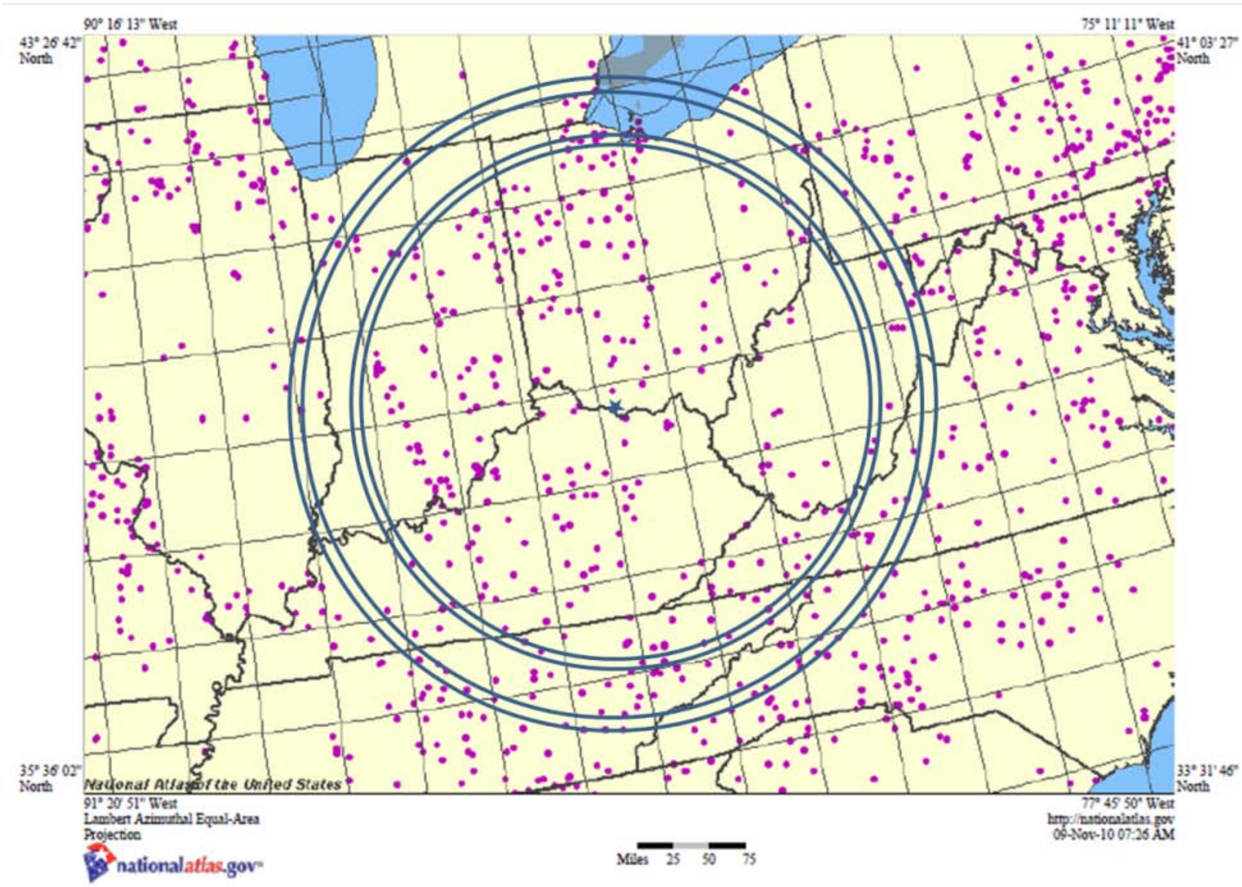
SCENARIO	EQUAL SHIPPING PRICE PER TON			EQUAL TOTAL PRICE PER TON		
	Base Competitive Radius (mi)	Control Competitive Radius (mi)	Increase Competitive Radius (mi)	Base Competitive Radius (mi)	Control Competitive Radius (mi)	Increase Competitive Radius (mi)
13	235	241	6	201	207	6
14	193	198	5	159	164	5
15	260	268	8	146	154	8
16	141	147	7	107	113	7

An increase in competitive radius of this magnitude is not expected to change the nature of the local stone markets by very much for the four scenarios under consideration with respect to both the number of additional quarries and the size of the increase in competitive radius.

3.1.4.1 Number of Additional Quarries

With regard to the number of additional facilities, this is illustrated in Figure 3-1, for Scenarios 13 and 14. Two sets of competitive radii are drawn around the J.M. Stuart power plant in southern Ohio. The outer set of circles represents the competitive radius for the primary Base and ECA cases for Scenario 13, while the inner set of circles is for Scenario 14, using the radius calculated based on equal shipping price per ton. As can be seen, there are many quarries located within the competitive radii of this facility. While adding 6 or 5 miles to the competitive radii increases the number of local quarries that could be competitive, the increase is not substantial compared to the number of quarries already located within the area.

Figure 3-1 Competitive Radius Analysis: J.M. Stuart Power Plant[C]



Figures 3-2 and 3-3 present similar information for the American Crystal Sugar Co. located in Crookston, Minnesota (Scenario 15), and the Bruce Mansfield Power Station in Shippingport, Pennsylvania (Scenario 16). In these cases, the addition of 8 and 7 miles, respectively, to the competitive radius around the using facility does not bring in a significant number of quarries and therefore would not be expected to change the competitive dynamics of these markets.

[C] The concentric circles in Figures 3-1, 3-2 and 3-3 are hand drawn, so the change in potentially competitive quarries is solely illustrative.

Figure 3-2 Competitive Radius Analysis: American Crystal Sugar Co.

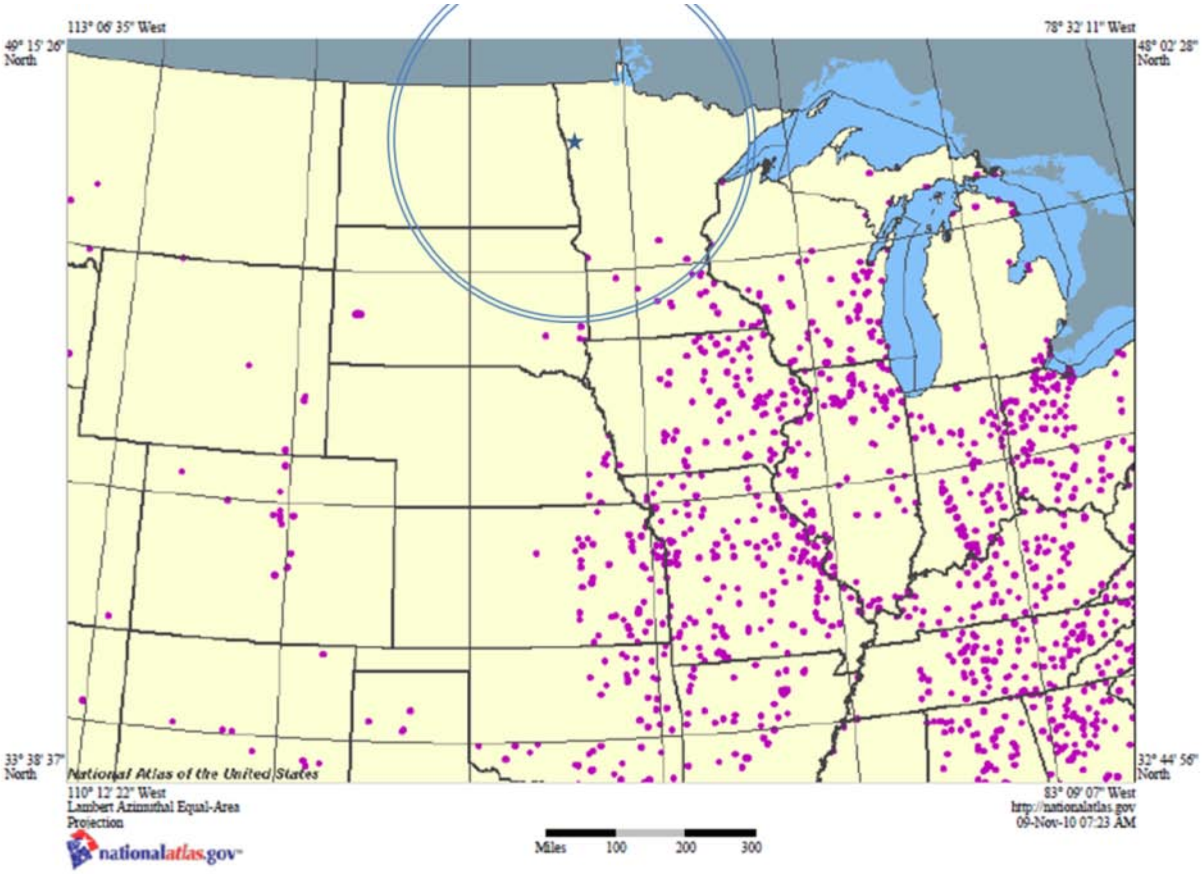
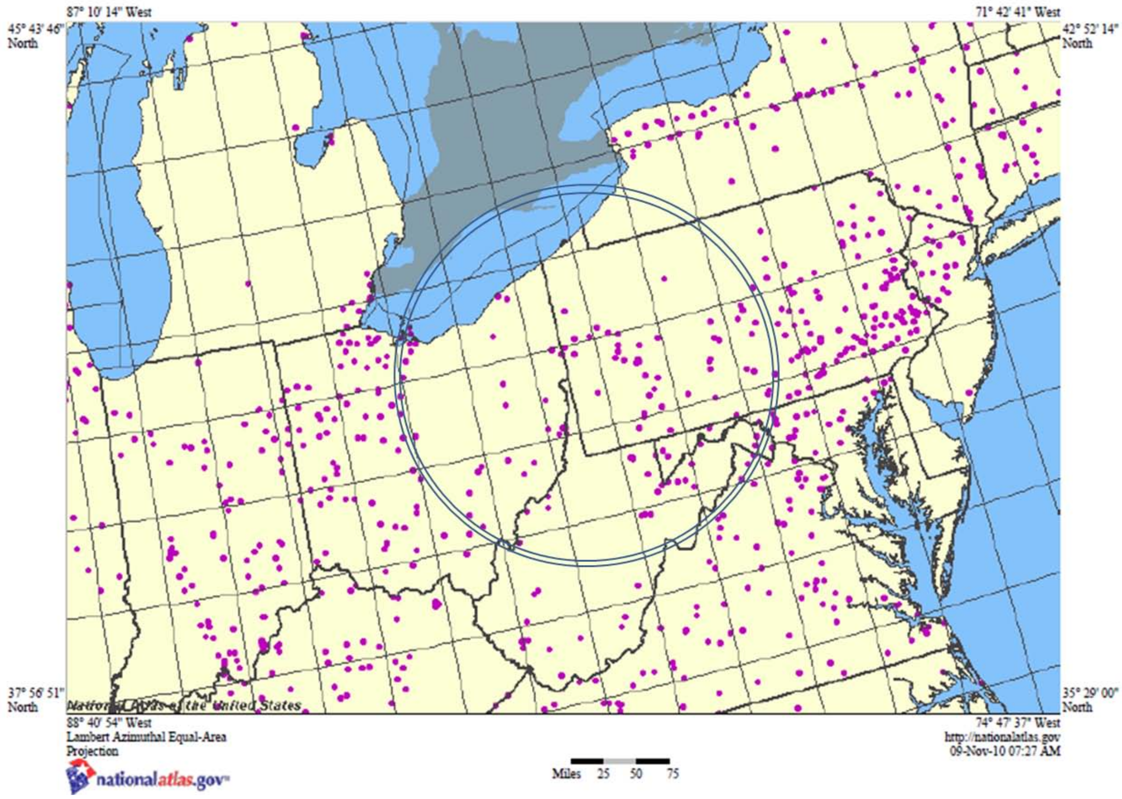


Figure 3-3 Competitive Radius Analysis: Bruce Mansfield Power Station



These above results are somewhat different from the results of the CSA study (see Section 1.6.3.2), where a $1.00 increase in marine rates was estimated to extend the competitive radius around Cleveland, Ohio, and Akron, Ohio, by about 13 to 16 km (8 to 10 miles). In the mode shift analysis described in Chapter 2, the maximum freight rate increase expected is about 31 cents, yielding an increase in competitive radius of up to 8 miles. This difference in the relation between freight rate increase and competitive radius increase may be due to differences in the freight rates applied in the two analyses (the CSA study does not provide the freight rates used).

While both the CSA study and the above analysis conclude that only a small number of quarries would be added to the stone market around the facilities in Cleveland and Akron, CSA estimates that this would result in a 20 percent transportation mode shift. This is based on an assumption that "one might expect that mode shift to truck transportation from local quarries could be double that of grain and apply to many more movements" (p. 23). However, the CSA analysis for grain is based on the application of a modal shift factor that is problematic (see discussion in Section 1.6.3.2). Also, CSA doesn't explain why transportation mode shift to truck would be double that of grain. In fact, CSA's analysis, as is the case with EPA's analysis, is simply an analysis of the potential for a change in the competitive dynamics in the crushed stone market for a given using facility based on an increase in the number of quarries located in an expanded competitive radius around a facility. Without a detailed analysis of competing freight rates and the constraints with road transportation to the destination facilities, as well as an analysis explaining why these facilities currently purchase their stone from quarries located farther away, it is not possible to speculate on the magnitude of mode shift that may occur if the competitive radius were significantly expanded. An increase in the number of potentially competing facilities is not, in itself, an indicator of the *amount* of mode shift that would be expected. It is an indicator for the potential for increased competition and therefore downward price pressures for delivered stone.

3.1.4.2 Additional Distance

The second way to evaluate the impact of an increase in the competitive radius is to examine increase in the distance from the using facility for a round trip. For all four scenarios, this increase is very small, 11 miles for Scenario 13, 10 miles for Scenario 14, 15 miles for Scenario 15, and 13 miles for Scenario 16. In fact, it is possible that quarries located within such a marginal extra distance can already compete with the quarries within the base case competitive radius. For example, in Scenario 15 (stone to American Crystal Sugar Company, MN) about 2 additional quarries would be drawn into the market. However, given the increase in round-trip distance of only 15 miles, those quarries may be considered competitive with the existing quarries even without the increase in ship freight rates. The additional 15 miles would increase the fuel costs per trip by about 3 percent, and total operating costs by about 1 percent. Averaged over miles in the original competitive radius, the increase in fuel costs is about $0.06/gallon/trip, which is well within the fluctuation of diesel fuel prices. Therefore, including these quarries in the revised competitive radius does not significantly change the competitive nature of this market. Table 3-3 contains the results of this analysis for the other three stone scenarios, with similar results.

Table 3-3 Stone Scenario; Fuel Costs Associated with Increase in Competitive Distance

	SCENARIO 13	SCENARIO 14	SCENARIO 15	SCENARIO 16
Transport price 1 truckload	$468	$383	$518	$280
Fuel costs for 1 truckload	$188	$154	$208	$113
Increased mileage round trip	11	10	15	13
Additional fuel for longer trip (gal)	2.2	2.0	3.0	2.7
Increased fuel costs for longer trip	$4.50	$3.98	$6.05	$5.36
Increased in base fuel costs ($/gal)	$0.05	$0.05	$0.06	$0.10
% increase in fuel costs for longer trip	2.4%	2.6%	2.9%	4.8%
% increase in total costs for longer trip	1.0%	1.0%	1.2%	1.9%

3.1.4.3 Sensitivity Analyses

We performed three sensitivity analyses, with respect to the size of the truck load, the truck freight rate, and the truck route. These results, reported in Table 3-4, show that a smaller delivery load (20 tons instead of 43 tons per truck) results in a smaller competitive radius for each scenario. A more expensive truck freight rate ($20/ton) also results in a smaller competitive radius for each scenario. Finally, to reflect a less direct route between a local quarry and the using facility, we assumed that a truck would use the same amount of fuel as in the primary case but diversions along the transport route would be increased by 10 percent. This reduces the competitive radius as well as the difference in competitive radius caused by the increase in fuel costs. For each of the sensitivity analyses, the change in competitive radius remains about the same, less than 10 miles, and is not large enough to change the competitive nature of the relevant market.

Table 3-4 Stone Scenarios Competitive Radius Analysis - Sensitivity Analyses

	SCENARIO 13	SCENARIO 14	SCENARIO 15	SCENARIO 16
Primary Results: Equal Shipping Price/Ton				
Baseline Radius (mi)	235	193	260	141
Control Radius (mi)	241	198	268	147
Net Increase (mi)	6	5	8	7
Sensitivity Results: 20 Ton Truck Load; Equal Shipping Price/Ton				
Baseline Radius (mi)	110	90	121	65
Control Radius (mi)	112	92	125	69
Net Increase (mi)	3	2	4	3
Sensitivity Results: Truck Freight Rate $20/ton; Equal Shipping Price/Ton				
Baseline Radius (mi)	128	86	157	46
Control Radius (mi)	131	88	161	48
Net Increase (mi)	3	2	5	2
Sensitivity Results: Truck Route Not Direct; Equal Shipping Price/Ton				
Baseline Radius (mi)	212	173	234	127
Control Radius (mi)	217	178	241	133
Net Increase (mi)	5	4	7	6

3.2 Production Shift Analysis

In addition to transportation mode shift and source shift, several stakeholders told EPA that an increase in the fuel costs for Great Lakes shipping could lead to a production shift, particularly for steel production and electrical generation. This section examines these potential impacts in two ways. First, a retail revenue analysis is used to compare the increase in industry coal and iron ore transportation costs to total sector revenues. This analysis shows that the impacts on the prices of electricity and steel are expected to be small, less than 0.5 percent for electricity, and less than 0.1 percent for steel, and are within historic price variation ranges. Second, the increased costs for transporting iron ore by Great Lakes ships using ECA fuel is compared with the costs of transporting steel to the Detroit area from out-of-area producers. This analysis shows that the costs of transporting out-of-area steel to Detroit would be greater than the increase in fuel costs to transport iron ore to regional steel mills that currently supply those using facilities. Both of these analyses show that application of the ECA fuel standards to the Great Lakes is not likely to result production shift away from the Great Lakes region for either of these two sectors.

3.2.1 Retail Revenue Analysis

To examine whether increased marine transportation costs on the Great Lakes would result in shift of steel and electrical production out of the Great Lakes regions, we us a two-part retail revenue analysis. This involves comparing the increase in transportation costs to revenues in each sector, and examining how that increase compares to actual price fluctuations experienced in the sector. If the transportation price increase is small and is within the range of historic price fluctuations, then we conclude that production is not likely to be shifted out of the region. This is especially so because moving the location of production could be very costly. Even if there is excess capacity at other production sites, moving production would require modifying another facility to accommodate increased production and/or creating new supply, production and transportation chains, all of which can be very costly. In addition, additional transportation costs would be incurred to transport the product – finished steel or electricity – to Great Lakes region users. For steel this would entail truck or rail transportation, which is more expensive than marine shipping on a ton-mile basis; for electricity it could entail electrical grid changes.

It should be noted that the impact analysis presented in this section is a sector-level analysis that is limited to the two specific sectors examined, electricity and steel, and is not for a specific producer. The actual impacts for a specific facility depend on the individual producer's cost data, and marginal or incremental cost analysis for that facility.

3.2.1.1 Methodology

In this retail revenue analysis, we estimate the impact of the expected increase in the transportation cost of coal and iron ore as a percentage of the revenues for the each of the electricity and steel markets. We then compare the expected percentage increase with historic price fluctuations on a percentage basis.

For this analysis, the transportation cost increases estimated in Chapter 2 are used. These cost increases, reproduced in Table 3-5, vary depending on transportation routes and the commodity shipped. The shipping cost for coal is expected to increase by 1.2 percent to 4.5 percent and the shipping cost for iron ore is expected to increase by 8.5 percent to 16.6 percent, depending on the scenario. One implication of using the estimated cost increases from Chapter 2 is that those cost increases are facility-specific while, as noted above, this production shift analysis is intended to represent aggregated sector impacts. As a result, we use the range of transportation cost increases estimated in Chapter 2. For coal shipped from the Rosebud Mine to facilities in Wisconsin or Michigan (1.2 percent to 4.5 percent), the range of cost increase is taken as being representative of the cost increases that would apply to power plants throughout the Great Lakes region. Because there is variation in the cost estimates (i.e., they are not homogeneous), the use of this range of cost estimates is reasonable.

Table 3-5 Estimated Shipping Cost Increases[a]

Scenario Number, Origin & Port Used, Destination & Port Used		Cargo	Base Case Total Freight Rate	MDO Case Total Freight Rate	% change
1	Rosebud Mine – Superior to Bayfront Power Plant – Ashland, WI	Coal	$19.99	$20.23	1.2% [c]
2	Elk Creek Mine – South Chicago to GP West Mill – Green Bay	Coal	--- [b]	---[b]	--- [b]
3	Rosebud Mine – Superior to DTE Power Plants – Port Huron	Coal	$21.19	$22.00	3.82%
4	Rosebud Mine – Superior to Weadock & Karn Generating Plants - Essexville	Coal	$25.28	$26.41	4.47% [d]
5	Empire and Tilden Mines – Marquette to Algoma Steel – Algoma	Iron ore	$4.12	$4.47	8.50% [c]
6	Quebec Cartier Mining Co. – Port Cartier to ArcelorMittal – Chicago/ Burns Harbor	Iron ore	$16.10	$18.77	16.58% [d]
7	Hull Rust Mine – Duluth to U.S. Steel – Gary	Iron ore	$6.21	$7.14	14.98%
8	Northshore Mining – Silver Bay to Severstal – Ashtabula	Iron ore	$6.83	$7.73	13.18%

Notes:
[a] Data from Appendix 2C, Table 76. Summary Results of Default Scenario Freight Rates compared to All-Rail Alternative Freight Rates, if available (all $/cargo ton).
[b] Results are inconclusive due to mis-specification of the scenario. See discussion in Chapter 2.
[c] Percent change represents "the lower bound scenario"
[d] Percent change represents "the upper bound scenario"

Data on the transportation cost for coal and iron ore, total material cost, and total sales are obtained from the 2007 Census Bureau, Census Data On Manufacture Industry: iron and steel industry, NAICS code 331111, for the steel sector, and from the EIA Publication: Electric Power Monthly, January 2010, DOE/EIA-0226 (2010/01), for the electric sector.

3.2.1.2 Impact on the Great Lakes Electric Sector

To estimate the impact of higher freight rates on the Great Lakes electricity generation sector, we need to have electricity cost data for the region (East North Central region[D]). These data are collected from a recent EIA release. [11] Two types of data are used in the analysis: (a) monthly data for October 2009 and October 2008, (b) year-to-date data through October 2009 and October 2008.

This analysis assumes that all coal used for electrical generation in the entire Great Lakes region is moved by water (not truck and rail). This is certainly not the case and therefore the results are a conservative estimate of the impacts of the ECA fuel sulfur requirements because this analysis applies the transportation cost increase to all coal used in electrical generation. Much of the coal used by power plants in the region is not transported by water, and some electricity is generated by hydroelectric rather than coal facilities.

[D] The East North Central region in EIA includes state of Illinois, Indiana, Michigan, Ohio, and Wisconsin.

We use a two-step approach to estimate the revenue impact. The first step is to estimate the impact of an increased shipping cost on “delivered coal cost” (the cost of coal delivered for electricity production use). The second step is to estimate the impact of the increased “delivered coal cost” on electricity revenue.

The EIA regional data for the electricity sector includes only delivered coal cost; it does not provide separate data for coal cost at the mine and coal shipping cost. Therefore, to perform this analysis we use EIA reported 2008 U.S. national average coal cost at the mine to approximate coal cost at the mine for the Great Lakes region. Then, we apply the lower and upper bound percent increase between the base case freight rate and MDO control case freight rate (Table 3-5) to the coal cost at the mine to estimate the “delivered coal cost” for the Great Lake area.

Using this method, shipping costs would be about 39 to 45 percent of “delivered coal cost,” and increasing shipping costs by about 1.2 percent to 4.47 percent would be equivalent to increasing “delivered coal cost” by about 0.47 percent to 2 percent. It should be noted that this increase in “delivered coal cost” does not back out the other transportation components such as the percentage delivered by truck or direct rail since we do not have this information. The estimated percent increase in “delivered coal cost” as a result of the switch from HFO to MDO is reported in columns (4) and (6), Table 3-6, for the low and high increase for the marine ECA-adjusted freight rates, respectively.

In the second step, electricity sales and cost data from EIA publication are used to estimate the impact of the increase in “delivered coal cost” on electricity revenue. The data used to perform this analysis are total electricity sales (in MWh) and revenue (in $Million).

The results of this analysis, set out in Table 3-6, indicate that if shipping costs increase by 1.2 percent (the lower bound scenario) due to implementing EPA’s fuel requirement, the increased transportation costs are small compared to electricity retail revenue, about 0.1 percent. If shipping costs increase 4.5 percent (the upper bound scenario), the comparison of the impact on shipping costs to electricity retail revenue increases to about 0.5 percent. The results reported in Table 3-6 also show that the impacts for independent power or public utility companies are similar. As a result, the increase in transportation costs due to the application of the ECA fuel requirements to the Great Lakes are not expected to generate a production shift, and are likely to be smaller than the costs facilities would incur to relocate production out of the region.

Table 3-6 Production Shift Results – Electrical Sector

	Revenue from retail sales of electricity generated with coal ($ million)	Delivered Coal Cost ($ million)	Low cost Case (Delivered Coal Cost increased 1.20%)	Low cost Case Increase in Delivered Coal costs % of electricity revenue	High Cost Case (Delivered Coal Cost increased 4.47%)	High Cost Case Increase in Delivered Coal costs % of electricity revenue
Elect. Utility October 2009	$2,185	$523	$526	0.11%	$533	0.48%
Indep. Power October 2009	$805	$178	$179	0.10%	$181	0.44%
Elect. Utility Annual 2009	$22,460	$5,324	$5,348	0.11%	$5,430	0.47%
Indep. Power Annual 2009	$8,468	$1,968	$1,978	0.11%	$2,008	0.46%

Notes:
Coal cost is around 22% to 24% of electricity revenue
For a public utility company, around 55% of electricity revenue is from coal generation and for an independent power generator, around 24% of revenue is from coal generation
Shipping cost of coal is around 40% of coal cost in this region. In general, national average is about 25%.

Source: Electric Power Monthly, January 2010, DOE/EIA-0226 (2010/01)
http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html

These estimated freight rate increases can be compared to the history of retail prices for electricity for the Great Lakes states, set out in Table 3-7. The expected freight rate increases of 0.1 and 0.5 percent are small compared to historic electricity price variations.

Table 3-7 Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, By State, Percent Increase, Year-to-Date July 2009 to July 2010

	Residential	Commercial	Industrial	Transportation	All Sectors
Middle Atlantic	6.0%	3.7%	2.6%	0.9%	4.6%
New Jersey	-0.3%	-4.2%	3.1%	-3.3%	-1.6%
New York	5.9%	6.8%	-3.8%	2.0%	5.9%
Pennsylvania	10.0%	6.1%	5.7%	-0.3%	7.6%
East North Central	2.6%	0.6%	-5.2%	-23.3%	-0.1%
Illinois	-0.6%	-4.2%	-3.8%	-23.5%	-2.2%
Indiana	-3.0%	-1.9%	-2.1%	-7.3%	-2.6%
Michigan	6.8%	6.8%	-1.1%	-4.3%	4.5%
Ohio	6.0%	1.8%	-12.2%	-14.8%	-0.3%
Wisconsin	2.8%	2.7%	-1.5%	N/A	1.7%

Source: http://www.eia.doe.gov/electricity/epm/table5_6_b.html (accessed October 2010)

This analysis certain limitations due to the assumptions used. For example, we assumed all the delivered costs in the region are increased by either 1.2 percent or 4.5 percent due to our fuel requirement. However, not all the coal used to generate power in the Great Lakes areas is transported by Category 3 vessels, and coal delivered by other modes is not affected. Therefore, the results of this analysis are likely overstated.

3.2.1.3 Impact on Steel

We used U.S. Census Bureau data for the iron and steel manufacture industry (NAICS code: 33111) to estimate shipping cost impacts on the steel sector. This analysis uses national-level data because steel production is a vertically integrated industry. Steel manufacturing begins with the processing of raw materials such as iron ore and coke, followed by iron and steel making, and then production of steel scrap, stabs, thin slabs, and many other final steel products. One company may use several facilities to complete its manufacturing process. Thus, national data more fully represent this input and output relationship. In 2002, there were 379 facilities listed under the iron & steel industry by NAICS code 331111 (Census Data, Geographic Distribution –Iron & Steel Mills[E]); 194 facilities (51 percent) are located in Great Lakes area or adjacent states.[F] With regard to shipments, facilities in the states of Ohio, Pennsylvania,[G] New York, Michigan and Illinois account for 63 percent of the value of U.S. shipments.

The total revenue and cost data of the iron and steel manufacturing industry from the 2007 census are selected to estimate the impacts.[H] Since Great Lakes coal movements are almost exclusively destined for power plants and almost no coal is used in steel production, this analysis considers iron ore as the only major input affected by increased freight rate for steel manufacturers.[I] The results from this approach represent the shipping cost impact on all final steel products in general.

[E] Census Bureau Website: http://www.census.gov/econ/census02/data/industry/E331111.HTM, accessed on March 2, 2011.

[F] States of Indiana, Ohio, Pennsylvania, Illinois, Michigan, New York, Minnesota, Wisconsin

[G] Pennsylvania's shipment value in % of U.S. in 1997 Census data is used because Pennsylvania does not provide shipment value in 2002 Census

[H] US Census Bureau, 2007 economic census on the iron and steel industry (NAICS code 331111), (1) Sector 31: EC073113: Manufacturing Industry Series: Materials Consumed by Kind for the United States: 2007, (2) Sector 00: EC0700A1: All Sectors: Geographic Area Series: Economic-Wide Key Statistics: 2007. Available at http://www.census.gov/econ/census07/index.html/

[I] One peer reviewer noted that "Great Lakes coal movements are almost exclusively destined for power plants and almost none is used in steel production (steel companies usually use coke [which] is rail supplied)." This peer reviewer also noted that "[t]here are a few exceptions, like the Rouge steel plant in Detroit, which occasionally receive[s] a shipload of metallurgical coal, but there aren't many. (Hull) EPA confirmed that coal is only used in facilities that also produce coke. Therefore, EPA removed the coal impacts from the steel analysis included in this section.

The American Spirit takes on a load of taconite at the ore loading facility in Escanaba, MI. Source: Photograph taken by and used with permission from Dick Lund, accessed here: http://www.dlund.20m.com/lund2.html

Similar to the two-step approach in the electricity impact analysis, the first step is to separate "the commodity cost at the mine" and "the shipping cost" in the "delivered commodity cost" reported in the census data.[J] Iron ore is assumed to be the only commodity shipped by water for the steel production. In addition, we assume that 80 percent of the delivered iron ore cost is "iron ore cost at the mine" and the other 20 percent of the delivered iron ore cost is "shipping cost." The USGS reports the value at the mine ($/metric ton) of iron ore in the United States has varied between $37.92 and $70.43 for the years 2004 through 2007[12]. Using our estimated base case total freight rate, we estimate that shipping costs would vary between about 6 percent and 30 percent of the total price of iron ore. Therefore, 20 percent is a mid-range value. This is a conservative estimate given the higher value of iron ore at the mine in recent years. However, the actual ratio between "iron ore cost at the mine" and "shipping cost" varies depending on many factors, including the price of iron ores in the world, the steel price, and the shipping cost. After applying the estimated shipping cost increase, "delivered commodity costs" are estimated. The second step applies these "delivered commodity costs" to steel costs and revenue data to estimate the impact on steel.

According to census data, total sales for this sector in 2007 were $100.2 billion. Iron ore inputs were valued at $3 billion, and iron ore transportation cost is valued at $0.6 billion (20 percent of iron ore cost).

The results of this analysis, set out in Table 3-8, indicate that if iron ore shipping costs increase by 8.5 percent (the lower bound scenario) or 16.6 percent (the higher bound scenario), due to implementing EPA's fuel requirement, this increase represents about 0.13 percent to 0.17

[J] Census Data only provides the delivered commodity (coal and iron ore) cost for the steel industry percent of total materials costs for the iron and steel industry, which represents 0.05 percent (lower bound scenario) or 0.1 percent (upper bound scenario) of industry revenues. In other words, while the program is expected to lead to an increase in freight rates of 8.5 percent to 16.6 percent, depending on the scenario, the increase in the transportation freight rate is only part of the price of iron ore, which is only one input to the production of steel, and therefore the impact on steel costs is less that 0.2 percent. These impacts are not expected to lead to a production shift because the cost of relocating production out of the region would almost certainly be more substantial. Relocation costs would include, among other things, the cost of creating or modifying steel production facilities in other locations (assuming there is enough excess capacity available to cover all the steel production in one or all Great Lakes steel mills), the cost of developing new supply chains and infrastructure, and the cost of transporting steel to manufacturers in the Great Lakes region who use it as an input.

Table 3-8 Impact on Steel due to Shipping Cost Increase

	$Million
(1) Total sale revenue	$100,240
(2) Total materials cost	$56,265
(3) Baseline case Iron ore input cost	$3,000
▪ Transp. Cost (%)	20%
▪ Transp. Cost ($)	$600.05
▪ Transp. Cost as % total materials cost	1.07%
▪ Transp. Cost as % revenue	0.60%
(4) Low bound scenario (shipping cost increased by 8.5%	
▪ New transp. Cost	$651.1
▪ Transp. Cost as % total materials cost	1.20%
▪ Transp. Cost as % revenue	0.65%
(5) Upper bound scenario (shipping cost increased by 16.6%	
▪ New transp. Cost	$699.6
▪ Transp. Cost as % total materials cost	1.24%
▪ Transp. Cost as % revenue	0.70%
(6) Transp. Cost increase impact in the lower bound case as % total materials/revenue	0.13%/0.05%
(7) Transp. Cost increase impact in the upper bound case as % total materials/revenue	0.17%/0.10%

In addition, while steel is used in a large variety of goods, ranging from vehicles to containers, appliances and electrical goods, and construction, it represents only one input among many to produce these goods. Therefore, the impact of increased transportation costs due to new fuel requirements on the steel sector can be expected to have only a negligible impact on the prices of these finished goods. Figures 3-4 and 3-5 illustrate historic fuel prices and the monthly price change for the period January 2009 through January 2011. According to steel industry data, monthly steel price fluctuations have ranged from a decrease of 12 percent to an increase of 14 percent. These steel price fluctuations are larger than the expected impacts on revenues for this sector.

Figure 3-4 World Steel Prices, 2009-2010 (US$/tonne)

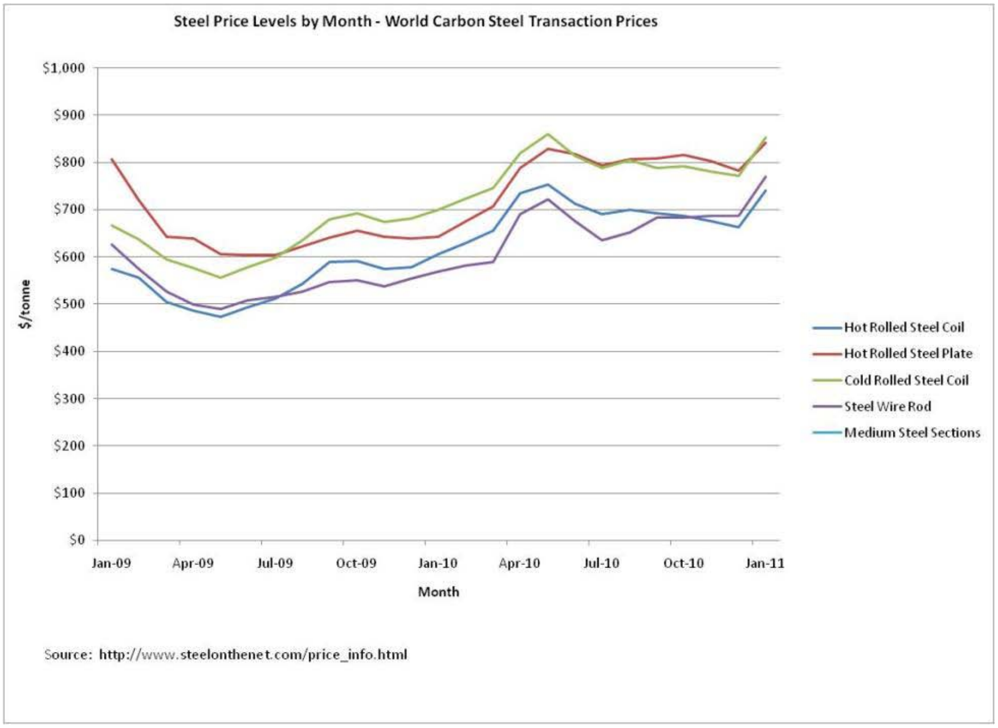
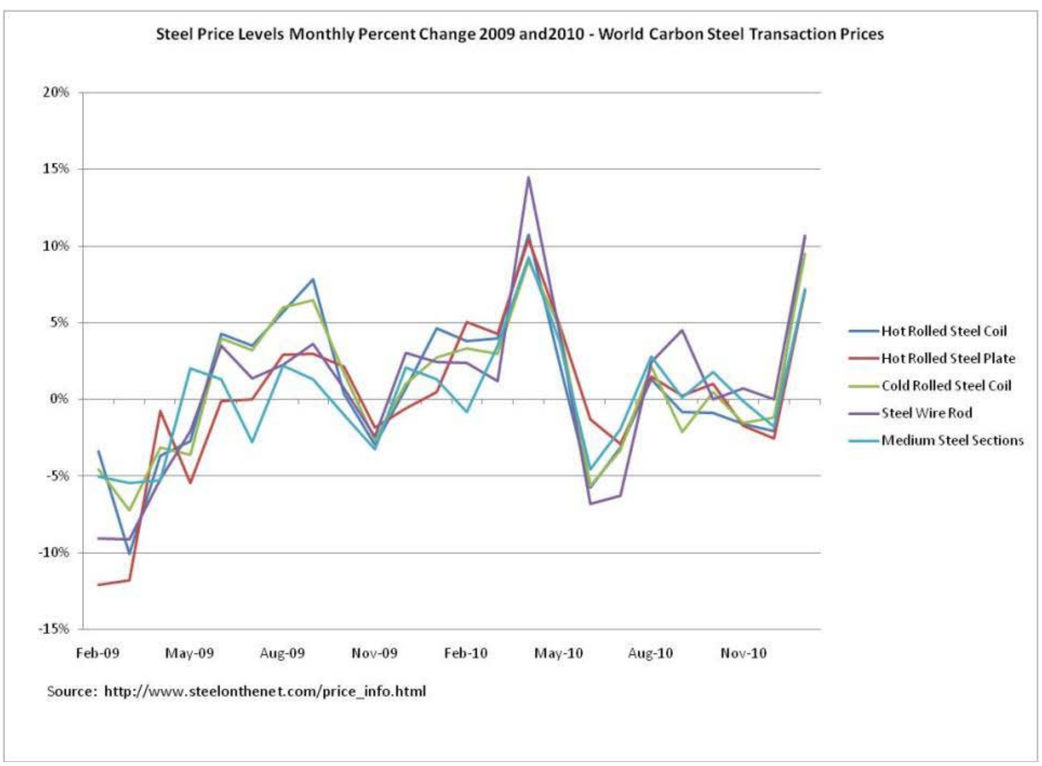


Figure 3-5 World Steel Prices, 2009-2010 (US$/tonne)



Since we could not obtain region-specific data on the steel industry, this analysis uses the national level industry data from the Census Bureau. Thus, the analysis assumes that all the delivered costs for iron ore and coal in the nation are affected by the new fuel regulation, and all iron ore and coal used for steel making in the nation are delivered on Category 3 ships. To the extent that these increased costs can be spread across steel production nationally, the results of this analysis may be overstated.

Finally, it is worth noting that steel production processes are changing and more steel is being produced from scrap metal. One source estimates that as much as 51 percent of iron used to make steel now comes from scrap.[13] This means that only a portion of steel produced, about half, will see a production cost increase due to the costs of transporting iron ore by ships using ECA-compliant fuel. Steel producers may be able to spread this cost increase over all steel output, thus reducing the impacts of ECA control per unit from both fresh iron ore and from scrap material.

3.2.2 Detroit Steel Scenario

A second way to explore production shift impacts is to examine a specific scenario. Commenters on our Category 3 rule were concerned that an increase in transportation costs for iron ore of the magnitude estimated in this analysis might result in a shift of U.S. steel production away from the Great Lakes. This section examines this potential shift with respect to both domestic and foreign steel production.

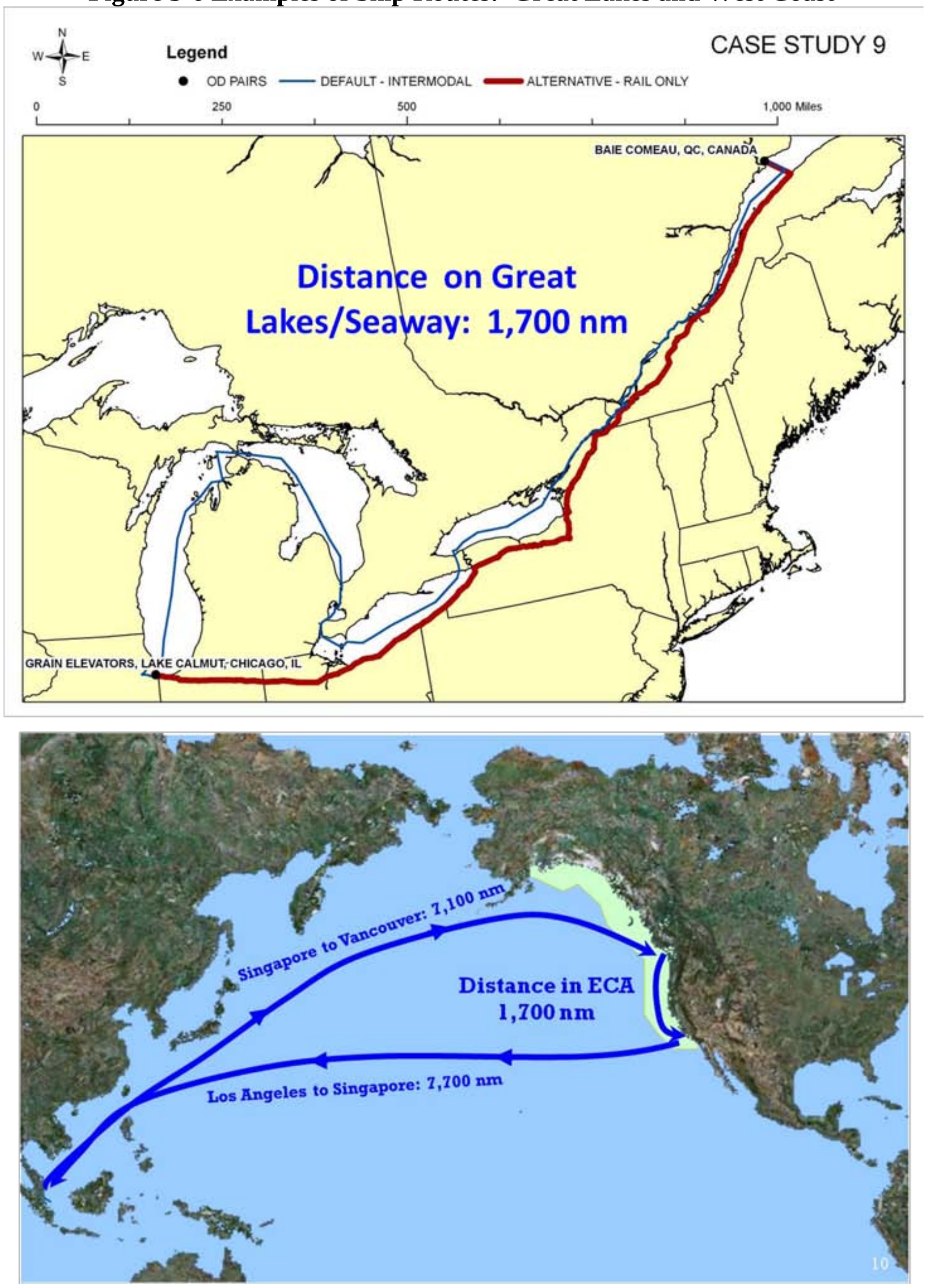
According to the American Iron and Steel Institute, approximately 40 percent of the steel produced in the United States during the week ending September 25, 2010, was produced in the Great Lakes region (Pittsburg/Youngstown, Lake Erie, Detroit, Indiana/Chicago).[14] The next highest producing region was the Southern region, with 33 percent. While production on the Great Lakes has decreased over time, from 75 percent in the early 1990s to 60 percent in the early 2000s to 40 percent currently, this region is still the most important in the United States for steel production.[15] The Great Lakes region is favorable for steel production not just due to the importance of the waterway for transportation of inputs but also because it can supply the large quantities of water used in steel manufacturing.[16]

If steel production were shifted out of the Great Lakes region, that steel would need to be transported to end-use facilities located in the Great Lakes region. This is important because nearly 60 percent of automobiles and 45 percent of light-duty trucks manufactured in the United States are produced in the four Great Lakes states of Michigan, Ohio, Indiana, and Illinois.[17] The region also has many producers of other goods that use steel produced in the area. If steel production were to move out of the Great Lakes region, the transportation costs associated with bringing that steel back into the region for these manufacturing facilities would be likely to be higher than the additional costs of transporting the steel inputs to the mills as a result of the ECA fuel requirements. This is largely due to the longer distances the steel would have to be shipped (from outside the Great Lakes region) and the higher cost of rail or truck transportation.

Similarly, a production shift to steel mills outside of the United States is not likely to result in reduced costs. Over the last 15 years, the United States has imported about 20 percent of its steel.[18] The main source countries are Canada and Mexico, which accounted for about 35 percent and 13 percent of steel imports, respectively, in 2009 (29 percent and 14 percent, respectively, in 2007). China, Japan and Korea account for about 18 percent, and Germany and Italy account for another 7 percent. Altogether, these seven countries account for nearly 60 percent of imported steel in the United States.

It is not clear that shifting more production to these countries would offset the additional costs associated with complying with ECA fuel requirements for transporting iron ore and coal on the Great Lakes. Not only is imported steel subject to import taxes, tariffs, and quotas but, in addition, steel transported from Asia or Europe would have to go through at least one ECA and potentially two. This is because all U.S. ports in the continental United States are located within the North American ECA, which extends about 200 nm from U.S. coasts in most cases (see Figure 1-3). Depending on the route, ships from Asia may spend as many as 1,700 miles in the North American ECA if they take the North Pacific route to Los Angeles, which is about the distance of the default route from Baie Comeau to Chicago in Scenario 9 (see Figure 3-5). Ships coming from Germany to an East Coast port would transit the North Sea ECA as well as the North American ECA. In addition, the steel would need to be transported by truck or rail from the coastal port to where it will be used in production facilities. Again, because rail transportation rates are more costly than ship freight rates, this alternative would result in a significantly more expensive increase in transportation costs when compared to shipping the raw material inputs for steel through a Great Lakes ECA. Even if ship owners have discretion in where they offload their cargo, the steel consumers are unlikely to want to bear the additional rail cost associated with this option.

Figure 3-6 Examples of Ship Routes: Great Lakes and West Coast



Source: EPA

The additional costs of importing steel can be illustrated by the example of steel that is manufactured in Indiana Harbor, Indiana, and for use in Detroit, Michigan.[19] Steel is made primarily of three raw materials; iron ore, limestone, and coke. Based on comments from industry, roughly 1.5 tons of iron ore and 0.7 ton of limestone are shipped on the Great Lakes for every ton of steel produced. Coke typically arrives by rail, and therefore will not be affected by a Great Lakes ECA. In addition, steel is typically transported from Indiana Harbor to Detroit by truck, so this part of the transportation also will not be affected by a Great Lakes ECA.

There are a number of sources of iron ore and limestone located on the Great Lakes. For this example, we consider iron ore originating from Two Harbors, Minnesota, Silver Bay, Minnesota, and Escanaba, Michigan, and limestone originating from Port Inland, Michigan, and Cedarville, Michigan. Assuming that iron ore comes 50 percent from the Two Harbors/Silver Bay area and 50 percent Escanaba, the average ton of iron ore travels 460 nm miles to Indiana Harbor. Splitting the distance between Port Inland and Cedarville, the average ton of limestone travels roughly 260 nm. Based on these estimates, a total of 2.2 tons of raw material must be transported by ship to produce one ton of steel. The net is 870 ton-nm (1000 ton-miles) of transportation on the Great Lakes for each ton of finished steel. Figure 3-7 presents the shipping routes used in this example.

Figure 3-7 Domestic Steel Shipping Routes

Source: Samulski, Michael. Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder – Information in Support of Applying Emission Control Area (ECA) Requirements to the Great Lakes Region. EPA-HQ-OAR-2007-0586. December 15, 2009.

For the imported steel case, the ship needs to pass through roughly 200 nm of the ECA before reaching the Canadian baseline. The ship then needs to pass through the St. Lawrence Seaway, Lake Ontario, and Lake Erie on its way to Detroit. The total distance is roughly 1,700 nm (1,960 miles). This shipping route is illustrated in Figure 3-8.

Figure 3-8 Imported Steel Shipping Route

Source: Samulski, Michael. Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder – Information in Support of Applying Emission Control Area (ECA) Requirements to the Great Lakes Region. EPA-HQ-OAR-2007-0586. December 15, 2009.

Based on this example, imported steel must travel roughly twice the distance through the ECA as the raw materials needed to produce domestic steel. Even if the domestic steel were transported from Indiana Harbor to Detroit by ship, this would add only another 550 miles of shipping in the ECA. As such, the imported steel still requires more shipping, in the ECA, per ton of finished steel. In either case, the impact of increased shipping costs on a ton of steel is much less than the historical month-to-month fluctuation in steel prices.

Table 3-9 presents the projected increased transportation costs of a ton of steel that could result from an ECA. Note that this analysis only considers ship traffic in one direction and assumes that the vessel will perform useful work on the return voyages (it would have a backhaul). This assumption is reasonable because it is generally the case that ships that bring import steel coil to the United States typically carry export grain on the backhaul. If a ship does not have a backhaul, this would have the effect of roughly doubling the shipping cost per ton of steel for both the domestic and import cases.

Table 3-9 Imported Steel Shipping Route Costs

	DOMESTIC STEEL	IMPORTED STEEL
Increased fuel cost [$/ton-mile]	$0.0009	$0.0009
Shipping distance in ECA [nautical miles]	870	1,700
Increased fuel cost [$/ton of steel]	$0.90	$1.75
Price of cold rolled steel (June 2009) [$/ton][a]	$525	$525
Estimated % cost increase for steel	**0.2%**	**0.3%**

[a] *See* http://www.steelonthenet.com/prices.html

Commenters also suggested that Category 3 ships carrying steel could offload cargo in New York, or other east coast ports, rather than entering the Great Lakes ECA. In this case, the ships would pass through roughly 200 nm of the ECA to the port of New York. Finished steel would then need to be transported over land, presumably by rail, for more than 600 miles to reach Detroit. Because rail transport rates can be more than three times shipping rates, this alternative would result in a significantly more expensive increase in transportation costs when compared to shipping through a Great Lakes ECA. The use of an East Coast port would also affect the ability of these ships to take on a grain backhaul; currently the grain is picked up in Canadian ports such as Baie Comeau, Quebec.

3.3 Emissions Impact Analysis

Great Lakes commenters on the Category 3 rule expressed concern that a shift away from ships to land-based transportation would result in an increase in air emissions, the opposite intent of the program. The analyses presented above and in Chapter 2 show that transportation mode shift, source shift, and production shift are not expected due to the use of higher cost fuel for the 16 at-risk routes studied. Nevertheless, EPA performed an emissions analysis for each of these 16 scenarios, to examine the emissions difference between ship, rail and truck transportation modes. EPA estimated the total air emissions of NO_X, fine PM and carbon dioxide (CO_2) for a single round trip, for each Base (HFO) Case, MDO (ECA) Case and All-Rail Case (or the highway truck alternative for the stone scenarios). The sections below present the methodology employed in this emissions analysis and the inputs used.

This analysis shows that the use of ECA fuel is always better for the environment when compared to current marine fuel. In addition, with the exception of two grain scenarios (Scenarios 11 and 12) and the crushed stone scenarios (Scenarios 13-16), marine transportation using ECA fuel is better for the environment than the alternative transportation mode.

3.3.1 Methodology

EPA estimated the emissions of a single round trip cargo movement scenario by applying emission factors for each mode of transportation, along with estimates of the efficiency of the vehicle employed for the various transportation options: Category 3 vessel; line haul locomotive; and heavy-duty highway truck. These factors were combined with the scenario-specific parameters defined in Chapter 2 regarding the volume of cargo moved and distances traveled for each leg of each trip. Thus, for a scenario where the cargo is moved by rail for one leg of the journey and by water for another, the general format of the emissions equations would be as follows.

Total Base or ECA Case Route Emissions = Marine Leg Emissions (see Equation 3-1) + Rail Leg Emissions (see Equation 2)

Scenarios 1-12 Total Alternative Case Route Emissions = Rail Emissions (see Equation 3-2)

Scenarios 13-16 Total Alternative Case Route Emissions = Truck Emissions (see Equation 3-3)

For purposes of the emissions analysis, all distances traveled assume round-trip vehicle movements, consistent with the mode shift analysis described in Chapter 2, which assumes that each of the scenarios would include an empty backhaul. Distances were estimated by ICF and its contractor, EERA, through study of existing transportation networks, and with stakeholder assistance.

Above in Section 3.1, EPA describes its analysis to assess the possibility that limestone customers in Scenarios 13 through 16 may choose to obtain stone from local quarries via highway truck rather than from more distant quarries via a water/rail route. One of the outputs of that analysis is the distance over which a customer may be willing to pay for truck transport of limestone to his plant. These distances are the same as those estimated in the source shift analysis presented in Section 3.1 and are presented in Table 3-2. The Control Competitive Radius distance under the Equal Total Price case estimated in Chapter 3 was employed in this emissions analysis to estimate emissions from highway trucks.

EPA's emission factors for each transport mode are described below. For each round trip route, it was assumed that the vessel load as specified for each scenario in Chapter 2 is the cargo volume moved, regardless of mode. Because the competing modes (locomotive and truck) carry much smaller volumes per vehicle, EPA normalized the emission estimates by multiplying the per-vehicle emissions of the competing modes by the number of vehicles that would be needed to carry a vessel load.

This analysis is solely for the Category 3 propulsion engines, and does not quantify emissions from auxiliary engines or loading or unloading activities at transfer points.[K] Consistent with the methodology of the transportation analyses above, which excluded the costs of the first loading at the origin and last unloading at the destination, the effects of those initial and final transfers have been deemed outside the scope of this analysis. EPA has not evaluated how the emissions profiles of the self-unloading equipment on the vessels differ from the emissions profiles of the land-based equipment. Furthermore, there are ranges in unloading rates for both vessels and rail cars. As described below in Chapter 7, the unloading rate of Great Lakes vessels ranges from approximately 6,000 to 10,000 tons per hour.[L] Given the variety of train car unloading systems and the associated unloading rates (from 800 to 20,000 tons/hr), EPA estimates the difference in duration of material transfer by rail could range from one third to six times the transfer time of a bulk self-unloading vessel.[20] These times exclude maneuvering and positioning times, which would be expected to increase with the alternate freight modes.

Chapter 8, Section 8A.8 includes an additional discussion of emissions from transfer equipment.

[K] Peer reviewer Hull suggested that EPA explain whether a modal shift would result in higher emissions from the material loading and unloading activities.
[L] See Sections 7.5.2.1 and 7.5.3.

The Hon. James L. Oberstar (formerly named the Charles M. Beeghly) unloading at South Chicago. Source: Gary Clark, Unloading at South Chicago, accessed at: www.boatnerd.com

3.3.2 Data Inputs

3.3.2.1 Marine

Vessel emission factors used in this analysis are EPA's fleet average medium speed diesel emission factors for Category 3 engines, forecast for 2015. Emission factors for diesel engines are distinguished by the speed of the engine. The two most common types of Category 3 engines are slow-speed diesel engines (SSD) with engine speeds of 150 rpm or less, and medium-speed diesel engines (MSD) with engine speeds of approximately 300 to 600 rpm. As described in Chapter 7, the C3 engines on the Great Lakes vessels are typically medium speed diesels. The emission factors are presented in Table 3-10. The $PM_{2.5}$ emission factor shown in Table 3-10 is based on 1.7 percent sulfur fuel. This $PM_{2.5}$ emission factor is different from that used in the full C3 emission inventory (2.7 percent) but is used here to show that even if the sulfur content of fuel sold on the Great Lakes were less than that used in our inventory, as suggested by commenters on the Category 3 rule, the emissions benefits of the ECA controls are nonetheless considerable and are favorable compared to rail or highway truck alternatives for most scenarios. The $PM_{2.5}$ emission factor for the control case is based on use of 0.1 percent sulfur fuel, consistent with the ECA fuel sulfur limit. The emission factors in Table 3-10 were applied to each scenario using the given vessel horsepower and operating speed values presented below in Table 3-11.

Although the ECA fuel standards are not set for the purpose of reducing NO_X or CO_2, Table 3-10 shows that the control emission factor is slightly less than the baseline emission factor for those pollutants. This is because there are small NO_X and CO_2 emission reductions brought about by switching from residual to distillate fuel. In the case of NO_X, this is because distillate fuel has a lower nitrogen content than residual fuel. In the case of CO_2, this is because distillate fuel has higher energy content, on a mass basis, than residual fuel, leading to lower fuel consumption estimates in the control (ECA) case.

Table 3-10 Category 3 2015 Fleet Average Vessel Emission Factors

POLLUTANT	BASELINE EMISSION FACTOR (G/kWh)	CONTROL EMISSION FACTOR (G/kWh)
NO_X	13.7	12.6
$PM_{2.5}$	1.01	0.17
CO_2	668.4	636.6

The following table presents the scenario inputs from Chapter 2. Of note is that the distances presented in the tables of Appendix 2C represent one-way distances, whereas the distances in Table 3-11 represent round trip distances. This is only a matter of presentation, not methodology. This emissions analysis, as well as the above energy and cost analyses, is based on fuel consumption for the full round trip. This assumes that the vehicle (vessel or other) carried cargo one way and had an empty backhaul.[M] For purposes of this simplified analysis, the same average emission factors are applied regardless of the amount of cargo loading.

Table 3-11 Emissions Scenario Inputs[a]

Scenario	Cargo Load	Vessel Power	Vessel Speed	Round Trip Miles		
	net short tons	hp	mph	By Sea (Base & ECA)	By Rail (Base & ECA)	Alternate[b]
Scenario 1	10,450	7,200	14	280	2,080	2,520
Scenario 2	11,730	7,200	14	780	2,620	2,860
Scenario 3	48,620	16,000	16	1,520	2,080	3,240
Scenario 4	28,290	16,000	16	1,240	2,080	3,320
Scenario 5	11,730	7,200	16	340	40	420
Scenario 6	15,430	7,200	16	3,460	400	N/A
Scenario 7	48,620	16,000	16	1,740	160	1,140
Scenario 8	48,620	16,000	16	1,680	200	1,800
Scenario 9	14,940	7,200	14	3,440	-	2,540
Scenario 10	15,430	7,200	14	3,460	-	3,280
Scenario 11	11,730	7,200	14	1,920	100	1,940
Scenario 12	4,030	7,200	14	370	10	480
Scenario 13	41,900	11,000	16	720	520	482
Scenario 14	41,900	11,000	16	640	520	396
Scenario 15	41,900	11,000	16	940	500	536
Scenario 16	41,900	11,000	16	860	220	294

Notes:
[a] Data compiled from Appendix 2C, Tables 17 through 32.

[M] As mentioned in Section 2.6.1 of Chapter 2, this is a conservative assumption from a freight rate perspective.

[b] Alternate mode is by rail for Scenarios 1-5 and 7-12, and by truck for Scenarios 13-16. No alternate route was identified for Scenario 6.

When applying the EPA emission factors to each scenario, resulting per-trip vessel emissions vary due to the range of inputs for the scenarios, engine power, and length of marine leg. The following equation shows the method used to calculate the emissions from each marine leg of a journey.

Equation 3-1 Marine Leg Emissions

Tons of Pollutant per Trip = EF × Power × Distance ÷ Speed × CF

Where:

EF = emission factor in g/kW-h
Power = main propulsion engine horsepower
Distance = round trip miles traveled by the vessel
Speed = average vessel service speed in mi/hr
CF = unit conversion factors

Combining the emission factors from Table 3-10 with relevant inputs from Table 3-11, the per-trip vessel emission rates are estimated on a cargo-related basis, set out in Table 3-12. These values can be compared with the emissions intensity of locomotive and truck transport, shown in Tables 3-13 and 3-14, respectively.

Table 3-12 Vessel Emission Intensity (g/100 ton-miles)

Scenario	Cargo Load (tons)	Base Vessel NO_X	Base Vessel $PM_{2.5}$	Base Vessel CO_2	ECA Vessel NO_X	ECA Vessel $PM_{2.5}$	ECA Vessel CO_2
Scenario 1	10,450	50	3.7	2,500	46	0.62	2,300
Scenario 2	11,730	45	3.3	2,200	41	0.56	2,100
Scenario 3	48,620	21	1.5	1,000	19	0.26	1,000
Scenario 4	28,290	36	2.7	1,800	33	0.45	1,700
Scenario 5	11,730	39	2.9	1,900	36	0.49	1,800
Scenario 6	15,430	30	2.2	1,500	27	0.37	1,400
Scenario 7	48,620	21	1.5	1,000	19	0.26	1,000
Scenario 8	48,620	21	1.5	1,000	19	0.26	1,000
Scenario 9	14,940	35	2.6	1,700	32	0.44	1,600
Scenario 10	15,430	34	2.5	1,700	31	0.42	1,600
Scenario 11	11,730	45	3.3	2,200	41	0.56	2,100
Scenario 12	4,030	130	9.6	6,400	120	1.6	6,100
Scenario 13	41,900	17	1.2	820	15	0.21	780
Scenario 14	41,900	17	1.2	820	15	0.21	780
Scenario 15	41,900	17	1.2	820	15	0.21	780
Scenario 16	41,900	17	1.2	820	15	0.21	780

3.3.2.2 Locomotive

For locomotives, EPA calculated the per-trip emissions from each rail leg of a journey, in tons, as well as the emissions intensity in grams of pollutant per 100 ton-miles. Locomotive emission factors used in this analysis are EPA's emission factors for the line-haul fleet average forecast for the year 2015, as depicted in Table 3-13, in grams of pollutant per gallon of fuel used.[N] To apply these factors for CO_2, the carbon content of the fuel was taken to be 2,778 g/gal, with 99 percent of the carbon converting to CO_2, in accordance with 40 CFR part 600. To be consistent with the diesel fuel heating value utilized by EERA in their methodology for locomotives, the energy content of the on-road diesel fuel was taken to be 138,490 Btu/gal, in accordance with the "low-sulfur diesel" fuel listed in the Department of Energy's GREET model, version 1.8b.[21]

Also for consistency with the values used in EERA's analysis, the energy efficiency for freight transport work for locomotives was taken to be 328 BTU/ton-mile,[O] This is a top-down value, derived from national energy consumed, in Btu, by rail freight transport divided by national cargo delivered, in ton-miles. Although actual energy consumption would vary by cargo load as well as other trip-specific circumstances such as terrain, the same freight efficiency value was used for all scenarios in this study.

For each scenario, the number of train cars needed to carry the given cargo load was calculated, using an assumed train configuration of 100 freight cars carrying 100 tons each. Note that most Base and ECA case routes include some amount of rail travel. Only Scenarios 9 and 10 are uni-modal in the Base and ECA cases.

To convert the locomotive rate to a cargo-based value in g/ton-mile, the applicable EPA emission factor was applied to the national average transport efficiency in Btu/ton-mile. These factors represent our estimate of the emissions intensity for each rail leg of a journey, excluding transfer points. Based on the above assumptions, the values in the third column of Table 3-13 are estimated to be the same for all scenarios. Thus, these can be taken as the All-Rail Alternative route emissions intensity for comparison with the Base Vessel and ECA Vessel emissions intensity values in Table 3-12, for the sea leg of each journey for each respective pollutant.

Table 3-13 2015 Fleet Average Locomotive Emission Factors

POLLUTANT	EPA EMISSION FACTOR (G/GAL)	EMISSIONS INTENSITY (G/100 TON-MILE)
NO_X	129	31
$PM_{2.5}$	3.4	0.81
CO_2	10,084	2,400

[N] US EPA (2009) Emission Factors for Locomotives, EPA-420-F-09-025, available at www.epa.gov/otaq/locomotives.htm

[O] *See* Table 16 of Appendix 2C, above.

The following equation shows the method used to calculate the per-trip emissions from each rail leg of a journey. The resulting emissions estimated from Equation 3-2 are presented in Tables 3-15, 3-16 and 3-17. For Base and ECA Case Route Emissions, this equation is combined with Equation 3-1 (Marine Leg Emissions) using Round Trip Miles by Sea and by Rail from Table 3-11. The Total Alternative Case Route Emissions presented in the three results tables for Scenarios 1-12 derive from Equation 3-2 using the Alternate distance from Table 3-11.

Equation 3-2 Rail Leg Emissions

$$\text{Tons of Pollutant per Trip} = EF \times T_E \times C_L \times N_T \times \text{Distance} \div EC$$

Where:

EF = emission factor in g/gallon
T_E = average transport efficiency in Btu/ton-mile
C_L = cargo load, in tons, of the vessel in the given scenario
N_T = Number of trains needed to carry an equivalent vessel load, at 10,000 tons/train
Distance = round trip miles traveled by the locomotive
EC = energy content of ULSD fuel in Btu/gal

3.3.2.3 Gravel Trucks

The emission factors for gravel trucks for the stone scenarios (Scenarios 13-16) used in this analysis are the highway truck emission rates taken from EPA's MOVES model. A run was performed for calendar year 2015, to estimate the nationwide fleet average emission rates for diesel long-haul highway tractor-trailers.[P] The resulting emission factors, used in this analysis, are presented in Table 3-14. As this model produces factors in units of gram of pollutant per mile driven, no additional adjustments were necessary to apply these rates to the scenarios. The values in the third column of Table 3-14 are estimated to be the same for all scenarios. Thus, these can be taken as the Alternative route emissions intensity for Scenarios 13 through 16, for comparison with the Base Vessel and ECA Vessel emissions intensity values in Table 3-12, for the sea leg of each journey for each respective pollutant.

For purposes of this study, we only evaluated movement of stone by truck along distances presented in the source shift analysis in Section 3.1, above. These are radial distances from the facilities (power plants, sugar processing plant) that are the destinations for Scenarios 13 through 16. As explained in Section 3.2, these are the distances at which a consuming facility would be indifferent between stone from distant quarries shipped by rail/ship and stone shipped from local quarries.

[P] MOVES2010 was run for this analysis. Related software and supporting materials can be found on the Web at http://www.epa.gov/otaq/models/moves/movesback.htm#moves2010. A newer version, MOVES2010a, is now available, and can be found at: http://www.epa.gov/otaq/models/moves/index.htm.

Table 3-14 2015 Fleet Average Truck Emission Factors

POLLUTANT	MOVES EMISSION FACTOR (G/MILE)	EMISSIONS INTENSITY (G/100 TON-MILE)
NO_X	9.57	22
$PM_{2.5}$	0.247	0.57
CO_2	2,176	5,100

The following equation shows the method used to calculate the per-trip emissions from each round-trip highway journey. The resulting emissions estimated from Equation 3-3, applying the Alternate distance from Table 3-11, are presented in Tables 3-19, 3-20 and 3-21, under the column labeled Truck Emissions from Alternate Quarry. For Base and ECA Case Route Emissions in those same results tables, Equations 3-1 and 3-2 are combined, as was done with the marine and locomotive emissions, using Round Trip Miles by Sea and by Rail from Table 3-11.

Equation 3-3 Truck Emissions

$$\textbf{Tons of Pollutant per Trip} = \textbf{EF} \times \textbf{N}_\textbf{T} \times \textbf{Distance x CF}$$

Where:

EF = emission factor in g/mile
N_T = Number of trucks needed to carry an equivalent vessel load, at 43 tons per truck
Distance = round trip miles traveled by the truck
CF = conversion factors

3.3.3 Results

This section presents the results of EPA's emissions analysis for each of the 16 scenarios in this study. First the results for Scenarios 1 through 12 are presented, comparing estimated emissions for each of the multimodal Base and ECA cases and all-rail cases modeled by EERA under the mode shift analysis. Following that, the results for Scenarios 13 to 16 are presented, comparing estimated emissions for the Base and ECA cases modeled by EERA and the alternative highway truck case from EPA's source shift analysis in Section 3.1.

Since each scenario is designed using different vessels, cargo loadings, and voyage leg distances, it is not recommended to compare results between scenarios. The per-trip emissions vary by one to two orders of magnitude between scenarios, depending on the pollutant.

As mentioned above, this emissions analysis presents results using estimated 2015 fleet average emission rates. The phase-in of current EPA regulations will cause a greater disparity between ship emissions and those of land-based alternatives farther into the future. The most stringent tier of EPA's current NO_X and PM regulations for locomotives becomes effective in 2015. Therefore, turnover is expected to bring down the fleet average locomotive emissions rates well beyond 2015. Similarly, EPA's current NO_X and PM regulations for highway trucks beginning in model year 2010 have not penetrated the fleet extensively, thus the truck fleet average emission rates are also expected to continue to decrease beyond 2015. Both of these fleets have a faster turnover rate than that of the Great Lakes fleet. Therefore where the results below indicate emissions increases in the event of mode shift, the magnitude of any such increase is likely to diminish in the future, and any emissions benefits from a shift would be likely to improve beyond those shown.

3.3.3.1 Emissions per Ton Mile

As described above and shown in Tables 3-12, 3-13 and 3-14, EPA calculated the emissions intensity of each transportation mode individually for comparison purposes. Because we held the characteristics of the land-based transportation modes constant, only the emissions intensity of the vessels varies across the scenarios. Table 3-15 summarizes the information from the three previous tables. The values shown are for a single-mode leg of a journey, not a complete O/D route. From this summary, it can be seen that both the locomotive and truck NO_X emissions intensities fall near the low end of the range of emissions intensities of the modeled hypothetical ships (See Table 3-11). The estimated CO_2 emissions intensities of the land-based modes fall near the high end of the range of emissions intensities of the ships. The lower bound of the PM emissions intensity of the Base ship falls above both other modes, while the lower bound of the PM emissions intensity of the ECA ship falls below both other modes. The high end of the Base and ECA ship PM emissions intensity falls above that of both other modes. Therefore, from an emissions perspective, the transport efficiency of a ship compared to land-based modes depends greatly on the vessel conditions.

Table 3-15 Comparison of Emissions Intensity (g/100 ton-miles)

POLLUTANT	BASE SHIP (MIN - MAX)	ECA SHIP (MIN - MAX)	LOCOMOTIVE	TRUCK
NO_X	17 - 130	15 - 120	31	22
$PM_{2.5}$	1.2 – 9.6	0.21 – 1.6	0.81	0.57
CO_2	820 – 6,400	780 – 6,100	2,400	5,100

3.3.3.2 Trip Emissions for Coal, Iron Ore and Grain

Estimated emissions of NO_X, $PM_{2.5}$ and CO_2 (in short tons) are presented in Table 3-16, Table 3-17, and Table 3-18, respectively, for a single round trip for each scenario moving coal, iron ore and grain. In the tables that follow, the last column on the right indicates the percent change in emissions from the ECA case to the emissions that would occur if the commodity for that trip were moved only using the rail mode between the specific origin and destination.

Table 3-16 NO_X Emissions Results for Coal, Iron Ore and Grain (short tons)

Scenario	Cargo	Number Trains per Marine Trip	Base Case Total Emissions Per Trip	ECA Case Total Emissions Per Trip	All-Rail Total Emissions Per Trip	Percent change from Base to ECA	Percent change from ECA to Alternative
1	Coal	1.0	9.3	9.1	9.3	-1.4%	1.4%
2		1.2	-- [a]	-- [a]	-- [a]	-- [a]	-- [a]
3		4.9	180	180	260	-0.8%	42%
4		2.8	70	69	89	-1.6%	30%
5	Iron Ore	1.2	1.9	1.8	1.9	-7.2%	10%
6		1.5	21	19	N/A	-6.8%	N/A
7		4.9	32	31	91	-4.9%	190%
8		4.9	35	33	140	-4.4%	330%
9	Grain	1.5	20	18	19	-8.0%	4.2%
10		1.5	20	18	26	-8.0%	43%
11		1.2	12	11	9.0	-7.7%	-16%
12		0.4	2.1	2.0	0.3	-8.0%	-87%

Note:
[a] Results are inconclusive due to mis-specification of the scenario.

Table 3-17 $PM_{2.5}$ Emissions Results for Coal, Iron Ore and Grain (short tons)

Scenario	Cargo	Number Trains per Marine Trip	Base Case Total Emissions Per Trip	ECA Case Total Emissions Per Trip	All-Rail Total Emissions Per Trip	Percent change from Base to ECA	Percent change from ECA to Alternative
1	Coal	1.0	0.32	0.22	0.24	-31%	10%
2		1.2	-- [a]	-- [a]	-- [a]	-- [a]	-- [a]
3		4.9	5.6	4.6	6.8	-19%	49%
4		2.8	2.5	1.7	2.4	-34%	43%
5	Iron Ore	1.2	0.13	0.03	0.05	-80%	95%
6		1.5	1.4	0.30	N/A	-78%	N/A
7		4.9	1.8	0.58	2.4	-67%	310%
8		4.9	1.8	0.65	3.8	-64%	480%
9	Grain	1.5	1.5	0.25	0.50	-83%	100%
10		1.5	1.5	0.25	0.69	-83%	180%
11		1.2	0.83	0.15	0.24	-82%	58%
12		0.4	0.16	0.03	0.01	-83%	-74%

Note:
[a] Results are inconclusive due to mis-specification of the scenario.

Table 3-18 CO_2 Emissions Results for Coal, Iron Ore and Grain (short tons)

Scenario	Cargo	Number Trains per Marine Trip	Base Case Total Emissions Per Trip	ECA Case Total Emissions Per Trip	All-Rail Total Emissions Per Trip	Percent change from Base to ECA	Percent change from ECA to Alternative
1	Coal	1.0	680	670	720	-0.6%	7.0%
2		1.2	-- [a]	-- [a]	-- [a]	-- [a]	-- [a]
3		4.9	13,800	13,700	20,200	-0.3%	47%
4		2.8	5,100	5,000	7,000	-0.6%	39%
5	Iron Ore	1.2	100	90	150	-4.1%	**61%**
6		1.5	1,100	1,100	N/A	-3.7%	N/A
7		4.9	2,000	1,900	7,100	-2.3%	270%
8		4.9	2,200	2,100	11,200	-2.0%	430%
9	Grain	1.5	970	930	1,490	-4.8%	61%
10		1.5	980	930	2,060	-4.8%	120%
11		1.2	580	550	700	-4.5%	27%
12		0.4	110	100	20	-4.7%	**-79%**

Note:
[a] Results are inconclusive due to mis-specification of the scenario.

As shown in the three tables above, per-trip emissions decrease for each scenario from the Base to ECA case, ranging from about one to eight percent decrease for NO_X, from about 20 to 80 percent for $PM_{2.5}$, and from less than one to about 5 percent for CO_2. This clearly demonstrates that the use of ECA-compliant fuel on the Great Lakes will provide a dramatic decrease in emissions from ships. While the decrease for each scenario is calculated through the use of the vessel emissions factors presented above in Table 3-10, the ranges of expected emissions decrease reflect the varying amount of rail travel embedded in each scenario's design. As noted above, Scenarios 9 and 10 are uni-modal in the Base and ECA cases (no rail travel), and both show the same 4.8 percent decrease from the Base to the ECA case. With respect to the emissions from the alternative shipping mode - all-rail - the results also indicate that, were mode shift to occur, some emissions could increase while others could decrease. As shown in Table 3-16, NO_X could increase under a shift to all-rail transport for all scenarios except Scenarios 11 and 12. $PM_{2.5}$ and CO_2 would also be likely to increase were a mode shift to rail occur, although Scenario 12 indicates those emissions could decrease. In Scenario 12 the cargo load is very small, reducing the marine advantage. No results are presented for Scenario 2; see explanation in Chapter 2.

Select parameters are presented in Table 3-19 for Scenarios 5 and 12, to help illustrate why the emissions could increase in Scenario 5 if there were mode shift to rail, but could improve if there were mode shift in Scenario 12. In Scenario 5, the scenario design stated that the hypothetical ship is loaded to 65 percent capacity. By contrast, in Scenario 12, the hypothetical ship is loaded to 22 percent capacity (due to draft restrictions along the route). For a second point of comparison, the ratio of cargo load to engine power (tons/hp) in Scenario 5 is

1.63, while that ratio is 0.56 in Scenario 12. These scenario parameters contribute to the predicted opposing emissions results if a mode shift were to occur.

Table 3-19 Scenarios 5 and 12 Vessel Characteristics

PARAMTER	SCENARIO 5	SCENARIO 12
Loaded % of Ship's Capacity	65%	22%
Ratio of Cargo Load to Engine Power (tons/hp)	1.63	0.56

3.3.3.3 Trip Emissions for Stone

Estimated emissions of NO_X, $PM_{2.5}$ and CO_2 (in short tons) for the four crushed stone scenarios are presented in Table 3-20, Table 3-21, and Table 3-22, respectively, for a single round trip. For those Base and ECA cases that include a rail segment, the number of trains needed to carry the given cargo load was calculated, using an assumed train configuration of 100 freight cars carrying 100 tons each. For the alternate case using trucks, the number of trucks needed to carry the cargo load was estimated assuming each truck pulled a trailer carrying 43 short tons of stone.

In the tables that follow, the last column on the right indicates the percent change in emissions from the ECA case to the emissions that would occur if the stone were sourced by an alternate quarry located at the distance from the customer (route destination) described in Section 3.1.4, above, and presented as a round-trip distance in Table 3-11.

Table 3-20 NO_X Emissions Results for Stone (short tons)

Scenario	Number Trains (Trucks) per Marine Trip	Base Case Total Emissions Per Trip	ECA Case Total Emissions Per Trip	Truck Emissions from Alternate Quarry	Percent change from Base to ECA	Percent change from ECA to Alternative
13	4.2 (974)	36.3	35.9	5.0	-1.2%	-86%
14	4.2 (974)	35.7	35.3	4.1	-1.1%	-88%
15	4.2 (974)	36.8	36.3	5.5	-1.6%	-85%
16	4.2 (974)	19.7	19.1	3.0	-2.7%	-84%

Table 3-21 $PM_{2.5}$ Emissions Results for Stone (short tons)

Scenario	Number Trains (Trucks) per Marine Trip	Base Case Total Emissions Per Trip	ECA Case Total Emissions Per Trip	Truck Emissions from Alternate Quarry	Percent change from Base to ECA	Percent change from ECA to Alternative
13	4.2 (974)	1.22	0.88	0.13	-28%	-85%
14	4.2 (974)	1.18	0.87	0.10	-26%	-88%
15	4.2 (974)	1.32	0.87	0.14	-34%	-84%
16	4.2 (974)	0.83	0.43	0.08	-49%	-82%

Table 3-22 CO_2 Emissions Results for Stone (short tons)

Scenario	Number Trains (Trucks) per Marine Trip	Base Case Total Emissions Per Trip	ECA Case Total Emissions Per Trip	Truck Emissions from Alternate Quarry	Percent change from Base to ECA	Percent change from ECA to Alternative
13	4.2 (974)	2,680	2,660	1,130	-0.5%	-58%
14	4.2 (974)	2,650	2,630	930	-0.4%	-65%
15	4.2 (974)	2,670	2,650	1,250	-0.6%	-53%
16	4.2 (974)	1,340	1,330	690	-1.2%	-48%

As shown in these three tables, emissions decrease for each scenario from the Base to ECA case, ranging from about one to three percent decrease for NO_X, from about 25 to 50 percent for $PM_{2.5}$, and up to about one percent for CO_2. This means that the use of ECA-compliant fuel is good for the environment, especially for reducing PM emissions. While the decrease occurs through the use of the vessel emission factors presented above in Table 3-10, the ranges reflect the varying amount of sea and rail travel embedded in each scenario's design.

The all-truck alternative scenario results shown above indicate that, were a source shift for these four crushed stone scenarios to occur, trip emissions could decrease. Today's highway trucks use fuel with 15 ppm sulfur, less than two percent of the sulfur in ECA-compliant fuel. This enables trucks to have significantly lower PM emissions than ships. As shown above, estimated per trip NO_X and $PM_{2.5}$ emissions associated with truck transportation of locally-quarried stone could decrease by nearly 90 percent, and per-trip CO_2 could decrease by 50 to 65 percent, compared to stone transported by ship from northern Michigan. It should be noted, however, that this analysis does not take into account the impacts of potential road congestion in these areas. Logistically it may be infeasible for local roadways to accommodate the increased truck traffic. Further, emissions from auxiliary engines and other material handling equipment, which are also not considered, may be greater for the alternate truck scenario routes than for the default marine scenario routes.

3.3.4 Key Findings

The analyses presented above and in Chapter 2 show that transportation mode shift, source shift, and production shift are not expected for the at-risk routes examined. The emission analysis presented in this section shows that, for the 12 All-Rail Alternative scenarios, the use of 1,000 ppm sulfur fuel on ships is better for the environment than rail transportation for all cases except Scenario 12 with respect to PM and CO_2 and Scenarios 11 and 12 with respect to NO_X. For the four crushed stone scenarios (Scenarios 13-16), while switching to stone produced in local quarries and transported by truck may reduce direct transportation emissions, other environmental aspects of such a source shift (e.g., road congestion, mining emissions) are not evaluated.

[1] U.S. Geological Survey Minerals Yearbook, 2008. March 2010. *See* http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/stat/, accessed September, 2010.

[2] U.S. Geological Survey Minerals Yearbook, 2008. March 2010. *See* http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/stat/, accessed September, 2010.

[3] U.S. Geological Survey Minerals Yearbook, 2008. March 2010. *See* http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/stat/, accessed September, 2010.

[4] U.S. Geological Survey Minerals Yearbook, 2008. March 2010. *See* http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/myb1-2008-stonc.pdf , accessed September, 2010.

[5] U.S. Geological Survey Minerals Yearbook, 2008. March 2010. *See* http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/myb1-2008-stonc.pdf , accessed September, 2010.

[6] Comments of the Great Lakes Maritime Task Force. EPA-HQ-OAR-2007-0121-0269.

[7] English, Gordon, et al. Study of Potential Mode Shift Associated with ECA Regulations in the Great Lakes. Prepared for the Canadian Shipowners' Association by Research and Traffic Group. August, 2009. Stone/Aggregate Assessment is Section 7. Available at www.regulations.gov under Docket ID No. EPA–HQ-OAR-2007-0121-0027. or at http://www.shipowners.ca/uploads/Documents/MODE%20SHIFT%20STUDY.pdf.

[8] English, Gordon, et al. Study of Potential Mode Shift Associated with ECA Regulations in the Great Lakes. Prepared for the Canadian Shipowners' Association by Research and Traffic Group. August, 2009. See OAR-2007-0121-0027. Page 22.

[9] Draft Regulatory Impact Analysis, Proposed Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, EPA-420-D-10-901, Figure 9-1, October 2010.

[10] U.S. Geological Survey 2008. 2008 Minerals Yearbook, Stone, Crushed (Advanced Release), March 2010. Table 4.

[11] EIA, "Electricity Power Monthly," Jan 2010. DOE/EIA-0226 (2010/01). http://tonto.eia.doe.gov/ftproot/electricity/epm/02261001.pdf & EIA, "Coal Prices and Outlook." 2010.

[12] See http://minerals.usgs.gov/minerals/pubs/commodity/iron_ore/myb1-2008-feore.pdf

[13] Great Lakes St. Lawrence Seaway Study. Final Report. Transport Canada, U.S. Army Corps of Engineers, U.S. Department of Transportation, The St. Lawrence Seaway Management Corporation, St. Lawrence Seaway Development Corporation, Environment Canada, and U.S. Fish and Wildlife Service. Fall 2007, p 39. A copy of this study can be found at http://www.marad.dot.gov/documents/GLSLs_finalreport_Fall_2007.pdf.

[14] *See* http://www.steel.org/AM/Template.cfm?Section=Home&TEMPLATE=/CM/HTMLDisplay.cfm&CONTENTID=36529, accessed September 28, 2010.

[15] *See* http://www.glc.org/docs/liqasset/liqasset.html, http://www.great-lakes.net/econ/busdev/manf.html, accessed September 28, 2010.

[16] *See* http://www.glc.org/docs/liqasset/liqasset.html, accessed September 28, 2010.

[17] *See* http://www1.eere.energy.gov/vehiclesandfuels/facts/2008_fotw539.html

[18] *See* http://www.ussteel.com/corp/investors/presentations/Morgan-Stanley-presentation-Feb-25-2010.pdf , accessed September 28, 2010.

[19] This discussion is taken from: Memorandum to Docket EPA-HQ-OAR-2007-0121. Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder – Information in Support of Applying Emission Control Area (ECA) Requirements to the Great Lakes Region. Michael J. Samulski. December 15, 2009.

[20] Power Plant Engineering (1995) L.F. Drbal et al, Black & Veatch, Chapter 5: Coal and Limestone Handling.

[21] U.S. Department of Energy, Argonne National Laboratory, Transportation Technology R & D Center (2008). Greenhouse gases, Regulated Emissions and Energy use in Transportation (GREET) Model, Version 1.8b, *available at* http://www.transportation.anl.gov/publications/transforum/v8/v8n2/greet_18b.html.

CHAPTER 4: Emission Inventory for the U.S. Great Lakes

Like all of EPA's mobile source programs, our Coordinated Strategy for Category 3 marine diesel engines and their fuels applies equally throughout the United States. While we typically do not estimate the benefits and costs of our mobile source programs on a regional basis, our final 2010 Category 3 marine rule contained information with respect to the impacts of emissions from Category 3 vessels on human health and the environment in a number of U.S. regions, including the Great Lakes region.[1] This chapter reproduces and expands on that information, demonstrating that Category 3 marine diesel engines and their fuels are significant contributors to air quality in the Great Lakes region. Additionally, in Chapters 5 and 6, we show that the application of ECA requirements to this area will improve air quality and human health at a reasonable cost.

4.1 Introduction

This chapter presents our estimated air emission inventories for C3 ships that operate in the U.S. Great Lakes. This chapter is organized into three parts. First, we describe the domain of ships included in the analysis. Second, we describe the modeling methodology. Third, we present the results of this modeling, for the baseline inventory year of 2002 as well as the baseline and control scenarios for 2020.

The U.S. emissions inventory presented in this section includes marine vessels of all flags with Category 3 engines. Emissions from both propulsion and auxiliary engines on these vessels are included, as well as emissions from vessels powered by steam boilers and gas turbine engines. The emission inventories are a combination of estimates for emissions in port and underway (or interport). Great Lakes inventories include only emissions from Category 3 vessels operated within the U.S. boundaries of the Great Lakes.

Using the methodology described below, the estimated ship emission inventories in the Great Lakes for 2020 are as set out in Table 4-1. Inventories for both the reference (baseline) and the control scenarios are presented. ECA designation is expected to reduce emissions of NO_X, SO_2, and PM by 17 percent, 97 percent, and 87 percent, respectively, in 2020.

Table 4-1 C3 Emission Inventories for the U.S. Great Lakes in 2020

	ANNUAL EMISSIONS (METRIC TONNES)[a,b]						
EMISSION TYPE	**NO_X**	**PM_{10}**	**$PM_{2.5}$[c]**	**HC**	**CO**	**SO_2**	**CO_2**
Reference	19,842	1,613	1,484	682	1,607	11,993	740,624
Control	16,420	207	190	676	1,602	420	704,390
Delta Emissions	*-3,422*	*-1,406*	*-1,294*	*0*	*0*	*-11,574*	*-36,235*
Delta Emissions (%)	*-17%*	*-87%*	*-87%*	*0%*	*0%*	*-97%*	*-5%*

Table 4-2 presents the Great Lakes inventories alongside the national C3 marine emission inventories.[A] Roughly 1.5 percent of nationwide emissions of these pollutants occur within the U.S. portion of the Great Lakes in 2020 and 1.1 percent in 2030. The fuel controls are expected to reduce PM and SO_X emissions by a considerable amount both nationally and on the Great Lakes, by about 85 percent and 95 percent, respectively. For NO_X, national emissions are expected to decrease by 30 percent in 2020 and by 57 percent in 2030. Expected NO_X emission reductions are not expected to be as high for the Great Lakes due to differences in the fleet age distribution and turnover rates. Within the U.S. portion of the Great Lakes, NO_X is expected to be reduced by 17 percent in 2020 and by 27 percent in 2030. The inventory estimates presented in Table 4-2 were used in the air quality and benefits analysis prepared for the Category 3 rule; the Great Lakes impacts are presented in Chapter 5. Note that distillate fuel has higher energy content, on a mass basis, than residual fuel which leads to lower fuel consumption estimates in the control case.

Table 4-2 U.S. and Great Lakes ECA Emission Inventory [metric tons]

POLLUTANT [METRIC TONNES]	GREAT LAKES 2020	GREAT LAKES 2030	NATIONAL 2020	NATIONAL 2030
NO_X				
NO_X emissions without ECA	19,842	22,471	1,234,879	1,867,484
NO_X emissions with ECA	16,420	16,369	863,642	796,140
NO_X reductions	3,422	6,102	371,237	1,071,344
Direct $PM_{2.5}$				
$PM_{2.5}$ emissions without ECA	1,484	1,757	100,128	152,016
$PM_{2.5}$ emissions with ECA	190	233	14,750	22,495
$PM_{2.5}$ reductions	1,294	1,524	85,378	129,521
SO_2				
SO_2 emissions without ECA	11,993	14,196	841,447	1,279,185
SO_2 emissions with ECA	420	501	46,168	70,630
SO_2 reductions	11,574	13,694	795,279	1,208,555
Fuel Consumption				
Fuel consumed without ECA	232,681	275,412	15,790,179	24,005,856
Fuel consumed with ECA	221,297	261,933	15,009,910	22,838,278

4.2 Description of Ships Included in the Analysis

The remainder of this chapter describes how the Great Lakes emission inventories were estimated and provides detailed information for the Great Lakes. The methodology used here is substantially similar to the methodology used to estimate the national emission inventories.

[A] The emission inventories set out in Table 4-2 do not include emissions from Jones Act vessels. Section 4.6 of this chapter describes an adjustment made to estimate the inventories including Great Lakes Jones Act shipping; the adjusted Great Lakes inventories are about 3 percent of the national inventories for these pollutants. The estimated inventory reduction as a result of the ECA controls is the same because the adjustment is applied to both the reference and control inventories.

Readers who are interested in the detailed data inputs for the national inventory should refer to the analysis performed for our 2010 Category 3 marine rule.[B]

The ship inventories reported in this chapter are for vessels with Category 3 propulsion engines. These are the ships that are most likely to be affected by the MARPOL Annex VI fuel sulfur limits since these vessels tend to use residual fuel. While smaller vessels could be affected by the ECA fuel requirements, the majority of these smaller vessels are already subject to comparable U.S. marine diesel engine and fuel requirements under the CAA. Therefore, switching to a lower sulfur diesel fuel to meet the ECA requirements is not expected to impose a significant burden on the owners of smaller vessels.

The ship emission inventories are based on the U.S. Army Corps of Engineers (USACE) foreign traffic entrances and clearances data set. This data is derived from U.S. Customs Vessels Entrances and Clearances data, in which the following vessels are required to file a Vessel Entrance or Clearance Statement.

- Any vessel from a foreign port or place;
- Any foreign vessel from a domestic port;
- Any vessel of the United States arriving from another U.S. port and having merchandise on board being transported in bond (this does not include bonded ship's stores or supplies), or transporting unentered foreign merchandise; or
- Any vessel, either U.S. or foreign, which has visited a hovering vessel (19 USC 1401(k)), or has delivered or received merchandise or passengers outside of U.S. waters.

The Entrances and Clearances data sets cover only foreign cargo movements. As a result, U.S./domestic ships operating solely within the continental United States (i.e., Jones Act ships) are not included. A portion of the Jones Act traffic is thought to be on ships with Category 2 propulsion engines or tug/barge combination vessels, and these smaller ships are already subject to U.S. marine diesel engine requirements, and the sulfur content of fuel available in the U.S. ports in which they operate, is also subject to federal controls. Estimated inventory adjustments to account for Jones Act shipping by Category 3 vessels are provided in Section 4.6.

4.3 Inventory Methodology

The inventory consists of two parts: port emissions and interport emissions.

- <u>Port emissions</u> in the Great Lakes include emissions during maneuvering and hoteling near the port center, emissions in the Reduced Speed Zone (RSZ) while nearing the port, and cruise emissions up to a seven mile radius outside of the RSZ. Port inventories were developed for 28 Great Lakes ports. Port-specific emissions were estimated using a "bottom-up" approach based on port-specific vessel calls, emission factors, and activity for each port. For all other ports, estimates from the STEEM model are used.

[B] "Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines," EPA-420-R-09-019, December 2009.

- Interport emissions consist of emissions that occur outside of the port but within the inventory domain. These inventories were obtained using the Waterway Network Ship Traffic, Energy and Environment Model (STEEM). STEEM also uses a "bottom-up" approach, estimating emissions from C3 vessels using historical shipping activity, ship characteristics, and activity-based emission factors. STEEM was used to quantify and geographically (i.e., spatially) represent interport vessel traffic and emissions for vessels traveling within the U.S. portion of the Great Lakes.

The regional emission inventories produced by the current STEEM interport model are most accurate for vessels while cruising in open waters; however, the near port inventories use more detailed local port information and are significantly more accurate near the ports. Therefore, to obtain the most accurate inventories, the inventories in this analysis were derived by merging together: 1) the port inventories, which extend seven nautical miles from the port entrance, and 2) the remaining interport portion of the STEEM inventory, which extends from the endpoint of the near port inventories to include the rest of the U.S. portion of the Great Lakes.

Merging these inventories requires spatially allocating the port emissions, removing the data for the 28 Great Lakes ports from the STEEM inventory, and replacing it with the detailed port inventories. The STEEM port data was retained for all other Great Lakes ports. The result of this process was a complete, spatially allocated inventory covering the entire inventory domain. Near some ports, a portion of the underlying STEEM emissions were retained if it was determined that the STEEM emissions included ships traversing the area near a port, but not actually entering or exiting the port.

The above methodology was used to develop inventories for a base year of 2002. Next, baseline and control inventories were developed for the entire inventory domain for 2020. The baseline inventories for 2020 were estimated by applying a growth rate and emission adjustment factors to the 2002 inventories. The emission adjustment factors account for emission controls that will be in effect in 2020, including the MARPOL Annex VI Tier I and Tier II NO_X standards for new engines and the Regulation 13 NO_X retrofit program. The control inventories for 2020 were estimated by applying the same growth rate as the 2020 baseline case but a different set of emission adjustment factors that also account for the ECA engine and fuel sulfur controls. The result of this process was a complete, spatially allocated inventory for 2020 covering the entire inventory domain, for both the baseline and control scenarios.

Finally, the inventories for the ECA in the 2020 baseline and control scenarios were developed by totaling the emissions within the ECA boundaries. Inventories are presented for the following pollutants: NO_X, $PM_{2.5}$, PM_{10}, SO_2, HC, CO, and CO_2. The PM inventories include directly emitted PM only.

4.4 Development of 2002 Emission Inventories

The total inventories for 2002 are the total of port and interport emission inventories described in this section. The result is a spatially allocated emission inventory for the entire domain.

4.4.1 Port Emissions

Port emissions are estimated for different modes of operation and then summed. Emissions for each operating mode are estimated using port-specific information for vessel calls, vessel characteristics, vessel activity, as well as other inputs that vary by vessel or engine type (e.g., emission factors). The methodology and port inventory development was conducted under contract; details of the methodology as applied to the U.S. ports is described in the contractor report.[2]

4.4.1.1 Great Lakes Ports Modeled

The 28 port inventories for the Great Lakes are an improvement upon STEEM's port results in several ways. First, the precision associated with STEEM's use of ship positioning data may be less accurate in some locations, especially as the shipping lanes approach shorelines where ships would need to follow more prescribed paths. Second, the STEEM model includes a maneuvering operational mode (i.e., reduced speed) that is generally assumed to occur within a 20 kilometer radius of each port. In reality, the distance when a ship is traveling at reduced speeds varies by port. Also, the distance a ship traverses at reduced speeds often consists of two operational modes: a reduced speed zone (RSZ) as a ship enters or leaves the port area and actual maneuvering at a very low speed near the dock. Third, the STEEM model assumes that the maneuvering distance occurs at an engine load of 20 percent, which represents a vessel speed of approximately 60 percent of cruise speed. This is considerably faster than ships would maneuver near the docks. The single maneuvering speed assumed by STEEM also does not reflect the fact that the reduced speed zone, and therefore emissions, may vary by port. Finally, the STEEM model does not include the emissions from auxiliary engines during hoteling operations at the port. The new-port inventories correct these issues.

Port emissions were estimated for the Great Lakes ports listed in Table 4-3. The 28 Great Lakes ports were chosen because of the availability of call data from the USACE Entrance and Clearance data.[3] The port coordinates are provided in Appendix 4A.

Table 4-3 Modeled Ports

GREAT LAKES PORTS	
Alpena, MI	Presque Isle, MI
Buffalo, NY	St Clair, MI
Burns Waterway, IN	Stoneport, MI
Calcite, MI	Two Harbors, MN
Cleveland, OH	Ashtabula, OH
Dolomite, MI	Chicago, IL
Erie, PA	Conneaut, OH
Escanaba, MI	Detroit, MI
Fairport, OH	Duluth-Superior, MN&WI
Gary, IN	Indiana, IN
Lorain, OH	Inland Harbor, MI
Marblehead, OH	Manistee, MI
Milwaukee, WI	Sandusky, OH
Muskegon, MI	Toledo, OH

As stated previously, for all other Great Lakes ports, emissions inventories estimated by the STEEM model were used.

4.4.1.2 Port Inventory Methodology

Emissions for each port were estimated using a bottom-up approach based on the number of vessel calls and vessel characteristics. Emissions are estimated for four modes of operation:

- Hoteling: Hoteling, or dwelling, occurs while the vessel is docked or anchored near a dock, and only the auxiliary engine(s) are being used to provide power to meet the ship's energy needs.
- Maneuvering: Maneuvering occurs within a very short distance of the docks.
- Reduced speed zone (RSZ): The RSZ varies from port to port, though generally the RSZ would begin and end when the pilots board or disembark, and typically occur when the port shipping lanes reach unconstrained shipping lanes. For the purpose of this inventory, the RSZ is fixed at three nautical miles for each of the 28 Great Lakes ports modeled.
- Cruise: The cruise mode emissions in the ports analysis extend seven nautical miles beyond the end of the RSZ lanes.

Emissions are calculated separately for propulsion and auxiliary engines.

The basic equation used to estimate emissions for an engine at each mode is shown below.

Equation 4-1

$$Emissions_{mode[eng]} = (calls) \times (P_{[eng]}) \times (hrs/call_{mode}) \times (LF_{mode[eng]}) \times (EF_{[eng]}) \times (Adj) \times (10^{-6}\ tonnes/g)$$

Where:

- Emissions$_{mode\ [eng]}$ = Metric tonnes emitted by mode and engine type
- Calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)

- $P_{[eng]}$ = Total engine power by engine type, in kilowatts
- $hrs/call_{mode}$ = Hours per call by mode
- $LF_{mode\ [eng]}$ = Load factor by mode and engine type (unitless)
- $EF_{[eng]}$ = Emission factor by engine type for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
- Adj = Low load adjustment factor, unitless (used when the load factor is below 0.20)
- 10^{-6} = Conversion factor from grams to metric tonnes

4.4.1.3 Data Inputs for Port Emission Inventories

The following inputs are required to estimate emissions inventories for each vessel at the four modes of operation (cruise, RSZ, maneuvering, and hoteling); these inputs are described in more detail below.

- Number of calls and ship characteristics (main engine power, cruise speed, and load factors)
- Cruise distance
- RSZ distances and speeds for each port
- Auxiliary engine power and load factors
- Main emission factors
- Auxiliary emission factors
- Low load adjustment factors for main engines
- Maneuvering time-in-mode (hours/call)
- Hoteling time-in-mode (hours/call)

Number of Calls and Ship Characteristics (main engine power, cruise speed, and load factors)

For this analysis, USACE entrance and clearance data for 2002,[4] together with Lloyd's Register-Fairplay Ltd. data for ship characteristics,[5] were used to identify average ship characteristics and calls by ship type for each port. Information for number of calls, propulsion engine power, and cruise speed were obtained from these data.

The records from the USACE Entrances and Clearances database were matched with Lloyd's data on ship characteristics for each port. Calls by vessels that have either Category 1 or 2 propulsion engines were eliminated from the data set. This was accomplished by matching all ship calls with information from Lloyd's data. Over 99.9 percent of the calls in the Entrances and Clearances data were directly matched with Lloyd's data. The remaining 0.1 percent was estimated based upon ships of similar type and size. Engine category was determined from engine make and model. Engine bore and stroke were found in the Marine Engine 2005 Guide[6] and displacement per cylinder was calculated. Ships with main propulsion engines with per cylinder displacement less than 30 liters were eliminated from the data set. Passenger ships and tankers that have either diesel-electric or gas turbine-electric engines used for both propulsion and auxiliary purposes were retained in the data set as they are subject to the ECA requirements.

The dataset for vessels with Category 3 propulsion engines was then binned by ship type, engine type, and dead weight tonnage (DWT) range. The number of entrances and clearances in each bin were counted, summed together and divided by two to determine the number of calls (i.e., one entrance and one clearance was considered a call). Propulsion power and vessel cruise speed are also averaged for each bin.

Main engine load factors were calculated directly from the propeller curve based upon the cube of actual speed divided by maximum speed (at 100% maximum continuous rating [MCR]). In addition, cruise mode activity is based on cruise distance and speed inputs. Appendix 4B provides the specific equations used to calculate propulsion and auxiliary emissions for each activity mode. Note that load factors for main engines are not listed explicitly, since they are calculated as a function of mode and/or cruise speed.

Cruise Distance

Cruise mode emissions were calculated for the Great Lakes ports assuming a seven nautical mile distance into and out of the port outside of the reduced speed and maneuvering zones.

RSZ Distances and Speeds by Port

The RSZ for each Great Lake port was fixed at three nautical miles. The RSZ speeds for the Great Lake ports vary by vessel type and are the average of the vessel service speed and the maneuvering speed.

Auxiliary Engine Power and Load Factors

Hoteling emissions are a significant part of port emission inventories, and it is important to distinguish propulsion engine emissions from auxiliary engine emissions when estimating ship emissions. This is because hoteling emissions are generally generated by auxiliary engines.

In the methodology used in this analysis, auxiliary engine maximum continuous rating power and load factors were calculated separately from propulsion engines and different emission factors (EFs) applied. All auxiliary engines were treated as Category 2 medium-speed diesel (MSD) engines for purposes of this analysis.

Auxiliary engine power is not contained in the USACE database and is only sparsely populated in the Lloyd's database; as a result, it must be estimated. The approach taken was to derive ratios of average auxiliary engine power to propulsion power based on survey data. The California Air Resources Board (ARB) conducted an Oceangoing Ship Survey of 327 ships in January 2005 that was principally used for this analysis.[7] Average auxiliary engine power to propulsion power ratios were estimated by ship type and are presented in Table 4-4. These ratios by ship type were applied to the propulsion power data to derive auxiliary power for the ship types at each port.

Table 4-4 Auxiliary Engine Power Ratios (ARB Survey, except as noted)

SHIP TYPE	AVERAGE PROPULSION ENGINE (kW)	Average Auxiliary Engines				AUXILIARY TO PROPULSION RATIO
		NUMBER	POWER EACH (kW)	TOTAL POWER (kW)	ENGINE SPEED	
Auto Carrier	10,700	2.9	983	2,850	Medium	0.266
Bulk Carrier	8,000	2.9	612	1,776	Medium	0.222
Container Ship	30,900	3.6	1,889	6,800	Medium	0.220
Passenger Ship[a]	39,600	4.7	2,340	11,000	Medium	0.278
General Cargo	9,300	2.9	612	1,776	Medium	0.191
Miscellaneous[b]	6,250	2.9	580	1,680	Medium	0.269
RORO	11,000	2.9	983	2,850	Medium	0.259
Reefer	9,600	4.0	975	3,900	Medium	0.406
Tanker	9,400	2.7	735	1,985	Medium	0.211

Notes:
[a] Many passenger ships typically use a different engine configuration known as diesel-electric. These vessels use large generator sets for both propulsion and ship-board electricity. The figures for passenger ships above are estimates taken from the Starcrest Vessel Boarding Program.
[b] Miscellaneous ship types were not provided in the ARB methodology, so values from the Starcrest Vessel Boarding Program were used.

Auxiliary engine to propulsion engine power ratios vary by ship type and operating mode from approximately 0.19 to 0.40. Auxiliary load, shown in Table 4-5, is used together with the total auxiliary engine power to calculate auxiliary engine emissions. Starcrest's Vessel Boarding Program[8] showed that auxiliary engines are on all of the time, except when using shoreside power during hoteling.

Table 4-5 Auxiliary Engine Load Factor Assumptions

SHIP TYPE	CRUISE	RSZ	MANEUVER	HOTEL
Auto Carrier	0.13	0.30	0.67	0.24
Bulk Carrier	0.17	0.27	0.45	0.22
Container Ship	0.13	0.25	0.50	0.17
Passenger Ship	0.80	0.80	0.80	0.64
General Cargo	0.17	0.27	0.45	0.22
Miscellaneous	0.17	0.27	0.45	0.22
RORO	0.15	0.30	0.45	0.30
Reefer	0.20	0.34	0.67	0.34
Tanker	0.13	0.27	0.45	0.67

Main Engine Emission Factors

An analysis of emission data was prepared and published in 2002 by Entec.[9] The resulting Entec emission factors include individual values for three speeds of diesel engines (slow-speed diesel (SSD), medium-speed diesel (MSD), and high-speed diesel (HSD)), steam turbines/steamships (ST), gas turbines (GT), and for the two types of fuel used, residual marine (RM) and marine distillate oil (MDO). Table 4-6 lists the propulsion engine emission factors for NO_X and HC that were used in the 2002 port inventory development. The CO, PM, SO_2 and CO_2 emission factors shown in the table come from other data sources as explained below. Since PM and SO_2 emission factors are dependent on the fuel sulfur level, the fuel types and fuel sulfur levels used in this analysis are described at the end of this section.

Table 4-6 Emission Factors for OGV Main Engines using RM, g/kWh

ENGINE	NO_X	CO	HC	CO_2	PM_{10}	$PM_{2.5}$	SO_2
SSD	18.1	1.40	0.60	620.62	1.4	1.3	10.29
MSD	14.0	1.10	0.50	668.36	1.4	1.3	11.09
ST	2.1	0.20	0.10	970.71	1.5	1.4	16.10
GT	6.1	0.20	0.10	970.71	1.5	1.4	16.10

CO emission factors were developed from information provided in the Entec appendices because they are not explicitly stated in the text. HC and CO emission factors were confirmed with a recent U.S. Government review.[10]

PM_{10}[C] values were determined based on existing engine test data in consultation with ARB.[11] GT PM_{10} emission factors were not part of the U.S. Government analysis but assumed here to be equivalent to ST PM_{10} emission factors. Test data shows PM_{10} emission rates as dependent upon fuel sulfur levels, with base PM_{10} emission rates of 0.23 g/kW-hr with distillate fuel (0.24% sulfur) and 1.35 g/kW-hr with residual fuel (2.46% sulfur).[12] The equation used to generate emission factors based on sulfur content is shown below. $PM_{2.5}$ is assumed to be 92 percent of PM_{10}. While the U.S. Government NONROAD model uses 0.97 for such conversion based upon low sulfur fuels, a reasonable value seems to be closer to 0.92 because higher sulfur fuels in medium and slow speed engines would tend to produce larger particulates than high speed engines on low sulfur fuels.

Equation 4-2 Calculation of PM_{10} Emission Factors Based on Fuel Sulfur Levels

$$PM_{EF} = PM_{Nom} + [(S_{Act} - S_{Nom}) \times BSFC \times FSC \times MWR \times 0.0001]$$

where:

PM_{EF} = PM emission factor adjusted for fuel sulfur
PM_{Nom} = PM emission rate at nominal fuel sulfur level
= 0.23 g/kW-hr for distillate fuel, 1.35 g/kW-hr for residual fuel
S_{Act} = Actual fuel sulfur level (weight percent)
S_{Nom} = nominal fuel sulfur level (weight percent)
= 0.24 for distillate fuel, 2.46 for residual fuel

[C] PM_{10} is particulate matter of aerodynamic diameter 10 micrometers or less.

BSFC = fuel consumption in g/kW-hr
= 200 g/kW-hr used for this analysis
FSC = percentage of sulfur in fuel that is converted to direct sulfate PM
= 2.247% used for this analysis
MWR = molecular weight ratio of sulfate PM to sulfur
= 224/32 = 7 used for this analysis

SO_2 emission factors were based upon a fuel sulfur to SO_2 conversion formula which was supplied by ENVIRON.[13] Emission factors for SO_2 emissions were calculated using the formula assuming that 97.753 percent of the fuel sulfur was converted to SO_2.[14] The brake specific fuel consumption (BSFC)[D] that was used for SSDs was 195 g/kWh, while the BSFC that was used for MSDs was 210 g/kWh and was based upon Lloyds (1995). The BSFC that was used for STs and GTs was 305 g/kWh and was based upon Entec.[15]

Equation 4-3 Calculation of SO_2 Emission Factors, g/kWh

$$SO_2 \text{ EF} = \text{BSFC} \times 64/32 \times 0.97753 \times \text{Fuel Sulfur Fraction}$$

CO_2 emission factors were calculated from the BSFC assuming a fuel carbon content of 86.7 percent by weight[15] and a ratio of molecular weights of CO_2 and C at 3.667.

Equation 4-4 Calculation of CO_2 Emission Factors, g/kWh

$$CO_2 \text{ EF} = \text{BSFC} \times 3.667 \times 0.867$$

Fuel consumption was calculated from CO_2 emissions based on a 1:3.183 ratio. Approximately 3.183 tons of CO_2 emissions are assumed produced from one metric ton of fuel.

SO_2 emission factors were calculated using Equation 4-3 while PM emissions were determined using Equation 4-2.

Note on Fuel Types and Fuel Sulfur Levels: There are primarily three types of fuel used by marine engines: residual marine (RM), marine diesel oil (MDO), and marine gas oil (MGO), with varying levels of fuel sulfur.[16] MDO and MGO are generally described as distillate fuels.[E] For this analysis, RM and MDO fuels are assumed to be used. Since PM and SO_2 emission factors are dependent on the fuel sulfur level, calculation of port emission inventories requires information about the fuel sulfur levels associated with each fuel type, as well as which fuel types are used by propulsion and auxiliary engines.

Table 4-7 sets out the mix of fuel types used for propulsion and auxiliary engines by ship type in this analysis. The average fuel sulfur level for residual marine was set to 2.7 percent, which is what was assumed in the North American ECA application for the eastern and gulf coast portions of the U.S. [17] A sulfur content of 1.5 percent was used for MDO.[18] We received anecdotal data suggesting that the sulfur content of residual fuel sold on the Great Lakes may be lower than 2.7 percent. However, we retained a sulfur content of 2.7 percent to reflect both the

[D] Brake specific fuel consumption is sometimes called specific fuel oil consumption (SFOC).
[E] While there are small differences in the fuel characteristics of MDO and MGO, these are both distillate fuel and are functionally the same. The price difference between MGO and MDO is small, averaging about +/1 percent.

higher sulfur content of ocean-going vessels that operate on the Great Lakes and to reflect the fact that fuel used on steam vessels remains uncontrolled. With regard to distillate fuel, the sulfur content of marine fuel sold in the United States is about 0.4 percent. However, the 1.5 percent value was retained for this analysis given the higher sulfur content of fuel sold in Canada. Because of the small proportion of distillate fuel used by ships relative to RM, the difference should not be significant.

Table 4-7 Estimated Mix of Fuel Types Used by Ships

SHIP TYPE	FUEL USED	
	PROPULSION	AUXILIARY
Passenger	100% RM	92% RM/8% MDO
Other	100% RM	71% RM/29% MDO

Auxiliary Engine Emission Factors

The most current set of auxiliary engine emission factors also comes from Entec, except as noted below for PM and SO_2. Table 4-8 provides these auxiliary engine emission factors.

Table 4-8 Auxiliary Engine Emission Factors by Fuel Type, g/kWh

ENGINE	FUEL	ALL PORTS						
		NO_X	CO	HC	CO_2	PM_{10}	$PM_{2.5}$	SO_2
MSD	RM	14.70	1.10	0.40	668.36	1.4	1.3	11.09
	MDO	13.90	1.10	0.40	668.36	0.6	0.55	6.16

Auxiliary engine power was estimated from average propulsion power using the ratio of auxiliary power to propulsion power ratios. Using the ratios of RM versus MDO as given in Table 4-7 together with the emission factors shown in Table 4-8, the auxiliary engine emission factor averages by ship type are listed in Table 4-9. Again, as explained above, while this fuel sulfur level may be higher than the average sulfur level of fuel used on the Great Lakes, we do not believe this emission factor has a significant effect on the total emission inventory estimates due to the small portion of fuel used in auxiliary engines as compared to main propulsion engines.

Table 4-9 Auxiliary Engine Emission Factors by Ship Type, g/kWh

SHIP TYPE	ALL PORTS						
	NO_X	CO	HC	CO_2	PM_{10}	$PM_{2.5}$	SO_2
Passenger	14.64	1.10	0.40	668.36	1.4	1.3	10.70
Others	14.47	1.10	0.40	668.36	1.2	1.1	9.66

Low Load Adjustment Factors for Propulsion Engines

Emission factors are considered to be constant down to about 20 percent load. Below that threshold, emission factors tend to increase as the load decreases. This trend results because diesel engines are less efficient at low loads and the brake specific fuel consumption (BSFC) tends to increase. Thus, while mass emissions (grams per hour) decrease with low loads, the engine power tends to decrease more quickly, thereby increasing the emission factor (grams per engine power) as load decreases. Energy and Environmental Analysis Inc. (EEA) demonstrated this effect in a study prepared for the U.S. Government in 2000.[19] In the EEA report, equations were developed for the various emissions. The low-load adjustment factors were developed based upon the concept that the BSFC increases as load decreases below about 20 percent load.

Using these algorithms, fuel consumption and emission factors versus load were calculated. By normalizing emission factors to 20% load, low-load multiplicative adjustment factors were calculated for propulsion engines and presented in Table 4-10. Due to their normal operation, there is no need for a low load adjustment factor for auxiliary engines.

Table 4-10: Calculated Low Load Multiplicative Adjustment Factors

LOAD (%)	NO_X	HC	CO	PM	SO_2	CO_2
1	11.47	59.28	19.32	19.17	5.99	5.82
2	4.63	21.18	9.68	7.29	3.36	3.28
3	2.92	11.68	6.46	4.33	2.49	2.44
4	2.21	7.71	4.86	3.09	2.05	2.01
5	1.83	5.61	3.89	2.44	1.79	1.76
6	1.60	4.35	3.25	2.04	1.61	1.59
7	1.45	3.52	2.79	1.79	1.49	1.47
8	1.35	2.95	2.45	1.61	1.39	1.38
9	1.27	2.52	2.18	1.48	1.32	1.31
10	1.22	2.20	1.96	1.38	1.26	1.25
11	1.17	1.96	1.79	1.30	1.21	1.21
12	1.14	1.76	1.64	1.24	1.18	1.17
13	1.11	1.60	1.52	1.19	1.14	1.14
14	1.08	1.47	1.41	1.15	1.11	1.11
15	1.06	1.36	1.32	1.11	1.09	1.08
16	1.05	1.26	1.24	1.08	1.07	1.06
17	1.03	1.18	1.17	1.06	1.05	1.04
18	1.02	1.11	1.11	1.04	1.03	1.03
19	1.01	1.05	1.05	1.02	1.01	1.01
20	1.00	1.00	1.00	1.00	1.00	1.00

Maneuvering and Hoteling Time-in-Mode

Specific information about the amount of time spent in maneuvering and hoteling modes was not available for the 28 Great Lakes ports included in the ports inventory. Instead, we used the approach that was used for the U.S. mainland ports, in which all commercial ports were mapped to one of a smaller set of "typical ports" and the operating characteristics of the relevant typical port was applied to the specific matched ports. For this analysis, Cleveland and Duluth-Superior were selected as the typical ports for the Great Lakes, due to the detailed information available. Three criteria were used for matching a given port to a typical port: regional differences, maximum vessel draft, and the ship types that call on a specific port. The Great Lakes ports were matched to either Cleveland or Duluth-Superior as shown below.

Table 4-11 Great Lake Match Ports

Port Name	Typical Like Port
Alpena, MI	Cleveland
Buffalo, NY	Cleveland
Burns Waterway, IN	Cleveland
Calcite, MI	Cleveland
Cleveland, OH	Cleveland
Dolomite, MI	Cleveland
Erie, PA	Cleveland
Escanaba, MI	Cleveland
Fairport, OH	Cleveland
Gary, IN	Cleveland
Lorain, OH	Cleveland
Marblehead, OH	Cleveland
Milwaukee, WI	Cleveland
Muskegon, MI	Cleveland
Presque Isle, MI	Cleveland
St Clair, MI	Cleveland
Stoneport, MI	Cleveland
Two Harbors, MN	Cleveland
Ashtabula, OH	Duluth-Superior
Chicago, IL	Duluth-Superior
Conneaut, OH	Duluth-Superior
Detroit, MI	Duluth-Superior
Duluth-Superior, MN&WI	Duluth-Superior
Indiana, IN	Duluth-Superior
Inland Harbor, MI	Duluth-Superior
Manistee, MI	Duluth-Superior
Sandusky, OH	Duluth-Superior
Toledo, OH	Duluth-Superior

4.4.1.4 2002 Port Emission Inventories

The resulting 2002 emission inventory for each of the 28 Great Lakes ports is provided in Table 4-12. These encompass the emissions within the seven nautical mile radius beyond the end of the RSZ lanes.

Table 4-12 2002 Emissions Summary for Twenty-Eight Great Lake Ports

PORT NAME	ANNUAL EMISSIONS (METRIC TONNES)						
	NO_X	PM_{10}	$PM_{2.5}$	HC	CO	SO_2	CO_2
Alpena, MI	1.5	0.3	0.2	0	0.1	2.5	156
Buffalo, NY	2.9	0.3	0.3	0.1	0.2	2.3	150
Burns Waterway, IN	45.5	3.9	3.6	1.5	3.7	30	1,982

PORT NAME	ANNUAL EMISSIONS (METRIC TONNES)						
	NO_X	PM_{10}	$PM_{2.5}$	HC	CO	SO_2	CO_2
Calcite, MI	3.4	0.3	0.3	0.1	0.3	2.5	158
Cleveland, OH	32.6	2.8	2.5	1	2.6	21.8	1,448
Dolomite, MI	1.9	0.2	0.1	0.1	0.2	1.1	73
Erie, PA	2.2	0.2	0.2	0.1	0.2	1.7	112
Escanaba, MI	3.1	0.3	0.3	0.1	0.3	2.3	146
Fairport, OH	3	0.3	0.3	0.1	0.3	2.5	156
Gary, IN	3.2	0.3	0.3	0.1	0.3	2.2	141
Lorain, OH	1.5	0.2	0.2	0.1	0.1	1.3	84
Marblehead, OH	0.5	0.1	0.1	0	0	0.5	34
Milwaukee, WI	26.1	2.3	2.1	0.8	2.1	17.8	1,177
Muskegon, MI	0.9	0.1	0.1	0	0.1	0.7	47
Presque Isle, MI	16.2	1.4	1.3	0.7	1.4	10	637
St Clair, MI	4.2	0.4	0.4	0.2	0.4	3	193
Stoneport, MI	0.7	0.1	0.1	0	0.1	0.4	28
Two Harbors, MN	1.2	0.1	0.1	0	0.1	0.9	56
Ashtabula, OH	36.8	3.4	3.1	1.3	3.1	26.4	1,688
Chicago, IL	22.1	1.9	1.8	0.7	1.8	15.3	1,003
Conneaut, OH	52.6	5	4.7	1.9	4.4	39.5	2,501
Detroit, MI	51.4	4.7	4.4	1.7	4.2	37.5	2,432
Duluth-Superior, MN&WI	131.8	12	11.1	4.5	10.7	94.5	6,130
Indiana, IN	5.9	0.5	0.5	0.2	0.5	4.1	272
Inland Harbor, MI	1.5	0.1	0.1	0.1	0.1	1.1	69
Manistee, MI	17.8	1.5	1.4	0.5	1.4	12.2	827
Sandusky, OH	21	2	1.8	0.8	1.8	15.2	962
Toledo, OH	57.9	5.1	4.7	2	4.7	39.3	2,550
Total Emissions	549	50	46	19	45	389	25,210
Total Emissions (short tons)	***606***	***55***	***50***	***21***	***50***	***429***	***27,790***

4.4.2 Interport Emission Inventories

The second part of the emissions inventory is emissions from ships traveling outside of the seven-mile port areas and for ports other than the 28 Great Lakes ports described above. These emissions were estimated using the Waterway Network Ship Traffic, Energy, and Environmental Model (STEEM).[20,21] This model geographically characterizes emissions from ships traveling along shipping lanes to and from individual ports, in addition to the emissions from vessels transiting near the ports. The shipping lanes were identified from actual ship positioning reports. The model then uses detailed information about ship destinations, ship attributes (e.g., vessel speed and engine horsepower), and emission factors to produce spatially allocated (i.e., gridded) emission estimates for ships engaged in foreign commerce.

This modeling was performed to estimate interport emissions from main propulsion and auxiliary engines used by vessels with Category 3 propulsion engines operating in the modeling domain consisting of the U.S. portion of the Great Lakes.

4.4.2.1 Interport Emission Inventory Methodology

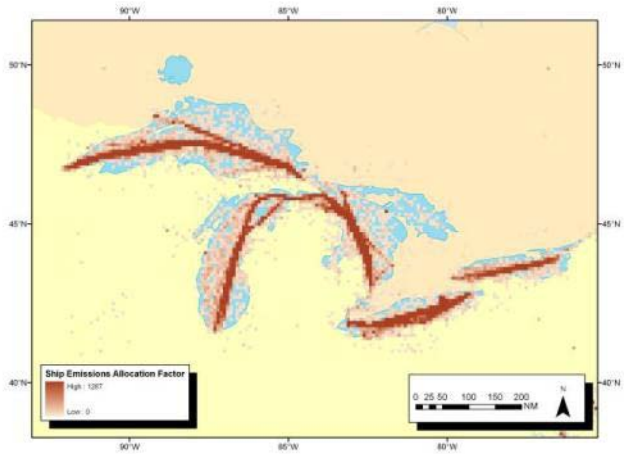
STEEM was developed by the University of Delaware as a comprehensive approach to quantify and geographically represent interport ship traffic, emissions, and energy consumption from large ocean-going vessels.[22,23] The model estimates emissions from main propulsion and auxiliary marine engines used on Category 3 vessels that engage in foreign commerce[F] using historical shipping activity, ship attributes (i.e., characteristics), and activity-based emission factor information. These inputs are assembled using a geographic information system (GIS) platform that also contains an empirically derived network of shipping lanes. It includes the emissions for all ship operational modes from cruising in unconstrained shipping lanes to maneuvering in a port. The model, however, excludes hoteling operations while the vessel is docked or anchored and very low speed maneuvering close to a dock. Due to these exclusions, STEEM is referred to as an "interport" model.

STEEM begins by building a spatially-defined waterway network based on empirical shipping location information from two global ship reporting databases. The first is the International Comprehensive Ocean-Atmosphere Data Set (ICOADS), which contains reports on marine surface and atmospheric conditions from the Voluntary Observing Ships (VOS) fleet,[24] which contains approximately 4,000 vessels worldwide. The ICOADS project is sponsored by the National Oceanic and Atmospheric Administration (NOAA) and National Science Foundation's (NSF) National Center for Atmospheric Research (NCAR). The second database is the Automated Mutual-Assistance Vessel Rescue (AMVER) system.[25] The AMVER data set is based on a ship search and rescue reporting network sponsored by the U.S. Coast Guard. The AMVER system is also voluntary, but is generally limited to ships over 1,000 gross tons on voyages of 24 hours or longer. About 8,600 vessels reported to AMVER in 2004.

The latitude and longitude coordinates for the ship reports in the above databases are used to statistically create and spatially define the direction and width of each shipping lane in the waterway network. Each statistical lane (route and segment) is given a unique identification number for computational purposes. For the current analysis, STEEM used 20 years of ICOADS data (1983-2002) and about one year of AMVER data (part of 2004 and part of 2005). This is illustrated in Figure 4-1.

[F] It should be noted that a large portion of activity on the U.S. side of the Great Lakes is by U.S. vessels that are not included in foreign commerce statistics. See section 4.5.2 for an explanation of how the inventory is adjusted to include U.S. domestic cargo.

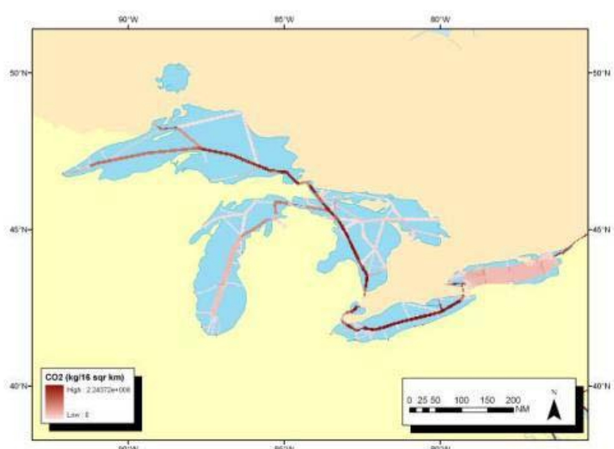
Figure 4-1 AMVER and ICOADS data



Every port is also spatially located in the waterway network using ArcGIS software.

As illustrated in Figure 4-2, the waterway network represented in STEEM resembles a highway network on land. It is composed of ports, which are origins and destinations of shipping routes: junctions where shipping routes intersect, and segments that are shipping lanes between two connected junctions. Each segment can have only two junctions or ports, and ship traffic flow can enter and leave a segment only through a junction or at a port. Figure 4-2 represents only a sample of the many routes contained in the model.

Figure 4-2 Illustration of STEEM Modeling Domain and Spatial Distribution of Shipping Lanes



The STEEM interport model also employs a number of databases to identify the movements for each vessel (e.g., trips), individual ship attributes (e.g., vessel size and horsepower), and related emission factor information (e.g., emission rates) that are subsequently used in the inventory calculations.

To allocate ships to the statistical lanes, STEEM uses the ArcGIS system Network Analyst tools along with specific information on each individual ship movement to solve the most probable path on the network between each pair of ports (i.e., a trip) for a certain ship size. This is assumed to represent the least-energy path, which in most cases is the shortest distance unless prevented by weather or sea conditions, water depth, channel width, navigational regulations, or other constraints that are beyond the model's capability to forecast.

After identifying the shipping route and resulting distance associated with each unique trip, the emissions are simply calculated for each operational mode using the following generalized equation along with information from the ship attributes and emission factor databases.

Equation 4-5

Emissions per trip = distance (nautical miles) / speed (nautical miles/hour) x horsepower (kW) x fractional load factor x emission factor (g/kW-hour)

In STEEM, emissions are calculated separately for distances representing cruise and maneuvering operational modes. Maneuvering occurs at slower speeds and load factors than during cruise conditions. In STEEM, maneuvering is assumed to occur within a 3 nautical mile radius of each port when a ship is entering or leaving a port. A ship is assumed to move at maneuvering speed for an entire trip if the distance is less than 3 nautical miles.

Finally, the emissions along each shipping route (i.e., segment) for all trips are proportioned among the respective cells that are represented by the gridded modeling domain. For this work, emissions estimates were produced at a cell resolution of 4 kilometers by 4 kilometers, which is appropriate for most atmospheric air quality models. The results for each cell are then summed, as appropriate, to produce emission inventories for the various geographic regions of interest in this analysis.

4.4.2.2 Data Inputs for Interport Emission Inventories

Traffic along each gridded shipping lane is derived from USACE Entrance and Clearance call data for 2002,[26] together with Lloyd's Register-Fairplay Ltd's data for ship characteristics, such as propulsion engine power and cruise speed.

The emission factors and load factors used as inputs to STEEM are very similar to those used for the ports analysis. Additional adjustments were made to interport emission results for PM_{10} and SO_2 in order to reflect recent U.S. Government review of available engine test data and fuel sulfur levels. Details of the STEEM emission inputs and adjustments are located in Appendix 4C.

4.4.3 Total Ship Emission Inventory for 2002

The national and regional inventories in this study are a combination of the results from the ports analysis and the STEEM interport modeling. Therefore, to obtain the total inventory for 2002 it is necessary to spatially allocate the emissions in a format that is compatible with the STEEM 4 kilometers by 4 kilometers gridded output. Once that has been accomplished as described below, the two inventories can be blended together. This work was conducted by

ENVIRON International as a subcontractor under the U.S. Government contract with ICF International.

4.4.3.1 Spatial Location of the Port Emission Inventories

The hoteling, maneuvering, RSZ, and cruise emissions from the port emission inventories were spatially located by their respective latitude and longitude coordinates. For this study, shapefiles were created that depicted the emission locations as described above. The following sections provide a more detailed description of how the shapefiles representing the hoteling, maneuvering, RSZ lanes, and cruise lanes were developed.

Hoteling and Maneuvering emissions

The designated location for hoteling and maneuvering emissions was modeled as a single latitude/longitude coordinate point using the estimated port center. The hoteling and maneuvering emissions represented by the latitude/longitude coordinate for each port were subsequently assigned to a single cell in the gridded inventory where that point was located. It should be noted that modeling a port as a point will over specify the location of the emissions associated with that port if it occupies an area greater than one grid cell (4 kilometers by 4 kilometers). The coordinates of the 28 Great Lakes ports used in this work are shown in Appendix 4A.

RSZ emissions

The RSZ routes associated with each of the 28 Great Lakes ports were modeled as lines. Each RSZ was assumed to be three nautical miles in length. The RSZ emissions were distributed evenly along the length of the line. The latitude/longitude coordinates for each point along the line were subsequently used to assign the emissions to a grid cell based on the proportion of the line segment that occurred in the respective cell.

Cruise emissions

The cruise mode links that extend seven nautical miles from the end of the RSZ end point were also modeled with line shapefiles. These links were spatially described for each port following the direction of the shipping lane evident in the STEEM data. Again, as with RSZ emissions, the latitude/longitude coordinates for each point along the line were subsequently used to assign the emissions to a grid cell based on the proportion of the line segment that occurred in the respective cell.

As the Great Lakes include a large number of ports in a rather small geographical location, some of the RSZ and cruise mode links overlap. In these cases, the calculated emissions were allocated to the same links, such that the total emissions allocated to the overlapping links are the sum of emissions from all of the ports sharing that link.

4.4.3.2 2002 Emission Inventory

After spatially defining the geographic location of the port emissions, but before actually inserting them into the gridded STEEM inventory, it was necessary to determine if all of the

STEEM emissions within an affected cell should be replaced, or if some of the emissions should be retained. In this latter case, ships would be traversing the area near a port, but not actually entering or exiting the port.

The percentage of STEEM emissions that are attributable to a port, and should be removed and replaced, was approximated by dividing the STEEM emissions in the isolated portion of the route that lead only to the port, while the STEEM emissions in the major shipping lane remained.

The actual merging of the two inventories was performed by creating a number of databases that identified the fraction of the port inventory for each pollutant species and operating mode that should be added to the grid cells for each port. A similar database was also created that identified how much of the original STEEM emissions should be reduced to account for ship movements associated directly with a port, while preserving those that represented transient vessel traffic near the port. These databases were subsequently used to calculate the new emission results for each affected cell in the original STEEM gridded inventory, resulting in the combined inventory results for this study.

For some ports, the outer edges of the port inventories fell outside the U.S. inventory domain and those portions outside the domain were removed. As a result, the port totals presented in the next section are slightly less than those reported in Section 4.4.1.

The total inventory was created by summing emission estimates for ships while at port and while underway (interport). The total 2002 inventory for the Great Lakes, along with the relative contributions of the port and interport emissions are presented in Table 4-13.

Table 4-13 2002 Total C3 Inventory for the U.S. Great Lakes Domain

	ANNUAL EMISSIONS (METRIC TONNES)[a]						
EMISSION TYPE	**NO_X**	**PM_{10}**	**$PM_{2.5}$**	**HC**	**CO**	**SO_2**	**CO_2**
Port	491	44	41	17	40	346	22,476
Interport	14,528	1,135	1,044	481	1,134	8,420	518,860
Total Emissions	*15,019*	*1,179*	*1,085*	*498*	*1,174*	*8,766*	*541,336*

[a] The port emission totals in this table are slightly less than those in Table 4-12 due to the gridding process and trimming to include only port emissions that fall within the emission inventory boundaries.

The interport and port inventories are about 96 percent and 4 percent of the total, respectively.

4.5 Development of 2020 Emission Inventories

To obtain the 2020 baseline and control inventories for the inventory domain, it is necessary to adjust the 2002 inventories to account for activity level growth and the emission reductions that would occur in 2020 absent the ECA controls (baseline case) and with the ECA controls (control case). This section describes how the adjustment factors were obtained and presents the inventories for the inventory domain for 2020. The inventories for the ECA are described in Section 4.6.

4.5.1 Adjustment Methodology

We used a multi-step approach to adjust the 2002 inventories to estimate the 2020 baseline and control scenarios for the inventory domain. Specifically, we applied a growth factor adjustment and an emission factor adjustment. The growth factor adjustment was derived from the growth factors that were estimated for the North American ECA. The emission factor adjustments were derived by developing a new set of emission factors based on the emission programs that will be in place in the baseline and control scenarios; the adjustment factor is the ratio of the 2020 emission factors to the 2002 emission factors.

4.5.1.1 Growth Factors for 2020

The starting point for developing the 2020 inventories was determining the average annual growth rates from 2002 through 2020. The average annual growth rate for the Great Lakes is estimated to be 1.7 percent. The methodology used to derive this growth rate is described in Appendix 4D. The growth rate was then compounded over the inventory projected time period for 2020 (i.e., 18 years). The growth rate and resulting multiplicative growth factor for the Great Lakes are provided in Table 4-14.

Table 4-14 Emission Inventory Growth Factors for the Great Lakes in 2020

REGION	2002-2020 AVERAGE ANNUALIZED GROWTH RATE (%)	MULTIPLICATIVE GROWTH FACTOR RELATIVE TO 2002
Great Lakes	1.7%	1.356

The multiplicative growth factor was applied to each of the pollutant totals for 2002 to project emissions to 2020. Additional adjustments were required to account for emission controls, which are described in the following sections.

4.5.1.2 Emission Requirements Included in the Adjustment: Baseline and Control

Application of the ECA requirements to the U.S. portion of the Great Lakes is expected to begin in August 2012. However, the inventory and air quality analysis performed for the Coordinated Strategy and this Great Lakes Study is for 2020. The year 2020 was chosen because it allows the use of detailed emission inventories that were created for other emission sources (e.g., land-based stationary and mobile sources) as part of wider scale air pollution modelling efforts. The choice of 2020 is also consistent with the fuel cost analysis. The choice of 2020 is not expected to affect this analysis, for the reasons discussed below.

With regard to engine controls, by 2020 ships will be required to be in compliance with the MARPOL Annex VI Tier I NO_X standard for marine diesel engines, as well as the Tier II standard. Also included in the 2020 baseline inventories is the NO_X retrofit program for pre-controlled engines in regulation 13 of MARPOL Annex VI. These requirements are included in our emissions baseline. Beginning in 2016, new ships constructed on or after January 1, 2016 that operate on the Great Lakes are to be equipped with engines that meet the Tier III NO_X limits. While 2020 will include five years of turnover to the Tier III standards, the long service life of Great Lakes vessels means that these impacts will be small and affect less than 25 percent of the total fleet, assuming an average 20-year service life.

With regard to fuel controls, ships operating on the Great Lakes in 2020 will need to comply with the ECA fuel requirements and ships will be required to use fuel with a maximum sulfur content of 0.10 percent. Although the 0.10 percent fuel sulfur requirement goes into place for all vessels operating in ECAs beginning in 2015, the use of 2020 as the analytic year will still provide a representative scenario for the impact of the 0.10 percent fuel sulfur requirement on human health and the environment. This is because the fuel requirements of the ECA go into effect all at once with no phase-in. In addition, the Great Lakes fuel availability waiver for 10,000 ppm fuel will no longer apply in 2020. As a result, the impacts of the 1,000 ppm fuel sulphur requirement on the Great Lakes in 2020 are expected to be the same as in 2015, with a small increase due to growth.

While the use of 2020 is not expected to affect the outcome of our inventory and air quality analyses, there are two other implications for the inventory analysis. First, with regard to the impacts of the ECA fuel sulphur requirements, the choice of 2020 slightly over-estimates the immediate benefits of the program in 2015. Therefore, the use of 2020 as the analytic year will provide a representative scenario for the impact of the 0.1 percent fuel sulphur requirement on human health and the environment. Second, with regard to the NO_X impacts, the use of 2020 includes only five years of turnover since the Tier III standards were implemented. Due to the long service lives of engines on ocean-going vessels, this means that the fleet will not be fully turned over for some time and the full benefits of the ECA NO_X controls will not be reflected in this analysis. The choice of 2020 as the analytic year provides a balance between modelling a year prior to full Tier III NO_X standard fleet implementation and modelling a future year where there may be more uncertainty associated with projecting emissions. It should be noted that, although the 0.5 percent global fuel sulphur standard goes into effect in 2020, we did not include the global standard in the 2020 analysis, as the sulphur content of the fuel used in the Great Lakes at that time would be lower than the 0.5 percent global standard.

The effects of these controls are reflected in the 2020 emission inventories by applying appropriate adjustment factors that reflect the percentage of the vessel fleet in those years that are estimated to comply with the controls. Adjustment factors are ratios of 2020 to 2002 calendar year (CY) emission factors (EFs). Adjustment factors are derived separately by engine type for propulsion and auxiliary engines. The adjustment factors for propulsion engines are applied to the propulsion portion of the port inventory and the interport portion of the inventory. The adjustment factors for auxiliary engines are applied to the auxiliary portion of the port inventory.

4.5.1.3 Emission Factors for 2020 Emission Inventory Adjustments

The emission factors for the 2020 emission inventory adjustments reflect the application of the engine controls described above. Note that the NO_X engine standards apply only to diesel reciprocating engines; gas and steam turbine engines are not subject to any of the NO_X standards.

For the NO_X limits, the current Tier I controls, which are modeled as achieving an 11 percent reduction from Tier 0, apply to the 2000 through 2010 model year (MY) engines. In 2011 thru 2015, Tier II controls are applied. Tier II controls are modeled as a 2.5 g/kW-hr reduction from Tier I. In the ECA area only, for 2016 MY engines and beyond, Tier III controls are applied. Tier III controls are modeled as achieving an 80 percent reduction from Tier I levels. The NO_X retrofit program for Tier 0 (pre-control) engines was modeled as 11 percent control from Tier 0 for 80 percent of 1990 thru 1999 MY engines greater than 90 liters per cylinder (l/cyl) starting in 2011. The retrofit program was also modeled with a five year phase-in. Control of fuel sulfur content within the ECA area to 0.10 percent affects both SO_2 and PM emissions.

The NO_X emission factors (EFs) by engine/ship type and Tier are provided in Table 4-15. Tier 0 refers to pre-control. There are separate entries for Tier 0/1/2 base and Tier 0/1/2 control, since the control engines would be using distillate fuel, and there are small NO_X emission reductions assumed when switching from residual to distillate fuel.[27] The NO_X control EFs by Tier were derived using the assumptions described above.

Table 4-15 Modeled NO_X Emission Factors by Tier

ENGINE/ SHIP TYPE	NO_X EF (g/kW-hr)								
	BASELINE				CONTROL AREAS				
	TIER 0	TIER 0 RETROFIT	TIER I	TIER II	TIER 0	TIER 0 RETROFIT	TIER I	TIER II	TIER III
Main[b]									
SSD	18.1	16.1	16.1	13.6	17	15.1	15.1	12.6	3
MSD	14	12.5	12.5	10.0	13.2	11.7	11.7	9.2	2.3
ST	2.1	n/a	n/a	n/a	2	n/a	n/a	n/a	n/a
GT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Aux									
Pass	14.6	n/a[a]	13.0	10.5	14.6	n/a[a]	13.0	10.5	2.6
Other	14.5	n/a[a]	12.9	10.4	14.5	n/a[a]	12.9	10.4	2.6

Notes:
[a] The retrofit program applies to engines over 90 l/cyl; auxiliary engines are smaller than this cutpoint and would therefore not be subject to the program.
[b] SSD is slow speed diesel, MSD is medium speed diesel, ST is steam turbine, GT is gas turbine, Pass is passenger.

Because this program phases in over time, it is necessary to estimate the adjustment factor for each year to obtain the appropriate adjustment factor for 2020. This is done by using vessel age distributions (Table 4-16) to generate calendar year NO_X EFs by engine/ship type for the base and control areas included in the scenarios. The adjustment factors for 2020 for the baseline and control scenarios are presented in Table 4-17.

Table 4-16 Vessel Age Distribution for Great Lake Ports by Engine Type

AGE GROUP (years old)	PROPULSION ENGINE TYPE (Fraction of Total)			ALL AUXILIARY ENGINES
	MSD	SSD	ST	
0	0.01610	0.03913	0.00000	0.02399
1	0.02097	0.03489	0.00000	0.02243
2	0.01370	0.04644	0.00000	0.02544
3	0.02695	0.03040	0.00000	0.02511
4	0.01571	0.04547	0.00000	0.02497
5	0.04584	0.01498	0.00000	0.02442
6	0.01494	0.02180	0.00000	0.01528
7	0.01327	0.01857	0.00000	0.01391
8	0.00099	0.04842	0.00000	0.02107
9	0.00027	0.03376	0.00000	0.01454
10	0.01085	0.01177	0.00000	0.01076
11	0.00553	0.01183	0.00000	0.00782
12	0.00739	0.00546	0.00000	0.00626
13	0.02289	0.02557	0.00000	0.02242
14	0.00000	0.00286	0.00000	0.00121
15	0.00275	0.00510	0.00000	0.00361
16	0.00069	0.00073	0.00000	0.00078
17	0.00000	0.00104	0.00000	0.00041
18	0.00342	0.01967	0.00000	0.01059
19	0.00219	0.01220	0.00000	0.00645
20	0.00867	0.06140	0.00000	0.03034
21	0.00000	0.05638	0.00000	0.02503
22	0.03375	0.02108	0.00000	0.02279
23	0.04270	0.02051	0.00000	0.02606
24	0.08161	0.01010	0.00000	0.03744
25	0.02935	0.05217	0.00000	0.03480
26	0.18511	0.00522	0.00000	0.07701
27	0.01870	0.00389	0.00000	0.01083
28	0.13815	0.01438	0.00000	0.06181
29	0.05487	0.01160	0.00000	0.02697
30	0.00000	0.00114	0.00000	0.00047
31	0.03986	0.00000	0.00000	0.01611
32	0.03654	0.00282	0.00000	0.01631
33	0.03358	0.00000	0.00000	0.01358
34	0.00295	0.00123	0.00000	0.00165
35+	0.06974	0.30796	1.00000	0.31734

Table 4-17 Modeled NO_X Emission Factors by Calendar Year and Control Type

ENGINE/ SHIP TYPE	CY NO_X EF (g/kW-hr)		
	2002	2020 BASE	2020 ECA CONTROL
Main			
SSD	18.1	17.12	13.07
MSD	14	13.64	11.79
ST	2.1	2.1	2.0
GT	n/a	n/a	n/a
Aux			
Pass	14.6	14.13	11.99
Other	14.5	13.97	11.99

The PM and SO_2 EFs are a function of fuel sulfur level. For the baseline portions of the inventory, the residual fuel sulfur level modeled is 27,000 ppm (see Fuel Sulfur Level discussion on page 4-12). The baseline distillate fuel sulfur level assumed for all areas is 15,000 ppm. As discussed previously, for the baseline, main engines use residual fuel and auxiliary engines use a mix of residual and distillate fuel. For the control areas, there is one level of distillate fuel sulfur assumed to be used by all engines: 1,000 ppm for the ECA control areas.

Table 4-18 provides the PM_{10} EFs by engine/ship type and fuel sulfur level. For modeling purposes, $PM_{2.5}$ is assumed to be 92 percent of PM_{10}. The PM EFs are adjusted to reflect the appropriate fuel sulfur levels using Equation 4-2.

Table 4-18 Modeled PM_{10} Emission Factors

ENGINE/ SHIP TYPE	PM_{10} EF (g/kW-hr)	
	BASELINE	CONTROL AREAS
	27,000 ppm S	ECA 1,000 ppm S
Main		
SSD	1.40	0.19
MSD	1.40	0.19
ST	1.50	0.17
GT	n/a	n/a
Aux		
Pass	1.40	0.19
Other	1.20	0.19

Table 4-19 provides the modeled SO_2 EFs. SO_2 emission reductions are directly proportional to reductions in fuel sulfur content.

Table 4-19 Modeled SO_2 Emission Factors

ENGINE/ SHIP TYPE	SO_2 EF (g/kW-hr)	
	BASELINE	CONTROL AREAS
	27,000 ppm S	ECA 1,000 ppm S
Main		
SSD	10.29	0.36
MSD	11.09	0.39
ST	16.10	0.57
GT	n/a	n/a
Aux		
Pass	10.70	0.39
Other	9.66	0.39

For the CO_2 emission factors, CO_2 is directly proportional to fuel consumed. Table 4-20 provides the modeled CO_2 and BSFC EFs. Due to the higher energy content of distillate fuel on a mass basis, the switch to distillate fuel for the control areas results in a small reduction to BSFC and, correspondingly, CO_2 emissions.[28]

Table 4-20 Modeled Fuel Consumption and CO_2 Emission Factors

ENGINE/ SHIP TYPE	EF (g/kW-hr)			
	BASELINE		CONTROL AREAS	
	BSFC	CO_2	BSFC	CO_2
Main				
SSD	195	621	185	589
MSD	210	668	200	637
ST	305	970	290	923
GT	n/a	n/a	n/a	n/a
Aux				
Pass	210	668	200	636
Other	210	668	200	636

The HC and CO emission factors are assumed to remain unchanged from the 2002 scenario, since there are no emission standards or requirements for those pollutants. The ECA NO_X and fuel sulfur requirements are anticipated to reduce the NO_X, SO_2 and PM emission factors. The switch to lower sulfur distillate fuel use is also expected to lower CO_2 emissions slightly.

4.5.1.4 Port Emission Adjustment Factors

The EF adjustment factors are a ratio of the control EF to the 2002 EF. Table 4-21 through Table 4-25 provides the EF adjustment factors for each pollutant for the 2020 baseline and control scenarios.

Table 4-21 NO_X EF Adjustment Factors by Engine/Ship Type and Control Type[a]

ENGINE/ SHIP TYPE	2020 BASE	2020 ECA CONTROL
Main		
SSD	0.9459	0.7219
MSD	0.9744	0.8423
ST	1.0000	0.9524
GT	n/a	n/a
Aux		
Pass	0.9657	0.8196
Other	0.9657	0.8295

[a] NO_X adjustment factors are a ratio of future base or control EFs to 2002 EFs

Table 4-22 PM_{10} EF Adjustment Factors by Engine/Ship Type and Control Type[a]

ENGINE/ SHIP TYPE	2020 BASE	2020 ECA CONTROL
Main		
SSD	1.0000	0.1352
MSD	1.0000	0.1328
ST	1.0000	0.1108
GT	n/a	n/a
Aux		
Pass	1.0000	0.1328
Other	1.0000	0.1550

[a] PM_{10} adjustment factors are a ratio of the control EFs to the 2002 EFs. PM is not adjusted for the future baseline because fuel sulfur levels are only assumed to change within the ECA.

Table 4-23 $PM_{2.5}$ EF Adjustment Factors by Engine/Ship Type and Control Type[a]

ENGINE/ SHIP TYPE	2020 BASE	2020 ECA CONTROL
Main		
SSD	1.0000	0.1339
MSD	1.0000	0.1316
ST	1.0000	0.1092
GT	n/a	n/a
Aux		
Pass	1.0000	0.1316
Other	1.0000	0.1555

[a] $PM_{2.5}$ adjustment factors are a ratio of the control EFs to the 2002 EFs. PM is not adjusted for the future baseline because fuel sulfur levels are only assumed to change within the ECA. The $PM_{2.5}$ adjustment factors are slightly different from those for PM_{10} due to rounding.

Table 4-24 SO_2 EF Adjustment Factors by Engine/Ship Type and Control Type[a]

ENGINE/ SHIP TYPE	2020 BASE	2020 ECA CONTROL
Main		
SSD	1.0000	0.0351
MSD	1.0000	0.0353
ST	1.0000	0.0352
GT	n/a	n/a
Aux		
Pass	1.0000	0.0365
Other	1.0000	0.0405

[a] SO_2 adjustment factors are a ratio of the control EFs to the 2002 EFs. SO_2 is not adjusted for the future baseline because fuel sulfur levels are only assumed to change within the ECA.

Table 4-25 CO_2 EF Adjustment Factors by Engine/Ship Type and Control Type[a]

ENGINE/ SHIP TYPE	2020 BASE	2020 ECA CONTROL
Main		
SSD	1.0000	0.9488
MSD	1.0000	0.9531
ST	1.0000	0.9509
GT	n/a	n/a
Aux		
Pass	1.0000	0.9525
Other	1.0000	0.9525

[a] CO_2 adjustment factors are a ratio of the control EFs to the 2002 EFs. CO_2 is not adjusted for the future baseline because fuel consumption (BSFC) is only assumed to change within the ECA.

4.5.1.5 Interport Emission Inventory Adjustment Factors

Since the interport portion of the inventory is not segregated by engine or ship type, it was necessary to develop a different set of emission adjustment factors for these emissions. This was done based on the assumed mix of main (propulsion) engine types in the Great Lakes. This is appropriate because the majority of emissions while underway are from propulsion, not auxiliary, engines. Using the ship call and power data, the mix of main engine types for the Great Lakes is 44 percent SSD, 48 percent MSD and 8 percent ST.

The EF adjustment factors by main engine type from the port calculations were used with a mix of main engine types to develop the Great Lakes interport EF adjustment factors. The resulting EF adjustment factors applied to the 2002 interport portion of the emission inventory are provided in Table 4-26.

Table 4-26 EF Adjustment Factors for 2020 Scenarios[a]

POLLUTANT	2002	2020 BASE	2020 ECA CONTROL
NO_X	1.0000	0.9641	0.7989
PM_{10}	1.0000	1.0000	0.1320
$PM_{2.5}$	1.0000	1.0000	0.1307
SO_2	1.0000	1.0000	0.0352
CO_2	1.0000	1.0000	0.9510

[a] Adjustment factors are ratios of future base or control EFs to 2002 EFs. These adjustment factors are used to adjust the interport portion of the 2002 inventory.

4.5.2 2020 Port and Interport Emission Inventories

The 2020 port and interport inventories were developed by applying the growth factors and emission factor adjustments to the 2002 inventories. These inventories were then combined to obtain the 2020 total inventories, for the baseline and control cases. The port inventories were created by applying the growth and emission adjustment factors to the 2002 port inventories. The port inventories were then converted into a gridded format using the same approach as for the 2002 inventory. Using this grid, STEEM values were removed from port cells and port emissions were used as replacement values. In cases where the emissions near ports were only partially attributable to port traffic, the STEEM inventory was reduced rather than removed. The interport inventories were scaled by a growth factor to 2020, as previously described, and the emission adjustment factors were applied.

Port and interport emissions were then aggregated to form regional totals. The resulting baseline (reference) and control inventories for 2020 are presented in Table 4-27. Also presented are the tonnes reduced and the percent reductions for each pollutant. The inventories include all emissions within the U.S. portion of the Great Lakes.

Table 4-27 Category 3 Vessel Inventories in the U.S. Great Lakes for 2020 Scenarios[a]

SCENARIO	ANNUAL EMISSIONS (METRIC TONNES)						
	NO_X	PM_{10}	$PM_{2.5}$	HC	CO	SO_2	CO_2
Reference	19,842	1,613	1,484	682	1,607	11,993	740,624
Control	16,420	207	190	676	1,602	420	704,390
Delta Emissions	*-3,422*	*-1,406*	*-1,294*	*-6*	*-5*	*-11,574*	*-36,235*
Delta Emissions (%)	*-17%*	*-87%*	*-87%*	*0%*	*0%*	*-97%*	*-5%*

[a] These inventories include all emissions within the U.S. Great Lakes.

The fuel consumption by fuel type in the baseline and ECA cases is presented in Table 4-28.

Table 4-28 Fuel Consumption by Category 3 Vessels for 2020 Scenarios[a]

SCENARIO	METRIC TONNES FUEL		
	DISTILLATE	RESIDUAL	TOTAL
Reference	1,719	230,962	232,681
Control	221,297	0	221,297

[a] These inventories include all emissions within the U.S. Great Lakes.

4.6 Adjustment to 2020 Inventories for Jones Act Shipping

Domestic traffic, i.e., U.S. ships delivering cargo from one U.S. port to another U.S. port, is covered under the Jones Act, and is not accounted for in the above inventories. For the final Category 3 rule, the contribution of Jones Act traffic by Category 3 vessels was estimated based on an analysis by ICF International, under contract to EPA.[29] For the Great Lakes, the ratio of estimated total installed power with Jones Act traffic to the actual installed power included in the emission inventory is 1.97. Installed power is used as a surrogate for emissions.

This ratio is applied to the C3 inventories in the previous section to obtain the adjusted Great Lakes 2020 inventories in Table 4-29. Since the adjustments are applied to both the reference and control emission inventories, the percent reductions are unchanged.

Table 4-29 Adjusted Category 3 Vessel Emission Inventories in the U.S. Great Lakes for 2020 Scenarios[a]

SCENARIO	ANNUAL EMISSIONS (METRIC TONNES)						
	NO_X	PM_{10}	$PM_{2.5}$	HC	CO	SO_2	CO_2
Reference	39,089	3,178	2,923	1343.54	3,166	23,626	1,459,029
Control	32,347	407.79	374.3	1331.72	3,156	827.4	1,387,648
Delta Emissions	*6,741*	*2,770*	*2,549*	*11.82*	*9.85*	*22,799*	*71,381*
Delta Emissions (%)	*-17%*	*-87%*	*-87%*	*-0%*	*0%*	*-96%*	*-5%*

[a] These inventories include all emissions within the U.S. Great Lakes, with an adjustment to account for Jones Act traffic.

This ratio can also be applied to estimated fuel consumption for the 2020 scenarios; the results are provided in Table 4-30.

Table 4-30 Adjusted Fuel Consumption by Category 3 Vessels for 2020 Scenarios[a]

SCENARIO	METRIC TONNES FUEL		
	DISTILLATE	RESIDUAL	TOTAL
Reference	2,500	455,882	458,382
Control	435,955	0	435,955

[a] These inventories include all emissions within the U.S. Great Lakes, with an adjustment to account for Jones Act traffic.

It should be noted that the application of this adjustment factor to the control inventories and the fuel consumption estimates does not take into account the exclusion of steamships operating on the Great Lakes from the ECA fuel control requirements, as provided in the Category 3 marine final rule. As a result, both the inventory reductions and the increase in distillate fuel use for the control program are over-estimated. The size of this discrepancy depends on how many steamships continue to be in service in 2020, and the degree to which they are used. There are currently 13 steamships in the U.S. fleet, built between 1942 and 1953, with one each built in 1959 and 1960 (this number includes both 12 diesel-powered steamships and one coal-fired steamship). The Canadian fleet consists of 8 steamships built between 1952 and 1963, with one built in 1906 and one built in 1967. Due to their age, these vessels are more likely to be retired or repowered (i.e., new diesel engines installed for propulsion) by 2020.

Appendices

Appendix 4A

Port Coordinates

Table 4A-1 Port Coordinates

Port Name	U.S. ACE CODE	PORT COORDINATES[a]	
		Longitude	Latitude
Alpena, MI	L3617	-83.4223	45.0556
Ashtabula, OH	L3219	-80.7917	41.91873
Buffalo, NY	L3230	-78.8953	42.8783
Burns Waterway Harbor, IN	L3739	-87.1552	41.64325
Calcite, MI	L3620	-83.7756	45.39293
Chicago, IL	L3749	-87.638	41.88662
Cleveland, OH	L3217	-81.6719	41.47852
Conneaut, OH	L3220	-80.5486	41.96671
Detroit, MI	L3321	-83.1096	42.26909
Duluth-Superior, MN and WI	L3924	-92.0964	46.77836
Erie, PA	L3221	-80.0679	42.15154
Escanaba, MI	L3795	-87.025	45.73351
Fairport Harbor, OH	L3218	-81.2941	41.76666
Gary, IN	L3736	-87.3251	41.61202
Indiana Harbor, IN	L3738	-87.4455	41.67586
Lorain, OH	L3216	-82.1951	41.48248
Manistee, MI	L3720	-86.3443	44.25082
Marblehead, OH	L3212	-82.7091	41.52962
Milwaukee, WI	L3756	-87.8997	42.98824
Muskegon, MI	L3725	-86.3501	43.19492
Port Dolomite, MI	L3627	-84.3128	45.99139
Port Inland, MI	L3803	-85.8628	45.95508
Presque Isle, MI	L3845	-87.3852	46.57737
Sandusky, OH	L3213	-82.7123	41.47022
St. Clair, MI	L3509	-82.4941	42.82663
Stoneport, MI	L3619	-83.4703	45.28073
Toledo, OH	L3204	-83.5075	41.66294
Two Harbors, MN	L3926	-91.6626	47.00428

[a] U.S. Army Corps of Engineers (USACE) data from http://www.iwr.usace.army.mil/ndc/db/pport/dbf/

Appendix 4B

Port Methodology and Equations

Emissions for each port were calculated for four modes of operation: 1) hoteling, 2) maneuvering, 3) reduced speed zone (RSZ), and 4) cruise. Hoteling, or dwelling, occurs while the vessel is docked or anchored near a dock, and only the auxiliary engine(s) are being used to provide power to meet the ship's energy needs. Maneuvering occurs within a very short distance of the docks. The RSZ varies from port to port, though generally the RSZ would begin and end when the pilots board or disembark, and typically occurs when the port shipping lanes reach unconstrained shipping lanes. The cruise mode emissions in the ports analysis extend seven nautical miles beyond the end of the RSZ lanes for the Great Lake ports.

Emissions were calculated separately for propulsion and auxiliary engines. The basic equation used is as follows.

Equation 4B-1

$$Emissions_{mode[eng]} = (calls) \times (P_{[eng]}) \times (hrs/call_{mode}) \times (LF_{mode[eng]}) \times (EF_{[eng]}) \times (Adj) \times (10^{-6}\ tonnes/g)$$

Where:
$Emissions_{mode\ [eng]}$ = Metric tonnes emitted by mode and engine type
Calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[eng]}$ = Total engine power by engine type, in kilowatts (kW)
$hrs/call_{mode}$ = Hours per call by mode
$LF_{mode\ [eng]}$ = Load factor by mode and engine type (unitless)
$EF_{[eng]}$ = Emission factor by engine type for the pollutant of interest, in g/kW-hr
(these vary as a function of engine type and fuel used, rather than activity mode)
Adj = Low load adjustment factor, unitless (used when the load factor is below 0.20)
10^{-6} = Conversion factor from grams to metric tonnes

Main engine load factors were calculated directly from the propeller curve based upon the cube of actual speed divided by maximum speed (at 100% maximum continuous rating [MCR]). In addition, cruise mode activity is based on cruise distance and speed inputs. The following sections provide the specific equations used to calculate propulsion and auxiliary emissions for each activity mode.

Cruise

Cruise emissions were calculated for both propulsion (main) and auxiliary engines. The basic equation used to calculate cruise mode emissions for the main engines is below.

Equation 4B-2

$$Emissions_{cruise[main]} = (calls) \times (P_{[main]}) \times (hrs/call_{cruise}) \times (LF_{cruise[main]}) \times (EF_{[main]}) \times (10^{-6}\ tonnes/g)$$

Where:
$Emissions_{cruise\,[main]}$ = Metric tonnes emitted from main engines in cruise mode
Calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[main]}$ = Total main engine power, in kilowatts (kW)
$hrs/call_{cruise}$ = Hours per call for cruise mode
$LF_{cruise\,[main]}$ = Load factor for main engines in cruise mode (unitless)
$EF_{[main]}$ = Emission factor for main engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
10^{-6} = Conversion factor from grams to metric tonnes

In addition, the time in cruise is calculated as follows.

Equation 4B-3

$$Hrs / call_{cruise} = Cruise\,Distance[nmiles] / Cruise\,Speed\,[knots] \times 2\,trips / call$$

Where:
Cruise distance = one way distance (7 nautical miles)
Cruise speed = vessel service speed, in knots
2 trips/call = Used to calculate round trip cruise distance

Main engine load factors are calculated directly from the propeller curve based upon the cube of actual speed divided by maximum speed (at 100% maximum continuous rating [MCR]).

Equation 4B-4

$$LoadFactor_{\,cruise[main]} = \left(Cruise\,Speed[knots] / MaximumSpeed[knots]\right)^3$$

Since cruise speed is estimated at 94 percent of maximum speed[30], the load factor for main engines at cruise is 0.83.

Substituting Equation 4B-3 for time in cruise into Equation 4B-2, and using the load factor of 0.83, the equation used to calculate cruise mode emissions for the main engines becomes the following.

Equation 4B-5 Cruise Mode Emissions for Main Engines

$$Emissions_{cruise[main]} = (calls) \times (P_{[main]}) \times (CruiseDistance/CruiseSpeed) \times (2\,trips/call) \times 0.83 \times (EF_{[main]}) \times (10^{-6}\,tonnes/g)$$

Where:
$Emissions_{cruise\,[main]}$ = Metric tonnes emitted from main engines in cruise mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[main]}$ = Total main engine power, in kilowatts (kW)
Cruise distance = one way distance (7 nautical miles)
Cruise speed = vessel service speed, in knots
2 trips/call = Used to calculate round trip cruise distance
0.83 = Load factor for main engines in cruise mode, unitless
$EF_{[main]}$ = Emission factor for main engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)

10^{-6} = Conversion factor from grams to metric tonnes

The equation used to calculate cruise mode emissions for the auxiliary engines is below.

Equation 4B-6 Cruise Mode Emissions for Auxiliary Engines

$$Emissions_{cruise[aux]} = (calls) \times (P_{[aux]}) \times (Cruise\,Distance/Cruise\,Speed) \times (2\,trips/call) \times (LF_{cruise[aux]}) \times (EF_{[aux]}) \times (10^{-6}\,tonnes/g)$$

Where:
$Emissions_{cruise[aux]}$ = Metric tonnes emitted from auxiliary engines in cruise mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[aux]}$ = Total auxiliary engine power, in kilowatts (kW)
Cruise distance = one way distance (7 nautical miles)
Cruise speed = vessel service speed, in knots
2 trips/call = Used to calculate round trip cruise distance
$LF_{cruise\,[aux]}$ = Load factor for auxiliary engines in cruise mode, unitless (these vary by ship type and activity mode)
$EF_{[aux]}$ = Emission factor for auxiliary engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
10^{-6} = Conversion factor from grams to metric tonnes

The inputs of calls, cruise distance, and vessel speed are the same for main and auxiliary engines. Relative to the main engines, auxiliary engines have separate inputs for engine power, load factor, and emission factors. The activity-related inputs, such as engine power, vessel speed, and calls, can be unique to each ship calling on a port, if ship-specific information is available. For this analysis, these inputs were developed by port for bins that varied by ship type, engine type, and dead weight tonnage (DWT) range.

Reduced Speed Zone

RSZ emissions were calculated for both propulsion (main) and auxiliary engines. The basic equation used to calculate RSZ mode emissions for the main engines is below.

Equation 4B-7

$$Emissions_{RSZ[main]} = (calls) \times (P_{[main]}) \times (hrs/call_{RSZ}) \times (LF_{RSZ[main]}) \times (EF_{[main]}) \times (Adj) \times (10^{-6}\ tonnes/g)$$

Where:
$Emissions_{RSZ[main]}$ = Metric tonnes emitted from main engines in RSZ mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[main]}$ = Total main engine power, in kilowatts (kW)
$hrs/call_{RSZ}$ = Hours per call for RSZ mode
$LF_{RSZ\,[main]}$ = Load factor for main engines in RSZ mode, unitless
$EF_{[main]}$ = Emission factor for main engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
Adj = Low load adjustment factor, unitless (used when the load factor is below 0.20)

10^{-6} = Conversion factor from grams to metric tonnes

In addition, the time in RSZ mode was calculated as follows.

Equation 4B-8

$$Hrs / call_{RSZ} = \quad RSZ\ Distance[nmiles] / RSZ\ Speed\,[knots] \times 2\,trips / call$$

Load factor during the RSZ mode was calculated as follows.

Equation 4B-9

$$LoadFactor_{RSZ\,[main]} = \left(RSZ\ Speed\ /\ Maximum\,Speed\right)^3$$

In addition,

Equation 4B-10

$$Maximum\,Speed\ = Cruise\,Speed / 0.94$$

Where:
0.94 = Fraction of cruise speed to maximum speed

Substituting Equation 4B-10 into Equation 4B-9, the equation to calculate load factor becomes

Equation 4B-11

$$LoadFactor_{RSZ\,[main]} = \left(RSZ\ Speed \times 0.94 / Cruise\,Speed\right)^3$$

Where:
0.94 = Fraction of cruise speed to maximum speed

Load factors below 2 percent were set to 2 percent as a minimum.

Substituting Equation 4B-8 for time in mode and Equation 4B-11 for load factor into Equation 4B-7, the expression used to calculate RSZ mode emissions for the main engines becomes

Equation 4B-12 RSZ Mode Emissions for Main Engines

$$Emissions_{RSZ[aux]} = (calls) \times (P_{[aux]}) \times (RSZ\ Distance/\ RSZ\ Speed) \times (2\,trips/call)$$
$$\times \left(RSZ\ Speed \times 0.94 / Cruise\,Speed\right)^3 \times (EF_{[aux]}) \times \left(Adj\right) \times (10^{-6}\ tonnes / g)$$

Where:
$Emissions_{RSZ[main]}$ = Metric tonnes emitted from main engines in RSZ mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[main]}$ = Total main engine power, in kilowatts (kW)
RSZ distance = one way distance, in nautical miles (3 nm for all Great Lake ports)
RSZ speed = speed, in knots
2 trips/call = Used to calculate round trip RSZ distance
Cruise speed = vessel service speed, in knots

$EF_{[main]}$ = Emission factor for main engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
Adj = Low load adjustment factor, unitless (used when the load factor is below 0.20)
10^{-6} = Conversion factor from grams to tons
0.94 = Fraction of cruise speed to maximum speed

Emission factors are considered to be relatively constant down to about 20 percent load. Below that threshold, emission factors tend to increase significantly as the load decreases. During the RSZ mode, load factors can fall below 20 percent. Low load multiplicative adjustment factors were developed and applied when the load fell below 20 percent (0.20). If the load factor is 0.20 or greater, the low load adjustment factor is set to 1.0.

The equation used to calculate RSZ mode emissions for the auxiliary engines is below.

Equation 4B-13 RSZ Mode Emissions for Auxiliary Engines

$$Emissions_{RSZ[aux]} = (calls) \times (P_{[aux]}) \times (RSZ\ Distance/\ RSZ\ Speed) \times (2\ trips/call) \times (LF_{RSZ[aux]}) \times (EF_{[aux]}) \times (10^{-6}\ tonnes\ /\ g)$$

Where:
$Emissions_{RSZ[aux]}$ = Metric tonnes emitted from auxiliary engines in RSZ mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[aux]}$ = Total auxiliary engine power, in kilowatts (kW)
RSZ distance = one way distance, in nautical miles (3 nm for all Great Lake ports)
RSZ speed = speed, in knots
2 trips/call = Used to calculate round trip cruise distance
$LF_{RSZ\ [aux]}$ = Load factor for auxiliary engines in RSZ mode, unitless (these vary by ship type and activity mode)
$EF_{[aux]}$ = Emission factor for auxiliary engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
10^{-6} = Conversion factor from grams to metric tonnes

Unlike main engines, there is no need for a low load adjustment factor for auxiliary engines, due to their normal operation. When low loads are needed for an auxiliary engine, one or more engines are shut off, allowing the remaining engines to maintain operation at a more efficient level.

The inputs of calls, RSZ distance, and RSZ speed are the same for main and auxiliary engines. Relative to the main engines, auxiliary engines have separate inputs for engine power, load factor, and emission factors. The RSZ distances are assumed to be 3 nm for all Great Lake ports.

Maneuvering

Maneuvering emissions were calculated for both propulsion (main) and auxiliary engines. The basic equation used to calculate maneuvering mode emissions for the main engines is below.

Equation 4B-14

$$Emissions_{man[main]} = (calls) \times (P_{[main]}) \times (hrs / call_{man}) \times (LF_{man[main]}) \times (EF_{[main]}) \times (Adj) \times (10^{-6}\ tonnes / g)$$

Where:
$Emissions_{man[main]}$ = Metric tonnes emitted from main engines in maneuvering mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[main]}$ = Total main engine power, in kilowatts (kW)
$hrs/call_{man}$ = Hours per call for maneuvering mode
$LF_{man\ [main]}$ = Load factor for main engines in maneuvering mode, unitless
$EF_{[main]}$ = Emission factor for main engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
Adj = Low load adjustment factor, unitless (used when the load factor is below 0.20)
10^{-6} = Conversion factor from grams to metric tonnes

Maneuvering time-in-mode is estimated based on the distance a ship travels from the breakwater or port entrance to the pier/wharf/dock (PWD). Maneuvering times also include shifts from one PWD to another or from one port within a greater port area to another. Average maneuvering speeds vary from 3 to 8 knots depending on direction and ship type. For consistency, maneuvering speeds were assumed to be the dead slow setting of approximately 5.8 knots.

Load factor during maneuvering is calculated as follows.

Equation 4B-15

$$LoadFactor_{man[main]} = (Man\,Speed[knots] / Maximum\,Speed[knots])^3$$

In addition,

Equation 4B-16

$$Maximum\,Speed = Cruise\,Speed[knots] / 0.94$$

Where:
0.94 = Fraction of cruise speed to maximum speed

Substituting Equation 4B-16 into Equation 4B-15 and using a maneuvering speed of 5.8 knots, the equation to calculate load factor becomes

Equation 4B-17

$$LoadFactor_{man[main]} = (5.45 / Cruise\,Speed)^3$$

Load factors below 2 percent were set to 2 percent as a minimum.

Substituting Equation 4B-17 for load factor into Equation 4B-14, the expression used to calculate maneuvering mode emissions for the main engines becomes

Equation 4B-18 Maneuvering Mode Emissions for Main Engines

$$Emissions_{man[main]} = (calls) \times (P_{[main]}) \times (hrs / call_{man}) \times (5.45 / Cruise\ Speed)^3 \times (EF_{[main]}) \times (Adj) \times (10^{-6}\ tonnes / g)$$

Where:
$Emissions_{man[main]}$ = Metric tonnes emitted from main engines in maneuvering mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[main]}$ = Total main engine power, in kilowatts (kW)
$hrs/call_{man}$ = Hours per call for maneuvering mode
Cruise speed = Vessel service speed, in knots
$EF_{[main]}$ = Emission factor for main engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
Adj = Low load adjustment factor, unitless (used when the load factor is below 0.20)
10^{-6} = Conversion factor from grams to metric tonnes

Since the load factor during maneuvering usually fell below 20 percent, low load adjustment factors were also applied accordingly. Maneuvering times were not readily available for all 28 Great Lakes ports. For this analysis, maneuvering times and load factors available for either Cleveland or Duluth-Superior were used to calculate maneuvering emissions for the Great Lake ports.

The equation used to calculate maneuvering mode emissions for the auxiliary engines is below.

Equation 4B-19 Maneuvering Mode Emissions for Auxiliary Engines

$$Emissions_{man[aux]} = (calls) \times (P_{[aux]}) \times (hrs / call_{man}) \times (LF_{man[aux]}) \times (EF_{[aux]}) \times (10^{-6}\ tonnes / g)$$

Where:
$Emissions_{man[aux]}$ = Metric tonnes emitted from auxiliary engines in maneuvering mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[aux]}$ = Total auxiliary engine power, in kilowatts (kW)
$hrs/call_{man}$ = Hours per call for maneuvering mode
$LF_{man\ [aux]}$ = Load factor for auxiliary engines in maneuvering mode, unitless (these vary by ship type and activity mode)
$EF_{[aux]}$ = Emission factor for auxiliary engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
10^{-6} = Conversion factor from grams to metric tonnes

Low load adjustment factors are not applied for auxiliary engines.

Hotelling

Hotelling emissions were calculated for auxiliary engines only, as main engines are not operational during this mode. The equation used to calculate hotelling mode emissions for the auxiliary engines is below.

Equation 4B-20 Hotelling Mode Emissions for Auxiliary Engines

$$Emissions_{hotel[aux]} = (calls) \times (P_{[aux]}) \times (hrs / call_{hotel}) \times (LF_{hotel[aux]}) \times (EF_{[aux]}) \times (10^{-6}\ tonnes / g)$$

Where:
$Emissions_{hotel[aux]}$ = Metric tonnes emitted from auxiliary engines in hotelling mode
calls = Round-trip visits (i.e., one entrance and one clearance is considered a call)
$P_{[aux]}$ = Total auxiliary engine power, in kilowatts (kW)
$hrs/call_{hotel}$ = Hours per call for hotelling mode
$LF_{hotel\ [aux]}$ = Load factor for auxiliary engines in hotelling mode, unitless (these vary by ship type and activity mode)
$EF_{[aux]}$ = Emission factor for auxiliary engines for the pollutant of interest, in g/kW-hr (these vary as a function of engine type and fuel used, rather than activity mode)
10^{-6} = Conversion factor from grams to metric tonnes

Hotelling times were not readily available for the 28 Great Lakes ports. For this analysis, hotelling times available for either Cleveland or Duluth-Superior were used to calculate hotelling emissions for the Great Lake ports.

Appendix 4C

Emission Inputs to STEEM

The STEEM waterway network model relies on a number of databases to identify the movements for each vessel, individual ship attributes, and related emission factor information. Each of these databases is described separately below.

Shipping Movements

The shipping activity and routes database provides information on vessel movements or trips. It is developed using port entrance and clearance information from the USACE report for the U.S. and the Lloyd's Maritime Intelligence Unit (LMIU) for Canada and Mexico.[31] These sources contain information for each vessel carrying foreign cargo at each major port or waterway that, most importantly for this analysis, includes vessel name and last port of call (entrance record) or next port of call (clearance record). The database then establishes unique identification numbers for each ship, each port pair, and each resulting trip.

Ship Attributes

The ship attributes data set contains the important characteristics of each ship that are necessary for the STEEM interport model to calculate the emissions associated with each trip. The information in this data set is matched to each previously assigned ship identification number. The following information comes from the USACE Entrances and Clearances report for each ship identification number.

- Ship type
- Gross registered tonnage (GRT)
- Net registered tonnage (NRT)

The ship attributes data set contains the following information from Lloyd's Register-Fairplay for each ship identification number.

- Main propulsion engine installed power (horsepower)
- Service speed (cruise speed)
- Ship size (length, width, and draft)

Sometimes data was lacking from the above references for ship speed. In these instances, the missing information was developed for each of the nine common vessel types and the appropriate value was applied to each individual ship of that type. Specifically, the missing ship speeds for each ship category were obtained from the average speeds used in a Lloyd's Register study of the Baltic Sea and from an Entec UK Limited study for the European Commission.[32,33] The resulting vessel cruise speeds for ships with missing data are shown in Table 4C-1.

Table 4C-1 Average Vessel Cruise Speed by Ship Type [a]

SHIP TYPE	AVERAGE CRUISE SPEED (knots)
Bulk Carrier	14.1
Container Ship	19.9
General Cargo	12.3
Passenger Ship	22.4
Refrigerated Cargo (Reefer)	16.4
Roll On-Roll Off (RORO)	16.9
Tanker	13.2
Fishing	11.7
Miscellaneous	12.7

[a] Used only when ship specific data were missing from the commercial database references.

The average speed during maneuvering is approximately 60 percent of a ship's cruise speed based on using the propeller law described earlier and the engine load factor for maneuvering that is presented later in this section.

As with vessel cruise speed, main engine installed power was sometimes lacking in the Lloyd's Register-Fairplay data set. Here again, the missing information was developed for nine common vessel types and the appropriate value was applied to each individual ship of that type when the data were lacking. In this case, the missing main engine horsepower was estimated by regressing the relationships between GRT and NRT, and between installed power and GRT for each vessel. This operation was performed internally in the model and the result was applied to each individual ship, as appropriate.

The ship attributes database also contains information on the installed power of engines used for auxiliary purposes. However, this information is usually lacking in the Lloyds data set, so an alternative technique was employed to estimate the required values. In short, the STEEM model uses a ratio of main engine horsepower to auxiliary engine horsepower that was determined for eight different vessel types using information primarily from ICF International.[34] (The ICF report attributed these power values to a study for the Port of Los Angeles by Starcrest Consulting.[30]) The auxiliary engine power for each individual vessel of a given ship type was then estimated by multiplying the appropriate main power to auxiliary power ratio and the main engine horsepower rating for that individual ship. The main and auxiliary power values and the resulting auxiliary engine to main engine ratios are shown in Table 4C-2.

Table 4C-2 Auxiliary Engine Power Ratios

VESSEL TYPE	AVERAGE MAIN ENGINE POWER (kW)	AVERAGE AUXILIARY ENGINE POWER (kW)	AUXILIARY TO MAIN ENGINE POWER RATIO
Bulk Carrier	7,954	1,169	0.147
Container Ship	30,885	5,746	0.186
General Cargo	9,331	1,777	0.190
Passenger Ship	39,563	39,563 [a]	1.000
Reefer	9,567	3,900 [b]	0.136
RORO	10,696 [c]	2,156 [c]	0.202
Tanker	9,409	1,985	0.211
Miscellaneous	6,252	1,680	0.269

[a] The ICF reference reported a value of 11,000 for auxiliary engines used on passenger vessels.[34]
[b] The STEEM used auxiliary engine power as reported in the ARB methodology document.
[c] The STEEM purportedly used values for RORO main and auxiliary engines that represent a trip weighted average of the auto carrier and cruise ship power values from the ICF reference.

Finally, the ship attributes database provides information on the load factors for main engines during cruise and maneuvering operations in addition to load factors for auxiliary marine engines. Main engine load factors for cruise operations were taken from a study of international shipping for all ship types, except passenger vessels.[35] For this analysis, the STEEM model used a propulsion engine load factor for passenger ship engines at cruise speed of 55 percent of the total installed power. This is based on engine manufacturer data contained in two global shipping studies.[35,36] During maneuvering, it was assumed that all main engines, including those for passenger ships, operate at 20 percent of the installed power. This is consistent with a study done by Entec UK for the European Commission. The main engine load factors at cruise speed by ship type are shown in Table 4C-3.

Auxiliary engine load factors, except for passenger ships, were obtained from the ICF International study referenced above. These values are also shown in Table 4C-3. For cruise mode, neither port nor interport portions of the inventory were adjusted for low load operation, as the low load adjustments are only applied to propulsion engines with load factors below 20 percent.

Table 4C-3 Main and Auxiliary Engine Load Factors at Cruise Speed by Ship Type

SHIP TYPE	AVERAGE MAIN ENGINE LOAD FACTOR (%)	AVERAGE AUXILIARY ENGINE LOAD FACTOR (%)
Bulk Carrier	75	17
Container Ship	80	13
General Cargo	80	17
Passenger Ship	55	25
Reefer	80	20
RORO	80	15
Tanker	75	13
Miscellaneous	70	17

Emission Factor Information

The emission factor data set contains emission rates for the various pollutants in terms of grams of pollutant per kilowatt-hour (g/kW-hr). The main engine emission factors are shown in Table 4C-4. The speed specific factors for NO_X, HC, and SO_2 were taken from several recent analyses of ship emissions in the U.S., Canada, and Europe.[37,38,39,40] The PM factor was based on discussions with the California Air Resources Board (ARB) staff. The fuel specific CO emission factor was taken from a report by ENVIRON International.[41] The STEEM model used the composite emission factors shown in the table because the voyage data used in the model do not explicitly identify main engine speed ratings, i.e., slow or medium, or the auxiliary engine fuel type, i.e., marine distillate or residual marine. The composite factor for each pollutant is determined by weighting individual emission factors by vessel engine population data from a 2005 survey of ocean-going vessels that was performed by ARB.[42]

Table 4C-4 Main Engine Emission Factors by Ship and Fuel Type

ENGINE TYPE	MAIN ENGINE EMISSION FACTORS (g/kW-hr)						
	FUEL TYPE	NO_X	PM_{10}	$PM_{2.5}$ [a]	HC	CO	SO_2
Slow Speed	Residual Marine	18.1	1.5	1.4	0.6	1.4	10.5
Medium Speed	Residual Marine	14	1.5	1.4	0.5	1.1	11.5
Composite EF	Residual Marine	17.9	1.5	1.4	0.6	1.4	10.6

[a] Estimated from PM_{10} using a multiplicative adjustment factor of 0.92.

The emission factors for auxiliary engines are shown in Table 4C-5. The fuel specific main emission factors for NO_X and HC were taken from several recent analyses of ship emissions in the U.S., Canada, and Europe, as referenced above for the main engine load factors. The PM factor for marine distillate was taken from a report by ENVIRON International, which was also referenced above. The PM factor for residual marine was based on discussions with the California Air Resources Board (ARB) staff. The CO factors are from the Starcrest Consulting study of the Port of Los Angeles.[30] For SO_2, the fuel specific emission factors were obtained from Entec and Corbett and Koehler.[,35] The composite emission factors displayed in the table are discussed below.

Table 4C-5 Auxiliary Engine Emission Factors by Ship and Fuel Type

ENGINE TYPE	AUXILIARY ENGINE EMISSION FACTORS (g/kW-hr)						
	FUEL TYPE	NO_X	PM_{10}	$PM_{2.5}$ [a]	HC	CO	SO_2
Medium Speed	Marine Distillate	13.9	0.3	0.3	0.4	1.1	4.3
Medium Speed	Residual Marine	14.7	1.5	1.4	0.4	1.1	12.3
Composite EF	Residual Marine	14.5	1.2	1.1	0.4	1.1	**

[a] Estimated from PM_{10} using a multiplicative adjustment factor of 0.92.
[b] See Table 4C-6 for composite SO_2 emission factors by vessel type.

As for main engines, the STEEM model used the composite emission factors for auxiliary engines. For all pollutants other than SO_2, underlying data used in the model do not explicitly identify auxiliary engine voyages by fuel type, i.e., marine distillate or residual marine. Again, the composite factor for those pollutants was determined by weighting individual emission factors by vessel engine population data from a 2005 survey of ocean-going vessels that was performed by ARB.[43]

For SO_2, composite emission factors for auxiliary engines were calculated for each vessel type. These composite factors were determined by taking the fuel specific emission factors from Table 4C-5 and weighting them with an estimate of the amount of marine distillate and residual marine that is used by these engines. The relative amount of each fuel type consumed was taken from the 2005 ARB survey. The relative amounts of each fuel type for each vessel type and the resulting SO_2 emission factors are shown in Table 4C-6.

Table 4C-6 Auxiliary Engine SO_2 Composite Emission Factors by Vessel Type

VESSEL TYPE	RESIDUAL MARINE (%)	MARINE DISTILLATE (%)	COMPOSITE EMISSION FACTOR (g/kW-hr)
Bulk Carrier	71	29	9.98
Container Ship	71	29	9.98
General Cargo	71	29	9.98
Passenger Ship	92	8	11.66
Reefer	71	29	9.98
RORO	71	29	9.98
Tanker	71	29	9.98
Miscellaneous	0	100	4.3

Adjustments to STEEM PM and SO_2 Emission Inventories

The interport emission inventories contained in this study for PM_{10} and SO_2 were taken from the STEEM inventories and then adjusted to reflect the U.S. Government's recent review of available engine test data and fuel sulfur levels for the port analysis. In the ports work, a PM emission factor of 1.4 g/kW-hr was used for most main engines, e.g., slow speed diesel and medium speed diesel engines, all of which are assumed to use residual marine. A slightly higher value was used for steam turbine and gas turbine engines, and a slightly lower value was used for most auxiliary engines. However, these engines represent only a small fraction of the total emissions inventory. The STEEM model used an emission factor of 1.5 g/kW-hr for all main engines and a slightly lower value for auxiliary engines. Here again, the auxiliary engines comprise only a small fraction of the total emissions from these ships. Therefore, for simplicity, the interport PM inventories were adjusted by multiplying the STEEM results by the ratio of the two primary emission factors, i.e., 1.4/1.5 or 0.933, to approximate the difference in fuel effects.

Appendix 4D

Growth Factor Development

This appendix describes the development of growth factors for the Great Lakes and other U.S. Regions that were used as the basis for the Great Lakes growth rate.

Geographic Regions

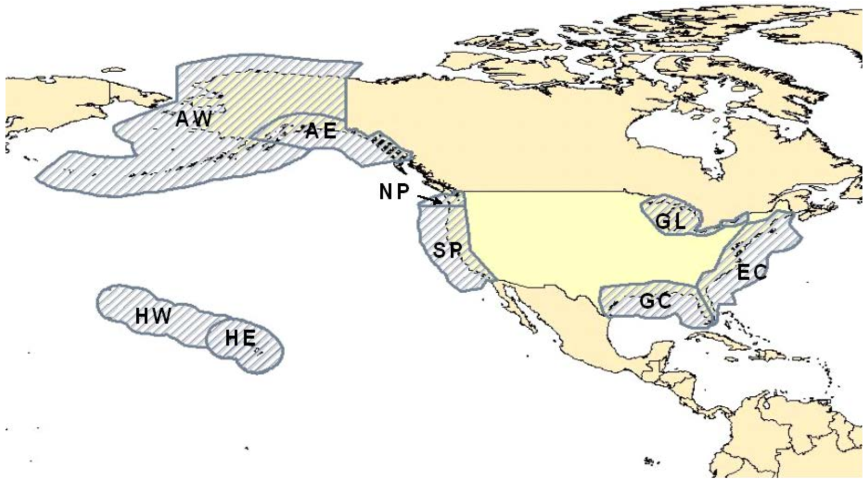
The geographic area reflects ship operations that occur within 200 nautical miles (nm) from the official U.S. baseline but excludes operations in Exclusive Economic Zones of other countries. The official U.S. baseline is recognized as the low-water line along the coast as marked on the official U.S. nautical charts in accordance with the articles of the Law of the Sea. The boundary was mapped using geographic information system (GIS) shapefiles obtained from the NOAA's Office of Coast Survey.[44] The accuracy of the NOAA shapefiles was verified with images obtained from the U.S. Geological Survey. The confirmed NOAA shapefiles were then combined with a shapefile of the U.S. international border from the National Atlas.[45] The resulting U.S. area was further subdivided for this analysis to create regions that were compatible with the geographic scope of the regional growth rates, which are used to project emission inventories for the year 2020.

- The Pacific Coast region was split into separate North Pacific and South Pacific regions along a horizontal line originating from the Washington/Oregon border (Latitude 46° 15' North).
- The East Coast and Gulf of Mexico regions were divided along a vertical line roughly drawn through Key Largo, FL (Longitude 80° 26' West).
- The Alaska region was divided into separate Alaska Southeast and Alaska West regions along a straight line intersecting the cities of Naknek and Kodiak. The Alaska Southeast region includes most of the State's population, and the Alaska West region includes the emissions from ships on a great circle route along the Aleutian Islands between Asia and the U.S. West Coast.
- For the Great Lakes domain, shapefiles were created containing all the ports and inland waterways in the port inventory and extending out into the lakes to the international border with Canada. The modeling domain spanned from Lake Superior on the west to the point eastward in the State of New York where the St. Lawrence River parts from U.S. soil.
- The Hawaiian domain was subdivided so that a distance of 200 nm beyond the southeastern islands of Hawai'i, Maui, O'ahu, Moloka'i, Ni'ihau, Kaua'i, Lanai, and Kahoolawe was contained in Hawaii East. The remainder of the Hawaiian Region was then designated Hawaii West.

This methodology resulted in nine separate regional modeling domains that are identified below and shown in Figure 4D-1. U.S. territories are not included in this analysis.

- South Pacific (SP)
- North Pacific (NP)
- East Coast (EC)
- Gulf Coast (GC)
- Alaska Southeast (AE)
- Alaska West (AW)
- Hawaii East (HE)
- Hawaii West (HW)
- Great Lakes (GL)

Figure 4D-1 Regional Modeling Domains



Growth Factors by Geographic Region

The growth factors that are used to estimate future year emission inventories are based on the expected demand for marine bunker fuels that is associated with shipping goods, i.e., commodities, into and out of the U.S. This section describes the growth factors that are used to project the emissions to 2020 for each of the nine geographic regions evaluated in this analysis. The use of bunker fuel as a surrogate for estimating future emissions is appropriate because the quantity of fuel consumed by C3 engines is highly correlated with the amount of combustion products, i.e., pollutants, that are emitted from those vessels. The term bunker fuel in this report also includes marine distillate oil and marine gas oil that are used in some auxiliary power engines.

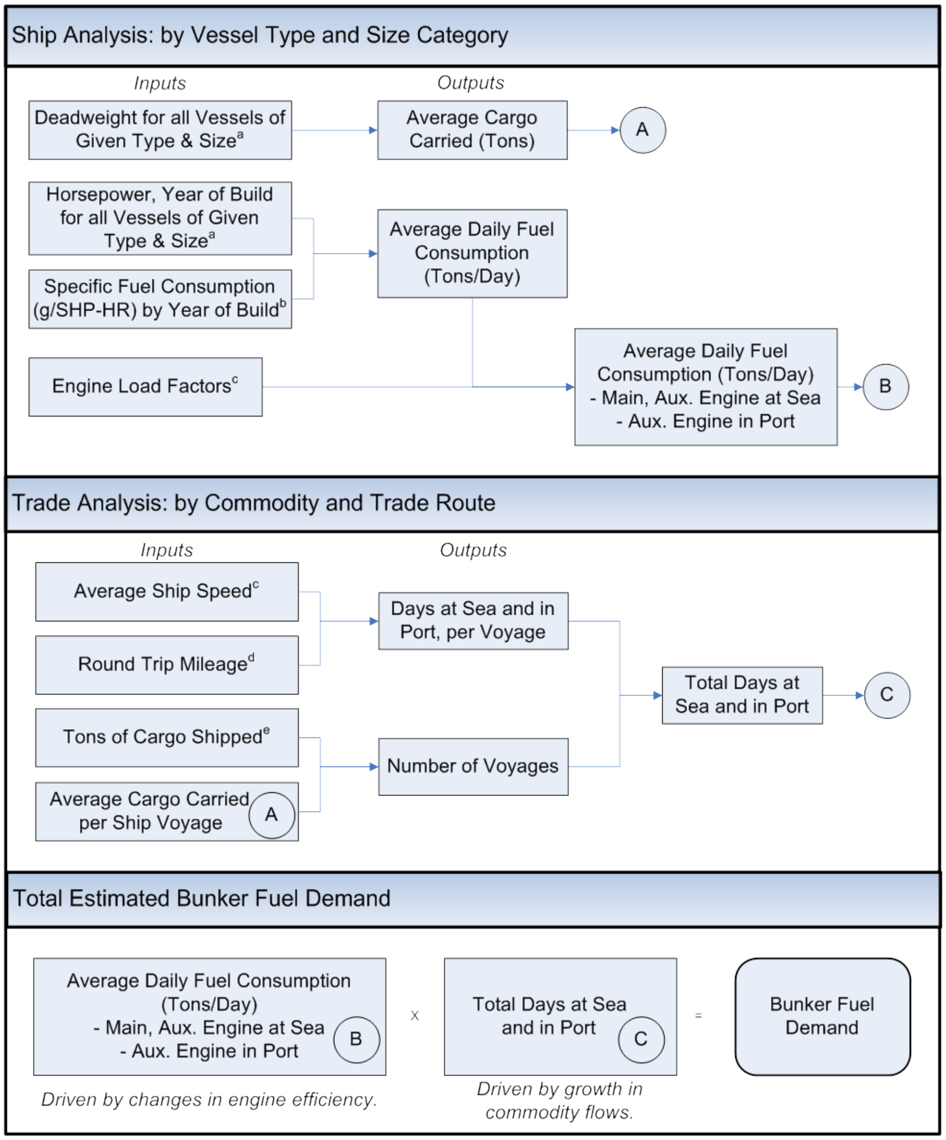
The remainder of this section first summarizes the development of growth rates by RTI International (RTI) for five geographic regions of the U.S., as performed under contract to the U.S. Government.[46,47] This is followed by the derivation of the growth factors for the nine geographic regions of interest.

Summary of Regional Growth Rate Development

RTI developed fuel consumption growth rates for five geographic regions of the U.S. These regions are the East Coast, Gulf Coast, North Pacific, South Pacific, and Great Lakes. The amount of bunker fuel required in any region and year is based on the demand for transporting various types of cargo by Category 3 vessels. This transportation demand is in turn driven by the demand for commodities that are produced in one location and consumed in another, as predicted by an econometric model. The flow of commodities is matched with typical vessels for trade routes (characterized according to cargo capacity, engine horsepower, age, specific fuel consumption, and engine load factors). Typical voyage parameters are then assigned to the trade routes that include average ship speed, round trip mileage, tons of cargo shipped, and days in port. Fuel consumption for each trade route and commodity type thus depends on commodity projections, ship characteristics, and voyage characteristics. Figure 4D-2 illustrates the approach to developing baseline projections of marine fuel consumption.

As a means of comparison, the IMO Secretary General's Informal Cross Government/Industry Scientific Group of Experts presented a growth rate that ranged from 3.3 percent to 3.7 percent.[48] RTI's overall U.S. growth rate was projected at 3.4 percent, which is consistent with the IMO range.

Figure 4D-2 Illustration of Method for Estimating Bunker Fuel Demand



a – Clarksons Ship Register Database
b – Engine Manufacturers' Data, Technical Papers
c – Corbett and Wang (2005) "Emission Inventory Review: SECA Inventory Progress Discussion"
d - Combined trade routes and heavy leg analysis
e – Global Insight Inc. (GII) Trade Flow Projections

Trade Analysis

Trade flows between geographic regions of the world, as illustrated by the middle portion of Figure 4D-2, were defined for the following eight general types of commodities.

- liquid bulk – crude oil
- liquid bulk – refined petroleum products
- liquid bulk – residual petroleum products
- liquid bulk – chemicals (organic and inorganic)
- liquid bulk –gas (including LNG and LPG)

- dry bulk (e.g., grain, coal, steel, ores, and scrap)
- general cargo (e.g., lumber/forest products)
- containerized cargo

The analysis specifically evaluated trade flows between 21 regions of the world. Table 4D-1 shows the countries associated with each region.

Table 4D-1 Aggregate Regions and Associated Countries

AGGREGATE REGIONS	BASE COUNTRIES / REGIONS
U.S. Atlantic Coast	U.S. Atlantic Coast
U.S. Great Lakes	U.S. Great Lakes
U.S. Gulf Coast	U.S. Gulf Coast
E. Canada[a]	Canada[a]
W. Canada[a]	Canada[a]
U.S. Pacific North	U.S. Pacific North
U.S. Pacific South	U.S. Pacific South
Greater Caribbean	Colombia, Mexico, Venezuela, Caribbean Basin, Central America
South America	Argentina, Brazil, Chile, Peru, Other East Coast of S. America, Other West Coast of S. America
Africa – West	Western Africa
Africa-North/East-Mediterranean	Mediterranean Northern Africa, Egypt, Israel,
Africa-East/South	Kenya, Other Eastern Africa, South Africa, Other Southern Africa
Europe-North	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Netherlands, Norway, Sweden, Switzerland, United Kingdom
Europe-South	Greece, Italy, Portugal, Spain, Turkey, Other Europe
Europe-East	Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovak Republic
Caspian Region	Southeast CIS
Russia/FSU	The Baltic States, Russia Federation, Other Western CIS
Middle East Gulf	Jordan, Saudi Arabia, UAE, Other Persian Gulf
Australia/NZ	Australia, New Zealand
Japan	Japan
Pacific-High Growth	Hong Kong S.A.R., Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand
China	China
Rest of Asia	Viet Nam, India, Pakistan, Other Indian Subcontinent

[a] Canada is treated as a single destination in the GI model. Shares of Canadian imports from and exports to regions of the world in 2004 are used to divide Canada trade into shipments to/from Eastern Canada ports and shipments to/from Western Canada ports.[49]

The overall forecast of demand for shipping services and bunker fuel was determined for each of the areas using information on commodity flows from Global Insight's (GI) World Trade

Service. Specifically, GI provided a specialized forecast that reports the flow of each commodity type for the period 1995–2024, based on a proprietary econometric model. The general structure of the GI model for calculating trade flow assumes a country's imports are driven by the importing country's demand forces (given that the exporting country possesses enough supply capacity), and are affected by exporting the country's export price and importing the country's import cost for the commodity. The model then estimates demand forces, country-specific exporting capacities, export prices, and import costs.

The salty Milo is led through the Soo Locks by the Tug Missouri – the Milo frequently carries wheat from the U.S. to Italy. Source: Photograph taken by and used with permission from Dick Lund, available here: http://dlund.20m.com/

The GI model includes detailed annual region-to-region trade flows for eight composite commodities from 1995 to 2024, in addition to the total trade represented by the commodities. Table 4D-2 illustrates the projections for 2012 and 2020, along with baseline data for 2005. In 2005, dry bulk accounted for 41 percent of the total trade volume, crude oil accounted for 28 percent, and containers accounted for 12 percent. Dry bulk and crude oil shipments are expected to grow more slowly over the forecast period than container shipments. By 2020, dry bulk represents 39 percent of the total trade volume, crude oil is 26 percent, and containers rise to 17 percent.

Table 4D-2 Illustration of World Trade Estimates for Composite Commodities, 2005, 2012, and 2020

COMMODITY TYPE	CARGO (millions of tons)		
	2005	2012	2020
Dry Bulk	2,473	3,051	3,453
Crude Oil	1,703	2,011	2,243
Container	714	1,048	1,517
Refined Petroleum	416	471	510
General Cargo	281	363	452
Residual Petroleum and Other Liquids	190	213	223
Chemicals	122	175	228
Natural Gas	79	91	105
Total International Cargo Demand	5,979	7,426	8,737

Ship Analysis by Vessel Type and Size

Different types of vessels are required to transport the different commodities to the various regions of the world. Profiles of these ships were developed to identify the various vessel types and size categories that are assigned to transport commodities of each type along each route. These profiles include attributes such as ship size, engine horsepower, engine load factors, age, and engine fuel efficiency. This information was subsequently used to estimate average daily fuel consumption for each typical ship type and size category.

The eight GI commodity categories were mapped to the appropriate vessel type using information from Clarkson's Shipping Database.[50] These assignments are shown in Table 4D-3.

Table 4D-3 Assignment of Commodities to Vessel Types

COMMODITY	SHIP CATEGORY	VESSEL TYPE
Liquid bulk – crude oil	Crude Oil Tankers	Tanker
Liquid bulk – refined petroleum products	Product Tankers	Product Carrier
Liquid bulk – residual petroleum products	Product Tankers	Product Carrier
Liquid bulk – chemicals (organic and inorganic)	Chemical Tankers	Chemical & Oil Carrier
Liquid bulk – natural gas (including LNG and LPG)	Gas Carriers	LNG Carrier, LPG Carrier, Chemical & LPG Carrier, Ethylene/LPG, Ethylene/LPG/Chemical, LNG/Ethylene/LPG, LNG/Regasification, LPG/Chemical, LPG/Oil, Oil & Liquid Gas Carrier
Dry bulk (e.g. grain, coal, steel, ores, and scrap)	Dry Bulk Carriers	Bulk Carrier
General cargo (including neobulk, lumber/forest products)	General Cargo	General Cargo Liner, Reefer, General Cargo Tramp, Reefer Fish Carrier, Ro-Ro, Reefer/Container, Ro-Ro Freight/Passenger, Reefer/Fleet Replen., Ro-Ro/Container, Reefer/General Cargo, Ro-Ro/Lo-Lo, Reefer/Pallets Carrier, Reefer/Pass./Ro-Ro, Reefer/Ro-Ro Cargo
Containerizable cargo	Container Ships	Fully Cellular Container

Each of the vessel types were classified by their cargo carrying capacity or deadweight tons (DWT). The size categories were identified based on both industry definitions and natural size breaks within the data. Table 4D-4 summarizes the size categories that were used in the analysis and provides other information on the general attributes of the vessels from Clarkson's Shipping Database. The vessel size descriptions are also used to define shipping routes based on physical limitations that are represented by canals or straits through which ships can pass.

Table 4D-4 Fleet Characteristics

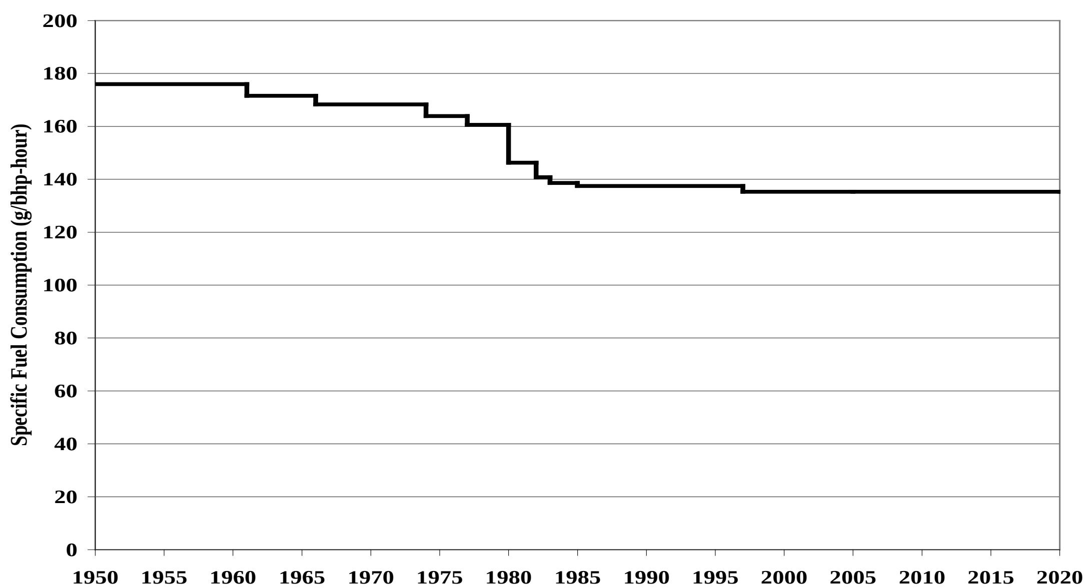
SHIP TYPE	SIZE BY DWT	MINIMUM SIZE (DWT)	MAXIMUM SIZE (DWT)	NUMBER OF SHIPS	TOTAL DWT (millions)	TOTAL HORSE-POWER (millions)	TOTAL KILO-WATTS (millions)
Container	Suezmax	83,000	140,000	101	9.83	8.56	6.38
	PostPanamax	56,500	83,000	465	30.96	29.3	21.85
	Panamax	42,100	56,500	375	18.04	15.04	11.21
	Intermediate	14,000	42,100	1,507	39.8	32.38	24.14
	Feeder	0	14,000	1,100	8.84	7.91	5.90
General Cargo	All	All		3,214	26.65	27.07	20.18
Dry Bulk	Capesize	79,000	0	715	114.22	13.81	10.30
	Panamax	54,000	79,000	1,287	90.17	16.71	12.46
	Handymax	40,000	54,000	991	46.5	10.69	7.97
	Handy	0	40,000	2,155	58.09	19.58	14.60
Crude Oil Tanker	VLCC	180,000	0	470	136.75	15.29	11.40
	Suezmax	120,000	180,000	268	40.63	5.82	4.34
	AFRAmax	75,000	120,000	511	51.83	8.58	6.40
	Panamax	43,000	75,000	164	10.32	2.17	1.62
	Handymax	27,000	43,000	100	3.45	1.13	0.84
	Coastal	0	27,000	377	3.85	1.98	1.48
Chemical Tanker	All	All		2,391	38.8	15.54	11.59
Petroleum Product Tanker	AFRAmax	68,000	0	226	19.94	3.6	2.68
	Panamax	40,000	68,000	352	16.92	4.19	3.12
	Handy	27,000	40,000	236	7.9	2.56	1.91
	Coastal	0	27,000	349	3.15	1.54	1.15
Natural Gas Carrier	VLGC	60,000	0	157	11.57	5.63	4.20
	LGC	35,000	60,000	140	6.88	2.55	1.90
	Midsize	0	35,000	863	4.79	3.74	2.79
Other	All	All		7,675	88.51	53.6	39.96
Total	--	--	--	26,189	888.4	308.96	230.36

The average fuel consumption for each vessel type and size category was estimated in a multi-step process using individual vessel data on engine characteristics. Clarkson's Shipping Database Register provides each ship's total installed horsepower (HP), type of propulsion (diesel or steam), and year of build. These characteristics are then matched to information on typical specific fuel consumption (SFC), which is expressed in terms of grams of bunker fuel burned per horsepower-hour (g/HP-hr), which is equivalent to 1.341 g/kW-hr.

The SFC values are based on historical data from Wärtsilä Sulzer, a popular manufacturer of diesel engines for marine vessels. RTI added an additional 10 percent to the reported historical number, (i.e.,"test bed" or "catalogue") to account for the guaranteed tolerance level and an in-service SFC differential. Overall, the 10 percent estimate is consistent with other analyses that show some variation between the "test bed" SFC values reported in the manufacturer product catalogues and those observed in actual service. This difference is explained by the fact that old engines tend to consume more fuel than brand new engines and in-service fuels may be different than the test bed fuels.[51]

Figure 4D-3 shows SFC values that were used in the model regarding the evolution of specific fuel oil consumption rates for diesel engines over time. Engine efficiency in terms of SFC has improved over time, most noticeably in the early 1980s in response to rising fuel prices. However, there is a tradeoff between improving fuel efficiency and reducing emissions. Conversations with engine manufacturers indicate that it is reasonable to assume SFC will remain constant for the projection period of this study, particularly as they focus on meeting NO_X emission standards as required by MARPOL Annex VI, or other potential pollution control requirements. Post-2000 SFC values are constant at approximately 135 g/hp-hr (180 g/kW-hr), for diesel engines. However, RTI assumed a fixed SFC of 220 g/HP-hr (295 g/kW-hr) for steam engines operating on bunker fuel.

Figure 4D--3 Diesel Engine Specific Fuel Consumption



Using the above information, the average daily fuel consumption (AFC), expressed in metric tons of fuel at full engine load, for each vessel type and size category is found using the following equation.

Equation 4D-1

$$\text{Fleet AFC}_{v,s} = \frac{1}{N}\sum\left[SFC_{v,s} \times HP_{v,s} \times 10^{-6}\, tonnes/g\right]$$

Where:

- Fleet AFC = Average daily fuel consumption in metric tonnes at full engine load
- *v* = Vessel type
- *s* = Vessel size category
- N = Number of vessels in the fleet
- SFC = Specific fuel consumption in grams of bunker fuel burned per horsepower-hour in use(g/HP-hr)
- HP = Total installed engine power, in horsepower (HP)
- 10^6 tonnes/g = Conversion from grams to metric tonnes

As previously noted, AFC values calculated in the above equation are based on total horsepower; therefore, they must be scaled down to reflect typical operation using less than 100 percent of the horsepower rating, i.e., actual engine load. Table 4D-5 shows the engine load factors that were used to estimate the typical average daily fuel consumption (tonnes/day) for the main propulsion engine and the auxiliary engines when operated at sea and in port.[52]

Table 4D-5 Main and Auxiliary Engine Load Factors

VESSEL TYPE	MAIN ENGINE LOAD FACTOR (%)	AUXILIARY ENGINE AS % OF MAIN ENGINE	AUXILIARY ENGINE AS % OF MAIN ENGINE AT SEA
Container Vessels	80	22.0	11.0
General Cargo Carriers	80	19.1	9.5
Dry Bulk Carriers	75	22.2	11.1
Crude Oil Tankers	75	21.1	10.6
Chemical Tankers	75	21.1	10.6
Petroleum Product Tankers	75	21.1	10.6
Natural Gas Carrier	75	21.1	10.6
Other	70	20.0	10.0

The RTI analysis also assumes that the shipping fleet changes over time as older vessels are scrapped and replaced with newer ships. Specifically, vessels over 25 years of age are retired and replaced by new ships of the most up-to-date configuration. This assumption leads to the following change in fleet characteristics over the projection period.

- New ships have engines rated at the current SFC, so even though there are no further improvements in specific fuel consumption, the fuel efficiency of the fleet as a whole will improve over time through retirement and replacement.
- Due to modern building materials and designs, new ships will weigh as much as the average ship built in 2005, so the total cargo capacity of the fleet will increase over time as smaller ships retire and are replaced.
- Container ships will increase in size over time on the trade routes between Asia to either North America or Europe due to new designs.

Trade Analysis by Commodity Type and Trade Route

Determining the total number of days at sea and in port requires information on the relative amount of each commodity that is carried by the different ship type size categories on each of the trade routes. For example, to serve the large crude oil trade from the Middle East Gulf region to the Gulf Coast of the U.S., 98 percent of the deadweight tonnage is carried on very large oil tankers, while the remaining 2 percent is carried on smaller Suezmax vessels. After the vessel type size distribution was found, voyage parameters were estimated. Specifically, these are days at sea and in port for each voyage (based on ports called, distance between ports, and ship speed**)**, and the number of voyages (based on cargo volume projected by GI and the DTW from Clarkson's Shipping Database). The length of each voyage and number of voyages were used to estimate the total number of days at sea and at port, which is a parameter used later to calculate total fuel consumption for each vessel type and size category over each route and for each commodity type. (More information on determining the round trip distance for each voyage that is associated with cargo demand for the U.S. is provided in the next section.)

The days at sea were calculated by dividing the round trip distance by the average vessel speed.

Equation 4D-2

$$\text{Days at Sea Per Voyage}_{v,s,route} = \frac{\text{round trip distance route}}{\text{speed}_{v,s} \times 24\text{ hrs}}$$

Where:

v = Vessel type
s = Vessel size category
route = Unique trip itinerary
round trip route distance = Trip length in nautical miles
speed = Vessel speed in knots or nautical miles per hour
24 hrs = Number of hours in one day

Table 4D-6 presents the speeds by vessel type that were used in the analysis.[52] These values are the same for all size categories, and are assumed to remain constant over the forecast period.

Table 4D-6 Vessel Speed by Type

VESSEL TYPE	SPEED (knots)
Crude Oil Tankers	13.2
Petroleum Product Tankers	13.2
Chemical Tankers	13.2
Natural Gas Carriers	13.2
Dry Bulk Carriers	14.1
General Cargo Vessels	12.3
Container Vessels	19.9
Other	12.7

The number of voyages along each trade route was estimated for each vessel type, *v*, and size category, *s*, serving a given route by dividing the tonnes of cargo moved by the amount of cargo (DTW) per voyage.

Equation 4D-3

$$\text{Number of Voyages}_{v,s,trade} = \frac{\text{total metric tonnes of cargo moved}}{\text{fleet average DWT}_{v,s} \times \text{utilization rate}}$$

Where:

v = Vessel type

s = Vessel size category

trade = Commodity type

Fleet average DWT = Median dead weight tonnage carrying capacity in metric tons

Utilization rate = Fraction of total ship DWT capacity used

The cargo per voyage is based on the fleet average ship size from the vessel profile analysis. For most cargo, a utilization rate of 0.9 is assumed to be constant throughout the forecast period. Lowering this factor would increase the estimated number of voyages required to move the forecasted cargo volumes, which would lead to an increase in estimated fuel demand.

In addition to calculating the average days at sea per voyage, the average days in port per voyage was also determined by estimating that most types of cargo vessels spend four days in port per voyage (two loading and two unloading). RTI notes, however, that this can vary somewhat by commodity and port.

Worldwide Estimates of Fuel Demand

This section describes how the information from the vessel and trade analyses were used to calculate the total annual fuel demand associated with international cargo trade. Specifically, for each year, *y*, of the analysis, the total bunker fuel demand is the sum of the fuel consumed on each route for each commodity type (trade). The fuel consumed on each route for each trade is the sum of the fuel consumed for each route and trade for that year by the main engines and auxiliary engines when operated at sea and in port. These summations are illustrated by the following equations.

Equation 4D-4

$$FC_y = \sum_{trade} \sum_{route} FC_{trade,route,year}$$
$$= \sum_{trade} \sum_{route} \left[AFC_{trade,route,y\,at\,sea} \text{ x } Days\ at\ Sea_{trade,route,y} + AFC_{trade,route,y\,at\,port} \text{ x } Days\ at\ Port_{trade,route,y} \right]$$

Where:

FC = Fuel consumed in metric tonnes
y = calendar year
trade = Commodity type
route = Unique trip itinerary
AFC = Average daily fuel consumption in metric tonnes
yatsea = Calendar year main and auxiliary engines are operated at sea
yatport = Calendar year main and auxiliary engines are operated in port

Equations 4D-5

$$AFC_{trade,route,y\,at\,sea} = \sum_{v,s,t,r} (\text{Percent of trade along route})_{v,s} \left[\text{Fleet AFC}_{v,s} \text{ x } \left(\text{MELF} + \text{AE at sea LF} \right) \right]$$
$$AFC_{trade,route,y\,at\,port} = \sum_{v,s,t,r} (\text{Percent of trade along route})_{v,s} \left[\text{Fleet AFC}_{v,s} \text{ x AE import LF} \right]$$
$$\text{Days at Sea}_{trade,route,y} = \sum_{v,s,t,r} (\text{Percent of trade along route})_{v,s} \left[\text{Days at sea per voyage}_{v,s} \text{ x Number of voyages}_{v,s} \right]$$
$$\text{Days at Port}_{trade,route,y} = \sum_{v,s,t,r} (\text{Percent of trade along route})_{v,s} \left[\text{Days at port per voyage x Number of voyages} \right]$$

Where:

- AFC = Average daily fuel consumption in metric tones
- *trade* = Commodity type
- *route* = Unique trip itinerary
- *yatsea* = Calendar year main and auxiliary engines are operated at sea
- *yatport* = Calendar year main and auxiliary engines are operated in port
- *y* = calendar year
- *v* = Vessel type
- *s* = Vessel size category
- *t* = Trade
- *r* = Route
- Fleet AFC = Average daily fuel consumption in metric tonnes at full engine load
- MELF = main engine load factor, unitless
- AE at sea LF = auxiliary engine at-sea load factor, unitless
- AE in port LF = auxiliary engine in-port load factor, unitless

The inputs for these last four equations were all derived from the vessel analysis and the trade analysis previously described.

Worldwide Bunker Fuel Consumption

Based on the methodology outlined above, estimates of global fuel consumption over time were computed, and growth rates were determined from these projections.

Figure 4D-4 Worldwide Bunker Fuel Consumption

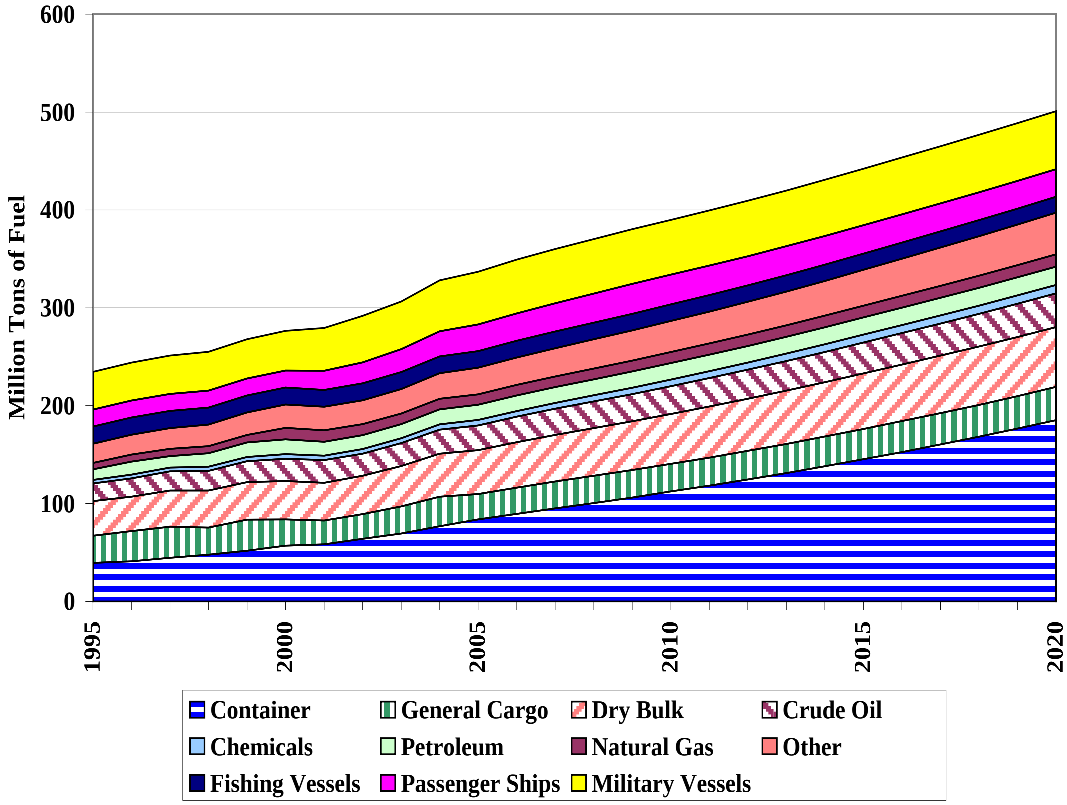
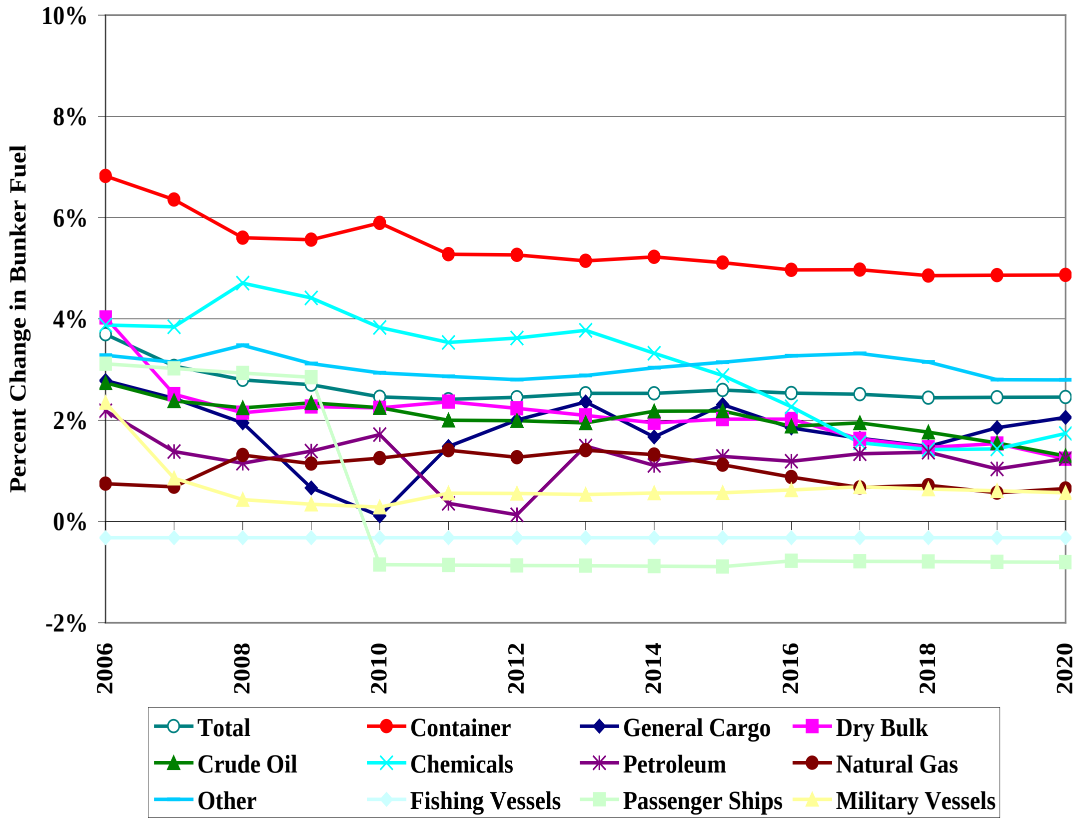


Figure 4D-4 shows estimated world-wide bunker fuel consumption by vessel type. Figure 4D-5 shows the annual growth rates by vessel-type/cargo that are used in the projections shown in Figure 4D-4. Total annual growth is generally between 2.5 percent and 3.5 percent over the time period between 2006 and 2020 and generally declines over time, resulting in an average annual growth rate of around 2.6 percent.

Figure 4D-5 Annual Growth Rate in World-Wide Bunker Fuel Use by Commodity Type



Fuel Demand Used to Import and Export Cargo for the United States

The methodology described previously provides an estimate of fuel consumption for international cargo worldwide. RTI also estimates the subset of fuel demand for cargo imported to and exported from five regions of the U.S. These five regions are North Pacific, South Pacific, Gulf Coast, East Coast, and the Great Lakes. For this analysis, the same equations as earlier were used, but were limited to routes that carried cargo between specific cities in Asia, Europe, and the Middle East to the various ports in the specific regions of the U.S.

The trip distances for non-container vessel types were developed from information provided by the Worldscale Association and Maritime Chain.[53] The data from Worldscale is considered to be the industry standard for measuring port-to-port distances, particularly for tanker traffic. The reported distances account for common routes through channels, canals, or straits. This distance information was supplemented by data from Maritime Chain, a web service that provides port-to-port distances along with some information about which channels, canals, or straits must be entered on the voyage.

Voyage distances for container vessels are based on information from the Containerization International Yearbook (CIY)[54] and calculations by RTI. CIY provides voyage information for all major container services. Based on the frequency of the service, number of vessels assigned to that service, and the number of days in operation per year, RTI estimated the average length of voyages for the particular bilateral trade routes in the Global Insights trade forecasts.

The distance information developed above was combined with the vessel speeds previously shown in Table 4D-6 to find the length of a voyage in days. Table 4D-7 presents the day lengths for non-containerized vessel types and Table 4D-8 shows the day lengths for container vessels.

Table 4D-7 Day Length for Voyages for Non-Container Cargo Ship (approximate average)

GLOBAL INSIGHTS TRADE REGIONS	DAYS PER VOYAGE				
	U.S. South Pacific	U.S. North Pacific	U.S. East Coast	U.S. Great Lakes	U.S. Gulf
Africa East-South	68	75	57	62	54
Africa North-Mediterranean	49	56	37	43	47
Africa West	56	63	36	46	43
Australia-New Zealand	48	47	65	81	63
Canada East	37	46	7	18	19
Canada West	11	5	40	58	39
Caspian Region	95	89	41	46	48
China	41	36	73	87	69
Europe Eastern	61	68	38	45	46
Europe Western-North	53	60	24	32	34
Europe Western-South	54	61	30	37	37
Greater Caribbean	26	33	16	29	17
Japan	35	31	65	81	62
Middle East Gulf	77	72	56	65	83
Pacific High Growth	52	48	67	76	88
Rest of Asia	68	64	66	64	73
Russia-FSU	64	71	38	46	48
Rest of South America	51	30	41	46	44

Table 4D-8 Day Length for Voyages for Container-Ship Trade Routes

ORIGIN – DESTINATION REGIONS	DAYS PER VOYAGE
Asia – North America (Pacific)	37
Europe – North America (Atlantic)	37
Mediterranean – North America	41
Australia/New Zealand – North America	61
South America – North America	48
Africa South – North America (Atlantic)	54
Africa West – North America (Atlantic)	43
Asia – North America (Atlantic)	68

ORIGIN – DESTINATION REGIONS	DAYS PER VOYAGE
Europe – North America (Pacific)	64
Africa South – North America (Pacific)	68
Africa West – North America (Pacific)	38
Caspian Region – North America (Atlantic)	42
Caspian Region – North America (Pacific)	38
Middle East/Gulf Region – North America (Atlantic)	63
Middle East/Gulf Region – North America (Pacific)	80

Bunker Fuel Consumption for the United States

Figure 4D-6 and Figure 4D-7 present the estimates of fuel use for delivering trade goods to and from the U.S. The results in Figure 4D-6 show an estimated historical bunker fuel use in year 2001 of around 47 million tonnes (note: while this fuel is used to carry trade goods to and from the U.S., it is not necessarily all purchased in the U.S. and is not all burned in U.S. waters). This amount is estimated to grow to over 90 million tonnes by 2020 with the most growth occurring on trade routes from the East Coast and the South Pacific region of the West Coast.

Figure 4D-6 Bunker Fuel Used to Import and Export Cargo by Region of the United States

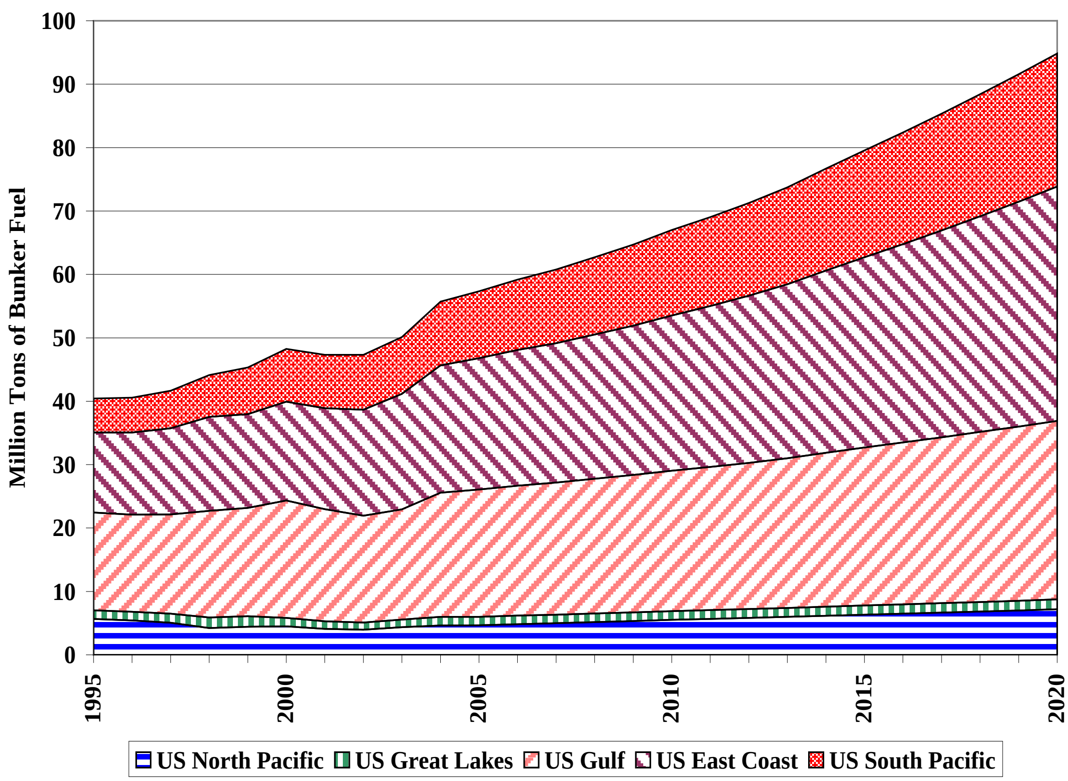
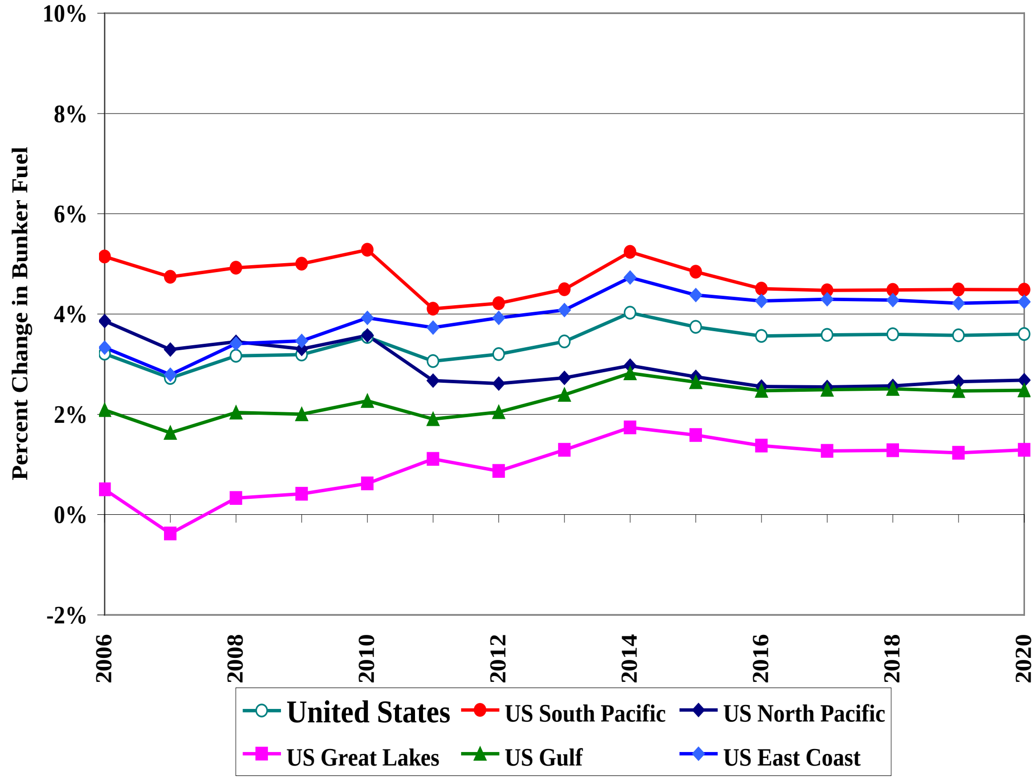


Figure 4D-7 shows the estimated annual growth rates for the fuel consumption which were used in the projections shown in Figure 4D-6. Overall, the average annual growth rate in marine bunkers associated with future U.S. trade is 3.4 percent between 2005 and 2020.

Figure 4D-7 Annual Growth Rates for Bunker Fuel Used to Import and Export Cargo by Region of the United States



2020 Growth Factors for Nine Geographic Regions

The results of the RTI analysis described above were used to develop the growth factors that were necessary to project the 2002 base year emissions inventory out to 2020. The next two sections describe how the five U.S. regions RTI examined were associated with the nine U.S. regions analyzed in this report, and how the specific growth rates for each of the nine U.S. regions were developed.

<u>Mapping the RTI Regional Results to the Nine Region Analysis</u>

The nine U.S. geographic regions analyzed in this study were designed to be consistent with the five RTI U.S. regional modeling domains. More specifically, four of the nine U.S. geographic areas in this study, i.e., Alaska East, Alaska West, Hawaii East, and Hawaii West are actually subsets of the two broader regional areas that were analyzed by RTI, i.e., the North Pacific for both Alaska regions and the South Pacific for Hawaii. Therefore, the growth rate information from the broader region was assumed to be representative for the smaller subset regions.

The nine U.S. geographic regions represented in the emission inventory study are presented in Figure 2-1. The association of the RTI U.S. regions to the emission inventory regions is shown in Table 4D-9.

Table 4D-9 Association of the RTI U.S. Regions to the Nine Emission Inventory Regions

CONSUMPTION REGION	CORRESPONDING EMISSION INVENTORY REGION
North Pacific	North Pacific (NP)
North Pacific	Alaska East (AE)
North Pacific	Alaska West (AW)
South Pacific	South Pacific (SP)
South Pacific	Hawaii East (HE)
South Pacific	Hawaii West (HW)
Gulf	Gulf Coast (GC)
East Coast	East Coast (EC)
Great Lakes	Great Lakes (GL)

Growth Factors for the Emission Inventory Analysis

Emission inventories for 2020 are estimated by multiplying the 2002 baseline inventory for each region by a corresponding growth factor that was developed from the RTI U.S. regional results. Specifically, the average annual growth rate from 2002-2020 was calculated for each of the five U.S. regions. Each regional growth rate was then compounded over the inventory projection time period for 2020, i.e., 18 years. The resulting multiplicative growth factors for each emission inventory region and the associated RTI average annual growth rates are presented in Table 4D-10 for 2020.

Table 4D-10 Regional Emission Inventory Growth Rate Factors for 2020

EMISSION INVENTORY REGION	2002-2020 AVERAGE ANNUALIZED GROWTH RATE (%)	MULTIPLICATIVE GROWTH RATE FACTOR RELATIVE TO 2002
Alaska East (AE)	3.3	1.79
Alaska West (AW)	3.3	1.79
East Coast (EC)	4.5	2.21
Gulf Coast (GC)	2.9	1.67
Hawaii East (HE)	5.0	2.41
Hawaii West (HW)	5.0	2.41
North Pacific (NP)	3.3	1.79
South Pacific (SP)	5.0	2.41
Great Lakes (GL)	1.7	1.35

Chapter 4 References

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CHAPTER 5: Air Quality, Health and Environmental Impacts and Quantified Benefits of Reduced Emissions from Great Lake Ships

The air quality and benefits modeling we performed in support of our 2010 Category 3 marine rule is a national-level analysis, reflecting the fact that our Coordinated Strategy is a national program that applies equally throughout the United States.[1] In response to stakeholder comments during the regulatory process, we also prepared a Memorandum to the Docket in which we broke out information with respect to air quality impacts, costs, and benefits associated with applying the engine and fuel ECA requirements to the Great Lakes.[2] This chapter expands on the air quality impacts and human health and welfare benefits discussion contained in that memorandum.

This chapter consists of four parts. First, we describe the air pollutants from Category 3 engines and their fuels that will be reduced by the Coordinated Strategy. Then we describe the human health and environmental effects associated with exposure to these pollutants. This is followed by a description of the air quality impacts of these pollutants and how these are expected to be reduced in the Great Lakes region as a result of the application of the ECA fuel and engine requirements. Finally, we discuss the human health and welfare benefits of these air quality improvements. While the focus of this study is on the ECA fuel sulfur limits, which will reduce PM emissions, this chapter includes information on the other benefits of the application of the Coordinated Strategy on the Great Lakes.

Because it is not possible to isolate the potential impacts of the inventory reductions occurring in the Northeast Atlantic portion of the North American ECA, estimated air quality improvements are presented only for the Great Lakes states west of Pennsylvania. In addition, because no new modeling was performed for this analysis, the estimates presented below do not take into account the Great Lakes inventory adjustments described in Chapter 4. While the impact of those adjustments on the air quality estimates presented below is unknown without additional modeling, the vessel inventory reductions of 87 and 96 percent for PM and SO_X, respectively, will undoubtedly assist Great Lakes states' efforts to achieve and maintain National Ambient Air Quality Standards (NAAQS) and help provide cleaner air throughout the region.

5.1 Types of Pollutants from Great Lakes Ships

The emissions that will be reduced from Great Lakes ships and their fuels include PM, SO_X and NO_X. These emissions contribute to air pollution in the form of elevated ambient levels of PM, ozone, NO_X, and SO_X, as well as air toxics. Each of these pollutants is presented in this section; their health and environmental effects are described in Section 5.2.

5.1.1 Particulate Matter

Particulate matter (PM) is a generic term for a broad class of chemically and physically diverse substances. It can be principally characterized as discrete particles that exist in the condensed (liquid or solid) phase spanning several orders of magnitude in size.

Particles span many sizes and shapes and consist of numerous different chemicals. Current NAAQS use $PM_{2.5}$ as the indicator for fine particles (with $PM_{2.5}$ referring to particles with a nominal mean aerodynamic diameter less than or equal to 2.5 µm). The NAAQS use PM_{10} as the indicator for purposes of controlling the coarse fraction of PM, referred to as thoracic coarse particles or coarse-fraction particles. This category generally includes particles with a nominal mean aerodynamic diameter greater than 2.5 µm and less than or equal to 10 µm, or $PM_{10-2.5}$). A third category of PM, ultrafine particles (UFPs), is a subset of fine particles, generally less than 100 nanometers (0.1 µm) in aerodynamic diameter.

Particles originate from various stationary and mobile sources and are also formed through atmospheric chemical reactions. The former are often referred to as "primary" particles, and the latter as "secondary" particles. In addition, there are also physical, non-chemical reaction mechanisms that contribute to secondary particles. Particle pollution also varies by time of year and location, and is affected by several weather-related factors, such as temperature, clouds, humidity, and wind. A further layer of complexity comes from a particle's ability to shift between solid, liquid, and gaseous phases, which is influenced by concentration, meteorology, and temperature.

Fine particles are produced primarily by combustion processes and by transformations of gaseous emissions (e.g., SO_X, NO_X and volatile organic compounds (VOCs)) in the atmosphere. The chemical and physical properties of $PM_{2.5}$ may vary greatly with time, region, meteorology and source category. Thus, $PM_{2.5}$ may include a complex mixture of different chemicals including sulfates, nitrates, organic compounds, elemental carbon and metal compounds. These particles can remain in the atmosphere for days to weeks and travel through the atmosphere up to hundreds or even thousands of kilometers.[3]

5.1.2 Ozone

Ground-level ozone pollution is typically formed by the reaction of VOCs and NO_X in the lower atmosphere in the presence of sunlight. These pollutants, often referred to as ozone precursors, are emitted by many types of pollution sources such as highway and nonroad motor vehicles and engines, power plants, chemical plants, refineries, makers of consumer and commercial products, industrial facilities, and smaller area sources.

The science of ozone formation, transport, and accumulation is complex. Ground-level ozone is produced and destroyed in a cyclical set of chemical reactions, many of which are sensitive to temperature and sunlight. When ambient temperatures and sunlight levels remain high for several days and the air is relatively stagnant, ozone and its precursors can build up and result in more ozone than typically occurs on a single high-temperature day. Ozone can be transported hundreds of miles downwind from precursor emissions, resulting in elevated ozone levels even in areas with low VOC or NO_X emissions.

The highest levels of ozone are produced when both VOC and NO_X emissions are present in significant quantities on clear summer days. Relatively small amounts of NO_X enable ozone to form rapidly when VOC levels are relatively high, but ozone production is quickly limited by removal of the NO_X. Under these conditions NO_X reductions are highly effective in reducing ozone while VOC reductions have little effect. Such conditions are called "NO_X-

limited." Since the contribution of VOC emissions from biogenic (natural) sources to local ambient ozone concentrations can be significant, even some areas where man-made VOC emissions are relatively low can be NO_X-limited.

Ozone concentrations in an area also can be lowered by the reaction of nitric oxide (NO) with ozone, forming nitrogen dioxide (NO_2); however as the air moves downwind and the cycle continues, the NO_2 forms additional ozone. The importance of this reaction depends, in part, on the relative concentrations of NO_X, VOC, and ozone, all of which change with time and location. When NO_X levels are relatively high and VOC levels relatively low, NO_X forms inorganic nitrates (i.e., particles) but relatively little ozone. Such conditions are called "VOC-limited." Under these conditions, VOC reductions are effective in reducing ozone, but NO_X reductions can actually increase local ozone under certain circumstances. Even in VOC-limited urban areas, NO_X reductions are not expected to increase ozone levels if the NO_X reductions are sufficiently large. Rural areas are usually NO_X-limited, due to the relatively large amounts of biogenic VOC emissions in such areas. Urban areas can be either VOC- or NO_X-limited, or a mixture of both, in which ozone levels exhibit moderate sensitivity to changes in either pollutant.

5.1.3 Sulfur Oxides and Nitrogen Oxides

Sulfur dioxide (SO_2), a member of the sulfur oxide (SO_X) family of gases, is formed from burning fuels containing sulfur (e.g., coal or oil), extracting gasoline from oil, or extracting metals from ore. Nitrogen dioxide (NO_2) is a member of the nitrogen oxide (NO_X) family of gases. Most NO_2 is formed in the air through the oxidation of nitric oxide (NO) emitted when fuel is burned at a high temperature. SO_2 and NO_2 can dissolve in water droplets and further oxidize to form sulfuric and nitric acid which react with ammonia to form sulfates and nitrates, both of which are important components of ambient PM. NO_X along with non-methane hydrocarbons (NMHC) are the two major precursors of ozone.

5.1.4 Air Toxics

Marine diesel engines emit diesel exhaust (DE), a complex mixture comprised of carbon dioxide, oxygen, nitrogen, water vapor, carbon monoxide, nitrogen compounds, sulfur compounds and numerous low-molecular-weight hydrocarbons. A number of these gaseous hydrocarbon components are individually known to be toxic including aldehydes, benzene and 1,3-butadiene. The diesel particulate matter (DPM) present in diesel exhaust consists of fine particles ($< 2.5\mu m$), including a subgroup with a large number of ultrafine particles ($< 0.1\ \mu m$). These particles have large surface areas which make them an excellent medium for adsorbing organics, and their small size makes them highly respirable and able to deposit deep in the lung. Diesel PM contains small quantities of numerous mutagenic and carcinogenic compounds associated with the particles (and also organic gases). In addition, while toxic trace metals emitted by marine diesel engines represent a very small portion of the national emissions of metals (less than one percent) and are a small portion of diesel PM (generally much less than one percent of diesel PM), we note that several trace metals of potential toxicological significance and persistence in the environment are emitted by diesel engines. These trace metals include chromium, manganese, mercury, and nickel. In addition, small amounts of dioxins have been measured in highway engine diesel exhaust, some of which may partition into the particulate phase. Dioxins are a major health concern but diesel engines are a minor contributor to overall dioxin emissions.

Diesel exhaust varies significantly in chemical composition and particle sizes between different engine types (heavy-duty, light-duty), engine operating conditions (idle, accelerate, decelerate), and fuel formulations (high/low sulfur fuel).[4] Also, there are emission differences between on-road and nonroad engines since the nonroad engines are generally of older technology. After being emitted, diesel exhaust undergoes dilution as well as chemical and physical changes in the atmosphere. The lifetime for some of the compounds present in diesel exhaust ranges from hours to days.

A number of health studies have been conducted regarding diesel exhaust. These include epidemiologic studies of lung cancer in groups of workers and animal studies focusing on non-cancer effects specific to diesel exhaust exposure. Diesel exhaust PM (including the associated organic compounds which are generally high molecular weight hydrocarbon types but not the more volatile gaseous hydrocarbon compounds) is generally used as a surrogate measure for diesel exhaust.

5.2 Human Health Effects Associated with Exposure to Pollutants

Ambient levels of PM, ozone, SO_X, NO_X, and air toxics contribute to serious human health and environmental concerns. The human health impacts are described in this section; environmental impacts are described in Section 5.3.

5.2.1 Particulate Matter

The summary of the health effects associated with exposure[A] to ambient concentrations of PM presented in this section is based on the information and conclusions in the Integrated Science Assessment (ISA) for Particulate Matter (December 2009) prepared by EPA's Office of Research and Development (ORD).[5B] Interested readers should refer to that document for more detailed information.

The ISA concludes that ambient concentrations of PM are associated with a number of adverse health effects.[C] The ISA characterizes the weight of evidence for different health effects associated with three PM size ranges: $PM_{2.5}$, $PM_{10-2.5}$, and UFPs. The discussion below highlights the ISA's conclusions pertaining to these three size fractions of PM, considering variations in both short-term and long-term exposure periods.

With respect to effects associated with short-term exposure to $PM_{2.5}$, the ISA concludes that cardiovascular effects and all-cause cardiovascular- and respiratory-related mortality are

[A] Personal exposure includes contributions from many different types of particles, from many sources, and in many different environments. Total personal exposure to PM includes both ambient and nonambient components; and both components may contribute to adverse health effects.
[B] The ISA is available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=216546
[C] The ISA evaluates the health evidence associated with different health effects, assigning one of five "weight of evidence" determinations: causal relationship, likely to be a causal relationship, suggestive of a causal relationship, inadequate to infer a causal relationship, and not likely to be a causal relationship. For definitions of these levels of evidence, please refer to Section 1.5 of the ISA.

causally associated with short-term exposure to $PM_{2.5}$.[6] It also concludes that respiratory effects are likely to be causally associated with short-term exposure to $PM_{2.5}$, including respiratory emergency department (ED) visits and hospital admissions for chronic obstructive pulmonary disease (COPD), respiratory infections, and asthma; and exacerbation of respiratory symptoms in asthmatic children.

With respect to effects associated with long-term exposure to $PM_{2.5}$, the ISA concludes that there are causal associations between long-term exposure to $PM_{2.5}$ and cardiovascular effects, such as the development/progression of cardiovascular disease (CVD), and premature mortality, particularly from cardiopulmonary causes.[7] It also concludes that long-term exposure to $PM_{2.5}$ is likely to be causally associated with respiratory effects, such as reduced lung function growth, increased respiratory symptoms, and asthma development. The ISA characterizes the evidence as suggestive of a causal relationship for associations between long-term $PM_{2.5}$ exposure and reproductive and developmental outcomes, such as low birth weight and infant mortality. It also characterizes the evidence as suggestive of a causal relationship between $PM_{2.5}$ and cancer incidence, mutagenicity, and genotoxicity.

With respect to effects associated with $PM_{10\text{-}2.5}$, the ISA summarizes evidence related to short-term exposure to $PM_{10\text{-}2.5}$. $PM_{10\text{-}2.5}$ is the fraction of PM_{10} particles that is larger than $PM_{2.5}$.[8] The ISA concludes that available evidence is suggestive of a causal relationship between short-term exposures to $PM_{10\text{-}2.5}$ and cardiovascular effects, such as hospitalizations for ischemic heart disease. It also concludes that the available evidence is suggestive of a causal relationship between short-term exposures to $PM_{10\text{-}2.5}$ and respiratory effects, including respiratory-related ED visits and hospitalizations and pulmonary inflammation. The ISA also concludes that the available literature suggests a causal relationship between short-term exposures to $PM_{10\text{-}2.5}$ and mortality. Data are inadequate to draw conclusions regarding health effects associated with long-term exposure to $PM_{10\text{-}2.5}$.[9]

Finally, with respect to effects associated with ultrafine particles, the ISA concludes that the evidence is suggestive of a causal relationship between short-term exposures to UFPs and cardiovascular effects, including changes in heart rhythm and vasomotor function (the ability of blood vessels to expand and contract).[10] The ISA also concludes that there is suggestive evidence of a causal relationship between short-term UFP exposure and respiratory effects. The types of respiratory effects examined in epidemiologic studies include respiratory symptoms and asthma hospital admissions, the results of which are not entirely consistent. There is evidence from toxicological and controlled human exposure studies that exposure to UFPs may increase lung inflammation and produce small asymptomatic changes in lung function. Data are inadequate to draw conclusions regarding health effects associated with long-term exposure to UFPs.[11]

5.2.2 Ozone

Exposure to ambient ozone contributes to a wide range of adverse health effects.[D] These health effects are well documented and are critically assessed in the EPA ozone air quality

[D] Human exposure to ozone varies over time due to changes in ambient ozone concentration and because people move between locations which have notable different ozone concentrations. Also, the amount of ozone delivered to the lung is not only influenced by the ambient concentrations but also by the individuals breathing route and rate.

criteria document (ozone AQCD) and EPA staff paper.[12,13] This summary is based on the data and conclusions in the ozone AQCD and staff paper, regarding the health effects associated with ozone exposure. Interested readers should refer to that document for more detailed information.

Ozone-related health effects include lung function decrements, respiratory symptoms, aggravation of asthma, increased hospital and emergency room visits, increased asthma medication usage, and a variety of other respiratory effects. Cellular-level effects, such as inflammation of lungs, have been documented as well. In addition, there is suggestive evidence of a contribution of ozone to cardiovascular-related morbidity and highly suggestive evidence that short-term ozone exposure directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality, but additional research is needed to clarify the underlying mechanisms causing these effects. In a recent report on the estimation of ozone-related premature mortality published by the National Research Council (NRC), a panel of experts and reviewers concluded that short-term exposure to ambient ozone is likely to contribute to premature deaths and that ozone-related mortality should be included in estimates of the health benefits of reducing ozone exposure.[14] People who appear to be more susceptible to effects associated with exposure to ozone include children, asthmatics and the elderly. Those with greater exposures to ozone, for instance due to time spent outdoors (e.g., children and outdoor workers), are also of concern.

Based on a large number of scientific studies, EPA has identified several key health effects associated with exposure to levels of ozone found today in many areas of the country. Short-term (1 to 3 hours) and prolonged exposures (6 to 8 hours) to ambient ozone concentrations have been linked to lung function decrements, respiratory symptoms, increased hospital admissions and emergency room visits for respiratory problems.[15, 16, 17, 18, 19, 20] Repeated exposure to ozone can increase susceptibility to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma.[21, 22, 23, 24, 25] Repeated exposure to sufficient concentrations of ozone can also cause inflammation of the lung, impairment of lung defense mechanisms, and possibly irreversible changes in lung structure, which over time could affect premature aging of the lungs and/or the development of chronic respiratory illnesses, such as emphysema and chronic bronchitis.[26, 27, 28, 29]

Children and adults who are outdoors and active during the summer months, such as construction workers, are among those most at risk of elevated ozone exposures.[30] Children and outdoor workers tend to have higher ozone exposure because they typically are active outside, working, playing and exercising, during times of day and seasons (e.g., the summer) when ozone levels are highest.[31] For example, summer camp studies in the Eastern United States and Southeastern Canada have reported statistically significant reductions in lung function in children who are active outdoors.[32, 33, 34, 35, 36, 37, 38, 39] Further, children are more at risk of experiencing health effects from ozone exposure than adults because their respiratory systems are still developing. These individuals (as well as people with respiratory illnesses, such as asthma, especially asthmatic children) can experience reduced lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during prolonged periods of moderate exertion.[40, 41, 42, 43]

5.2.3 Nitrogen Oxides

Information on the health effects of NO_2 can be found in the EPA Integrated Science Assessment (ISA) for Nitrogen Oxides.[44] Interested readers should refer to that document for more detailed information.

The EPA has concluded that the findings of epidemiologic, controlled human exposure, and animal toxicological studies provide evidence that is sufficient to infer a likely causal relationship between respiratory effects and short-term NO_2 exposure. The ISA concludes that the strongest evidence for such a relationship comes from epidemiologic studies of respiratory effects including symptoms, emergency department visits, and hospital admissions. The ISA also draws two broad conclusions regarding airway responsiveness following NO_2 exposure. First, the ISA concludes that NO_2 exposure may enhance the sensitivity to allergen-induced decrements in lung function and increase the allergen-induced airway inflammatory response following 30-minute exposures of asthmatics to NO_2 concentrations as low as 0.26 ppm. In addition, small but significant increases in non-specific airway hyperresponsiveness were reported following 1-hour exposures of asthmatics to 0.1 ppm NO_2. Second, exposure to NO_2 has been found to enhance the inherent responsiveness of the airway to subsequent nonspecific challenges in controlled human exposure studies of asthmatic subjects. Enhanced airway responsiveness could have important clinical implications for asthmatics since transient increases in airway responsiveness following NO_2 exposure have the potential to increase symptoms and worsen asthma control. Together, the epidemiologic and experimental data sets form a plausible, consistent, and coherent description of a relationship between NO_2 exposures and an array of adverse health effects that range from the onset of respiratory symptoms to hospital admission.

Although the weight of evidence supporting a causal relationship is somewhat less certain than that associated with respiratory morbidity, NO_2 has also been linked to other health endpoints. These include all-cause (nonaccidental) mortality, hospital admissions or emergency department visits for cardiovascular disease, and decrements in lung function growth associated with chronic exposure.

5.2.4 Sulfur Oxides

This section provides an overview of the health effects associated with SO_2. Additional information on the health effects of SO_2 can be found in the EPA Integrated Science Assessment for Sulfur Oxides.[45] Interested readers should refer to that document for more detailed information.

Following an extensive evaluation of health evidence from epidemiologic and laboratory studies, the U.S. EPA has concluded that there is a causal relationship between respiratory health effects and short-term exposure to SO_2. The immediate effect of SO_2 on the respiratory system in humans is bronchoconstriction. Asthmatics are more sensitive to the effects of SO_2 likely resulting from preexisting inflammation associated with this disease. In laboratory studies involving controlled human exposures to SO_2, respiratory effects have consistently been observed following 5-10 min exposures at SO_2 concentrations $\geq$ 0.4 ppm in asthmatics engaged in moderate to heavy levels of exercise, with more limited evidence of respiratory effects among exercising asthmatics exposed to concentrations as low as 0.2-0.3 ppm. A clear concentration-response relationship has been demonstrated in these studies following exposures to SO_2 at concentrations between 0.2 and 1.0 ppm, both in terms of increasing severity of respiratory symptoms and decrements in lung function, as well as the percentage of asthmatics adversely affected.

In epidemiologic studies, respiratory effects have been observed in areas where the mean 24-hour SO_2 levels range from 1 to 30 ppb, with maximum 1 to 24-hour average SO_2 values ranging from 12 to 75 ppb. Important new multicity studies and several other studies have found an association between 24-hour average ambient SO_2 concentrations and respiratory symptoms in children, particularly those with asthma. Generally consistent associations also have been observed between ambient SO_2 concentrations and emergency department visits and hospitalizations for all respiratory causes, particularly among children and older adults ($\geq$ 65 years), and for asthma. A limited subset of epidemiologic studies have examined potential confounding by copollutants using multipollutant regression models. These analyses indicate that although copollutant adjustment has varying degrees of influence on the SO_2 effect estimates, the effect of SO_2 on respiratory health outcomes appears to be generally robust and independent of the effects of gaseous and particulate copollutants, suggesting that the observed effects of SO_2 on respiratory endpoints occur independent of the effects of other ambient air pollutants.

Consistent associations between short-term exposure to SO_2 and mortality have been observed in epidemiologic studies, with larger effect estimates reported for respiratory mortality than for cardiovascular mortality. While this finding is consistent with the demonstrated effects of SO_2 on respiratory morbidity, uncertainty remains with respect to the interpretation of these associations due to potential confounding by various copollutants. The U.S. EPA has therefore concluded that the overall evidence is suggestive of a causal relationship between short-term exposure to SO_2 and mortality. Significant associations between short-term exposure to SO_2 and emergency department visits and hospital admissions for cardiovascular diseases have also been reported. However, these findings have been inconsistent across studies and do not provide adequate evidence to infer a causal relationship between SO_2 exposure and cardiovascular morbidity.

5.2.5 Air Toxics

Motor vehicle emissions, including emissions from Great Lakes vessels, contribute to ambient levels of air toxics known or suspected as human or animal carcinogens, or that have noncancer health effects.

The population experiences an elevated risk of cancer and other noncancer health effects from exposure to air toxics.[46] These compounds include, but are not limited to, benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, diesel particulate matter and exhaust organic gases, polycyclic organic matter (POM), and naphthalene. All of these air toxics are present in emissions from diesel engines.

These compounds were identified as national or regional risk drivers or contributors in the 2005 National-scale Air Toxics Assessment (NATA) and have significant inventory contributions from mobile sources. Although the 2005 NATA did not quantify cancer risks associated with exposure to diesel exhaust, EPA has concluded that diesel exhaust ranks with the other emissions that the 2005 NATA suggests pose the greatest relative risk. According to NATA for 2005, mobile sources were responsible for 43 percent of outdoor toxic emissions and over 50 percent of the cancer risk and noncancer hazard attributable to direct emissions from mobile and stationary sources.[E]

Noncancer health effects can result from chronic,[F] subchronic,[G] or acute[H] inhalation exposures to air toxics, and include neurological, cardiovascular, liver, kidney, and respiratory effects as well as effects on the immune and reproductive systems. According to the 2005 NATA, about three-fourths of the U.S. population was exposed to an average concentration of air toxics that has the potential for adverse noncancer respiratory health effects. This will continue to be the case in 2030, even though toxics concentrations will be lower.[47]

The NATA modeling framework has a number of limitations which prevent its use as the sole basis for setting regulatory standards. These limitations and uncertainties are discussed on the 2005 NATA website.[48] Even so, this modeling framework is very useful in identifying air toxic pollutants and sources of greatest concern, setting regulatory priorities, and informing the decision making process.

5.2.5.1 Potential Cancer Effects of Exposure to Diesel Exhaust

Exposure to diesel exhaust is of specific concern because it has been judged by EPA to pose a lung cancer hazard for humans at environmental levels of exposure.

EPA's 2002 final "Health Assessment Document for Diesel Engine Exhaust" (the EPA Diesel HAD) classified exposure to diesel exhaust as likely to be carcinogenic to humans by inhalation at environmental exposures, in accordance with the revised draft 1996/1999 EPA cancer guidelines.[49,50] In accordance with earlier EPA guidelines, exposure to diesel exhaust would similarly be classified as probably carcinogenic to humans (Group B1).[51,52] A number of other agencies (National Institute for Occupational Safety and Health, the International Agency for Research on Cancer, the World Health Organization, California EPA, and the U.S. Department of Health and Human Services) have made similar classifications.[53, 54,55,56,57] The Health Effects Institute has prepared numerous studies and reports on the potential carcinogenicity of exposure to diesel exhaust.[58,59,60]

More specifically, the EPA Diesel HAD states that the conclusions of the document apply to diesel exhaust in use today including both on-road and nonroad engines, such as those in Great

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[E] NATA also includes estimates of risk attributable to background concentrations, which includes contributions from long-range transport, persistent air toxics, and natural sources; as well as secondary concentrations, where toxics are formed via secondary formation. Mobile sources substantially contribute to long-range transport and secondarily formed air toxics.

[F] Chronic exposure is defined in the glossary of the Integrated Risk Information (IRIS) database (http://www.epa.gov/iris) as repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species).

[G] Defined in the IRIS database as exposure to a substance spanning approximately 10% of the lifetime of an organism.

[H] Defined in the IRIS database as exposure by the oral, dermal, or inhalation route for 24 hours or less.

Lakes vessels. The EPA Diesel HAD acknowledges that the studies were done on engines with generally older technologies and that "there have been changes in the physical and chemical composition of some diesel exhaust emissions (onroad vehicle emissions) over time, though there is no definitive information to show that the emission changes portend significant toxicological changes."

For the Diesel HAD, EPA reviewed 22 epidemiologic studies on the subject of the carcinogenicity of exposure to diesel exhaust in various occupations, finding increased lung cancer risk, although not always statistically significant, in 8 out of 10 cohort studies and 10 out of 12 case-control studies which covered several industries. Relative risk for lung cancer, associated with exposure, ranged from 1.2 to 1.5, although a few studies show relative risks as high as 2.6. Additionally, the Diesel HAD also relied on two independent meta-analyses, which examined 23 and 30 occupational studies respectively, and found statistically significant increases of 1.33 to 1.47 in smoking-adjusted relative lung cancer risk associated with diesel exhaust. These meta-analyses demonstrate the effect of pooling many studies and in this case show the positive relationship between diesel exhaust exposure and lung cancer across a variety of diesel exhaust-exposed occupations.[61,62,63]

EPA generally derives cancer unit risk estimates to calculate population risk more precisely from exposure to carcinogens. In the simplest terms, the cancer unit risk is the increased risk associated with average lifetime exposure of 1 $\mu g/m^3$. EPA concluded in the Diesel HAD that it is not currently possible to calculate a cancer unit risk for diesel exhaust due to a variety of factors that limit the current studies, such as a lack of standard exposure metric for diesel exhaust and the absence of quantitative exposure characterization in retrospective studies.

In the absence of a cancer unit risk, the Diesel HAD sought to provide additional insight into the significance of the diesel exhaust-cancer hazard by estimating possible ranges of risk that might be present in the population. An exploratory analysis was used to characterize a possible risk range by comparing a typical environmental exposure level for highway diesel sources to a selected range of occupational exposure levels. The occupationally observed risks were then proportionally scaled according to the exposure ratios to obtain an estimate of the possible environmental risk. If the occupational and environmental exposures are similar, the environmental risk would approach the risk seen in the occupational studies whereas a much higher occupational exposure indicates that the environmental risk is lower than the occupational risk. A comparison of environmental and occupational exposures showed that for certain occupations the exposures are similar to environmental exposures while, for others, they differ by a factor of about 200 or more.

A number of calculations are involved in the exploratory analysis of a possible risk range, and these can be seen in the EPA Diesel HAD. The outcome was that environmental risks from diesel exhaust exposure could range from a low of 10^{-4} to 10^{-5} to as high as 10^{-3}, reflecting the range of occupational exposures that could be associated with the relative and absolute risk levels observed in the occupational studies. Because of uncertainties, the analysis acknowledged that the risks could be lower than 10^{-4} or 10^{-5}, and a zero risk from diesel exhaust exposure was not ruled out.

EPA recently assessed air toxic emissions and their associated risk (the 2005 NATA), and we concluded that diesel exhaust ranks with other emissions that the national-scale assessment suggests pose the greatest relative risk.[64] This national assessment estimates average population inhalation exposures to DPM for nonroad as well as on-highway sources. These are the sum of ambient levels in various locations weighted by the amount of time people spend in each of the locations.

In summary, even though EPA does not have a specific carcinogenic potency with which to accurately estimate the carcinogenic impact of exposure to diesel exhaust, the likely hazard to humans together with the potential for significant environmental risks leads us to conclude that diesel exhaust emissions present public health issues of concern.

5.2.5.2 Other Health Effects of Exposure to Diesel Exhaust

Noncancer health effects of acute and chronic exposure to diesel exhaust emissions are also of concern to the EPA. The Diesel HAD established an inhalation Reference Concentration (RfC) specifically based on animal studies of diesel exhaust exposure. An RfC is defined by EPA as "an estimate of a continuous inhalation exposure to the human population, including sensitive subgroups, with uncertainty spanning perhaps an order of magnitude, which is likely to be without appreciable risks of deleterious noncancer effects during a lifetime." EPA derived the RfC from consideration of four well-conducted chronic rat inhalation studies showing adverse pulmonary effects.[65,66,67,68] The diesel RfC is based on a "no observable adverse effect" level of 144 $\mu g/m^3$ that is further reduced by applying uncertainty factors of 3 for interspecies extrapolation and 10 for human variations in sensitivity. The resulting RfC derived in the Diesel HAD is 5 $\mu g/m^3$ for diesel exhaust as measured by DPM. This RfC does not consider allergenic effects such as those associated with asthma or immunologic effects. There is growing evidence that exposure to diesel exhaust can exacerbate these effects, but the exposure-response data is presently lacking to derive an RfC. The EPA Diesel HAD states, "With DPM [diesel particulate matter] being a ubiquitous component of ambient PM, there is an uncertainty about the adequacy of the existing DE [diesel exhaust] noncancer database to identify all of the pertinent DE-caused noncancer health hazards."

While there have been relatively few human studies associated specifically with the noncancer impact of exposure to DPM alone, DPM is a component of the ambient particles studied in numerous epidemiologic studies. The conclusion that health effects associated with ambient PM in general are relevant to DPM is supported by studies that specifically associate observable human noncancer health effects with exposure to DPM. As described in the Diesel HAD, these studies identified some of the same health effects reported for ambient PM, such as respiratory symptoms (cough, labored breathing, chest tightness, wheezing), and chronic respiratory disease (cough, phlegm, chronic bronchitis and suggestive evidence for decreases in pulmonary function). Symptoms of immunological effects such as wheezing and increased allergenicity are also seen. Studies in rodents, especially rats, show the potential for human inflammatory effects in the lung and consequential lung tissue damage from chronic diesel exhaust inhalation exposure. The Diesel HAD concludes "that acute exposure to DE [diesel exhaust] has been associated with irritation of the eye, nose, and throat, respiratory symptoms (cough and phlegm), and neurophysiological symptoms such as headache, lightheadedness, nausea, vomiting, and numbness or tingling of the extremities."[69] There is also evidence for an immunologic effect such as the exacerbation of allergenic responses to known allergens and asthma-like symptoms.[70,71,72]

The Diesel HAD briefly summarizes health effects associated with ambient PM and discusses the $PM_{2.5}$ NAAQS. There is a much more extensive body of human data, which is also mentioned earlier in the health effects discussion for $PM_{2.5}$ (Section 5.2.1 of this document), showing a wide spectrum of adverse health effects associated with exposure to ambient PM, of which diesel exhaust is an important component. The $PM_{2.5}$ NAAQS is designed to provide protection from the non-cancer and premature mortality effects of $PM_{2.5}$ as a whole.

5.2.5.3 Ambient Levels of Diesel Exhaust PM

Because DPM is part of overall ambient PM and cannot be easily distinguished from overall PM, we do not have direct measurements of DPM in the ambient air. DPM concentrations are estimated using ambient air quality modeling based on DPM emission inventories. DPM concentrations were recently estimated as part of the 2005 NATA.[73] Ambient impacts of mobile source emissions were predicted using the Assessment System for Population Exposure Nationwide (ASPEN) dispersion model.

Concentrations of DPM were calculated at the census tract level in the 2005 NATA. Table 5-1 below summarizes the distribution of ambient DPM concentrations at the national scale. The median DPM concentration calculated nationwide is 0.53 $\mu g/m^3$. A map of ambient diesel PM concentrations is provided in Figure 5-1. The Great Lakes region contains areas with high median concentrations.

Figure 5-1 Estimated Ambient Concentration of Diesel Particulate Matter

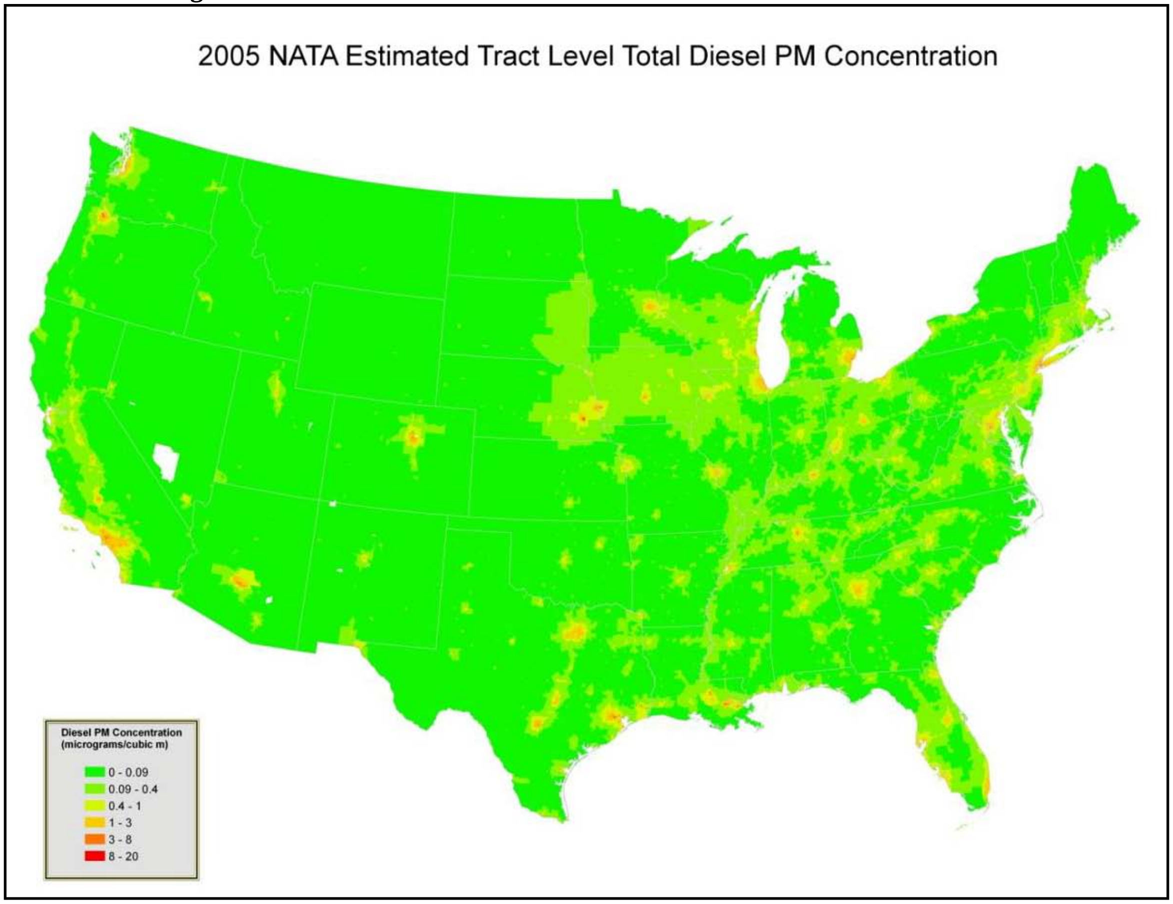


Table 5-1 Distribution of Census Tract Ambient Concentrations of DPM at the National Scale in 2005 NATA[a]

	NATIONWIDE (MG/M^3)
5th Percentile	0.03
25th Percentile	0.17
Median	0.53
75th Percentile	1.22
95th Percentile	2.91

Note:
[a] This table is generated from data contained in the diesel particulate matter Microsoft Access database file found in the Tract-Level Ambient Concentration Summaries section of the 2005 NATA webpage (http://www.epa.gov/ttn/atw/nata2005/tables.html).

5.2.5.4 Exposure to Diesel Exhaust PM

Exposure of people to diesel exhaust depends on their various activities, the time spent in those activities, the locations where these activities occur, and the levels of diesel exhaust pollutants in those locations. The major difference between ambient levels of diesel particulate and exposure levels for diesel particulate is that exposure levels account for a person moving from location to location, the proximity to the emission source, and whether the exposure occurs in an enclosed environment.

Occupational exposures to diesel exhaust from mobile sources can be several orders of magnitude greater than typical exposures in the non-occupationally exposed population. Over the years, diesel particulate exposures have been measured for a number of occupational groups resulting in a wide range of exposures from 2 to 1280 $\mu g/m^3$ for a variety of occupations. As discussed in the Diesel HAD, the National Institute of Occupational Safety and Health (NIOSH) has estimated a total of 1,400,000 workers are occupationally exposed to diesel exhaust from on-road and nonroad vehicles.

In addition, due to the nature of marine ports, emissions from a large number of diesel engines are concentrated in a small area. As a result, regions immediately downwind of marine ports may experience elevated ambient concentrations of directly-emitted $PM_{2.5}$ from diesel engines.

5.3 Environmental Effects Associated with Exposure to Pollutants

In addition to their impacts on human health, ambient levels of PM, NO_X, SO_X, and ozone can also contribute to serious environmental impacts. These environmental impacts are summarized in this section, including impacts that are specific to the Great Lakes region.

5.3.1 Atmospheric Deposition of Contaminants

Ship engines emit large amounts of NO_X, SO_X and direct PM over a wide area. Depending on prevailing winds and other meteorological conditions, these emissions may be transported hundreds and even thousands of kilometers across the Great Lakes region and impact not only ambient air concentrations but also contribute to deposition in many sensitive ecological areas. The large surface area of the Great Lakes makes them particularly vulnerable to atmospheric deposition of contaminants.[74]

Deposition can occur either in a wet or dry form. Wet deposition includes rain, snow, sleet, hail, clouds, or fog. Dry deposition includes gases and dust. The chemical form of deposition is determined by ambient conditions (e.g., temperature, humidity, oxidant levels) and the pollutant source. Chemical and physical transformations of ambient particles occur in the atmosphere and in the media (terrestrial or aquatic) on which they deposit. These transformations influence the fate, bioavailability and potential toxicity of these compounds.

Ships operating on high sulfur fuel emit both SO_2 and sulfate PM. The sulfur in marine fuel is primarily emitted as sulfur dioxide (SO_2), with a small fraction (about two percent) being converted to sulfur trioxide (SO_3).[75] SO_3 almost immediately forms sulfate, which is emitted as primary PM by the engine, and consists of carbonaceous material, sulfuric acid, and ash (trace metals). These particles also react in the atmosphere to form secondary PM, such as sulfuric acid aerosols or sulfate particles.

Ships also emit large amounts of nitric oxide (NO) and nitrogen dioxide (NO_2) which are carried into the atmosphere where they may be chemically altered and transformed into new compounds. For example, NO_2 can be further oxidized to nitric acid (HNO_3) and can also form ambient particulate nitrate (pNO_3).

5.3.2 Nitrogen and Sulfur Deposition

Nitrogen and sulfur interactions in the environment are highly complex. Both are essential, and sometimes limiting, nutrients needed for growth and productivity. Excess of nitrogen or sulfur can lead to acidification and nutrient enrichment, which can have significant ecological impacts. These ecological impacts are described in this section.

5.3.2.1 Acidification and Nutrient Enrichment

Deposition of nitrogen and sulfur species causes acidification, which alters biogeochemistry and affects animal and plant life in terrestrial and aquatic ecosystems across the Great Lakes region. Major effects include a decline in sensitive tree species and a loss of biodiversity of fishes, zooplankton, and macro invertebrates. The sensitivity of terrestrial and aquatic ecosystems to acidification from nitrogen and sulfur deposition is predominantly governed by the earth's geology.

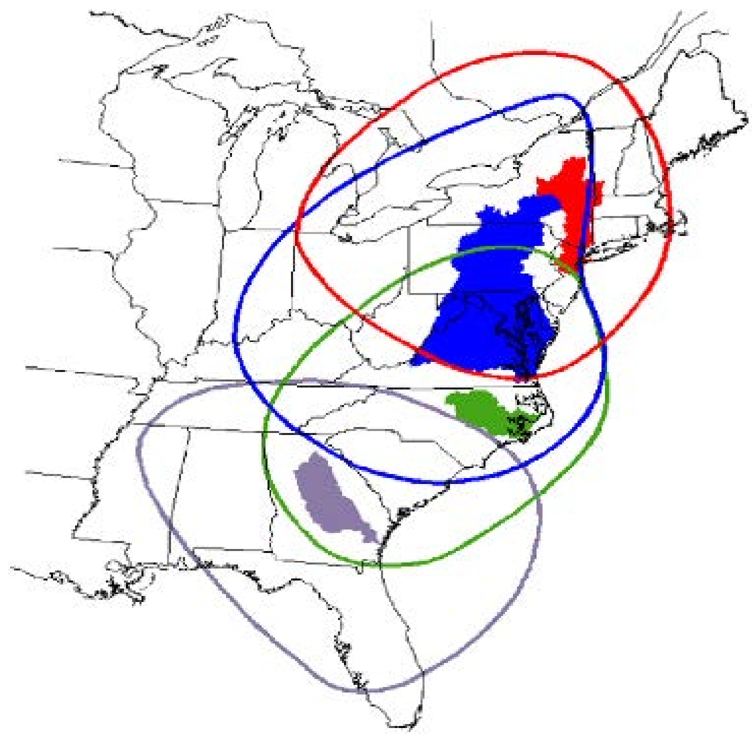
Biological effects of acidification in terrestrial ecosystems are generally linked to aluminum toxicity and decreased ability of plant roots to take up base cations. Decreases in acid neutralizing capacity and increases in inorganic aluminum concentration also contribute to declines in zooplankton, macro invertebrates, and fish species richness in aquatic ecosystems. Across the Great Lakes, ecosystems continue to be acidified by NO_X and SO_X emissions, including those from vessels in the Great Lakes.

In addition to the role nitrogen deposition plays in acidification, it also causes ecosystem nutrient enrichment and eutrophication. Nutrient enrichment alters biogeochemical cycles and harms animal and plant life and alters biodiversity of terrestrial ecosystems, such as forests and grasslands. Eutrophication of estuaries and waterbodies result in toxic algal blooms and fish kills.

The addition of nitrogen to most ecosystems causes changes in primary productivity and growth of plants and algae, which can alter competitive interactions among species. Some species grow more than others, leading to shifts in population dynamics, species composition, and community structure. The most extreme effects of nitrogen deposition include a shift of ecosystem types in terrestrial ecosystems, and hypoxic zones that are devoid of life in aquatic ecosystems.[76] Inputs of new nitrogen, i.e., non-recycled mostly anthropogenic in origin, are often key factors controlling primary productivity in nitrogen-sensitive estuarine and coastal waters.[77] Increasing trends in urbanization, agricultural intensity, and industrial expansion have led to increases in nitrogen deposited from the atmosphere on the order of a factor of 10 in the past 100 years.[78] Atmospheric nitrogen is dominated by a number of sources, most importantly transportation sources, including ships.

Direct and indirect deposition of nitrogen and sulfur to watersheds depends on air pollutant concentrations in the airshed above the watershed. The shape and extent of the airshed is quite different from that of the watershed. In a watershed, everything that falls in its area, by definition, flows into a single body of water. An airshed, by contrast, is a theoretical concept that defines the source area containing the emissions contributing a given level, often 75 percent, to the deposition in a particular watershed or to a given water body. Hence, airsheds are modeled domains containing the sources estimated to contribute a given level of deposition from each pollutant of concern. The principal NO_X airsheds and corresponding watersheds for several regions in the eastern U.S. are shown in Figure 5-2.[79] These airsheds include much of the Great Lakes. In addition, airsheds for other regions in the U.S., which would include the rest of the Great Lakes, are not shown on this figure.

Figure 5-2 Principal Airsheds and Watersheds for Oxides of Nitrogen for Estuaries. Hudson/Raritan Bay; Chesapeake Bay; Pamlico Sound; and Altamaha Sound (listed from north to south)



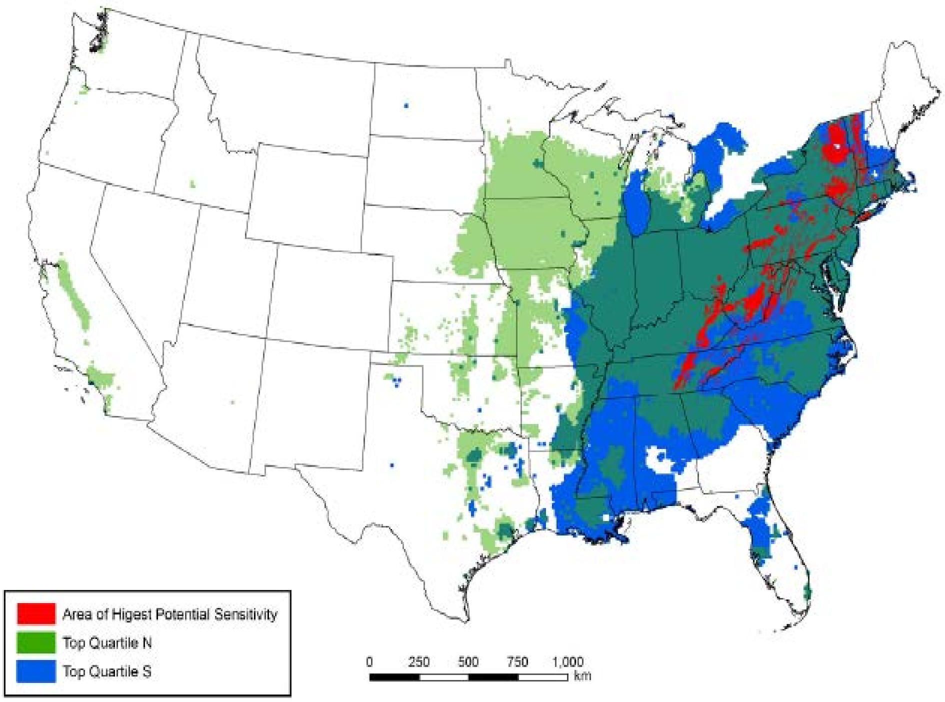
5.3.2.2 Ecological Effects of Acidification

The principal factor governing the sensitivity of terrestrial and aquatic ecosystems to acidification from nitrogen and sulfur deposition is geology (particularly surficial geology).[80] Geologic formations having low base cation supply generally underlie the watersheds of acid-sensitive lakes and streams. Bedrock geology has been used in numerous acidification studies.[81,82,83,84,85] Other factors contributing to the sensitivity of soils and surface waters to acidifying deposition, include: topography, soil chemistry, land use, and hydrologic flow path.

5.3.2.2.1 Terrestrial Ecosystems

Figure 5-3 depicts areas across the U.S. that are potentially sensitive to terrestrial acidification. Many areas adjacent and nearby to the Great Lakes are in the top quartile for N or S sensitivity or have been labeled as areas of highest potential sensitivity.

Figure 5-3 Areas Potentially Sensitive to Terrestrial Acidification

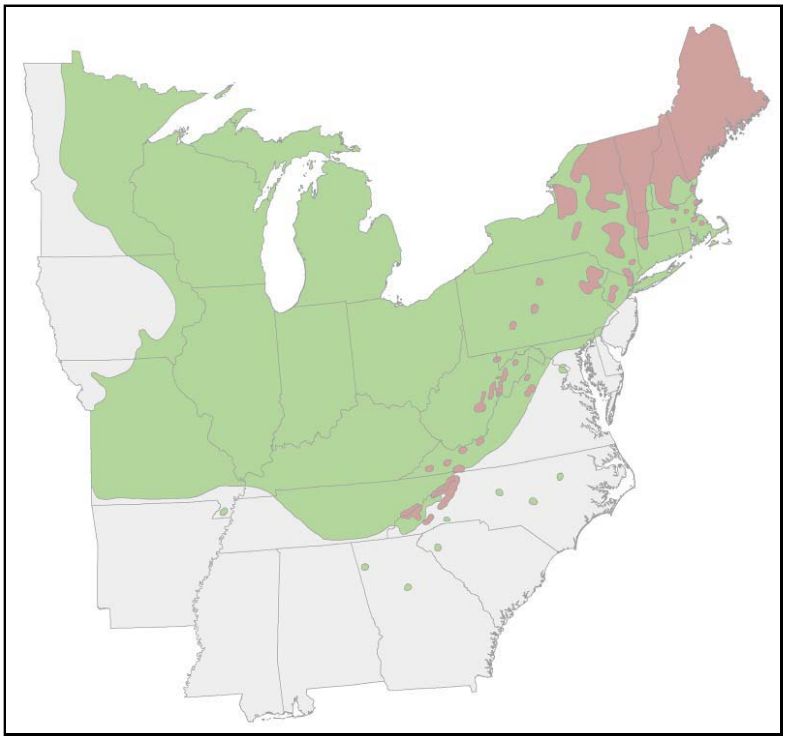


Acidifying deposition has altered major biogeochemical processes in the U.S., including the Great Lakes, by increasing the nitrogen and sulfur content of soils, accelerating nitrate and sulfate leaching from soil to drainage waters, depleting base cations (especially calcium and magnesium) from soils, and increasing the mobility of aluminum. Inorganic aluminum is toxic to some tree roots. Plants affected by high levels of aluminum from the soil often have reduced root growth, which restricts the ability of the plant to take up water and nutrients, especially calcium.[86] These direct effects can influence the response of these plants to climatic stresses such as droughts and cold temperatures. They can also influence the sensitivity of plants to other stresses, including insect pests and disease[87] leading to increased mortality of canopy trees. Terrestrial effects of acidification are best described for forested ecosystems (especially red spruce and sugar maple ecosystems) with additional information on other plant communities, including shrubs and lichen.[88] There are several indicators of stress to terrestrial vegetation including percent dieback of canopy trees, dead tree basal area (as a percent), crown vigor index and fine twig dieback.[89]

5.3.2.2.2 Health, Vigor, and Reproduction of Tree Species in Forests

Both coniferous and deciduous forests throughout the eastern U.S., including the Great Lakes region, are experiencing gradual losses of base cation nutrients from the soil due to accelerated leaching for acidifying deposition. This change in nutrient availability may reduce the quality of forest nutrition over the long term. Evidence suggests that red spruce and sugar maple in some areas in the eastern U.S. have experienced declining health as a consequence of this deposition. Figure 5-4 shows the distribution of red spruce (brown) and sugar maple (green) in the eastern U.S. For red spruce, dieback or decline has been observed across high elevation landscapes of the northeastern U.S., and to a lesser extent, the southeastern U.S. Acidifying deposition has been implicated as a causal factor.[90] Since the 1980s, red spruce growth has increased at both the higher- and lower-elevation sites corresponding to a decrease in SO_2 emissions in the U.S. (to about 20 million tons/year by 2000), while NO_X emissions held fairly steady (at about 25 million tons/year). Research indicates that annual emissions of sulfur plus NO_X explained about 43 percent of the variability in red spruce tree ring growth between 1940 and 1998, while climatic variability accounted for about 8 percent of the growth variation for that period.[91] The observed dieback in red spruce has been linked, in part, to reduced cold tolerance of the spruce needles, caused by acidifying deposition. Results of controlled exposure studies showed that acidic mist or cloud water reduced the cold tolerance of current-year needles by 3 to 10° F.[92] More recently, studies have found a link between availability of soil calcium and winter injury.[93]

Figure 5-4 Distribution of Red Spruce (pink) and Sugar Maple (green) in the Eastern U.S.[94]

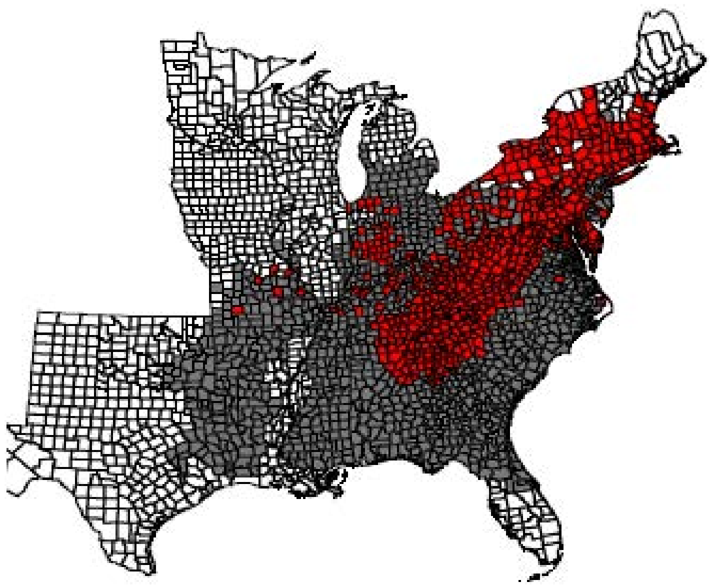


Sugar maple is the deciduous tree species, whose range includes the Great Lakes region (See Figure 5-4), that is most commonly associated with adverse acidification-related effects of nitrogen and sulfur deposition.[95] In general, evidence indicates that acidifying deposition in combination with other stressors is a likely contributor to the decline of sugar maple trees that occur at higher elevation, on geologies dominated by sandstone or other base-poor substrate, and that have base-poor soils having high percentages of rock fragments.[96]

In hardwood forests, species nutrient needs, soil conditions, and additional stressors work together to determine sensitivity to acidifying deposition. Stand age and successional stage also can affect the susceptibility of hardwood forests to acidification effects. In northeastern hardwood forests, older stands exhibit greater potential for calcium depletion in response to acidifying deposition than younger stands. Thus, with the successional change from pin cherry, striped maple, white ash, yellow birch and white birch in younger stands to beech and red maple in older stands, there is an increase in sensitivity to acidification.[97]

Loss of calcium ions in the base cations has also been implicated in increased susceptibility of flowering dogwood to its most destructive disease, dogwood anthracnose, a mostly fatal disease. Figure 5-5 shows the native range of flowering dogwood in the U.S. (dark gray) as well as the range of the anthracnose disease as of 2002 in the eastern U.S. (red). The ranges for the tree species and the disease are within the Great Lakes region. Flowering dogwood is a dominant understory species of hardwood forests in the eastern U.S.[98]

Figure 5-5 Native Range of Flowering Dogwood (dark gray) and the Documented Range of Dogwood Anthracnose (red)[99]



Source: Holzmueller et al. (2006). Reprinted with permission.

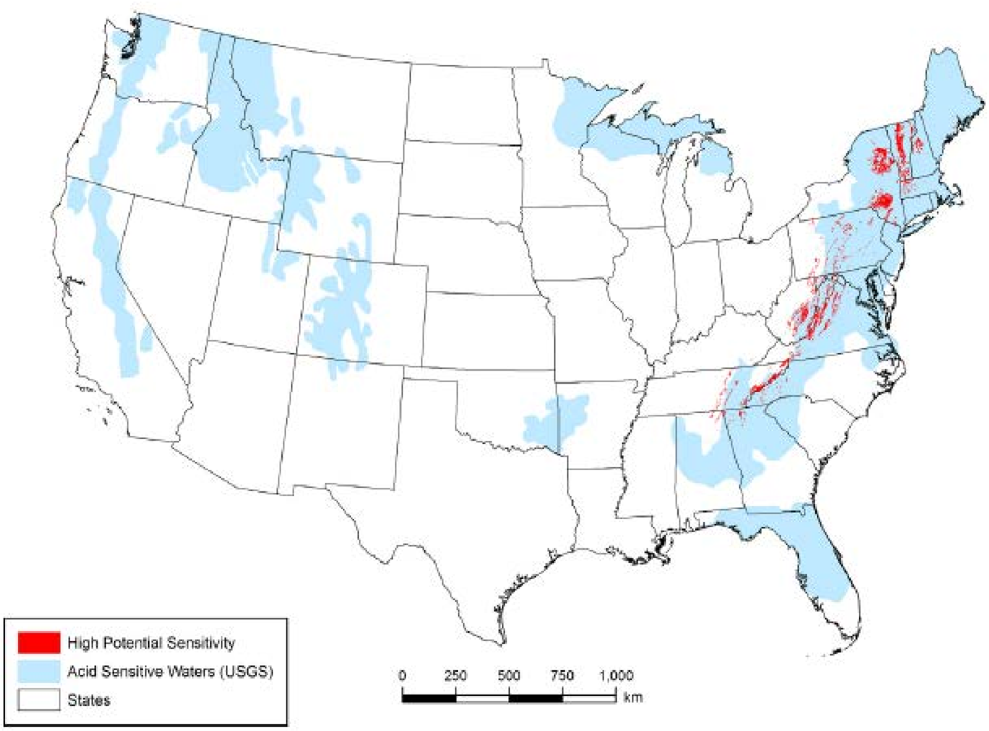
5.3.2.2.3 Health and Biodiversity of Other Plant Communities

The U.S. EPA NO_XSO_X ISA found that available data suggest that it is likely that a variety of shrub and herbaceous species are sensitive to base cation depletion and/or aluminum toxicity. The U.S. EPA NO_XSO_X ISA also found that lichens and bryophytes are among the first components of the terrestrial ecosystem to be affected by acidifying deposition. Vulnerability of lichens to increased nitrogen input is generally greater than that of vascular plants.[100] Even in the Pacific Northwest, which receives uniformly low levels of nitrogen deposition – generally lower than the levels in the Great Lakes - changes from acid-sensitive and nitrogen-sensitive to pollution tolerant nitrophillic lichen taxa are occurring in some areas.[101,102] Lichens remaining in areas affected by acidifying deposition were found to contain almost exclusively the families Candelariaccae, Physciaceae, and Teloschistaceae, which are pollution tolerant species.[103]

5.3.2.2.4 Aquatic Ecosystems

A number of national and regional assessments have been conducted to estimate the distribution and extent of surface water acidity in the U.S.[104,105,106,107,108,109,110,111,112] As a result, several regions of the U.S. have been identified as containing a large number of lakes and streams which are seriously impacted by acidification. Figure 5-6 illustrates those areas of the U.S. where aquatic ecosystems are at risk from acidification. These sensitive ecological regions include portions of the northwest Great Lakes and areas nearby or adjacent to the eastern Great Lakes.

Figure 5-6 Areas Potentially Sensitive to Aquatic Acidification



Aquatic effects of acidification have been well studied in the U.S. and elsewhere at various trophic levels. These studies indicate that aquatic biota have been affected by acidification at virtually all levels of the food web in acid sensitive aquatic ecosystems. Effects have been most clearly documented for fish, aquatic insects, other invertebrates, and algae.

Biological effects are primarily attributable to a combination of low pH and high inorganic aluminum concentrations. Such conditions occur more frequently during rainfall and snowmelt that cause high flows of water and less commonly during low-flow conditions, except where chronic acidity conditions are severe. Biological effects of episodes include reduced fish condition factor, changes in species composition and declines in aquatic species richness across multiple taxa, ecosystems and regions. These conditions may also result in direct mortality.[113] Biological effects in aquatic ecosystems can be divided into two major categories: effects on health, vigor, and reproductive success; and effects on biodiversity.

5.3.2.3 Ecological Effects of Nutrient Enrichment

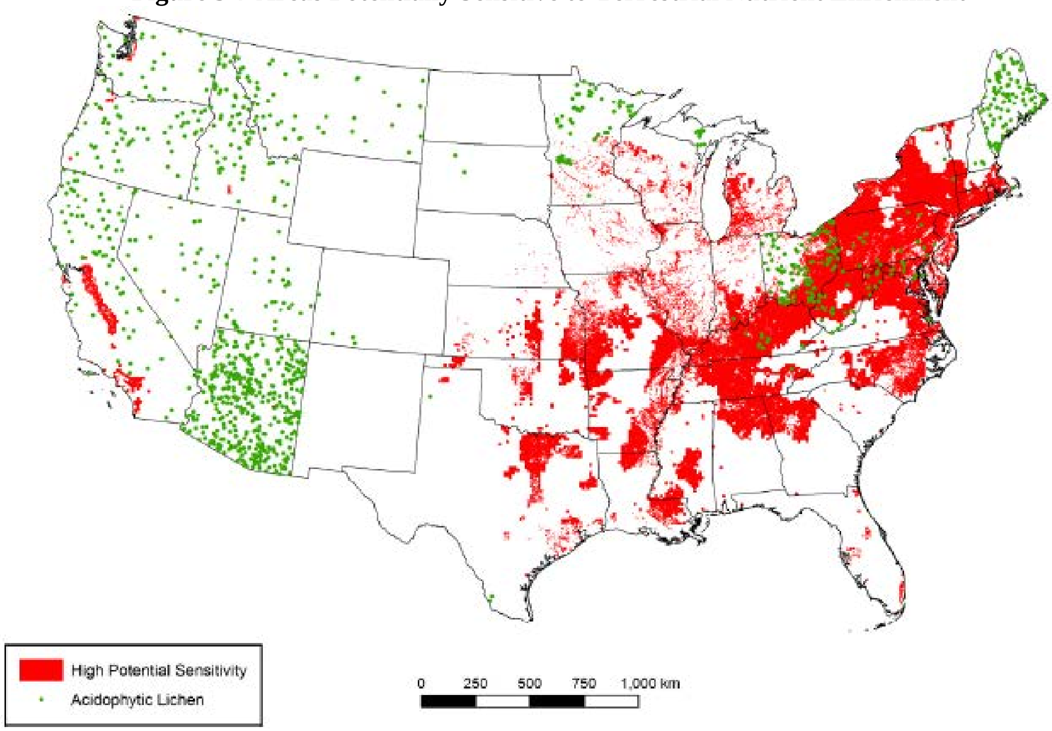
In general, ecosystems that are most responsive to nutrient enrichment from atmospheric nitrogen deposition are those that receive high levels of nitrogen loading, are nitrogen-limited, or contain species that have evolved in nutrient-poor environments. Species that are adapted to low nitrogen supply will often be more readily outcompeted by species that have higher nitrogen demands when the availability of nitrogen is increased.[114,115, 116,117] As a consequence, some native species can be eliminated by nitrogen deposition.[118,119,120, 121] Note the terms "low" and "high" are relative to the amount of bioavailable nitrogen in the ecosystem and the level of deposition.

5.3.2.3.1 Terrestrial Ecosystems

Nitrogen deposition affects terrestrial ecosystems throughout large areas of the U.S., including in the Great Lakes region.[122] Atmospheric nitrogen deposition is the main source of new nitrogen in many terrestrial ecosystems throughout the U.S.[123] Figure 5-7 depicts those ecosystems potentially sensitive to terrestrial nutrient enrichment resulting from nitrogen deposition, including nitrogen deposition from ships.

Severe symptoms of nutrient enrichment or nitrogen saturation, have been observed in areas adjacent to and nearby the Great Lakes including in high-elevation spruce-fir ecosystems in the Appalachian Mountains;[124] in spruce-fir ecosystems throughout the northeastern U.S.;[125,126] and in lower-elevation eastern U.S. forests.[127,128,129,130] In general, it is believed that deciduous forest stands in the eastern U.S. have not progressed toward nitrogen saturation as rapidly or as far as coniferous stands in the eastern U.S.[131]

Figure 5-7 Areas Potentially Sensitive to Terrestrial Nutrient Enrichment



Ecological effects of nitrogen deposition occur in a variety of taxa and ecosystem types including: forests, grasslands, arid and semi-arid areas, deserts, lichens, alpine, and mycorrhizae. Atmospheric inputs of nitrogen can alleviate deficiencies and increase growth of some plants at the expense of others. Nitrogen deposition alters the competitive relationships among terrestrial plant species and therefore alters species composition and diversity.[132,133,134] Wholesale shifts in species composition are easier to detect in short-lived terrestrial ecosystems such as annual grasslands, in the forest understory, or mycorrhizal associations, than for long-lived forest trees where changes are evident on a decade or longer time scale. Note species shifts and ecosystem changes can occur even if the ecosystem does not exhibit signs of nitrogen saturation.

There are a number of important quantified relationships between nitrogen deposition levels and ecological effects.[135] Certain lichen species are the most sensitive terrestrial taxa to nitrogen in the U.S. with clear adverse effects occurring at just 3 kg N/ha/yr. Figure 5-7 shows the geographic distribution of lichens in the U.S. Among the most sensitive U.S. ecosystems are Alpine ecosystems where alteration of plant covers of an individual species (*Carex rupestris*) was estimated to occur at deposition levels near 4 kg N/ha/yr and modeling indicates that deposition levels near 10 kg/N/ha/yr alter plant community assemblages.[136] Within grasslands, the onset of declining biodiversity was found to occur at levels of 5 kg N/ha/yr. Forest encroachment into temperate grasslands was found at 10 kg N/ha/yr and above in the U.S. Table 5-2 provides a brief list of nitrogen deposition levels and associated ecological effects.

Table 5-2 Examples of Quantified Relationship between Nitrogen Deposition Levels and Ecological Effects

Kg N/ha/yr	Ecological effect
~1.5	Altered diatom communities in high elevation freshwater lakes and elevated nitrogen in tree leaf tissue high elevation forests in the U.S.
3.1	Decline of some lichen species in the Western U.S. (critical load)
4	Altered growth and coverage of alpine plant species in U.S.
5	Onset of decline of species richness in grasslands of the U.S. and U.K.
5.6 - 10	Onset of nitrate leaching in Eastern forests of the U.S.
5-10	Multiple effects in tundra, bogs and freshwater lakes in Europe (critical loads)
5-15	Multiple effects in arctic, alpine, subalpine and scrub habitats in Europe (critical loads)

Source: EPA, Integrated Science Assessment for Oxides of Nitrogen and Sulfur-Ecological criteria

Most terrestrial ecosystems are nitrogen-limited, therefore they are sensitive to perturbation caused by nitrogen additions.[137] The factors that govern the vulnerability of terrestrial ecosystems to nutrient enrichment from nitrogen deposition include the degree of nitrogen limitation, rates and form of nitrogen deposition, elevation, species composition, length of growing season, and soil nitrogen retention capacity.

In the eastern U.S., the degree of nitrogen saturation of the terrestrial ecosystem is often assessed in terms of the degree of nitrate leaching from watershed soils into ground water or surface water. Studies have estimated the number of surface waters at different stages of saturation across several regions in the eastern U.S.[138] Of the 85 northeastern watersheds examined, 40 percent were in nitrogen-saturation Stage 0,[I] 52 percent in Stage 1, and 8 percent in Stage 2. Of the northeastern sites for which adequate data were available for assessment, those in Stage 1 or 2 were most prevalent in the Adirondack and Catskill Mountains in the State of New York.

5.3.2.3.2 Aquatic Ecosystems

Aquatic nutrient enrichment impacts a wide range of waters within the U.S., and within the Great Lakes region, from wetlands, to streams, rivers, and lakes. All are vital ecosystems and all are impacted by ship emissions that contribute to the annual total nitrogen deposition. Nitrogen deposition is the main source of nitrogen for many surface waters in the U.S. including headwater streams, lower order streams, and high elevation lakes.[139,140] Nitrogen deposition alters species richness, species composition and biodiversity in freshwater aquatic ecosystems.[141]

Increased nitrogen deposition can cause a shift in community composition and reduce algal biodiversity. Elevated nitrogen deposition results in changes in algal species composition, especially in sensitive oligotrophic lakes. There are oligotrophic lakes in the Great Lakes region, including Lake Superior.

Wetlands are found throughout the U.S. and support over 4200 native plant species, of which 121 have been designated by the U.S. Government as threatened or endangered.[142] Freshwater wetlands are particularly sensitive to nutrient enrichment resulting from nitrogen deposition since they contain a disproportionately high number of rare plant species that have evolved under nitrogen-limited conditions.[143] Freshwater wetlands receive nitrogen mainly from precipitation, land runoff or ground water.

Fens and bogs are the most vulnerable type of wetland ecosystems with regard to nutrient enrichment effects of nitrogen deposition.[144] In the U.S., they are mostly found in the glaciated northeast and Great Lakes regions and in the State of Alaska.[145] Like bogs, fens are mostly a northern hemisphere phenomenon, occurring in the northeastern United States, the Great Lakes region, western Rocky Mountains, and much of Canada, and are generally associated with low temperatures and short growing seasons where ample precipitation and high humidity cause excessive moisture to accumulate.[146]

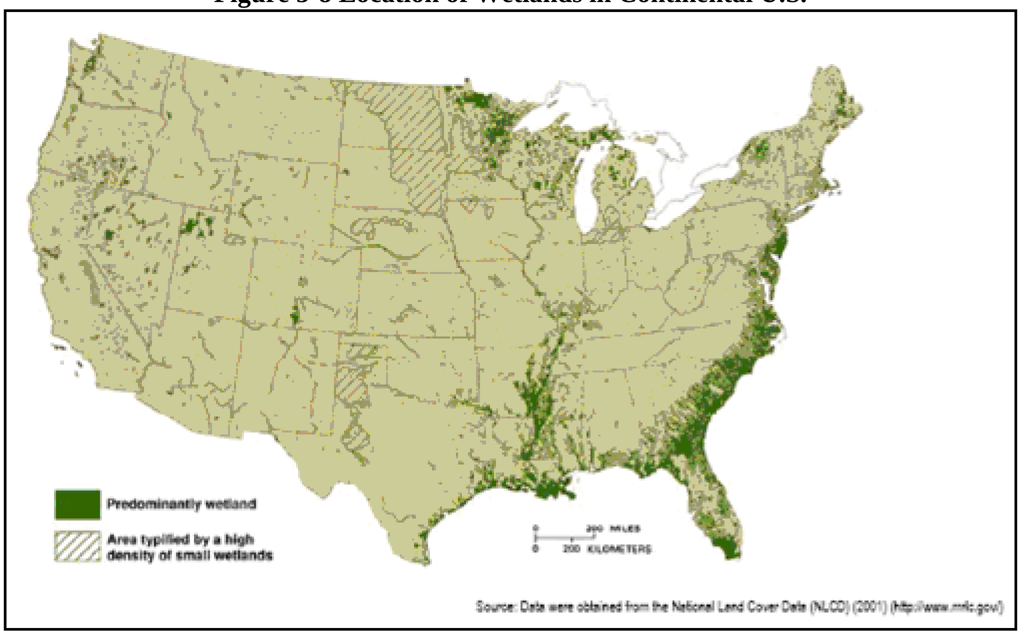
The third type of wetlands sensitive to nitrogen deposition are marshes, characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions. There are many different kinds of marshes in the U.S., ranging from the prairie potholes in the interior of the U.S. to the Everglades found in the extreme southern portion of the State of Florida. U.S. fresh water marshes are important for recharging groundwater supplies, and moderating stream flow by providing water to streams and as habitats for many wildlife species.[147]

[I] In Stage 0, nitrogen inputs are low and there are strong nitrogen limitations on growth. Stage 1 is characterized by high nitrogen retention and fertilization effect of added nitrogen on tree growth. Stage 2 includes the induction of nitrification and some nitrate leaching, though growth may still be high. In Stage 3 tree growth declines, nitrification and nitrate loss continue to increase, but nitrogen mineralization rates begin to decline.

About 107.7 million acres of wetlands are widely distributed in the conterminous U.S., including throughout the Great Lakes region (Figure 5-8). The effect of nitrogen deposition on these ecosystems depends on the fraction of rainfall in the areas total water budget. Excess nitrogen deposition can cause shifts in wetland community composition by altering competitive relationships among species, which potentially leads to effects such as decreasing biodiversity, increasing non-native species establishment, and increasing the risk of extinction for sensitive and rare species.

U.S. wetlands contain a high number of rare plant species.[148,149, 150] High levels of atmospheric nitrogen deposition increase the risk of decline and extinction of these species that are adapted to low nitrogen conditions. In general, these include the genus *Isoetes sp*., of which three species are federally endangered; insectivorous plants like the endangered green pitcher *Sarracenia oreophila*; and the genus *Sphagnum*, of which there are 15 species listed as endangered by eastern U.S. Roundleaf sundew (*Drosera rotundifolia*) is also susceptible to elevated atmospheric nitrogen deposition.[151] This plant is native to, and broadly distributed across, the U.S. and is federally listed as endangered in Illinois and Iowa, threatened in Tennessee, and vulnerable in New York.[152] In the U.S., *Sarracenia purpurea* can be used as a biological indicator of local nitrogen deposition in some locations.[153]

Figure 5-8 Location of Wetlands in Continental U.S.



5.3.3 Particulate Matter Deposition

Ships emit small amounts of metals and air toxics. The atmospheric deposition of metals and toxic compounds is implicated in severe ecosystem effects.[154] Shipping emissions of $PM_{2.5}$ contain small amounts of metals: nickel, vanadium, cadmium, iron, lead, copper, zinc, and aluminum.[155,156,157] Investigations of trace metals near roadways and industrial facilities indicate that a substantial burden of heavy metals can accumulate on vegetative surfaces. Copper, zinc, and nickel are shown to be directly toxic to vegetation under field conditions.[158] While metals typically exhibit low solubility, limiting their bioavailability and direct toxicity, chemical transformations of metal compounds occur in the environment, particularly in the presence of acidic or other oxidizing species. These chemical changes influence the mobility and toxicity of metals in the environment. Once taken up into plant tissue, a metal compound can undergo chemical changes, accumulate and be passed along to herbivores or can re-enter the soil and further cycle in the environment.

Although there has been no direct evidence of a physiological association between tree injury and heavy metal exposures, heavy metals have been implicated because of similarities between metal deposition patterns and forest decline.[159] This hypothesized correlation was further explored in high elevation forests in the northeastern U.S. These studies measured levels of a group of intracellular compounds found in plants that bind with metals and are produced by plants as a response to sublethal concentrations of heavy metals. These studies indicated a systematic and significant increase in concentrations of these compounds associated with the extent of tree injury. These data strongly imply that metal stress causes tree injury and contributes to forest decline in Northeast U.S.[160] Contamination of plant leaves by heavy metals can lead to elevated concentrations in the soil. Trace metals absorbed into the plant, frequently bind to the leaf tissue, and then are lost when the leaf drops. As the fallen leaves decompose, the heavy metals are transferred into the soil.[161,162]

Ships also emit air toxics, including polycyclic aromatic hydrocarbons (PAHs) -- a class of polycyclic organic matter (POM) that contain compounds which are known or suspected carcinogens. Since the majority of PAHs are adsorbed onto particles less than 1.0 µm in diameter, long range transport is possible. Particles of this size can remain airborne for days or even months and travel distances up to 10,000 km before being deposited on terrestrial or aquatic surfaces.[163,164,165,166,167] Atmospheric deposition of particles is believed to be the major source of PAHs to the sediments of Lake Michigan in the Great Lakes.[168] PAHs tend to accumulate in sediments and reach high enough concentrations in some coastal environments to pose an environmental health threat that includes cancer in fish populations, toxicity to organisms living in the sediment and risks to those (e.g., migratory birds) that consume these organisms.[169,170] PAHs tend to accumulate in sediments and bioaccumulate in freshwater, flora and fauna.

The effects of the deposition of atmospheric pollution, including ambient PM, on materials are related to both physical damage and impaired aesthetic qualities. The deposition of PM (especially sulfates and nitrates) can physically affect materials, adding to the effects of natural weathering processes, by potentially promoting or accelerating the corrosion of metals, by degrading paints, and by deteriorating building materials such as concrete and limestone. Only chemically active fine particles or hygroscopic coarse particles contribute to these physical effects. In addition, the deposition of ambient PM can reduce the aesthetic appeal of buildings and culturally important articles through soiling. Particles consisting primarily of carbonaceous compounds cause soiling of commonly used building materials and culturally important items such as statues and works of art.

5.3.4 Impacts of Particles on Visibility

Shipping activity, including that within the Great Lakes, contributes to poor visibility through their primary $PM_{2.5}$ emissions as well as NO_X and SO_X emissions (which contribute to the formation of secondary $PM_{2.5}$).[171] These airborne particles degrade visibility by scattering and absorbing light. Good visibility increases the quality of life where individuals live and work, and where they engage in recreational activities.

5.3.4.1.1 Visibility Monitoring

In conjunction with the U.S. National Park Service, the U.S. Forest Service, other Federal land managers, and State organizations in the U.S., the U.S. EPA has supported visibility monitoring in national parks and wilderness areas, including 3 mandatory class I federal areas located on the shores of the Great Lakes, since 1988. This long-term visibility monitoring network is known as IMPROVE (Interagency Monitoring of Protected Visual Environments).

IMPROVE provides direct measurement of fine particles that contribute to visibility impairment. The IMPROVE network employs aerosol measurements at all sites, and optical and scene measurements at some of the sites. Aerosol measurements are taken for PM_{10} and $PM_{2.5}$ mass, and for key constituents of $PM_{2.5}$, such as sulfate, nitrate, organic and elemental carbon, soil dust, and several other elements. Measurements for specific aerosol constituents are used to calculate "reconstructed" aerosol light extinction by multiplying the mass for each constituent by its empirically-derived scattering and/or absorption efficiency, with adjustment for the relative humidity. Knowledge of the main constituents of a site's light extinction "budget" is critical for source apportionment and control strategy development. Optical measurements are used to directly measure light extinction or its components. Such measurements are taken principally with either a transmissometer, which measures total light extinction, or a nephelometer, which measures particle scattering (the largest human-caused component of total extinction). Scene characteristics are typically recorded three times daily with 35 millimeter photography and are used to determine the quality of visibility conditions (such as effects on color and contrast) associated with specific levels of light extinction as measured under both direct and aerosol-related methods. Directly measured light extinction is used under the IMPROVE protocol to cross check that the aerosol-derived light extinction levels are reasonable in establishing current visibility conditions. Aerosol-derived light extinction is used to document spatial and temporal trends and to determine how proposed changes in atmospheric constituents would affect future visibility conditions.

Annual average visibility conditions (reflecting light extinction due to both anthropogenic and non-anthropogenic sources) vary regionally across the U.S. The rural East generally has higher levels of impairment than remote sites in the West. Higher visibility impairment levels in the East, including the Great Lakes region, are due to generally higher concentrations of anthropogenic fine particles, particularly sulfates, and higher average relative humidity levels. In fact, sulfates account for 60-86 percent of the haziness in eastern sites.[172] Aerosol light extinction due to sulfate on the 20 percent haziest days is significantly larger in eastern class I areas as compared to western areas (Figures 4-40a and 4-40b in the Air Quality Criteria Document for Particulate Matter).[173]

5.3.4.1.2 Addressing Visibility in the U.S.

The U.S. EPA is pursuing a two-part strategy to address visibility. First, EPA has set secondary $PM_{2.5}$ standards which act in conjunction with the establishment of a regional haze program. In setting the secondary $PM_{2.5}$ standard, EPA concluded that $PM_{2.5}$ causes adverse effects on visibility in various locations, depending on PM concentrations and factors such as chemical composition and average relative humidity. Second, section 169 of the Clean Air Act provides additional authority to address existing visibility impairment and prevent future visibility impairment in the 156 mandatory class I federal areas (62 FR 38680-81, July 18, 1997). In July 1999, the regional haze rule (64 FR 35714) was put in place to protect the visibility in mandatory class I federal areas. Visibility can be said to be impaired in both $PM_{2.5}$ nonattainment areas and mandatory class I federal areas.[J]

5.3.5 Environmental Effects Associated with Ozone

There are a number of environmental or public welfare effects associated with the presence of ozone in the ambient air.[174] Great Lakes vessels emit NO_X, which is a precursor to ozone. In this section, we discuss the impact of ozone on plants, including trees, agronomic crops and urban ornamentals.

5.3.5.1.1 Impacts of Ozone on Plants and Ecosystems

The Air Quality Criteria Document for Ozone and related Photochemical Oxidants notes that, "ozone affects vegetation throughout the United States, impairing crops, native vegetation, and ecosystems more than any other air pollutant".[175] Like carbon dioxide (CO_2) and other gaseous substances, ozone enters plant tissues primarily through apertures (stomata) in leaves in a process called "uptake".[176] Once sufficient levels of ozone (a highly reactive substance), or its reaction products, reaches the interior of plant cells, it can inhibit or damage essential cellular components and functions, including enzyme activities, lipids, and cellular membranes, disrupting the plant's osmotic (i.e., water) balance and energy utilization patterns.[177,178] If enough tissue becomes damaged from these effects, a plant's capacity to fix carbon to form carbohydrates, which are the primary form of energy used by plants is reduced,[179] while plant respiration increases. With fewer resources available, the plant reallocates existing resources away from root growth and storage, above ground growth or yield, and reproductive processes, toward leaf repair and maintenance, which leads to reduced growth and/or reproduction. Studies have shown that plants stressed in these ways may exhibit a general loss of vigor, which can lead to secondary impacts that modify plants' responses to other environmental factors. Specifically, plants may become more sensitive to other air pollutants, more susceptible to disease, insect attack, harsh weather (e.g., drought, frost) and other environmental stresses. Furthermore, there is evidence that ozone can interfere with the formation of mycorrhiza, essential symbiotic fungi associated with the roots of most terrestrial plants, by reducing the amount of carbon available for transfer from the host to the symbiont.[180,181]

This ozone damage may or may not be accompanied by visible injury on leaves, and likewise, visible foliar injury may or may not be a symptom of the other types of plant damage described above. When visible injury is present, it is commonly manifested as chlorotic or necrotic spots, and/or increased leaf senescence (accelerated leaf aging). Since ozone damage

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[J] As mentioned above, the EPA recently amended the PM NAAQS, making the secondary NAAQS equal, in all respects, to the primary standards for both $PM_{2.5}$ and PM_{10}, (71 FR 61144, Oct. 17, 2006). In February 2009, the D.C. Circuit Court remanded the secondary standards for fine particles, based on EPA's failure to adequately explain why setting the secondary $PM_{2.5}$ NAAQS equivalent to the primary standards provided the required protection for public welfare including protection from visibility impairment.

can consist of visible injury to leaves, it can also reduce the aesthetic value of ornamental vegetation and trees in urban landscapes, and negatively affect scenic vistas in protected natural areas.

Ozone can produce both acute and chronic injury in sensitive species depending on the concentration level and the duration of the exposure. Ozone effects also tend to accumulate over the growing season of the plant, so that even lower concentrations experienced for a longer duration have the potential to create chronic stress on sensitive vegetation. Not all plants, however, are equally sensitive to ozone. Much of the variation in sensitivity between individual plants or whole species is related to the plant's ability to regulate the extent of gas exchange via leaf stomata (e.g., avoidance of ozone uptake through closure of stomata)[182,183,184] Other resistance mechanisms may involve the intercellular production of detoxifying substances. Several biochemical substances capable of detoxifying ozone have been reported to occur in plants, including the antioxidants ascorbate and glutathione. After injuries have occurred, plants may be capable of repairing the damage to a limited extent.[185]

Due to the differing sensitivities among plants to ozone, ozone pollution can also exert a selective pressure that leads to changes in plant community composition. Given the range of plant sensitivities and the fact that numerous other environmental factors modify plant uptake and response to ozone, it is not possible to identify threshold values above which ozone is consistently toxic for all plants. The next few paragraphs present additional information on ozone damage to trees, ecosystems, agronomic crops and urban ornamentals.

Ozone also has been conclusively shown to cause discernible injury to forest trees.[186,187] In terms of forest productivity and ecosystem diversity, ozone may be the pollutant with the greatest potential for regional-scale forest impacts. Studies have demonstrated repeatedly that ozone concentrations commonly observed in polluted areas can have substantial impacts on plant function.[188,189]

Because plants are at the base of the food web in many ecosystems, changes to the plant community can affect associated organisms and ecosystems (including the suitability of habitats that support threatened or endangered species and below ground organisms living in the root zone). Ozone impacts at the community and ecosystem level vary widely depending upon numerous factors, including concentration and temporal variation of tropospheric ozone, species composition, soil properties and climatic factors.[190] In most instances, responses to chronic or recurrent exposure in forested ecosystems are subtle and not observable for many years. These injuries can cause stand-level forest decline in sensitive ecosystems.[191,192,193] It is not yet possible to predict ecosystem responses to ozone with much certainty; however, considerable knowledge of potential ecosystem responses has been acquired through long-term observations in highly damaged forests in the United States.

Laboratory and field experiments have also shown reductions in yields for agronomic crops exposed to ozone, including vegetables (e.g., lettuce) and field crops (e.g., cotton and wheat). The most extensive field experiments, conducted under the National Crop Loss Assessment Network (NCLAN), examined 15 species and numerous cultivars. The NCLAN results show that "several economically important crop species are sensitive to ozone levels typical of those found in the United States."[194] In addition, economic studies have shown reduced economic benefits as a result of predicted reductions in crop yields associated with observed ozone levels.[195,196,197]

Urban ornamentals represent an additional vegetation category likely to experience some degree of negative effects associated with exposure to ambient ozone levels. It is estimated that more than $20 billion (1990 dollars) are spent annually on landscaping using ornamentals, both by private property owners/tenants and by governmental units responsible for public areas.[198] This is therefore a potentially costly environmental effect. However, in the absence of adequate exposure-response functions and economic damage functions for the potential range of effects relevant to these types of vegetation, no direct quantitative analysis has been conducted.

Air pollution can have cumulative impacts on forested ecosystems by affecting regeneration, productivity, and species composition.[199] In the U.S., ozone in the lower atmosphere is one of the pollutants of primary concern. Ozone injury to forest plants can be diagnosed by examination of plant leaves. Foliar injury is usually the first visible sign of injury to plants from ozone exposure and indicates impaired physiological processes in the leaves.[200]

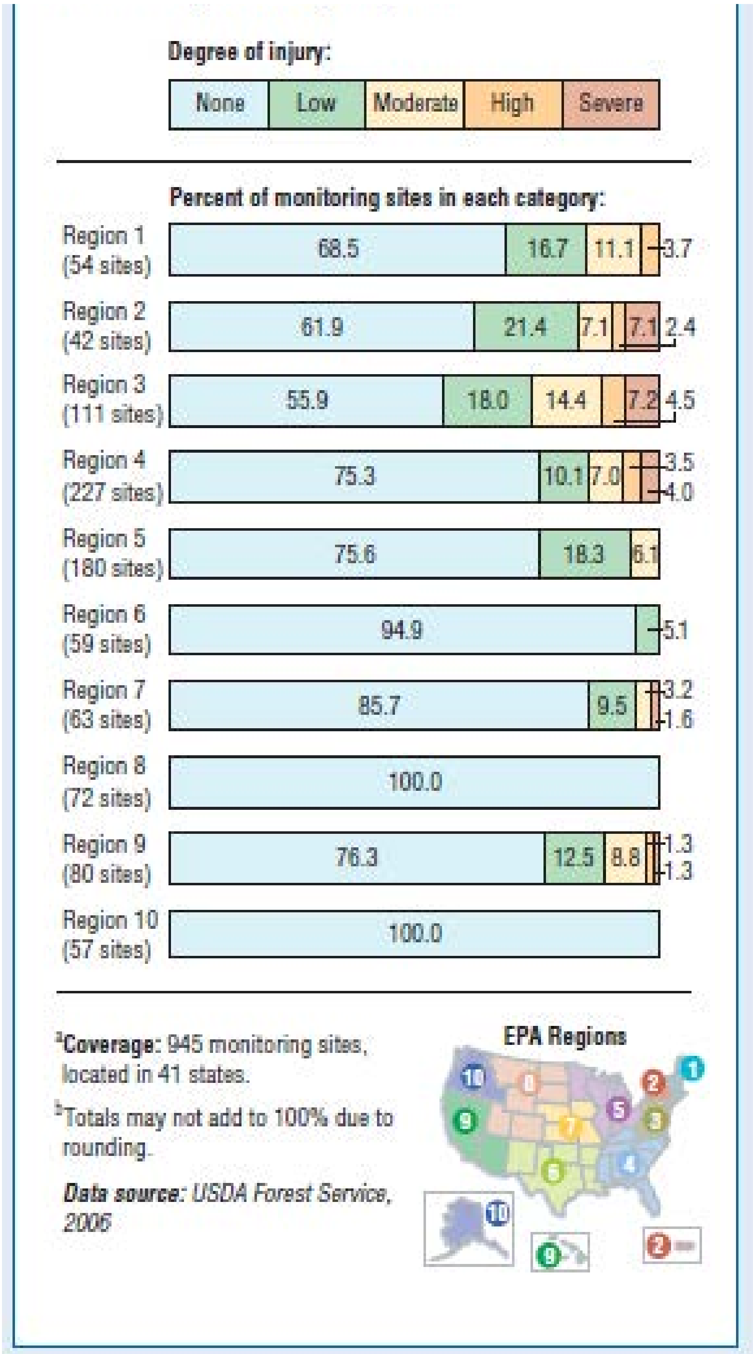
In the U.S. this indicator is based on data from the U.S. Department of Agriculture (USDA) Forest Service Forest Inventory and Analysis (FIA) program. As part of its Phase 3 program, formerly known as Forest Health Monitoring, FIA examines ozone injury to ozone-sensitive plant species at ground monitoring sites in forest land across the country. For this indicator, forest land does not include woodlots and urban trees. Sites are selected using a systematic sampling grid, based on a global sampling design.[201,202] At each site that has at least 30 individual plants of at least three ozone-sensitive species and enough open space to ensure that sensitive plants are not protected from ozone exposure by the forest canopy, FIA looks for damage on the foliage of ozone-sensitive forest plant species. Monitoring of ozone injury to plants by the USDA Forest Service has expanded from monitoring sites in 10 states in 1994 to nearly 1,000 monitoring sites in 41 states in 2002.

5.3.5.1.2 Recent Ozone Effects Data for the U.S.

There is considerable regional variation in ozone-related visible foliar injury to sensitive plants in the U.S. The U.S. EPA has developed an environmental indicator based on data from the USDA FIA program which examines ozone injury to ozone-sensitive plant species at ground monitoring sites in forest land across the country (this indicator does not include woodlots and urban trees). Sites are selected using a systematic sampling grid, based on a global sampling design.[203, 204] Since ozone injury is cumulative over the course of the growing season, examinations are conducted in July and August, when ozone injury is typically highest. The data underlying the indictor in Figure 5-9 are based on averages of all observations collected in 2002, the latest year for which data were publicly available at the time the study was conducted, and are broken down by U.S. EPA Regions. Ozone damage to forest plants is classified using a subjective five-category biosite index based on expert opinion, but designed to be equivalent from site to site. Ranges of biosite values translate to no injury, low or moderate foliar injury (visible foliar injury to highly sensitive or moderately sensitive plants, respectively), and high or severe foliar injury, which would be expected to result in tree-level or ecosystem-level responses, respectively.[205]

As mentioned above, Figure 5-9 presents the ozone injury to forest plants by EPA Regions. Region 5, which includes the Great Lakes, has 18 percent of monitoring sites with low ozone injury and 6 percent of sites with moderate ozone injury. The Coordinated Strategy emissions reductions will reduce ozone injury to forest plants in the Great Lakes region.

Figure 5-9 Ozone Injury to Forest Plants in U.S. by EPA Regions, 2002[ab]



5.4 Contribution of Shipping to Great Lakes Air Quality

The preceding sections describe the human health and environmental impacts of exposure to particulate matter, ozone, NO_X, SO_X, and air toxics. In this section, we describe the contribution of ships to levels of particulate matter, ozone, NO_X and SO_X in the Great Lakes and the air quality impacts of the Coordinated Strategy in the Great Lakes region. This analysis shows that application of the ECA requirements to the Great Lakes is expected to result in important air quality benefits for the Great Lakes, reducing ambient levels of both PM and ozone.

The air quality and benefits modeling we performed in support of our 2010 Category 3 marine rule is a national-level analysis, reflecting the fact that our Coordinated Strategy is a national program that applies equally throughout the United States (see the RIA for the final Category 3 marine rulemaking and the Appendix to this chapter for a description of the methodology used for that modeling).[206] While emissions from ships operating on the Pacific or Gulf coasts are not likely to affect the Great Lakes, some portion of emissions from ships operating in the Saint Lawrence Seaway or Northern Atlantic states may have an impact. Because it is not possible to isolate the potential impacts of the inventory reductions occurring in the Northeast Atlantic portion of the North American ECA, estimated air quality improvements are presented only for the Great Lakes states west of Pennsylvania: Minnesota, Wisconsin, Illinois, Indiana, Ohio and Michigan.

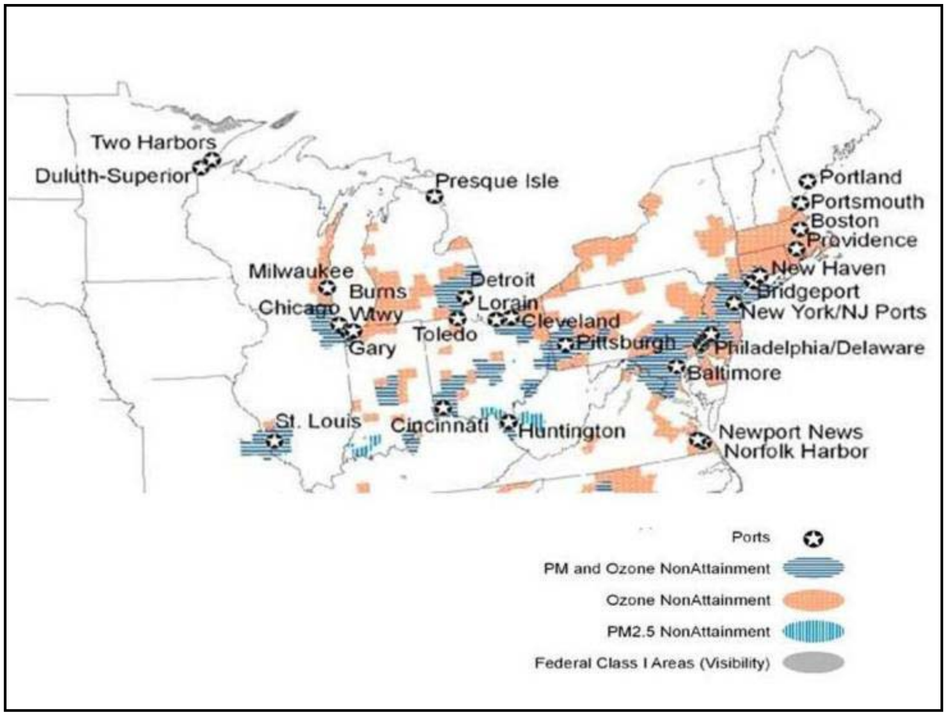
In addition, because no new modeling was performed for this analysis, the estimates presented below do not take into account the Great Lakes inventory adjustments described in Chapter 4. While the impact of those adjustments on the air quality estimates presented below is unknown without additional modeling, the estimated vessel inventory reductions of 87 and 96 percent for PM and SO_X, respectively, will assist Great Lakes states' efforts to achieve and maintain National Ambient Air Quality Standards and help provide cleaner air throughout the region.

Finally, the estimated air quality improvements presented below do not include improvements in air quality that would occur in Canada as a result of reduced emissions from ships operating in the U.S. portion of the Great Lakes.

5.4.1 PM and Ozone Nonattainment in the Great Lakes

Over 27 million people live in the Great Lakes basin and are affected by ship emissions from the Great Lakes.[207] Many counties in the Great Lakes area are in nonattainment for the National Ambient Air Quality Standards for $PM_{2.5}$ and ozone, and ships are contributors to those ozone and PM levels. Figure 5-10 presents ports along with these nonattainment areas.

Figure 5-10 Great Lakes Nonattainment Areas (based on data through May 2007)



5.4.2 Impacts of the Coordinated Strategy at the National Level

The air quality modeling we performed in support of the Coordinated Strategy and our Category 3 marine rule indicates that a significant portion of the country, including areas located well inland, are expected to experience air quality improvements as a result of the Coordinated Strategy. With respect to $PM_{2.5}$, the modeling shows that in 2020 and 2030 all of the modeled counties will experience decreases in their annual and 24-hour $PM_{2.5}$ design values. For areas with annual $PM_{2.5}$ design values greater than 15µg/m^3, the modeled future-year, population-weighted annual $PM_{2.5}$ design values are expected to decrease on average by 0.8 µg/m^3 in 2020 and by 1.7 µg/m^3 in 2030. For areas with 24-hour $PM_{2.5}$ design values greater than 35µg/m^3, the modeled future-year, population-weighted annual $PM_{2.5}$ design values are expected to decrease on average by 1.3 µg/m^3 in 2020 and by 3.4 µg/m^3 in 2030. With respect to ozone, the air quality modeling results also indicate that emission reductions achieved through the Coordinated Strategy will improve both the average and population-weighted average ozone design value concentrations nationwide in 2020 and 2030. In projected nonattainment counties, on a population-weighted basis, the 8-hour ozone design value will on average decrease by 0.5 ppb in 2020 and 1.6 ppb in 2030.[K]

[K] It should be noted that even though our air quality modeling predicts important reductions in nationwide ozone levels, three counties (of 661 that were part of the analysis) are expected to experience an increase in their ozone design values in 2030. There are two counties in Washington, Clallam County and Clark County, and Orange County CA, which will experience 8-hour ozone design value increases due to the NO_X disbenefits which occur in these VOC-limited ozone nonattainment areas. Briefly, NO_X reductions at certain times and in some areas can lead to increased ozone levels. We do not see any ozone increases in the Great Lakes region.

5.4.3 Projected Particulate Matter Air Quality Impacts in the Great Lakes Region

The analysis described in this section shows the projected $PM_{2.5}$ air quality improvements in the Great Lakes region due to the Coordinated Strategy emissions reductions. Our analysis indicates that the reductions from the Coordinated Strategy will provide Great Lakes-wide improvements in ambient $PM_{2.5}$ concentrations and minimize the risk of exposures in future years. In addition, since the emission reductions from the Coordinated Strategy go into effect during the period when some areas are still working to attain the $PM_{2.5}$ NAAQS, the projected emission reductions will assist state and local agencies in their effort to attain the $PM_{2.5}$ standard and help others maintain the standard.

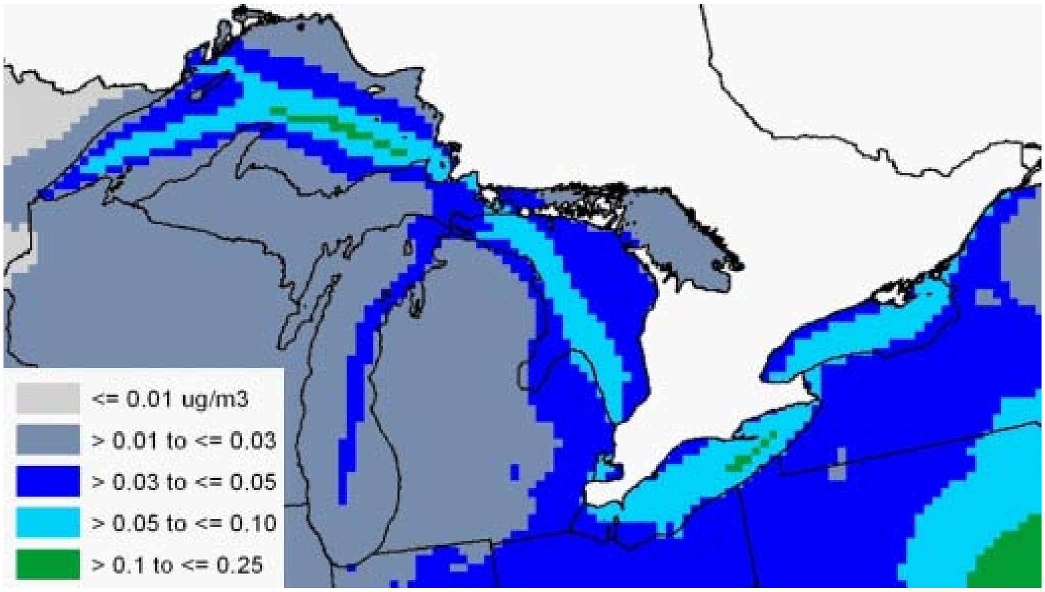
EPA has issued two NAAQS for $PM_{2.5}$: an annual standard (15 $\mu g/m^3$) and a 24-hour standard (35 $\mu g/m^3$). The most recent revisions to these standards were in 1997 and 2006. In 2005, the U.S. EPA designated nonattainment areas for the 1997 $PM_{2.5}$ NAAQS (70 FR 19844, April 14, 2005).[L] On October 8, 2009, the EPA issued final nonattainment area designations for the 2006 24-hour $PM_{2.5}$ NAAQS (74 FR 58688, November 13, 2009).

Great Lakes states with $PM_{2.5}$ nonattainment areas, including Michigan, Wisconsin, Indiana, Illinois and Ohio, will be required to take action to bring those areas into compliance in the future. Most 1997 $PM_{2.5}$ nonattainment areas are required to attain the 1997 $PM_{2.5}$ NAAQS in the 2010 to 2015 time frame and then required to maintain the 1997 $PM_{2.5}$ NAAQS thereafter.[208][209] The 2006 24-hour $PM_{2.5}$ nonattainment areas will be required to attain the 2006 24-hour $PM_{2.5}$ NAAQS in the 2014 to 2019 time frame and then be required to maintain the 2006 24-hour $PM_{2.5}$ NAAQS thereafter.[210] The U.S. Government and individual states and local areas have already put in place many $PM_{2.5}$ and $PM_{2.5}$ precursor emission reduction programs. However, we expect many of the $PM_{2.5}$ nonattainment areas will need to adopt additional emissions reduction programs to attain and maintain the $PM_{2.5}$ NAAQS. In the Great Lakes Category 3 vessels are contributors to $PM_{2.5}$ and reductions from this source in a timely manner will help the states to meet their air quality goals. The Coordinated Strategy for Category 3 marine engines and their fuels will provide additional needed inventory reductions to the Great Lakes and will assist $PM_{2.5}$ nonattainment areas in reaching the standard by each area's respective attainment date and/or assist attainment areas in maintaining the $PM_{2.5}$ standard in the future.

Figure 5-11 presents the projected annual $PM_{2.5}$ improvements in 2020 from the Coordinated Strategy for the Great Lakes region.[M] Based on the air quality modeling performed for the Coordinated Strategy, we project that most of the eastern portion of this region, including the metropolitan areas of Cleveland and Detroit, will see improvements of between 0.03 and 0.05 $\mu g/m^3$.

[L] A nonattainment area is defined in the Clean Air Act (CAA) as an area that is violating an ambient standard or is contributing to a nearby area that is violating the standard.
[M] Maps for improvements in 24-hour $PM_{2.5}$ were not created because the mapping methodology was being finalized at the time the Coordinated Strategy modeling occurred.

Figure 5-11 Improvement in Annual Average $PM_{2.5}$ Concentrations in 2020 from the Coordinated Strategy



One way to estimate the air quality impacts from the Great Lakes Fleet is to consider only the 6 mid-western states that border the Great Lakes (IL, IN, MI, MN, OH, and WI). This method minimizes the impact that East Coast emissions reductions may be having in the eastern Great Lakes states like New York and Pennsylvania. Within the 6 mid-western states that border the Great Lakes, the average modeled future-year annual $PM_{2.5}$ design values will decrease by 0.03 $\mu g/m^3$ in 2020 and the average modeled future-year 24-hour $PM_{2.5}$ design values will also decrease by 0.03 $\mu g/m^3$ in 2020. These design value decreases indicate the overall improvement in air quality in the Great Lakes region due to the emissions reductions in Great Lakes vessels from the Coordinated Strategy.

Table 5-3 and Table 5-4 list the counties on the shores of the Great Lakes with projected annual and/or 24-hour $PM_{2.5}$ design values that violate or are within 10 percent of the $PM_{2.5}$ standard in 2020. Counties marked with a "V" in the table have projected design values greater than or equal to the standard. Counties marked with an "X" in the table have projected design values within 10 percent below the standard. The counties marked "X" are not projected to violate the standard, but to be close to it, so the rule will help assure that these counties continue to meet the standard. Reducing emissions from Great Lakes vessels will help assure that these counties attain or maintain the standard.

Table 5-3 Great Lakes Counties with 2020 Projected $PM_{2.5}$ Design Values in Violation or Within 10 percent of the Annual $PM_{2.5}$ Standard in the Base and Control Cases

State	County	2000-2004 Average annual $PM_{2.5}$ DV ($\mu/^3$)	2020 modeling projections of Base annual $PM_{2.5}$ DV ($\mu G/M^3$)	2020 modeling projections of Control annual $PM_{2.5}$ DV ($\mu G/M^3$)	2020 Projected Population[a]
IL	Cook Co	17.07	X	X	5,669,479
MI	Wayne Co	19.32	V	V	1,908,196
OH	Cuyahoga Co	18.37	X	X	1,326,680

[a] Woods & Poole Economics Inc. 2001. Population by Single Year of Age CD. Woods & Poole Economics, Inc.

Table 5-4 Great Lakes Counties with 2020 Projected $PM_{2.5}$ Design Values in Violation or Within 10 percent of the 24-hour $PM_{2.5}$ Standard in the Base and Control Cases

State	County	2000-2004 Average 24-hour $PM_{2.5}$ DV ($\mu/^3$)	2020 modeling projections of Base 24-Hour $PM_{2.5}$ DV ($\mu G/M^3$)	2020 modeling projections of Control 24-hour $PM_{2.5}$ DV ($\mu G/M^3$)	2020 Projected Population[a]
IL	Cook Co	43.3	V	V	5,669,479
MI	Wayne Co	42.9	V	V	1,908,196
OH	Cuyahoga Co	44.0	V	V	1,326,680
IN	Lake Co	43.8	V	V	509,293

[a] Woods & Poole Economics Inc. 2001. Population by Single Year of Age CD. Woods & Poole Economics, Inc.

5.4.4 Projected Ozone Air Quality Impacts in the Great Lakes Region

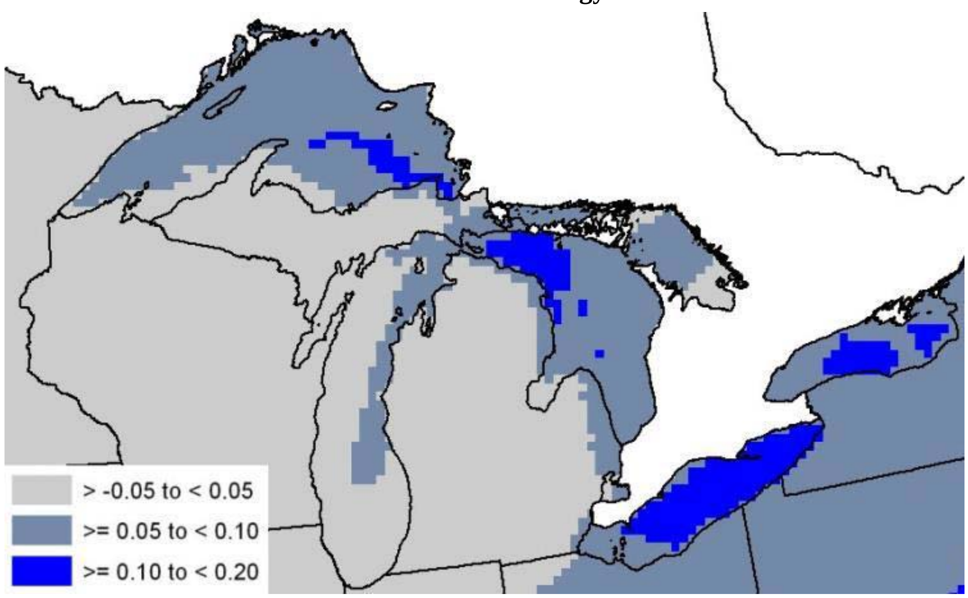
The analysis described in this section shows the projected ozone air quality impacts in the Great Lakes region in the future due to the Coordinated Strategy emissions reductions. Our analysis indicates that the reductions from the Coordinated Strategy will provide Great Lakes-wide improvements in ambient ozone concentrations and minimize the risk of exposures in future years. In addition, since the emission reductions from the Coordinated Strategy go into effect during the period when some areas are still working to attain the ozone NAAQS, the projected emission reductions will assist state and local agencies in their effort to attain the ozone standard and help others maintain the standard. Emissions reductions from this rule will also help to counter potential ozone increases due to climate change, which are expected in many urban areas in the United States, but were not reflected in the Coordinated Strategy modeling.[211,212]

EPA's national ambient air quality standard (NAAQS) for ozone is an 8-hour standard set at 0.075 ppm. The most recent revision to this standard was in 2008, the previous 8-hour ozone standard, set in 1997, had been 0.08 ppm. In 2004, the U.S. EPA designated nonattainment areas for the 1997 8-hour ozone NAAQS (69 FR 23858, April 30, 2004).[N] The nonattainment areas associated with the more stringent 2008 8-hour ozone NAAQS have not yet been designated.[O]

Great Lakes states with ozone nonattainment areas, including Michigan, Wisconsin, Indiana, Illinois and New York, are required to take action to bring those areas into compliance in the future. The attainment date assigned to an ozone nonattainment area is based on the area's classification. Most ozone nonattainment areas are required to attain the 1997 8-hour ozone NAAQS in the 2007 to 2013 time frame and then be required to maintain it thereafter. In addition, there will be attainment dates associated with the designation of nonattainment areas as a result of the reconsideration of the 2008 ozone NAAQS. We expect many of the ozone nonattainment areas will need to adopt additional emissions reduction programs to attain and maintain the ozone NAAQS. The expected NO_X reductions from the Coordinated Strategy will be useful to states as they seek to either attain or maintain the ozone NAAQS.

Figure 5-12 presents the projected ozone improvements in 2020 from the Coordinated Strategy. Most of the eastern Great Lakes region, including the metropolitan areas of Cleveland and Detroit, are projected to see improvements of between 0.05 and 0.1 ppb.

Figure 5-12 Improvement in Summertime Maximum 8-hour Average Ozone Concentrations in 2020 from the Coordinated Strategy



[N] A nonattainment area is defined in the Clean Air Act (CAA) as an area that is violating an ambient standard or is contributing to a nearby area that is violating the standard.

[O] On September 16, 2009, the Administrator announced that the EPA is reconsidering the 2008 ozone standards to determine whether they adequately protect public health and the environment. She also announced that the Agency will propose to temporarily stay the 2008 standards for the purpose of attainment and nonattainment area designations. Under the stay, all activities to designate areas for the 2008 ozone standards would be suspended for the duration of the reconsideration period. EPA intends to complete the reconsideration by July 31, 2011. If, as a result of the reconsideration, EPA determines that the 2008 ozone standards are not supported by the scientific record and promulgates different ozone standards, the new 2011 ozone standards would replace the 2008 ozone standards and the requirement to designate areas for the 2008 standards would no longer apply. If EPA promulgates new ozone standards in 2011, the designations would likely be effective in 2013.

As mentioned above, one way to estimate the air quality impacts from the Great Lakes Fleet is to consider only the 6 mid-western states that border the Great Lakes (IL, IN, MI, MN, OH, and WI). Within the 6 mid-western states that border the Great Lakes the average modeled future-year ozone design values will decrease by 0.03 ppb in 2020. These design value decreases indicate the overall improvement in air quality in the Great Lakes region due to the emissions reductions in Great Lakes vessels from the Coordinated Strategy.

Table 5-5 lists the counties on the shores of the Great Lakes with projected 8-hour ozone design values that violate or are within 10 percent of the 2008 8-hour ozone standard in 2020. Counties marked with a "V" in the table have projected design values greater than or equal to the standard. Counties marked with an "X" in the table have projected design values within 10 percent below the standard. The counties marked "X" are not projected to violate the standard, but to be close to it, so the rule will help assure that these counties continue to meet the standard. Reducing emissions from Great Lakes vessels will help assure that these counties attain or maintain the standard.

Table 5-5 Great Lakes Counties with 2020 Projected 8-hour Ozone Design Values in Violation or Within 10% of the Standard in the Base and Control Cases

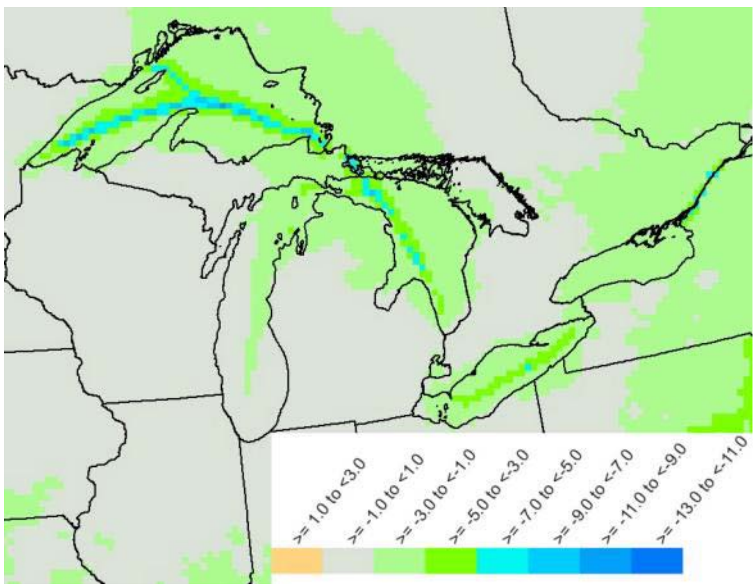
State	County	2000-2004 Average 8-hour Ozone DV ($\mu/^3$)	2020 modeling projections of Base 8-hour Ozone DV ($\mu G/M^3$)	2020 modeling projections of Control 8-hour Ozone DV ($\mu G/M^3$)	2020 Projected Population[a]
Wisconsin	Kenosha	98.3	V	V	184,825
Wisconsin	Sheboygan	97.0	V	V	128,777
Ohio	Ashtabula	95.7	V	V	108,355
Indiana	Lake	88.3	V	V	509,293
Wisconsin	Ozaukee	93.0	V	V	110,294
Wisconsin	Racine	91.7	V	V	212,351
Michigan	Allegan	94.0	X	X	141,851
Michigan	Macomb	92.3	X	X	894,095
Wisconsin	Milwaukee	91.0	X	X	927,845
Indiana	La Porte	90.3	X	X	114,207
Indiana	Porter	86.3	X	X	188,604
Wisconsin	Door	91.0	X	X	34,106
Illinois	Cook	85.3	X	X	5,669,479
Ohio	Lake	92.7	X	X	250,353
Michigan	Muskegon	90.0	X	X	183,444
Ohio	Lucas	90.0	X	X	445,152
Michigan	Berrien	88.0	X	X	169,437
Michigan	Wayne	86.0	X	X	1,908,196
Michigan	St Clair	88.0	X	X	194,501
Wisconsin	Kewaunee	89.3	X	X	21,040
Illinois	Lake	84.7	X	X	861,958
Wisconsin	Manitowoc	87.0	X	X	85,187
Ohio	Lorain	87.0	X	X	309,007
Ohio	Cuyahoga	88.0	X	X	1,326,680

[a] Woods & Poole Economics Inc. 2001. Population by Single Year of Age CD. Woods & Poole Economics, Inc.

5.4.5 Projected Nitrogen and Sulfur Deposition Air Quality Impacts in the Great Lakes Region

The emissions reductions from the Coordinated Strategy will also reduce nitrogen and sulfur deposition levels for the Great Lakes region in 2020. Our analysis shows that sulfur deposition would be reduced from 1 percent to 3 percent and nitrogen deposition would be reduced from between 0 to 1 percent. Figure 5-13 illustrates the sulfur deposition reductions that will occur in the Great Lakes region. Many of the areas that will see the reductions in sulfur deposition are the same areas that have aquatic ecosystems which are particularly sensitive to acidifying deposition (see Figure 5-6). These projected nitrogen and sulfur deposition reductions will assist the U.S. in its efforts to reduce acidification impacts in both terrestrial and aquatic ecosystems in the Great Lakes.

Figure 5-13 Percent Change in Annual Total Sulfur Deposition in 2020 from the Coordinated Strategy



The modeling provides estimates of the amount of nitrogen and sulfur deposition in the Great Lakes region. Additionally, we conducted analyses using a separate methodology in which the model outputs were used to estimate the impacts on deposition levels by creating wet deposition relative reduction factors, more detail is available in Section 2.4.5.6 of the RIA for the final Category 3 marine rulemaking. This analysis was completed for each individual 8-digit hydrological unit code (HUC) within the U.S. modeling domain. Table 5-6 presents the results of this analysis for the Great Lakes. This assessment corroborated the deposition modeling results. Both analyses indicate that the Coordinated Strategy will help reduce nitrogen and sulfur deposition within the Great Lakes region.

Table 5-6 Percent reduction in Nitrogen (N) and Sulfur (S) deposition averaged over the Great Lakes HUC sub region. The reductions are shown in parentheses.

HUC SUB REGION GREAT LAKES	POLLUTANT	COORDINATED STRATEGY PERCENT REDUCTION
Great Lakes (4)	Nitrogen	0.2% (0.1 to 0.5%)
	Sulfur	1.0% (0.5 to 2.7%)

5.4.6 Projected Visibility Impacts in the Great Lakes Region

As discussed in Section 5.3.4, visibility impairment is experienced throughout the U.S., in multi-state regions, urban areas, and remote mandatory class I federal areas, including those within the Great Lakes.[213,214] The CMAQ model was also used to estimate visibility impacts based on the projected improvement in annual average visibility at mandatory federal class I federal areas. The mandatory class I federal areas are required to achieve natural background visibility levels by 2064 under the Regional Haze Rule.

Table 5-7 presents the CMAQ visibility results from the 2020 Coordinated Strategy scenario for the 3 mandatory class I federal areas on the shores of the Great Lakes. The results indicate that although the areas would continue to have annual average deciview levels above background in 2020, reductions in regional haze would occur in all of the areas as a result of the emissions reductions in the Coordinated Strategy.

Table 5-7 Visibility Levels in Deciviews for Great Lakes Mandatory Class 1 Federal Areas on the 20 percent Worst Days

CLASS 1 AREA (20% WORST DAYS)	STATE	BASELINE VISIBILITY	2020 BASE	ECA	NATURAL BACKGROUND
Isle Royale NP	MI	20.74	18.99	18.84	12.37
Seney	MI	24.16	21.54	21.49	12.65
Voyageurs NP	MN	19.27	17.55	17.52	12.06

5.5 Quantified and Monetized Health and Environmental Impacts

EPA's Coordinated Strategy to control emissions from ships will result in a substantial improvement in air quality and related human health and environmental impacts throughout the United States, including the Great Lakes region.[215] We have estimated the human health benefits associated with the air quality improvements projected for the U.S. portion of the Great Lakes region. These benefits are derived from the modeling that was performed in support of our Coordinated Strategy and are based on the national inventories developed for those actions (see Chapter 4 for more information about our estimated marine inventory). No new air quality modeling or benefits analysis was performed specifically for this Great Lakes study.

This section describes the methods and assumptions used to estimate the air quality-related benefits in the Great Lakes region associated with EPA's Coordinated Strategy to control emissions from ships and describes in more detail the related methods and assumptions that underpin the benefits presented in the final RIA for the Coordinated Strategy.[216] Using these methods, we project monetized health benefits for 2030 associated with the application of the

ECA controls on the Great Lakes to be between $1.5 and $3.7 billion for the six western states bordering the Great Lakes.

5.5.1 Estimated Benefits of the Coordinated Strategy on the National Level

Benefits modeling begins with estimates of the air quality impacts of a program. EPA used the CMAQ model described in Appendix 5A to model the national-level ozone and PM air quality impacts of total shipping emissions, as well as the air quality improvements associated with EPA's Coordinated Strategy to control emissions from ships. That modeled ambient air quality data serves as an input to the Environmental Benefits Mapping and Analysis Program (BenMAP).[P] BenMAP is a computer program developed by the EPA that integrates a number of the modeling elements used in previous EPA analyses (e.g., interpolation functions, population projections, health impact functions, valuation functions, analysis and pooling methods) to translate modeled air concentration estimates into health effect incidence estimates. EPA then monetized health impacts related to the implementation of the Coordinated Strategy based on well established methods. These methods are described in Appendix 5B.

EPA estimates that by 2020, implementation of the Coordinated Strategy is expected to result in the reduction of a significant number of $PM_{2.5}$-related health impacts, including 5,300 to 14,000 fewer premature mortalities, the reduction of 3,900 hospital admissions (related to both cardiovascular and respiratory causes), 720,000 days of work lost avoided, 8,800 fewer non-fatal heart attacks, and the reduction of 4.3 million days of restricted physical activity.

EPA also estimates that by 2030, implementation of the Coordinated Strategy is expected to result in an even larger reduction of $PM_{2.5}$-related health impacts, including 12,000 to 30,000 fewer premature mortalities, the reduction of 9,300 hospital admissions (related to both cardiovascular and respiratory causes), 1,400,000 days of work lost avoided, 20,000 fewer non-fatal heart attacks, and the reduction of 8.5 million days of restricted physical activity.

5.5.2 Benefits Analysis for Great Lakes

Similar to the air quality analyses above, this benefits analysis considers only the 6 mid-western states that border the Great Lakes (IL, IN, MI, MN, OH, and WI). For this analysis, we disaggregated the $PM_{2.5}$-related benefits that accrue to these states from the nationally aggregated $PM_{2.5}$ benefits totals presented in the rulemaking support documentation that accompanied the Coordinated Strategy to control ship emissions.[Q] Table 5-8 presents both the disaggregated quantified and monetized $PM_{2.5}$-related health impacts estimated for the 6 Great Lakes states as well as the benefits associated with the national program.

[P] Information on BenMAP, including downloads of the software, can be found at http://www.epa.gov/ttn/ecas/ benmodels.html.

[Q] For national-level benefits analyses, such as EPA's Coordinated Strategy to control ship emissions, we typically present total benefits for the nation as a whole. For this analysis, however, we utilized BenMAP to sum and report those benefits that accrue to the six "Great Lakes" states (IL, IN, MI, MN, OH, and WI) under the Coordinated Strategy.

Based on the estimated improvements in concentrations of ambient $PM_{2.5}$ presented in the previous section, EPA estimates that by 2020, implementation of the Coordinated Strategy in the Great Lakes is expected to result in 87 - 230 fewer PM-related premature deaths, the reduction of 70 hospital admissions (related to both cardiovascular and respiratory causes), 11,000 days of work lost avoided, 160 fewer non-fatal heart attacks, and the reduction of 63,000 days of restricted physical activity. By 2030, PM-related health impacts improve even more, with 170 – 430 fewer PM-related premature deaths, the reduction 140 hospital admissions (related to both cardiovascular and respiratory causes), 18,000 days of lost work avoided, 310 fewer non-fatal heart attacks, and the reduction of 110,000 days of restricted physical activity.

Table 5-8 shows that the monetized PM-related benefits in the 6 Great Lakes states range from $0.8 to $1.9 billion in 2020 and from $1.5 to $3.7 billion in 2030. This represents between 1.4 and 1.7 percent of the nationally-aggregated monetized benefits.

Table 5-8 Selected $PM_{2.5}$-related Health Benefits of Ships Operating in the U.S. Portion of the North American ECA

Health Impact	Great Lakes 2020	Great Lakes 2030	National 2020	National 2030
Premature Mortality[a]	87 - 230	170 - 430	5,300 – 14,000	12,000 – 30,000
Chronic Bronchitis	64	110	3,800	8,100
Non-Fatal Heart Attacks	160	310	8,800	20,000
Hospital Admissions[b]	70	140	3,900	9,300
Acute Bronchitis	140	250	8,500	17,000
Acute Respiratory Symptoms	63,000	110,000	4,300,000	8,500,000
Avoided Work Loss Days	11,000	18,000	720,000	1,400,000
Total Monetized $PM_{2.5}$ Benefits [billions, 2006$][c]	**$0.8 – $1.9**	**$1.5 - $3.7**	**$46 - $110**	**$110 - $270**

Notes:
[a] Includes only $PM_{2.5}$-related estimates of premature mortality. The range is based on the high- and low-end estimate of incidence derived from two alternative studies used to estimate $PM_{2.5}$-related premature mortality in the U.S. (Pope et al., 2002 and Laden et al., 2006).
[b] Includes estimates of both cardiovascular- and respiratory-related hospital admissions.
[c] Only PM benefits are included here which are monetized at a discount rate of 3 percent and presented in year 2006 dollars. The range is based on the high- and low-end estimate of incidence derived from two alternative studies used to estimate $PM_{2.5}$-related premature mortality in the U.S. (Pope et. al. and Laden et. al.)

The national-level benefits, and those specific to the Great Lakes states, presented in Table 5-8 omit a number of benefits categories, including human health and environmental benefits from reductions in ozone formation, air toxics, and other PM-related impacts that we do not quantify or monetize. These benefit categories remain unquantified because of current limitations in methods or available data and are listed in Table 5-9. As a result, the quantified health and environmental benefits, both nationally and in the Great Lakes region, are likely underestimates of the total benefits attributable to the implementation of the Coordinated Strategy.

Table 5-9 Unquantified and Non-Monetized Potential Effects of a Coordinated U.S. Strategy to Control Ship Emissions

Pollutant/ Effects	Effects Not Included in Analysis - Changes in:
Ozone Health[a]	Premature mortality – short term exposures Hospital admissions – respiratory causes Emergency room visits – asthma Minor restricted activity days School absence days Chronic respiratory damage[b] Premature aging of the lungs[b] Non-asthma respiratory emergency room visits Exposure to UVb (+/-)[e]
Ozone Welfare	Yields for -commercial forests -some fruits and vegetables -non-commercial crops Damage to urban ornamental plants Impacts on recreational demand from damaged forest aesthetics Ecosystem functions Exposure to UVb (+/-)[e]
PM Health[c]	Premature mortality - short term exposures[d] Low birth weight Pulmonary function Chronic respiratory diseases other than chronic bronchitis Non-asthma respiratory emergency room visits Exposure to UVb (+/-)[e]
PM Welfare	Residential and recreational visibility in non-Class I areas Soiling and materials damage Damage to ecosystem functions Exposure to UVb (+/-)[e]
Nitrogen and Sulfate Deposition Welfare	Commercial forests due to acidic sulfate and nitrate deposition Commercial freshwater fishing due to acidic deposition Recreation in terrestrial ecosystems due to acidic deposition Existence values for currently healthy ecosystems Commercial fishing, agriculture, and forests due to nitrogen deposition Recreation in estuarine ecosystems due to nitrogen deposition Ecosystem functions Passive fertilization
CO Health	Behavioral effects
HC/Toxics Health	Cancer (benzene, 1,3-butadiene, formaldehyde, acetaldehyde) Anemia (benzene) Disruption of production of blood components (benzene) Reduction in the number of blood platelets (benzene) Excessive bone marrow formation (benzene) Depression of lymphocyte counts (benzene) Reproductive and developmental effects (1,3-butadiene) Irritation of eyes and mucus membranes (formaldehyde) Respiratory irritation (formaldehyde) Asthma attacks in asthmatics (formaldehyde) Asthma-like symptoms in non-asthmatics (formaldehyde) Irritation of the eyes, skin, and respiratory tract (acetaldehyde) Upper respiratory tract irritation and congestion (acrolein)
HC/Toxics Welfare	Direct toxic effects to animals Bioaccumulation in the food chain

Pollutant/ Effects	Effects Not Included in Analysis - Changes in:
	Damage to ecosystem function Odor

Notes:
[a] The public health impact of biological responses such as increased airway responsiveness to stimuli, inflammation in the lung, acute inflammation and respiratory cell damage, and increased susceptibility to respiratory infection are likely partially represented by our quantified endpoints.
[b] The public health impact of effects such as chronic respiratory damage and premature aging of the lungs may be partially represented by quantified endpoints such as hospital admissions or premature mortality, but a number of other related health impacts, such as doctor visits and decreased athletic performance, remain unquantified.
[c] In addition to primary economic endpoints, there are a number of biological responses that have been associated with PM health effects including morphological changes and altered host defense mechanisms. The public health impact of these biological responses may be partly represented by our quantified endpoints.
[d] While some of the effects of short-term exposures are likely to be captured in the estimates, there may be premature mortality due to short-term exposure to PM not captured in the cohort studies used in this analysis.
[e] May result in benefits or disbenefits.

5.5.3 Economic Values for Health Outcomes

Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects for a large population. Therefore, the appropriate economic measure is willingness-to-pay (WTP) for changes in risk of a health effect rather than WTP for a health effect that would occur with certainty (Freeman, 1993). Epidemiological studies generally provide estimates of the relative risks of a particular health effect that is avoided because of a reduction in air pollution. We converted those to units of avoided statistical incidence for ease of presentation. We calculated the value of avoided statistical incidences by dividing individual WTP for a risk reduction by the related observed change in risk. For example, suppose a pollution-reduction regulation is able to reduce the risk of premature mortality from 2 in 10,000 to 1 in 10,000 (a reduction of 1 in 10,000). If individual WTP for this risk reduction is $100, then the WTP for an avoided statistical premature death is $1 million ($100/0.0001 change in risk).

WTP estimates generally are not available for some health effects, such as hospital admissions. In these cases, we used the cost of treating or mitigating the effect as a primary estimate. These cost-of-illness (COI) estimates generally understate the true value of reducing the risk of a health effect, because they reflect the direct expenditures related to treatment, but not the value of avoided pain and suffering (Harrington and Portney, 1987; Berger, 1987). We provide unit values for health endpoints (along with information on the distribution of the unit value) in Table 5-10. All values are in constant year 2000 dollars, adjusted for growth in real income out to 2020 and 2030 using projections provided by Standard and Poor's. Economic theory argues that WTP for most goods (such as environmental protection) will increase if real income increases. Many of the valuation studies used in this analysis were conducted in the late 1980s and early 1990s. Because real income has grown since the studies were conducted, people's willingness to pay for reductions in the risk of premature death and disease likely has grown as well. We did not adjust cost of illness-based values because they are based on current costs. Similarly, we did not adjust the value of school absences, because that value is based on current wage rates. For details on valuation estimates for PM-related endpoints, see the 2006 PM NAAQS RIA. For details on valuation estimates for ozone-related endpoints, see the 2008 Ozone NAAQS RIA.

5.5.4 Methods for Describing Uncertainty

The National Research Council (NRC)[217] highlighted the need for EPA to conduct rigorous quantitative analysis of uncertainty in its benefits estimates and to present these estimates to decision makers in ways that foster an appropriate appreciation of their inherent uncertainty. In response to these comments, EPA's Office of Air and Radiation (OAR) is developing a comprehensive strategy for characterizing the aggregate impact of uncertainty in key modeling elements on both health incidence and benefits estimates. Components of that process include emissions modeling, air quality modeling, health effects incidence estimation, and valuation.

In benefit analyses of air pollution regulations conducted to date, the estimated impact of reductions in premature mortality has accounted for 85 percent to 95 percent of total benefits. Therefore, it is particularly important to characterize the uncertainties associated with reductions in premature mortality. The health impact functions used to estimate avoided premature deaths associated with reductions in ozone have associated standard errors that represent the statistical errors around the effect estimates in the underlying epidemiological studies.[R] In our results, we report credible intervals based on these standard errors, reflecting the uncertainty in the estimated change in incidence of avoided premature deaths. We also provide multiple estimates, to reflect model uncertainty between alternative study designs.

For premature mortality associated with exposure to PM, we follow the same approach that has been used in several recent RIAs.[218,219,220] First, we use Monte Carlo methods for estimating random sampling error associated with the concentration response functions from epidemiological studies and economic valuation functions. Monte Carlo simulation uses random sampling from distributions of parameters to characterize the effects of uncertainty on output variables, such as incidence of premature mortality. Specifically, we used Monte Carlo methods to generate confidence intervals around the estimated health impact and dollar benefits. Distributions for individual effect estimates are based on the reported standard errors in the epidemiological studies. Distributions for unit values are described in Table 5-10.

Second, as a sensitivity analysis, we use the results of our expert elicitation of the concentration response function describing the relationship between premature mortality and ambient $PM_{2.5}$ concentration.[S, 221] Incorporating only the uncertainty from random sampling error omits important sources of uncertainty (e.g., in the functional form of the model; whether or not a threshold may exist). This second approach attempts to incorporate these other sources of uncertainty.

Use of the expert elicitation and incorporation of the standard errors approaches provide insights into the likelihood of different outcomes and about the state of knowledge regarding the benefits estimates. Both approaches have different strengths and weaknesses, which are fully described in Chapter 5 of the PM NAAQS RIA.

[R] Health impact functions measure the change in a health endpoint of interest, such as hospital admissions, for a given change in ambient ozone or PM concentration.

[S] Expert elicitation is a formal, highly structured and well documented process whereby expert judgments, usually of multiple experts, are obtained (Ayyb, 2002).

These multiple characterizations, including confidence intervals, omit the contribution to overall uncertainty of uncertainty in air quality changes, baseline incidence rates, populations exposed and transferability of the effect estimate to diverse locations. Furthermore, the approach presented here does not yet include methods for addressing correlation between input parameters and the identification of reasonable upper and lower bounds for input distributions characterizing uncertainty in additional model elements. As a result, the reported confidence intervals and range of estimates give an incomplete picture about the overall uncertainty in the estimates. This information should be interpreted within the context of the larger uncertainty surrounding the entire analysis.

As mentioned above, total benefits are driven primarily by the reduction in $PM_{2.5}$-related premature mortalities each year. Some key assumptions underlying the premature mortality estimates include the following, which may also contribute to uncertainty:

- Inhalation of fine particles is causally associated with premature death at concentrations near those experienced by most Americans on a daily basis. Although biological mechanisms for this effect have not yet been completely established, the weight of the available epidemiological, toxicological, and experimental evidence supports an assumption of causality. The impacts of including a probabilistic representation of causality were explored in the expert elicitation-based results of the PM NAAQS RIA.

- All fine particles, regardless of their chemical composition, are equally potent in causing premature mortality. This is an important assumption, because PM produced via transported precursors emitted from engines may differ significantly from PM precursors released from electric generating units and other industrial sources. However, no clear scientific grounds exist for supporting differential effects estimates by particle type.

- The C-R function for fine particles is approximately linear within the range of ambient concentrations under consideration. Thus, the estimates include health benefits from reducing fine particles in areas with varied concentrations of PM, including both regions that may be in attainment with $PM_{2.5}$ standards and those that are at risk of not meeting the standards.

- There is uncertainty in the magnitude of the association between ozone and premature mortality. The range of ozone impacts associated with the final rule is estimated based on the risk of several sources of ozone-related mortality effect estimates. In a recent report on the estimation of ozone-related premature mortality published by the National Research Council, a panel of experts and reviewers concluded that short-term exposure to ambient ozone is likely to contribute to premature deaths and that ozone-related mortality should be included in estimates of the health benefits of reducing ozone exposure.[222] EPA has requested advice from the National Academy of Sciences on how best to quantify uncertainty in the relationship between ozone exposure and premature mortality in the context of quantifying benefits.

Acknowledging omissions and uncertainties, we present a best estimate of the total benefits based on our interpretation of the best available scientific literature and methods supported by EPA's technical peer review panel, the Science Advisory Board's Health Effects Subcommittee (SAB-HES). The National Academies of Science (NRC, 2002) has also reviewed EPA's methodology for analyzing the health benefits of measures taken to reduce air pollution. EPA addressed many of these comments in the analysis of the final PM NAAQS.[223,224] This analysis incorporates this most recent work to the extent possible.

Table 5-10 Unit Values Used for Economic Valuation of Health Endpoints (2000$)[a]

Health Endpoint	Central Estimate of Value Per Statistical Incidence			Derivation of Estimates
	1990 Income Level	2020 Income Level[b]	2030 Income Level[b]	
Premature Mortality (Value of a Statistical Life): $PM_{2.5}$- and Ozone-related	$6,320,000	$7,590,000	$7,800,000	EPA currently recommends a default central Value of a Statistical Life (VSL) of $6.3 million based on a Weibull distribution fitted to twenty-six published VSL estimates (5 contingent valuation and 21 labor market studies). The underlying studies, the distribution parameters, and other useful information are available in Appendix B of EPA's current Guidelines for Preparing Economic Analyses. The guidelines can be accessed at: http://yosemite.epa.gov/ee/epa/eermfile.nsf/vwAN/EE-0516-01.pdf/$File/EE-0516-01.pdf
Chronic Bronchitis (CB)	$340,000	$420,000	$430,000	Point estimate is the mean of a generated distribution of WTP to avoid a case of pollution-related CB. WTP to avoid a case of pollution-related CB is derived by adjusting WTP (as described in Viscusi et al., 1991[225]) to avoid a severe case of CB for the difference in severity and taking into account the elasticity of WTP with respect to severity of CB.
Nonfatal Myocardial Infarction (MI) (heart attack)				Age-specific cost-of-illness values reflect lost earnings and direct medical costs over a 5-year period following a nonfatal MI. Lost earnings estimates are based on Cropper and Krupnick (1990).[226] Direct medical costs are based on simple average of estimates from Russell et al. (1998)[227] and Wittels et al. (1990).[228]
3% discount rate	$66,902	$66,902	$66,902	Lost earnings:
Age 0–24	$74,676	$74,676	$74,676	Cropper and Krupnick (1990). Present discounted value of 5 years of lost earnings:
Age 25–44	$78,834	$78,834	$78,834	age of onset: at 3% at 7%
Age 45–54	$140,649	$140,649	$140,649	25-44 $8,774 $7,855
Age 55–65	$66,902	$66,902	$66,902	45-54 $12,932 $11,578
Age 66 and over				55-65 $74,746 $66,920
7% discount rate	$65,293	$65,293	$65,293	Direct medical expenses: An average of:
Age 0–24	$73,149	$73,149	$73,149	1. Wittels et al. (1990) ($102,658—no discounting)
Age 25–44	$76,871	$76,871	$76,871	2. Russell et al. (1998), 5-year period ($22,331 at 3% discount rate; $21,113 at 7% discount rate)
Age 45–54	$132,214	$132,214	$132,214	
Age 55–65	$65,293	$65,293	$65,293	
Age 66 and over				

Health Endpoint	Central Estimate of Value Per Statistical Incidence			Derivation of Estimates
	1990 Income Level	2020 Income Level[b]	2030 Income Level[b]	
Hospital Admissions				
Chronic Obstructive Pulmonary Disease (COPD) (ICD codes 490-492, 494-496)	$12,378	$12,378	$12,378	The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Agency for Healthcare Research and Quality (2000)[229] (www.ahrq.gov).
Pneumonia (ICD codes 480-487)	$14,693	$14,693	$14,693	The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total pneumonia category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
Asthma Admissions	$6,634	$6,634	$6,634	The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total asthma category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
All Cardiovascular (ICD codes 390-429)	$18,387	$18,387	$18,387	The COI estimates (lost earnings plus direct medical costs) are based on ICD-9 code-level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total cardiovascular category illnesses) reported in Agency for Healthcare Research and Quality (2000) (www.ahrq.gov).
Emergency Room Visits for Asthma	$286	$286	$286	Simple average of two unit COI values: (1) $311.55, from Smith et al. (1997)[230] and (2) $260.67, from Stanford et al. (1999).[231]
Respiratory Ailments Not Requiring Hospitalization				
Upper Respiratory Symptoms (URS)	$25	$27	$27	Combinations of the three symptoms for which WTP estimates are available that closely match those listed by Pope et al. result in seven different “symptom clusters,” each describing a “type” of URS. A dollar value was derived for each type of URS, using mid-range estimates of WTP (IEc, 1994)[232] to avoid each symptom in the cluster and assuming additivity of WTPs. The dollar value for URS is the average of the dollar values for the seven different types of URS.

Health Endpoint	Central Estimate of Value Per Statistical Incidence			Derivation of Estimates
	1990 Income Level	2020 Income Level[b]	2030 Income Level[b]	
Lower Respiratory Symptoms (LRS)	$16	$17	$17	Combinations of the four symptoms for which WTP estimates are available that closely match those listed by Schwartz et al. result in 11 different "symptom clusters," each describing a "type" of LRS. A dollar value was derived for each type of LRS, using mid-range estimates of WTP (IEc, 1994) to avoid each symptom in the cluster and assuming additivity of WTPs. The dollar value for LRS is the average of the dollar values for the 11 different types of LRS.
Asthma Exacerbations	$42	$45	$45	Asthma exacerbations are valued at $42 per incidence, based on the mean of average WTP estimates for the four severity definitions of a "bad asthma day," described in Rowe and Chestnut (1986).[233] This study surveyed asthmatics to estimate WTP for avoidance of a "bad asthma day," as defined by the subjects. For purposes of valuation, an asthma attack is assumed to be equivalent to a day in which asthma is moderate or worse as reported in the Rowe and Chestnut (1986) study.
Acute Bronchitis	$360	$380	$390	Assumes a 6-day episode, with daily value equal to the average of low and high values for related respiratory symptoms recommended in Neumann et al. (1994).[234]
Restricted Activity and Work/School Loss Days				
Work Loss Days (WLDs)	Variable (national median =)			County-specific median annual wages divided by 50 (assuming 2 weeks of vacation) and then by 5—to get median daily wage. U.S. Year 2000 Census, compiled by Geolytics, Inc.
School Absence Days	$75	$75	$75	Based on expected lost wages from parent staying home with child. Estimated daily lost wage (if a mother must stay at home with a sick child) is based on the median weekly wage among women age 25 and older in 2000 (U.S. Census Bureau, Statistical Abstract of the United States: 2001, Section 12: Labor Force, Employment, and Earnings, Table No. 621). This median wage is $551. Dividing by 5 gives an estimated median daily wage of $103. The expected loss in wages due to a day of school absence in which the mother would have to stay home with her child is estimated as the probability that the mother is in the workforce times the daily wage she would lose if she missed a day = 72.85% of $103, or $75.

Health Endpoint	Central Estimate of Value Per Statistical Incidence			Derivation of Estimates
	1990 Income Level	2020 Income Level[b]	2030 Income Level[b]	
Worker Productivity	$0.95 per worker per 10% change in ozone per day	$0.95 per worker per 10% change in ozone per day	$0.95 per worker per 10% change in ozone per day	Based on $68 – median daily earnings of workers in farming, forestry and fishing – from Table 621, Statistical Abstract of the United States ("Full-Time Wage and Salary Workers – Number and Earnings: 1985 to 2000") (Source of data in table: U.S. Bureau of Labor Statistics, Bulletin 2307 and Employment and Earnings, monthly).
Minor Restricted Activity Days (MRADs)	$51	$54	$55	Median WTP estimate to avoid one MRAD from Tolley et al. (1986).[235]

[a] All monetized annual benefit estimates are presented in year 2000 dollars. We use the Consumer Price Indexes to adjust both WTP- and COI-based benefits estimates to 2007 dollars from 2000 dollars.[236] For WTP-based estimates, we use an inflation factor of 1.20 based on the CPI-U for "all items." For COI-based estimates, we use an inflation factor of 1.35 based on the CPI-U for medical care.

[b] Our analysis accounts for expected growth in real income over time. Economic theory argues that WTP for most goods (such as environmental protection) will increase if real incomes increase. Benefits are therefore adjusted by multiplying the unadjusted benefits by the appropriate adjustment factor to account for income growth over time. For a complete discussion of how these adjustment factors were derived, we refer the reader to the PM NAAQS regulatory impact analysis. Note that similar adjustments do not exist for cost-of-illness-based unit values. For these, we apply the same unit value regardless of the future year of analysis.

Appendices

Appendix 5A

Air Quality Modeling Methodology

This Appendix presents information on the air quality modeling for the Coordinated Strategy, including the model domain and modeling inputs.

Air Quality Modeling Overview

A national scale air quality modeling analysis was performed to estimate future year annual $PM_{2.5}$ concentrations, 8-hour ozone concentrations, nitrogen and sulfur deposition, and visibility levels. The 2002-based CMAQ modeling platform was used as the tool for the air quality modeling of future baseline emissions and control scenarios for the Coordinated Strategy. This platform represents a structured system of connected modeling-related tools and data that provide a consistent and transparent basis for assessing the air quality response to changes in emissions, meteorology, and/or model formulation. The base year of data used to construct this platform includes emissions and meteorology for 2002. The platform was developed by the U.S. EPA's Office of Air Quality Planning and Standards in collaboration with the Office of Research and Development and is intended to support a variety of regulatory and research model applications and analyses.

The CMAQ modeling system is a non-proprietary comprehensive three-dimensional, grid-based Eulerian air quality model designed to estimate the formation and fate of oxidant precursors, primary and secondary PM concentrations and deposition, over regional and urban spatial scales for given input sets of meteorological conditions and emissions.[237,238,239] CMAQ is a publicly available, peer reviewed,[T] state-of-the-science model consisting of a number of science attributes that are critical for simulating the oxidant precursors and non-linear organic and inorganic chemical relationships associated with the formation of sulfate, nitrate, and organic aerosols. CMAQ also simulates the transport and removal of directly emitted particles which are speciated as elemental carbon, crustal material, nitrate, sulfate, and organic aerosols. The CMAQ model version 4.6 was most recently peer-reviewed in February of 2007 for the U.S. EPA as reported in the "Third Peer Review of the CMAQ Model."[240] The CMAQ model is a well-known and well-respected tool and has been used in numerous national and international applications.[241,242,243]

This 2002 multi-pollutant modeling platform used the latest publicly-released CMAQ version 4.6[U] with a few minor changes and new features made internally by the U.S. EPA CMAQ model developers, all of which reflects updates to earlier versions in a number of areas to improve the underlying science. The model enhancements in CMAQ v4.6.1 include: (1) an in-cloud sulfate chemistry module that accounts for the nonlinear sensitivity of sulfate formation to

[T] Community Modeling & Analysis System (CMAS) – Reports from the CMAQ Review Process can be found at: http://www.cmascenter.org/r_and_d/cmaq_review_process.cfm?temp_id=99999.
[U] CMAQ version 4.6 was released on September 30, 2006. It is available from the Community Modeling and Analysis System (CMAS) as well as previous peer-review reports at: http://www.cmascenter.org.

varying pH; (2) an improved vertical asymmetric convective mixing module (ACM2) that allows in-cloud transport from a source layer to all other-in cloud layers (combined non-local and local closure scheme); (3) a heterogeneous reaction involving nitrate formation (gas-phase reactions involving N_2O_5 and H_2O); (4) the heterogeneous N_2O_5 reaction probability is now temperature- and humidity-dependent, (5) an updated version of the ISORROPIA aerosol thermodynamics module including improved representation of aerosol liquid water content and correction in activity coefficients for temperature other than 298K, and (6) an updated gas-phase chemistry mechanism, Carbon Bond 05 (CB05) and associated Euler Backward Iterative (EBI) solver, with extensions to model explicit concentrations of air toxic species.[V]

Model Domain and Configuration

The CMAQ modeling domain encompasses all of the lower 48 States (including the Great Lakes region) and portions of Canada and Mexico. The modeling domain is made up of a large continental U.S. 36 km grid and two 12 km grids (an Eastern U.S. and a Western U.S. domain), as shown in Figure 5A-1.[W,X] The modeling domain contains 14 vertical layers with the top of the modeling domain at about 16,200 meters, or 100 millibars (mb). Air quality conditions at the outer boundary of the 36 km domain were taken from the global GEOS-Chem model and did not change over the simulated scenarios. The 36 km grid was only used to establish the incoming air quality concentrations along the boundaries of the 12 km grids. All of the modeling results assessing the air quality impacts of emissions reductions from the application of ECA controls were taken from the 12 km grids. Table 5A-1 provides some basic geographic information regarding the CMAQ domains. Table 5A-2 provides information on the vertical structure of the CMAQ modeling as well as the model which provided meteorological inputs. Table 5A-3 indicates which CMAQ configuration options were chosen for this analysis.

[V] An updated version of CMAQ, version 4.7, has recently been released. Version 4.7 includes updates to the organic aerosol module and is available at: www.cmaq-model.org.
[W] We were unable to consider effects beyond the 48-State area due to the unavailability of gridded meteorological data for locations like Alaska and Hawaii.
[X] In the overlapping portion of the two fine grids we used the WUS results for the States of MT, WY, CO, and NM, and the EUS results for ND, MN, SD, IA, NE, MO, KS, OK, and TX.

Figure 5A-1 Map of the CMAQ Modeling Domain

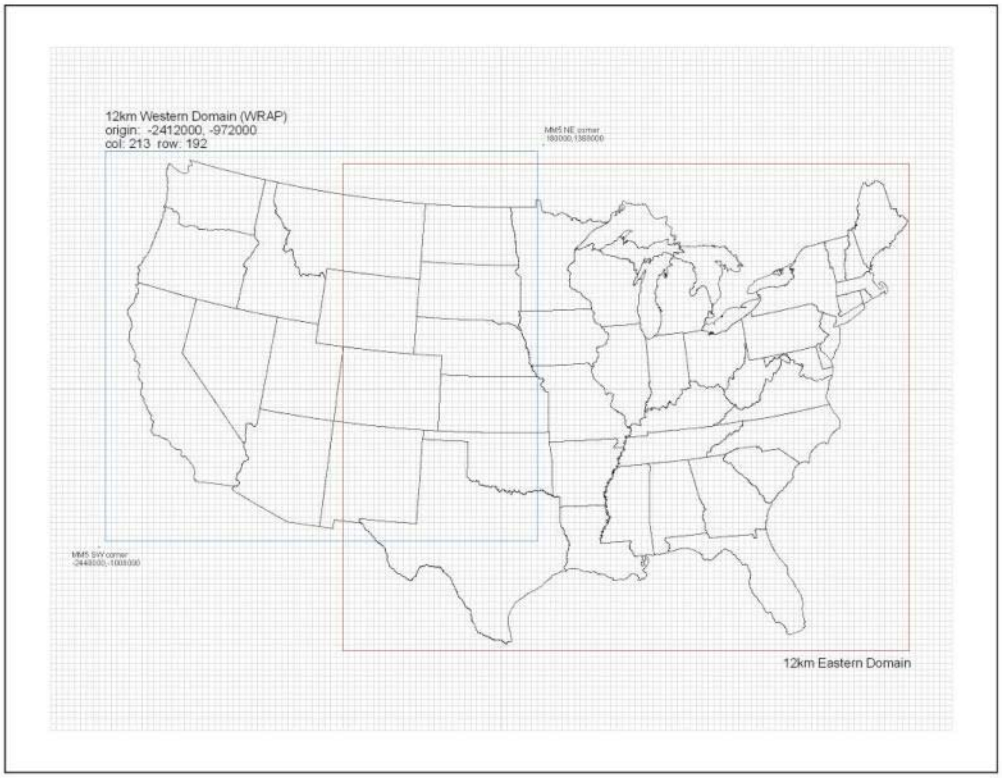


Table 5A-1 Geographic Elements of Domains Used in the ECA Modeling

CMAQ MODELING CONFIGURATION			
	National Grid	**Western U.S. Fine Grid**	**Eastern U.S. Fine Grid**
Map Projection	Lambert Conformal Projection		
Grid Resolution	36 km	12 km	12 km
Coordinate Center	97 deg W, 40 deg N		
True Latitudes	33 deg N and 45 deg N		
Dimensions	148 x 112 x 14	213 x 192 x 14	279 x 240 x 14
Vertical extent	14 Layers: Surface to 100 millibar level (see Table 5A-2)		

Table 5A-2 Vertical Layer Structure for MM5 and CMAQ (heights are layer top)

CMAQ LAYERS	MM5 LAYERS	SIGMA P	APPROXIMATE HEIGHT (M)	APPROXIMATE PRESSURE (MB)
0	0	1.000	0	1000
1	1	0.995	38	995
2	2	0.990	77	991
3	3	0.985	115	987
	4	0.980	154	982
4	5	0.970	232	973
	6	0.960	310	964
5	7	0.950	389	955
	8	0.940	469	946
6	9	0.930	550	937
	10	0.920	631	928
	11	0.910	712	919
7	12	0.900	794	910
	13	0.880	961	892
	14	0.860	1,130	874
8	15	0.840	1,303	856
	16	0.820	1,478	838
	17	0.800	1,657	820
9	18	0.770	1,930	793
	19	0.740	2,212	766
10	20	0.700	2,600	730
	21	0.650	3,108	685
11	22	0.600	3,644	640
	23	0.550	4,212	595
12	24	0.500	4,816	550
	25	0.450	5,461	505
	26	0.400	6,153	460
13	27	0.350	6,903	415
	28	0.300	7,720	370
	29	0.250	8,621	325
	30	0.200	9,625	280
14	31	0.150	10,764	235
	32	0.100	12,085	190
	33	0.050	13,670	145
	34	0.000	15,674	100

Table 5A-3 Additional Details Regarding the CMAQ Model Configuration

GAS-PHASE CHEMICAL MECHANISMKRER	CB05
Gas-Phase Chemical Solver	Euler Backward Iterative (EBI) scheme
PM Module	AERO4 aerosol module which contains mechanisms dealing with sea salt emissions. Three-mode approach: One coarse mode, two fine modes with variable standard deviations.
Inorganic PM module	ISORROPIA
Organic PM module	Updated SOA module based on Odum/Griffin et al., (1997, 1999)
Advection Scheme (vertical and horizontal)	Piecewise Parabolic Method (PPM)
Planetary Boundary Layer Scheme	Asymmetric Convective Mixing module (ACM2) scheme which permits gradual layer-by-layer downward mixing through compensatory subsidence
Dry Deposition	M3DRY module modified RADM scheme
Aqueous Chemistry	RADM Bulk scheme
Cloud Scheme	RADM Cloud scheme
Vertical Coordinate	Terrain-following Sigma coordinate

The 36 km and both 12 km CMAQ modeling domains were modeled for the entire year of 2002. We also modeled ten days at the end of December 2001 as a model "ramp up" period. These days are used to minimize the effects of initial conditions and are not considered as part of the output analyses. All 365 model days were used in the calculations of the ECA impacts on annual average levels of $PM_{2.5}$. For the 8-hour ozone results, we only used the modeling results from the period between May 1 and September 30, 2002. This 153-day period generally conforms to the ozone season across most parts of the U.S. and contains the majority of days with observed high ozone concentrations in 2002.

Model Inputs

The key inputs to the CMAQ model include emissions from anthropogenic and biogenic sources, meteorological data, and initial and boundary conditions.

Meteorological Data Inputs

The CMAQ meteorological input files were derived from a simulation of the Pennsylvania State University/National Center for Atmospheric Research Mesoscale Model[244] for the entire year of 2002. This model, commonly referred to as MM5, is a limited-area, nonhydrostatic, terrain-following system that solves for the full set of physical and thermodynamic equations which govern atmospheric motions.[245]

Meteorological model input fields were prepared separately for each of the domains shown in Figure 5A-1 above. The 36 km national domain was modeled using MM5 v.3.6.0 and the 12 km Eastern U.S grid was modeled with MM5 v3.7.2. Both of these two sets of meteorological inputs were developed by the U.S. EPA. For the 12 km western U.S. grid, we utilized existing MM5 meteorological model data prepared by the Western Regional Air Partnership.[246] All three sets of MM5 model runs were conducted in 5.5 day segments with 12 hours of overlap for spin-up purposes. Additionally, all three domains contained 34 vertical layers with an approximately 38 m deep surface layer and a 100 millibar top. The MM5 and CMAQ vertical structures are shown in Table 5A-2 and do not vary by horizontal grid resolution.

The meteorological outputs from MM5 were processed to create model-ready inputs for CMAQ using the Meteorology-Chemistry Interface Processor (MCIP) version 3.1 to derive the specific inputs to CMAQ, for example: horizontal wind components (i.e., speed and direction), temperature, moisture, vertical diffusion rates, and rainfall rates for each grid cell in each vertical layer. Before initiating the air quality simulations, an evaluation was conducted to identify the biases and errors associated with the meteorological modeling inputs. The U.S. EPA 2002 MM5 model performance evaluations used an approach which included a combination of qualitative and quantitative analyses to assess the adequacy of the MM5 simulated fields. More detail on the meteorological modeling evaluations can be found in the following references.[247,248] The general conclusion of each of these meteorological evaluations was that the simulated meteorology reproduced the actual meteorology with sufficient accuracy for them to be used in subsequent air quality analyses.

Initial and Boundary Conditions Data Inputs

The lateral boundary and initial species concentrations are provided by a three-dimensional global atmospheric chemistry model, the GEOS-CHEM model.[249] The global GEOS-CHEM model simulates atmospheric chemical and physical processes driven by assimilated meteorological observations from the NASA's Goddard Earth Observing System (GEOS). This model was run for 2002 with a grid resolution of 2.0 degree x 2.5 degree (latitude-longitude) and 20 vertical layers. The predictions were used to provide one-way dynamic boundary conditions at three-hour intervals and an initial concentration field for the 36 km CMAQ simulations. The 36 km coarse grid modeling was used as the initial/boundary conditions for the 12 km EUS and WUS finer grid modeling. More information is available about the GEOS-CHEM model and other applications using this tool at: http://www-as.harvard.edu/chemistry/trop/geos.

Emissions Inventory Data Inputs

With the exception of the marine emissions discussed in Chapter 4 of this document and Chapter 3 of the C3 RIA, the CMAQ gridded 2002 emissions input data were based on emissions from the 2002 National Emissions Inventory (NEI) version 3.0. This inventory includes emissions of criteria pollutants[Y] from point, stationary area, and mobile source categories. With the exception of California[Z], monthly onroad and nonroad emissions were generated from the National Mobile Inventory Model (NMIM) using versions of MOBILE6.0 and NONROAD2005

[Y] Criteria pollutant emissions include sulfur dioxide, oxides of nitrogen, carbon monoxide, volatile organic compounds, ammonia, and fine particles.

[Z] The California Air Resources Board submitted annual emissions for California. These were allocated to monthly resolution prior to emissions modeling using data from the National Mobile Inventory Model (NMIM).

consistent with recent national rule analyses.[AA,BB] The 2002-based platform and its associated chemical mechanism (CB05) employs updated speciation profiles using data included in the SPECIATE4.0 database.[CC] The 2002-based platform also incorporates several temporal profile updates for both mobile and stationary sources.

The 2002-based platform includes emissions for a 2002 base year model evaluation case, a 2002 base case and a 2020 future base case. The model evaluation case uses prescribed burning and wildfire emissions specific to 2002, which were developed and modeled as day-specific, location-specific emissions using an updated version of Sparse Matrix Operator Kernel Emissions (SMOKE) system, version 2.3, which computes plume rise and vertically allocates the fire emissions. SMOKE also provides mobile, area, and point source emissions as gridded, temporalized, and speciated data inputs to CMAQ (Houyoux and Vukovich, 1999).[250] The 2002 evaluation case also includes continuous emissions monitoring (CEM) data for 2002 for electric generating units (EGUs) with CEMs. The 2002 and projection year baselines include multi-year averages for the fire sector and EGU emissions that are temporally allocated based on a combination of multi-year average and 2002 temporal profiles. Projections from 2002 were developed to account for the expected impact of national regulations, consent decrees or settlements, known plant closures, and, for some sectors, activity growth. Biogenic emissions were processed using the Biogenic Emissions Inventory System (BEIS) version 3.13.

CMAQ Evaluation

An operational model performance evaluation for ozone and $PM_{2.5}$ and its related speciated components was conducted using 2002 State/local monitoring data in order to estimate the ability of the CMAQ modeling system to replicate the base year concentrations for the 12-km EUS and WUS grids. This evaluation principally comprises statistical assessments of model versus observed pairs that were paired in space and time on a daily or weekly basis, depending on the sampling frequency of each monitoring network. For any time periods with missing ozone and $PM_{2.5}$ observations we excluded the CMAQ predictions from those time periods in our calculations. It should be noted when pairing model and observed data that each CMAQ concentration represents a grid-cell volume-averaged value, while the ambient network measurements are made at specific locations. In conjunction with the model performance statistics, we also provide spatial plots for individual monitors of the calculated bias and error statistics (defined below). Statistics were generated for the 12-km EUS and WUS grids and five large subregions.[DD] The Atmospheric Model Evaluation Tool (AMET) was used to conduct the evaluation described in this document.[251]

[AA] MOBILE6 version was used in the Mobile Source Air Toxics Rule: *Regulatory Impact Analysis for Final Rule:* Control *of Hazardous Air Pollutants from Mobile Sources*, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division, Ann Arbor, MI 48105, EPA420-R-07-002, February 2007.

[BB] NONROAD2005 version was used in the proposed rule for small spark ignition (SI) and marine SI rule: Draft Regulatory Impact Analysis: *Control of Emissions from Marine SI and Small SI Engines, Vessels, and Equipment*, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Office of Transportation and Air Quality, Assessment and Standards Division, Ann Arbor, MI, EPA420-D-07-004, April 2007.

[CC] See http://www.epa.gov/ttn/chief/software/speciate/index.html for more details.

[DD] The subregions are defined by States where: Midwest is IL, IN, MI, OH, and WI; Northeast is CT, DE,MA, MD, ME, NH, NJ, NY, PA, RI, and VT; Southeast is AL, FL, GA, KY, MS, NC, SC, TN, VA, and WV; Central is AR, The ozone evaluation primarily focused on observed hourly ozone concentrations and eight-hour daily maximum ozone concentrations above a threshold of 40 ppb. The ozone model performance evaluation was limited to the ozone season modeled for the ECA: May, June, July, August, and September. Ozone ambient measurements for 2002 were obtained from the Air Quality System (AQS) Aerometric Information Retrieval System (AIRS). A total of 1178 ozone measurement sites were included for evaluation. The ozone data were measured and reported on an hourly basis.

The $PM_{2.5}$ evaluation focuses on $PM_{2.5}$ total mass and its components including sulfate (SO_4), nitrate (NO_3), total nitrate (TNO_3=NO_3+HNO_3), ammonium (NH_4), elemental carbon (EC), and organic carbon (OC). The $PM_{2.5}$ performance statistics were calculated for each month and season individually and for the entire year, as a whole. Seasons were defined as: winter (December-January-February), spring (March-April-May), summer (June-July-August), and fall (September-October-November). $PM_{2.5}$ ambient measurements for 2002 were obtained from the following networks for model evaluation: Speciation Trends Network (STN, total of 199 sites), Interagency Monitoring of Protected Visual Environments (IMPROVE, total of 150), and Clean Air Status and Trends Network (CASTNet, total of 83). The pollutant species included in the evaluation for each network are listed in Table 5A-4. For $PM_{2.5}$ species that are measured by more than one network, we calculated separate sets of statistics for each network.

Table 5A-4 $PM_{2.5}$ Monitoring Networks and Pollutants Species Included in the CMAQ Performance Evaluation

AMBIENT MONITORING NETWORKS	PARTICULATE SPECIES						
	$PM_{2.5}$ Mass	SO_4	NO_3	TNO_3	NH_4	EC	OC
IMPROVE	X	X	X		X	X	X
CASTNet		X		X	X		
STN	X	X	X		X	X	X
Note that TNO_3 = (NO_3 + HNO_3)							

There are various statistical metrics available and used by the science community for model performance evaluation. The four evaluation statistics used to evaluate CMAQ performance were two bias metrics, normalized mean bias and fractional bias; and two error metrics, normalized mean error and fractional error.

The "acceptability" of model performance was judged by comparing our CMAQ 2002 performance results to the range of performance found in recent regional ozone and $PM_{2.5}$ model applications. These other modeling studies represent a wide range of modeling analyses which cover various models, model configurations, domains, years and/or episodes, chemical mechanisms, and aerosol modules. Overall, the statistical calculations of model bias and error indicate that the CMAQ predicted ozone and $PM_{2.5}$ concentrations for 2002 are within the range or close to that found in recent U.S. EPA applications.[252] Figure 5A-2, Figure 5A-3, Figure 5A-4

IA, KS, LA, MN, MO, NE, OK, and TX; West is AK, CA, OR, WA, AZ, NM, CO, UT, WY, SD, ND, MT, ID, and NV.

and Figure 5A-5 show the seasonal aggregate normalized mean bias for 8-hourly ozone and $PM_{2.5}$ over the two 12-km grids. The CMAQ model performance results give us confidence that our applications of CMAQ using this 2002 modeling platform provide a scientifically credible approach for the impacts of ECA controls on ozone and $PM_{2.5}$ concentrations, visibility levels, and acid deposition amounts.

Figure 5A-2 Normalized Mean Bias (%) of hourly ozone (40 ppb threshold) by monitor for 12-km Eastern U.S. domain, seasonal aggregate

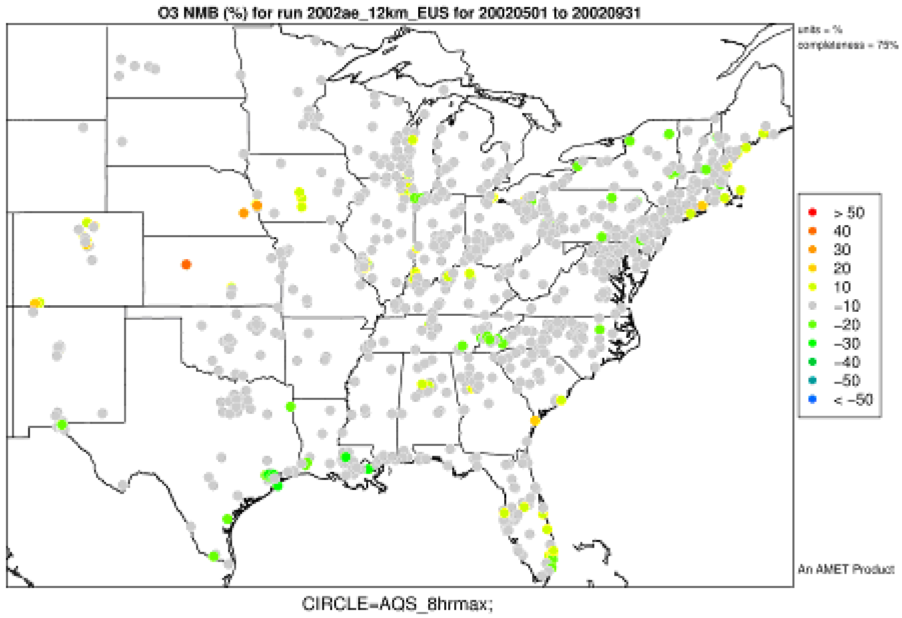


Figure 5A-3 Normalized Mean Bias (%) of hourly ozone (40 ppb threshold) by monitor for 12-km Western U.S. domain, seasonal aggregate

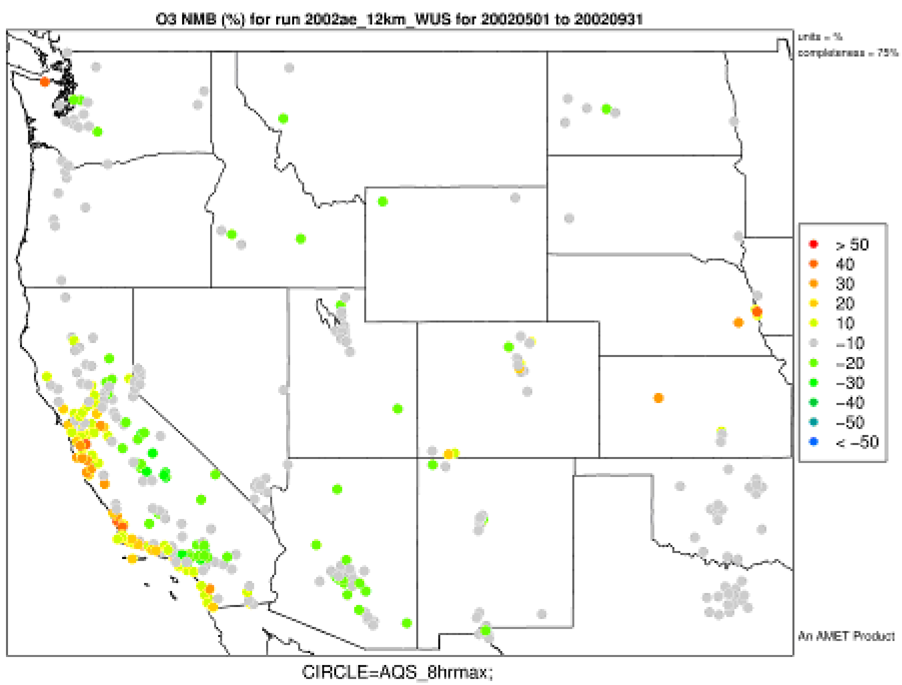


Figure 5A-4 Normalized Mean Bias (%) of annual $PM_{2.5}$ by monitor for 12-km Eastern U.S. domain, 2002

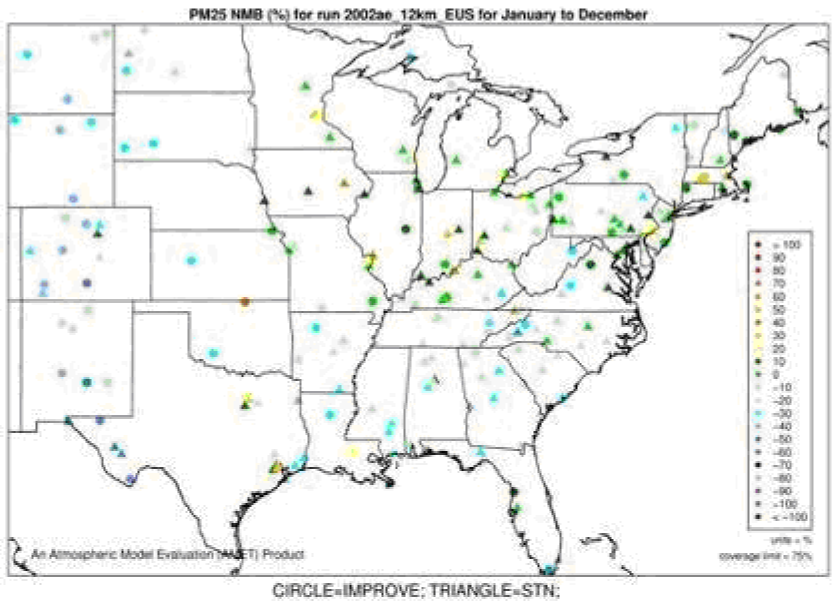
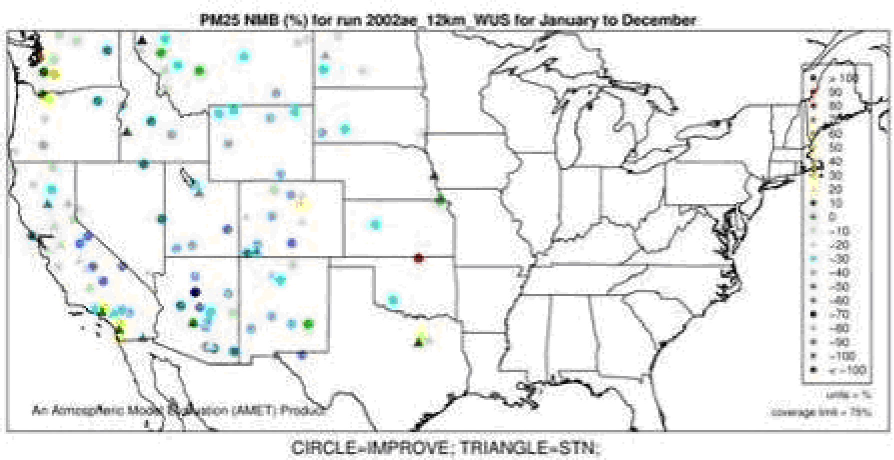


Figure 5A-5 Normalized Mean Bias (%) of annual $PM_{2.5}$ by monitor for 12-km Western U.S. domain, 2002



Model Simulation Scenarios

As part of our analysis for the Coordinated Strategy, the CMAQ modeling system was used to calculate annual $PM_{2.5}$ concentrations, 8-hour ozone concentrations, nitrogen and sulfur deposition levels and visibility estimates for each of the following emissions scenarios:

- 2002 base year
- 2020 base line projection
- 2020 base line projection with Coordinated Strategy emission reductions

- 2030 base line projection
- 2030 base line projection with Coordinated Strategy emission reductions

It should be noted that the emission control scenarios used in the air quality and benefits modeling are slightly different than in the Coordinated Strategy. The differences reflect further refinements of the regulatory program since we performed the air quality modeling for this rule. Chapter 3 of the RIA for the final Category 3 marine rule describes the changes in the inputs and resulting emission inventories between the preliminary assumptions used for the air quality modeling and the final regulatory scenario. Additionally, the emission control scenarios do not consider the exclusion of Great Lakes steamships from the final fuel sulfur standards. These refinements to the program would not significantly change the results summarized here or our conclusions drawn from this analysis.

We use the predictions from the model in a relative sense by combining the 2002 base-year predictions with predictions from each future-year scenario and applying these modeled ratios to ambient air quality observations to estimate annual $PM_{2.5}$ concentrations, 8-hour ozone concentrations, nitrogen and sulfur deposition levels, and visibility levels for each of the 2020 and 2030 scenarios. The ambient air quality observations are average conditions, on a site by site basis, for a period centered around the model base year (i.e., 2000-2004).

The projected annual $PM_{2.5}$ design values were calculated using the Speciated Modeled Attainment Test (SMAT) approach. The SMAT uses an Federal Reference Method FRM mass construction methodology that results in reduced nitrates (relative to the amount measured by routine speciation networks), higher mass associated with sulfates (reflecting water included in FRM measurements), and a measure of organic carbonaceous mass that is derived from the difference between measured $PM_{2.5}$ and its non-carbon components. This characterization of $PM_{2.5}$ mass also reflects crustal material and other minor constituents. The resulting characterization provides a complete mass balance. It does not have any unknown mass that is sometimes presented as the difference between measured $PM_{2.5}$ mass and the characterized chemical components derived from routine speciation measurements. However, the assumption that all mass difference is organic carbon has not been validated in many areas of the U.S. The SMAT methodology uses the following $PM_{2.5}$ species components: sulfates, nitrates, ammonium, organic carbon mass, elemental carbon, crustal, water, and blank mass (a fixed value of 0.5 $\mu g/m^3$). More complete details of the SMAT procedures can be found in the report "Procedures for Estimating Future $PM_{2.5}$ Values for the CAIR Final Rule by Application of the (Revised) Speciated Modeled Attainment Test (SMAT)."[253] For this latest analysis, several datasets and techniques were updated. These changes are fully described within the technical support document for the Small SI Engine Rule modeling AQM TSD.[254] The projected 8-hour ozone design values were calculated using the approach identified in EPA's guidance on air quality modeling attainment demonstrations.[255]

Deposition Modeling Methodology

The CMAQ model provides estimates of the amount of nitrogen and sulfur deposition in each of the simulated scenarios. Additionally, we conducted analyses using a separate methodology in which the CMAQ outputs were used to estimate the impacts on deposition levels in a manner similar to how the model is used for ozone and fine particulate matter. In this methodology, CMAQ outputs of annual wet deposition from the 2002 base year model run are used in conjunction with annual wet deposition predictions from the control or future case scenarios to calculate relative reduction factors (RRFs) for wet deposition. Separate wet deposition RRFs are calculated for reduced nitrogen, oxidized nitrogen, and sulfur. These RRFs are multiplied by the corresponding measured annual wet deposition of reduced nitrogen, oxidized nitrogen, and sulfur from the National Atmospheric Deposition Program (NADP) network. The result is a projection of the NADP wet deposition for the control or future case scenarios. The projected wet deposition for each of the three species is added to the CMAQ-predicted dry deposition for each of these species to produce total reduced nitrogen, total oxidized nitrogen, and total sulfur deposition for the control/future case scenario. The reduced and oxidized nitrogen depositions are summed to calculate total nitrogen deposition.

This analysis was completed for each individual 8-digit hydrological unit code (HUC) within the U.S. modeling domain. Each 8-digit HUC represents a local drainage basin. There were 2,108 8-digit HUCs considered as part of this analysis. This assessment corroborated the absolute deposition modeling results.

Visibility Modeling Methodology

The modeling platform described in this section was also used to project changes in visibility. The estimate of visibility benefits was based on the projected improvement in annual average visibility at mandatory class I federal areas. There are 156 mandatory class I federal areas which, under the Regional Haze Rule, are required to achieve natural background visibility levels by 2064. These mandatory class I federal areas are mostly national parks, national monuments, and wilderness areas. There are currently 116 Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring sites (representing all 156 mandatory class I federal areas) collecting ambient $PM_{2.5}$ data at mandatory class I federal areas, but not all of these sites have complete data for 2002. For this analysis, we quantified visibility improvement at the 133 mandatory class I federal areas which have complete IMPROVE ambient data for 2002 or are represented by IMPROVE monitors with complete data.[EE]

Visibility impairment is quantified in extinction units. Visibility degradation is directly proportional to decreases in light transmittal in the atmosphere. Scattering and absorption by both gases and particles decrease light transmittance. To quantify changes in visibility, our analysis computes a light-extinction coefficient (b_{ext}) and visual range. The light extinction coefficient is based on the work of Sisler, which shows the total fraction of light that is decreased per unit distance. This coefficient accounts for the scattering and absorption of light by both particles and gases and accounts for the higher extinction efficiency of fine particles compared to coarse particles. Fine particles with significant light-extinction efficiencies include sulfates, nitrates, organic carbon, elemental carbon, and soil.[256]

Visual range is a measure of visibility that is inversely related to the extinction coefficient. Visual range can be defined as the maximum distance at which one can identify a

[EE] There are 100 IMPROVE sites with complete data for 2002. Many of these sites collect data that is "representative" of other nearby unmonitored mandatory class I federal areas. There are a total of 133 mandatory class I federal areas that are represented by the 100 sites. The matching of sites to monitors is taken from "Guidance for Tracking Progress Under the Regional Haze Rule".

black object against the horizon sky. Visual range (in units of kilometers) can be calculated from b_{ext} using the formula: Visual Range (km) = $3912/b_{ext}$ (b_{ext} units are inverse megameters [Mm^{-1}])

The future year visibility impairment was calculated using a methodology which applies modeling results in a relative sense similar to the Speciated Modeled Attainment Test (SMAT). In calculating visibility impairment, the extinction coefficient is made up of individual component species (sulfate, nitrate, organics, etc). The predicted change in visibility is calculated as the percent change in the extinction coefficient for each of the PM species (on a daily average basis). The individual daily species extinction coefficients are summed to get a daily total extinction value. The daily extinction coefficients are converted to visual range and then averaged across all days. In this way, we can calculate annual average extinction and visual range at each IMPROVE site. Subtracting the annual average control case visual range from the base case visual range gives a projected improvement in visual range (in km) at each mandatory class I federal area. This serves as the visibility input for the benefits analysis (See Chapter 6 of this RIA).

For visibility calculations, we are continuing to use the IMPROVE program species definitions and visibility formulas which are recommended in the modeling guidance.[257] Each IMPROVE site has measurements of $PM_{2.5}$ species and therefore we do not need to estimate the species fractions in the same way that we did for FRM sites (using interpolation techniques and other assumptions concerning volatilization of species).

Appendix 5B

Benefits Methodology

This Appendix provides details about the benefits methods applied in the estimation of benefits for the Category 3 marine final rulemaking, from which the estimate of Great Lakes-related benefits were derived.

Human Health Impact Functions

Health impact functions measure the change in a health endpoint of interest, such as hospital admissions, for a given change in ambient ozone or PM concentration. Health impact functions are derived from primary epidemiology studies, meta-analyses of multiple epidemiology studies, or expert elicitations. A standard health impact function has four components: (1) an effect estimate from a particular study; (2) a baseline incidence rate for the health effect (obtained from either the epidemiology study or a source of public health statistics such as the Centers for Disease Control); (3) the size of the potentially affected population; and (4) the estimated change in the relevant ozone or PM summary measures.

A typical health impact function might look like:

$$\Delta y = y_0 \cdot \left(e^{\beta \cdot \Delta x} - 1\right),$$

where y_0 is the baseline incidence (the product of the baseline incidence rate times the potentially affected population), β is the effect estimate, and Δx is the estimated change in the summary pollutant measure. There are other functional forms, but the basic elements remain the same. The following subsections describe the sources for each of the first three elements: size of the potentially affected populations; $PM_{2.5}$ and ozone effect estimates; and baseline incidence rates. We also describe the treatment of potential thresholds in PM-related health impact functions. Section 7.2 describes the ozone and PM air quality inputs to the health impact functions.

Potentially Affected Populations

The starting point for estimating the size of potentially affected populations is the 2000 U.S. Census block level dataset.[258] Benefits Modeling and Analysis Program (BenMAP) incorporates 250 age/gender/race categories to match specific populations potentially affected by ozone and other air pollutants. The software constructs specific populations matching the populations in each epidemiological study by accessing the appropriate age-specific populations from the overall population database. BenMAP projects populations to 2030 using growth factors based on economic projections.[259]

Effect Estimate Sources

The most significant quantifiable benefits of reducing ambient concentrations of ozone and PM are attributable to reductions in human health risks. EPA's Ozone and PM Criteria Documents[260,261] and the World Health Organization's 2003 and 2004[262,263] reports outline numerous human health effects known or suspected to be linked to exposure to ambient ozone and PM. EPA recently evaluated the ozone and PM literature for use in the benefits analysis for the final 2008 Ozone NAAQS and final 2006 PM NAAQS analyses. We use the same literature in this analysis; for more information on the studies that underlie the health impacts quantified in this RIA, please refer to those documents.

It is important to note that we are unable to separately quantify all of the possible PM and ozone health effects that have been reported in the literature for three reasons: (1) the possibility of double counting (such as hospital admissions for specific respiratory diseases versus hospital admissions for all or a sub-set of respiratory diseases); (2) uncertainties in applying effect relationships that are based on clinical studies to the potentially affected population; or (3) the lack of an established concentration-response (CR) relationship. Table 5B-1 lists the health endpoints included in this analysis.

Table 5B-1 Health Impact Functions Used in BenMAP to Estimate Impacts of $PM_{2.5}$ and Ozone Reductions

ENDPOINT	*POLLUTANT*	*STUDY*	*STUDY POPULATION*
Premature Mortality			
Premature mortality – daily time series	O_3	Multi-city Bell et al (2004) (NMMAPS study)[264] – Non-accidental Huang et al (2005)[265] - Cardiopulmonary Schwartz (2005)[266] – Non-accidental Meta-analyses: Bell et al (2005)[267] – All cause Ito et al (2005)[268] – Non-accidental Levy et al (2005)[269] – All cause	All ages
Premature mortality — cohort study, all-cause	$PM_{2.5}$	Pope et al. (2002)[270] Laden et al. (2006)[271]	>29 years >25 years
Premature mortality, total exposures	$PM_{2.5}$	Expert Elicitation (IEc, 2006)[272]	>24 years
Premature mortality — all-cause	$PM_{2.5}$	Woodruff et al. (1997)[273]	Infant (<1 year)
Chronic Illness			
Chronic bronchitis	$PM_{2.5}$	Abbey et al. (1995)[274]	>26 years
Nonfatal heart attacks	$PM_{2.5}$	Peters et al. (2001)[275]	Adults (>18 years)
Hospital Admissions			
Respiratory	O_3	Pooled estimate: Schwartz (1995) - ICD 460-519 (all resp)[276] Schwartz (1994a; 1994b) - ICD 480-486 (pneumonia)[277,278] Moolgavkar et al. (1997) - ICD 480-487 (pneumonia)[279] Schwartz (1994b) - ICD 491-492, 494-496 (COPD) Moolgavkar et al. (1997) – ICD 490-496 (COPD)	>64 years
		Burnett et al. (2001)[280]	<2 years
	$PM_{2.5}$	Pooled estimate: Moolgavkar (2003)—ICD 490-496 (COPD)[281] Ito (2003)—ICD 490-496 (COPD)[282]	>64 years

ENDPOINT	*POLLUTANT*	*STUDY*	*STUDY POPULATION*
	$PM_{2.5}$	Moolgavkar (2000)—ICD 490-496 (COPD)[283]	20–64 years
	$PM_{2.5}$	Ito (2003)—ICD 480-486 (pneumonia)	>64 years
	$PM_{2.5}$	Sheppard (2003)—ICD 493 (asthma)[284]	<65 years
Cardiovascular	$PM_{2.5}$	Pooled estimate: Moolgavkar (2003)—ICD 390-429 (all cardiovascular) Ito (2003)—ICD 410-414, 427-428 (ischemic heart disease, dysrhythmia, heart failure)	>64 years
	$PM_{2.5}$	Moolgavkar (2000)—ICD 390-429 (all cardiovascular)	20–64 years
Asthma-related ER visits	O_3	Pooled estimate: Jaffe et al (2003)[285] Peel et al (2005)[286] Wilson et al (2005)[287]	 5–34 years All ages All ages
Asthma-related ER visits (con't)	$PM_{2.5}$	Norris et al. (1999)[288]	0–18 years
Other Health Endpoints			
Acute bronchitis	$PM_{2.5}$	Dockery et al. (1996)[289]	8–12 years
Upper respiratory symptoms	$PM_{2.5}$	Pope et al. (1991)[290]	Asthmatics, 9–11 years
Lower respiratory symptoms	$PM_{2.5}$	Schwartz and Neas (2000)[291]	7–14 years
Asthma exacerbations	$PM_{2.5}$	Pooled estimate: Ostro et al. (2001)[292] (cough, wheeze and shortness of breath) Vedal et al. (1998)[293] (cough)	6–18 years[a]
Work loss days	$PM_{2.5}$	Ostro (1987)[294]	18–65 years
School absence days	O_3	Pooled estimate: Gilliland et al. (2001)[295] Chen et al. (2000)[296]	5–17 years[b]
Minor Restricted Activity Days (MRADs)	O_3	Ostro and Rothschild (1989)[297]	18–65 years
	$PM_{2.5}$	Ostro and Rothschild (1989)	18–65 years

Notes:

[a] The original study populations were 8 to 13 for the Ostro et al. (2001) study and 6 to 13 for the Vedal et al. (1998) study. Based on advice from the Science Advisory Board Health Effects Subcommittee (SAB-HES), we extended the applied population to 6 to 18, reflecting the common biological basis for the effect in children in the broader age group. See: U.S. Science Advisory Board. 2004. Advisory Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis –Benefits and Costs of the Clean Air Act, 1990—2020. EPA-SAB-COUNCIL-ADV-04-004. See also National Research Council (NRC). 2002. *Estimating the Public Health Benefits of Proposed Air Pollution Regulations*. Washington, DC: The National Academies Press.

[b] Gilliland et al. (2001) studied children aged 9 and 10. Chen et al. (2000) studied children 6 to 11. Based on recent advice from the National Research Council and the EPA SAB-HES, we have calculated reductions in school absences for all school-aged children based on the biological similarity between children aged 5 to 17.

In selecting epidemiological studies as sources of effect estimates, we applied several criteria to develop a set of studies that is likely to provide the best estimates of impacts in the U.S. To account for the potential impacts of different health care systems or underlying health status of populations, we give preference to U.S. studies over non-U.S. studies. In addition, due to the potential for confounding by co-pollutants, we give preference to effect estimates from models including both ozone and PM over effect estimates from single-pollutant models.[298,299]

Baseline Incidence Rates

Epidemiological studies of the association between pollution levels and adverse health effects generally provide a direct estimate of the relationship of air quality changes to the *relative risk* of a health effect, rather than estimating the absolute number of avoided cases. For example, a typical result might be that a 100 ppb decrease in daily ozone levels might, in turn, decrease hospital admissions by 3 percent. The baseline incidence of the health effect is necessary to convert this relative change into a number of cases. A baseline incidence rate is the estimate of the number of cases of the health effect per year in the assessment location, as it corresponds to baseline pollutant levels in that location. To derive the total baseline incidence per year, this rate must be multiplied by the corresponding population number. For example, if the baseline incidence rate is the number of cases per year per 100,000 people, that number must be multiplied by the number of 100,000s in the population.

Tables 5B-2 summarizes the sources of baseline incidence rates and provides average incidence rates for the endpoints included in the analysis. For both baseline incidence and prevalence data, we used age-specific rates where available. We applied concentration-response functions to individual age groups and then summed over the relevant age range to provide an estimate of total population benefits. In most cases, we used a single national incidence rate, due to a lack of more spatially disaggregated data. Whenever possible, the national rates used are national averages, because these data are most applicable to a national assessment of benefits. For some studies, however, the only available incidence information comes from the studies themselves; in these cases, incidence in the study population is assumed to represent typical incidence at the national level. Regional incidence rates are available for hospital admissions, and county-level data are available for premature mortality. We have projected mortality rates such that future mortality rates are consistent with our projections of population growth.[300]

Table 5B-2a National Average Baseline Incidence Rates[a]

ENDPOINT	SOURCE	NOTES	RATE PER 100 PEOPLE PER YEAR[d] BY AGE GROUP						
			<18	*18-24*	*25-34*	*35-44*	*45-54*	*55-64*	*65+*
Mortality	CDC Compressed Mortality File, accessed through CDC Wonder (1996-1998)	non-accidental	0.025	0.022	0.057	0.150	0.383	1.006	4.937
Respiratory Hospital Admissions	1999 NHDS public use data files[b]	incidence	0.043	0.084	0.206	0.678	1.926	4.389	11.62
Asthma ER visits	2000 NHAMCS public use data files[c]; 1999 NHDS public use data files[b]	incidence	1.011	1.087	0.751	0.438	0.352	0.425	0.232
Minor Restricted Activity Days (MRADs)	Ostro and Rothschild (1989, p. 243)	incidence	–	780	780	780	780	780	–
School Loss Days	National Center for Education Statistics (1996) and 1996 HIS (Adams et al., 1999, Table 47); estimate of 180 school days per year	all-cause	990.0	–	–	–	–	–	–

Notes:
[a] The following abbreviations are used to describe the national surveys conducted by the National Center for Health Statistics: HIS refers to the National Health Interview Survey; NHDS - National Hospital Discharge Survey; NHAMCS - National Hospital Ambulatory Medical Care Survey.
[b] See ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHDS/
[c] See ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHAMCS/
[d] All of the rates reported here are population-weighted incidence rates per 100 people per year. Additional details on the incidence and prevalence rates, as well as the sources for these rates are available upon request.

Table 5B-2b National Average Baseline Incidence Rates

ENDPOINT	SOURCE	NOTES		RATE PER 100 PEOPLE PER YEAR
Asthma Exacerbations	Ostro et al. (2001)	Incidence (and prevalence) among asthmatic African-American children	Daily wheeze Daily cough Daily dyspnea	0.076 (0.173) 0.067 (0.145) 0.037 (0.074)
	Vedal et al. (1998)	Incidence (and prevalence) among asthmatic children	Daily wheeze Daily cough Daily dyspnea	0.038 0.086 0.045

Chapter 5 References

[1] See in particular Memorandum to Docket EPA-HQ-OAR-2007-0121, Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder – Information in Support of Applying Emission Control Area (ECA) Requirements to the Great Lakes Region. Michael J. Samulski, December 15, 2009.

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CHAPTER 6: Costs of Controlling Emissions from Vessels on the Great Lakes

This chapter presents our estimate of the costs that are expected to be incurred by operators of U.S.-flagged vessels as a result of the application of the ECA requirements on the Great Lakes. We provide estimates of hardware and operating costs associated with the use of ECA-compliant distillate fuel as well as costs associated with repowering a vessel with Tier 2 or Tier 3 compliant engines; we do not include new vessel cost impacts because Great Lakes vessels have very long service lives and are more likely to be repowered than replaced. As there are thousand-footer vessels powered by either a single Category 3 engine, or multiple Category 2 engines, it is conceivable that a Category 3 vessel could be repowered with Category 2 engines; however, these costs are not presented here.[A] While there is no requirement that a vessel must be repowered, if a vessel is repowered, under most circumstances, the new engine must meet current NO_X standards, therefore, we are presenting these engine costs for the sake of completeness. The cost estimates presented here are based on the cost analysis we performed for our Coordinated Strategy as announced in our 2010 Category 3 rulemaking, the fuel prices described in Chapter 2 of this report and the individual characteristics of the Category 3 vessels of the U.S. Great Lakes fleet to provide cost estimates on a per-vessel basis.[1,B] Costs to comparable Canadian or other foreign vessels operating on the Great Lakes would be similar to the costs presented here for U.S. vessels.

This cost analysis considers the compliance costs for existing vessels only. Because Great Lakes vessels operate in fresh water, they have a very long service life; in fact, the last new Category 3 vessel to enter the U.S. Great Lakes fleet was built in 1981. As a result, it is more likely that an existing vessel would be upgraded or repowered than a new vessel would be built for this fleet. However, we estimated the new vessel costs of our Coordinated Strategy; these costs are presented in the Economic Impact Analysis of the 2010 Category 3 rulemaking. While these costs are for ocean-going vessels, they provide an indicator of the likely costs for newly constructed Great Lakes vessels.[2]

We estimate the hardware costs of complying with the ECA fuel requirement for vessels operating on the Great Lakes to be between $42,000 to $71,000 per vessel depending on the size and power of the vessel. This is a one-time cost to accommodate the change from a residual fuel system to a distillate fuel system. With regard to operating costs we examined two ships for each of two routes. The estimated increase in fuel costs associated with the use of ECA-compliant distillate fuel for a 1,000-foot vessel traveling one-way from the port of Duluth-Superior, MN to Gary, IN (about 870 miles) is between $24,000 and $30,000, depending on the size and power of the vessel; this is an approximate 39 percent increase in the one-way voyage fuel costs for this route. The estimated increase in fuel costs for a smaller vessel (600 to 800 foot) traveling one-way from the port of Roger City, MI to Ashtabula, OH (about 430 miles) can range from $2,100

[A] Standards and estimated costs for Category 2 engines were presented in 2008 rulemaking "Control of Emissions of Air Pollution From Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder" available here: http://www.epa.gov/otaq/marine.htm

[B] Consistent with the 2010 Category 3 Marine Final Rulemaking, hardware costs are presented in U.S. $2006. Fuel operational costs are consistent with Chapter 2 of this report and are presented in U.S. $2008.

to over $5,000, depending on the vessel. This is an approximate 39 percent increase in the one-way voyage fuel costs.

6.1 Hardware Costs

This section presents estimated hardware costs associated with modifying a Great Lakes ship to accommodate the use of ECA compliant fuel. We also present estimated hardware costs for repowering a vessel. It should be noted that our program does not require vessel repowering; these estimated costs are presented for informational purposes only.

Because only twelve Great Lakes vessels have Category 3 marine diesel engines that use residual fuel and thus are affected by the fuel requirements, we can provide hardware cost estimates for each of these vessels. After identifying each of these ships, this report presents estimates of fuel system hardware costs and engine repowering costs for each ship. Note that while these are EPA's best estimates, actual estimates prepared by a shipyard for each vessel may be different.

6.1.1 Great Lakes Vessels Included in this Cost Analysis

There are 57 U.S.-flagged freighters, tug-barge combinations, and ferries working on the Great Lakes today that are over 2,000 GRT. According to the 2010 Greenwood's Guide to Great Lakes Shipping, Lloyd's Sea-Web database, and comments we received on our 2010 Category 3 marine rule, twelve of these are Category 3 ships that use residual fuel.[3,4,5] These twelve vessels are listed in Table 6-1. The other large U.S. freighters include 32 U.S.-flagged Category 2 powered large freighters, as well as numerous small vessels, under 2,000 GRT, such as ferries that work on the Great Lakes and are powered by either Category 1 or Category 2 engines that are subject to a different regulatory framework and therefore are not included in this analysis. Steamships operating on the Great Lakes are also not included in the analysis because they are excluded from the ECA fuel sulfur standards and are not covered by the engine NO_X limits (see Chapter 1). Finally, this analysis estimates costs for U.S. vessels only. While non-Canadian foreign vessels are also required to comply with the ECA fuel sulfur limits when operating on the U.S. side of the Great Lakes, they are assumed to have installed the relevant fuel hardware in response to compliance with the North American ECA and not for the Great Lakes specifically. Hardware costs for Canadian ships operating on the Great Lakes are also not presented in this analysis. The costs for comparable Canadian vessels would be similar to the costs estimated here, but are assumed to be incurred as a result of a Canadian national program and not as a result of this program.

Table 6-1 Category 3 U.S. -Flagged Great Lakes Vessels

Ship Name	Engine Manufacturer
American Spirit	Pielstick
Hon. James L. Oberstar	Rolls-Royce Bergen
Edgar B. Speer	Pielstick
Edwin H. Gott	Enterprise
James R. Barker	Pielstick
Lee A. Tregurtha	Rolls-Royce Bergen
Maumee	Nordberg

Ship Name	Engine Manufacturer
Mesabi Miner	Pielstick
Paul R. Tregurtha	MaK
Presque Isle	Mirrlees Blackstone
Roger Blough	Pielstick
Victory	Krupp – MAK

The fleet of twelve U.S.-flagged Category 3 vessels that ply the Great Lakes is diverse in terms of age, size, and engine power. This fleet includes ten self-unloading bulk freighters as well as two tugboats. Table 6-3 lists the detailed specifications for each of the 12 ships included in this analysis.

The average age of these twelve vessels is just over 41 years old, and no vessel was built after 1981. The oldest vessel is the Maumee, operated by the Grand River Navigation Company. She was launched in 1929 and was initially a steam powered vessel; she was repowered with diesel engines in 1964 and is pictured in Figure 6-1.

Figure 6-1 The Maumee Unloads Coal in Menominee, MI, August 1, 2007

Source: Photo taken by and used with permission from Dick Lund, available here: http://dlund.20m.com

With respect to size, the gross registered tonnage of these twelve vessels ranges from 950 to 36,400 tons, with an average of nearly 25,000 tons, compared to the 16,000 GRT average size of all 57 U.S. freighters, large tugs, and ferries working on the Great Lakes. It should be noted that there are six 1,000 foot U.S. freighters with Category 2 propulsion engines that operate on the same routes as these twelve Category 3 ships.

The main engine power of the U.S. Category 3 Great Lakes fleet ranges from 2,400 kW to 14,500 kW, with an average of approximately 10,000 kW, compared to an average of 6,200 kW for all 57 U.S. ships in the fleet. All of the twelve U.S.-flagged Category 3 vessels currently operate on residual fuel oil.

Table 6-2 Characteristics of the U.S.-Flagged Category 3 Powered Fleet

SHIP NAME	GROSS REGISTERED TONS	YEAR BUILT	SHIP TYPE	POWER (kW)	OVERALL LENGTH	YEAR REPOWERED	ORE CAPACITY (gross tons)
American Spirit	34,600	1978	Self-Unloader	11,900	1004'0"		62,400
Hon. James L. Oberstar	16,300	1959	Self-Unloader	6,300	806'0"	2009	31,000
Edgar B. Speer	34,600	1980	Self-Unloader	14,400	1004'0"		73,700
Edwin H. Gott	36,000	1978	Self-Unloader	14,500	1004'0"		74,100
James R. Barker	34,700	1976	Self-Unloader	11,900	1004'0"		63,300
Lee A. Tregurtha	14,700	1942	Self-Unloader	6,000	826'0"	2006	29,300
Maumee	8,200	1929	Self-Unloader	2,400	604'9"	1964	12,650
Mesabi Miner	34,700	1977	Self-Unloader	11,900	1004'0"		63,300
Paul R. Tregurtha	36,400	1981	Self-Unloader	12,000	1013'6"	2010	68,000
Presque Isle	22,600	1973	Tugboat	11,200	144'4"		57,500
Roger Blough	22,000	1972	Self-Unloader	11,900	858"		43,900
Victory	950	1981	Tugboat	5,900	140'0"		NA

The two Category 3 powered tugboats are both articulated tug/barge combinations. These two tugboats are each over 140 feet long and, according to Greenwood's 2010 Guide to Shipping, both use residual fuel.[3] While the use of residual fuel oil in a tugboat requires a substantial amount of space for heating, centrifuging, filtering and otherwise conditioning the fuel for use, very large tugboats such as the Victory and the Presque Isle have the space necessary for this equipment.[6] Each of these tugs is mated to a particular barge that she was designed to work with: the Victory is paired with the barge James L. Kuber while the Presque Isle is paired with the barge Presque Isle; both of these barges are self-unloading. Great Lakes barges are often made out of older freighters and can be up to 740 feet long. For example, the steamship Reserve was converted into the barge James L. Kuber.

The Lee A. Tregurtha unloading. Source: Interlake Steamship Company Photo Gallery, available here: http://www.interlake-steamship.com

6.1.2 Engineering Cost Methodology

This analysis is based on the cost analysis performed for the Coordinated Strategy as announced in the 2010 Category 3 Rule and uses the same methodology. In the Coordinated Strategy, the estimated hardware costs associated with fuel system and engine upgrades needed to comply with the Coordinated Strategy are presented for a number of different vessel types and sizes. To develop these cost estimates, the EPA contracted with ICF International (ICF) to conduct a cost study of the various compliance strategies expected to be used to meet the new fuel and engine requirements.[7] A series of both slow-speed and medium-speed engine configurations were selected and used to provide an understanding of the costs to apply emission control technologies associated with fuel system upgrades and new engine emission standards. Table 6-3 lists the engine configurations used in the Coordinated Strategy analysis. The engine configurations were selected based on a review of 2005 U.S. Army Corps of Engineers 'Entrances and Clearances' data which was used to determine the characteristics of engines on those vessels that call on U.S. ports most frequently. This data represents a broad range of propulsion power for each engine type (slow and medium speed engines). The costs developed for these engine configurations were used to develop a relationship between costs and engine size ($/kW) that could be applied to estimate the compliance costs for any slow or medium speed engine to obtain a hardware cost estimate for that engine.

Table 6-3 Engine Configurations Used in the 2010 Category 3 Rulemaking Cost Analyses

ENGINE TYPE	MEDIUM-SPEED			LOW-SPEED		
Engine Power (kW)	4,500	9,500	18,000	8,500	15,000	48,000
Cylinders	9	12	16	6	8	12
Liters/cylinder	35	65	95	380	650	1400
Engine Speed (rpm)	650	550	500	130	110	100
BSFC (g/kWh)	210			195		

For the cost analysis associated with the Coordinated Strategy, engine speed information was not explicitly available, therefore, 2-stroke engines were assumed to be slow speed engines (SSD), and 4-stroke engines were assumed to be medium speed engines (MSD); the same assumption is used for this Great Lakes cost analysis. All twelve of the Category 3 Great Lakes vessels discussed in this chapter were confirmed to be either medium-speed or powered by 4-stroke engines, therefore, all twelve were assumed to be medium-speed engines.

After ICF developed their initial cost estimates, they provided surveys to several engine and emission control technology manufacturers to determine the reasonableness of their approach and cost estimates. Input received from those surveyed was incorporated into the final cost estimates discussed in the 2010 analysis of the Coordinated Strategy. The resulting cost estimates were used to determine a $/kW equation which could be scaled according to engine type and size to arrive at a per vessel cost. These equations were presented in the 2010 Coordinated Strategy and are also presented in the Appendix to this chapter. In this analysis for Great Lakes vessels, these equations are used along with the engine characteristics for each of the twelve Category 3 Great Lakes vessels to estimate the cost per vessel for complying with the ECA requirements on the Great Lakes.

The hardware cost estimates include variable costs for components, assembly, and associated markup and fixed costs for tooling, research and development, redesign efforts, and certification. For technologies sold by a supplier to an engine manufacturer, cost estimates are based on a direct cost to manufacture the system components plus a 29 percent markup to account for the supplier's overhead and profit.[7] Variable costs also include a 29 percent markup to account for both manufacturer and dealer overhead and carrying costs. We believe the hardware costs from our Coordinated Strategy are applicable to this analysis as the engine and hardware manufacturers available for repowering Great Lakes vessels are the same as those that provide power for ocean-going vessels and produce engines that power similar sized vessels used in other applications. Further details on these costs can be found in the Appendix to this chapter.

6.1.3 Estimates for Equipment to Accommodate the Use of Lower Sulfur Fuel

There are different technologies that may be available to meet the ECA standards on the Great Lakes, and we expect that each manufacturer or vessel owner/operator will evaluate all possible technological avenues to determine how to minimize the cost of compliance. This cost analysis, however, does make certain assumptions regarding compliance with the fuel sulfur standards. In particular, this analysis assumes that the ECA fuel standards will be met through the use of lower sulfur fuel. Alternative control strategies that provide equivalent reductions, such as scrubbers, can be used to meet the fuel standards; however, this section does not provide cost estimates for this technology. Vessel owners would presumably use scrubbers only if this were a lower-cost option.

This section presents the cost estimates for each of the twelve U.S.-flagged vessels to install equipment to accommodate the use of lower sulfur fuel. Note that while these are EPA's best estimates, actual estimates prepared by a shipyard for each vessel may be different. Estimated costs to install this equipment include both fixed costs, generally for engineering and tooling and variable costs generally for hardware and labor. As part of the effort to prepare an analysis of the Coordinated Strategy, ICF developed cost estimates for installing equipment to accommodate the use of lower sulfur fuel on existing vessels. This included separate estimates for three low-speed engines and three medium-speed engines representing a range of power ratings. The cost estimate was based on installing a new distillate fuel system to operate in tandem with the original residual fuel system. The new hardware installed included new distillate fuel tanks, fuel coolers, pumps, filters, and piping. It also included at least 480 hours of labor to install the new equipment. Applying a curve fit to the cost data allowed us to develop an equation for estimating the cost of compliance as a function of power rating for low-speed and medium-speed engines. Using these equations, we estimated the compliance cost for modifying each of the twelve U.S.-flagged Category 3 vessels to accommodate the use of lower sulfur fuel based on the power rating of the installed main engine(s). In the case of Great Lakes vessels, these figures may overestimate the actual cost; for example, it may be possible to convert the original fuel tanks to hold distillate fuel instead of residual fuel, and it may be possible to remove the fuel heating system. Appendix 6A of this document contains the details of the estimated fuel system costs and the curve-fit equation.

Table 6-4 presents the estimated cost for each of the twelve Category 3 vessels operating on the Great Lakes to modify their fuel system to accommodate the use of lower sulfur fuel. It is estimated that the cost to install this hardware ranges from $42,000 to $71,000 per vessel.

Table 6-4 Estimated Hardware Costs for Equipment to Accommodate the Use of Lower Sulfur Fuel

SHIP NAME	ENGINE POWER (kW)	EXISTING VESSEL HARDWARE COSTS
American Spirit	11,900	$65,000
Hon. James L. Oberstar	6,000	$51,000
Edgar B. Speer	14,400	$71,000
Edwin H. Gott	14,500	$71,000
James R. Barker	11,900	$65,000
Lee A. Tregurtha	6,000	$51,000
Maumee	2,400	$42,000
Mesabi Miner	11,900	$65,000
Paul R. Tregurtha	12,800	$65,000
Presque Isle	11,200	$63,000
Roger Blough	11,200	$61,000
Victory	5,900	$50,000

6.1.4 Estimated Costs of Repowering

Because Great Lakes vessels operate in fresh water, they have a very long service life; in fact, the last new Category 3 vessel to enter the U.S. Great Lakes fleet was built in 1981. This section, therefore, only presents the costs for modifications that would be made to existing vessels as it is more likely that an existing vessel would be upgraded or repowered than it would be for a new vessel to enter the fleet.

Category 3 vessels in the Great Lakes fleet are not expected to incur costs associated with the engine standards, as the Tier 2 and Tier 3 standards for Category 3 engines apply only to new engines. The cost to new vessels is presented in the Economic Impact Analysis of the 2010 Coordinated Strategy, which considered ocean-going vessels as well.[8] Due to the longevity of vessels that trade on the fresh-water Great Lakes, in many cases the hulls long outlive their original power plants, and investments are made that increase the fuel efficiency of these vessels by repowering them with new engines.[9]

While Great Lakes vessels can be repowered, this would be done in response to individual company concerns and not to comply with a mandatory regulatory requirement as there is no obligation for ships to repower. However, if they do repower there are requirements the new engine must meet under Regulation 13 of Annex VI and the Clean Air Act. For example, if a ship is repowered in 2016 the installer must look at using a Tier 3 engine, however, if it is not possible for a Tier 3 engine to fit there are exemptions that can be granted to allow the use of a Tier 2 engine in existing vessels. Therefore, this section will also report the estimated additional costs to repower each of the twelve vessels with Tier 2 or Tier 3 compliant engines; this section assumes a Category 3 vessel would be repowered with a Category 3 engine. The appendix to this chapter shows how the Tier 2 and Tier 3 costs are estimated; more information is contained in the analysis provided in the 2010 Category 3 rulemaking. Note that while these are EPA's best estimates, actual estimates prepared by a shipyard for each vessel may be different.

The estimated repowering costs presented below in Table 6-5 reflect the incremental cost above the cost of the new engine that would be incurred as a result of purchasing a new engine that is either Tier 2 or Tier 3 compliant. We estimate that the incremental cost of purchasing a Tier 2 engine for the twelve Category 3 vessels would range from $53,000 to $111,000. This is the incremental cost over that of a Tier 1 engine and assumes that the new engine would have the same power rating as the existing engine. The estimated cost to repower with a Tier 3 compliant engine includes the cost of an SCR system and ranges from $385,000 to $641,000. As stated above, there is no obligation for a ship to repower; we are providing these incremental engine costs for the sake of completeness. These costs include the cost of adding emission control equipment that may be required to make the engine compliant with current standards; these costs do not include the base engine costs, labor to install the engine, or any modifications to the vessel that may be done during the repower; while the incremental engine costs presented here would apply to any new engine, additional costs of installation may vary depending on a vessel's existing powerplant and would likely be different for compression-ignition powered vessels than for steamships.

Table 6-5 Incremental Cost of Tier 2 and Tier 3 Compliant Engines

SHIP NAME	MAIN ENGINE POWER (kW)	TIER 2 ENGINE COSTS (variable and fixed costs)[a]	TIER 3 ENGINE AND SCR COSTS (variable and fixed costs)
American Spirit	11,900	$104,000	$640,000
Hon. James L. Oberstar	6000	$83,000	$488,000
Edgar B. Speer	14,400	$110,000	$700,000
Edwin H. Gott	14,500	$111,000	$710,000
James R. Barker	11,900	$104,000	$640,000
Lee A. Tregurtha	6,000	$83,000	$488,000
Maumee	2,400	$53,000	$385,000
Mesabi Miner	11,900	$104,000	$640,000
Paul R. Tregurtha	12,800	$105,000	$641,000
Presque Isle	11,200	$102,000	$617,000
Roger Blough	11,200	$101,000	$605,000
Victory	5,900	$82,000	$478,000

[a] Tier 2 costs assume that all vessels had mechanical fuel injection and were upgraded to common rail for Tier 2.

6.2 Estimated Fuel Operational Costs

Chapter 2 of this report presents the estimated increase in fuel operational costs associated with the use of ECA-compliant fuel for certain routes along the Great Lakes including both rail and ship activity. The same fuel prices were used in this chapter as were used in Chapter 2 and are presented in U.S. $2008. This section will present the estimated increase in vessel fuel costs for two of these routes and for four U.S.-flagged Category 3 vessels currently in the Great Lakes fleet. These estimates are provided as an example of the costs a vessel owner might see and are not meant to represent the typical or average costs for these routes for Category 3 vessels. The methodology used here is intended to be consistent with the information provided for these routes in Chapter 2 and uses the same assumptions for distance traveled, main engine specific fuel oil consumption, and operating speed. Actual fuel operational costs for these routes would vary with a number of factors, for example: maneuvering time, speed restrictions in certain areas, actual specific fuel consumption of each vessel, and the installed engine power.

This section does not present a yearly fuel operational cost estimate for each vessel or for the fleet as it is unknown what routes each vessel travels and how often, nor is it clear what layup costs are or how these costs might be passed on to customers. This section also does not provide an estimate of the annualized Great Lakes Category 3 fuel related operational costs associated with the ECA. While we could use the CO_2 numbers provided by the inventory to estimate the total increase in fuel costs for all vessels operating within the Great Lakes inventory domain, we only have an emissions inventory available for the U.S. side of the Great Lakes, and we do not have a way to determine what percentage of this fuel is used by U.S.-flagged, Canadian-flagged, or foreign-flagged vessels. In addition, we cannot distinguish how much of this fuel is used by steamships as the usage patterns for U.S.-flagged steamships are unknown, and while the percentage of steamships in the national inventory is small, estimated to be 3 percent of the North American ECA, in terms of number of vessels, they make up a large portion of the U.S.-flagged Great Lakes fleet, made up of thirteen U.S.-flagged steamships (this number includes both 12 diesel-powered steamships and one coal-fired steamship) compared to twelve U.S.-flagged Category 3 vessels.

This section will present the estimated increase in fuel costs to a Category 3 vessel that would be incurred during a one-way trip for two specific routes on the Great Lakes, due to a switch from residual fuel to distillate fuel. This section uses vessel characteristic data published in the 2010 Greenwood's Guide to Shipping and contained in Lloyd's Sea-web database.[3,4]

6.2.1 Estimated Trip Cost: Duluth-Superior, Minnesota to Gary, Indiana

This analysis uses Scenario 7 presented in Chapter 2 to estimate the increase in fuel costs a vessel would see when traveling along the water portion of this trip which starts at the port of Duluth-Superior, Minnesota, and ends at Gary, Indiana, as shown in Figure 6-2 (it does not include the land-based portion of this route from Hibbing, Minnesota to Duluth-Superior, Minnesota). This scenario was based on a 1,000 foot vessel, therefore, the cost estimates for this route could be applicable to the American Spirit and the Edwin H. Gott, both of which are over 1,000 feet long. The scenario also assumes that over 48,000 net tons of iron ore would be hauled. Both the American Spirit and the Edwin H. Gott are capable of carrying this much ore, and are representative of ships that could carry iron ore along this route.

Figure 6-2 Scenario 7: Iron Ore from the Duluth-Superior, Minnesota to Gary, Indiana

The actual main engine power for each vessel (11,900 kW and 14,500 kW respectively) is used in this analysis with the main engine fuel consumption value of 231 g/kWh presented in Chapter 2. The fuel consumption numbers were adjusted for the difference in energy density between residual and distillate fuel as shown in Equation 6-2. Finally, the operating speed was assumed to be 14 knots for the entire trip, consistent with Scenario 7. These values were input into Equation 6-1 and Equation 6-2 to estimate the amount of fuel used by each vessel per one-way trip for both distillate and residual fuel. The fuel prices used to estimate the increase in cost per trip are the same as those presented in Chapter 2, $424 per tonne for residual fuel and $617 per tonne for distillate fuel. This results in an estimated increase in cost of approximately $24,000 for the American Spirit and $30,000 for the Edwin H. Gott, as shown in Table 6-6 below.

Equation 6-1 Tonnes of Fuel Used per Trip per Vessel – Residual Fuel

$$distance\_(nm) * \frac{1}{speed(knots)} * BSFC \frac{g}{kWh} * power(kW) * \frac{0.000001 tonne}{g} = tonnes\_fuel$$

Equation 6-2 Tonnes of Fuel Used per Trip per Vessel – Distillate Fuel

$$distance\_(nm) * \frac{1}{speed(knots)} * BSFC \frac{g}{kWh} * power(kW) * \frac{0.000001 tonne}{g} = tonnes\_fuel$$

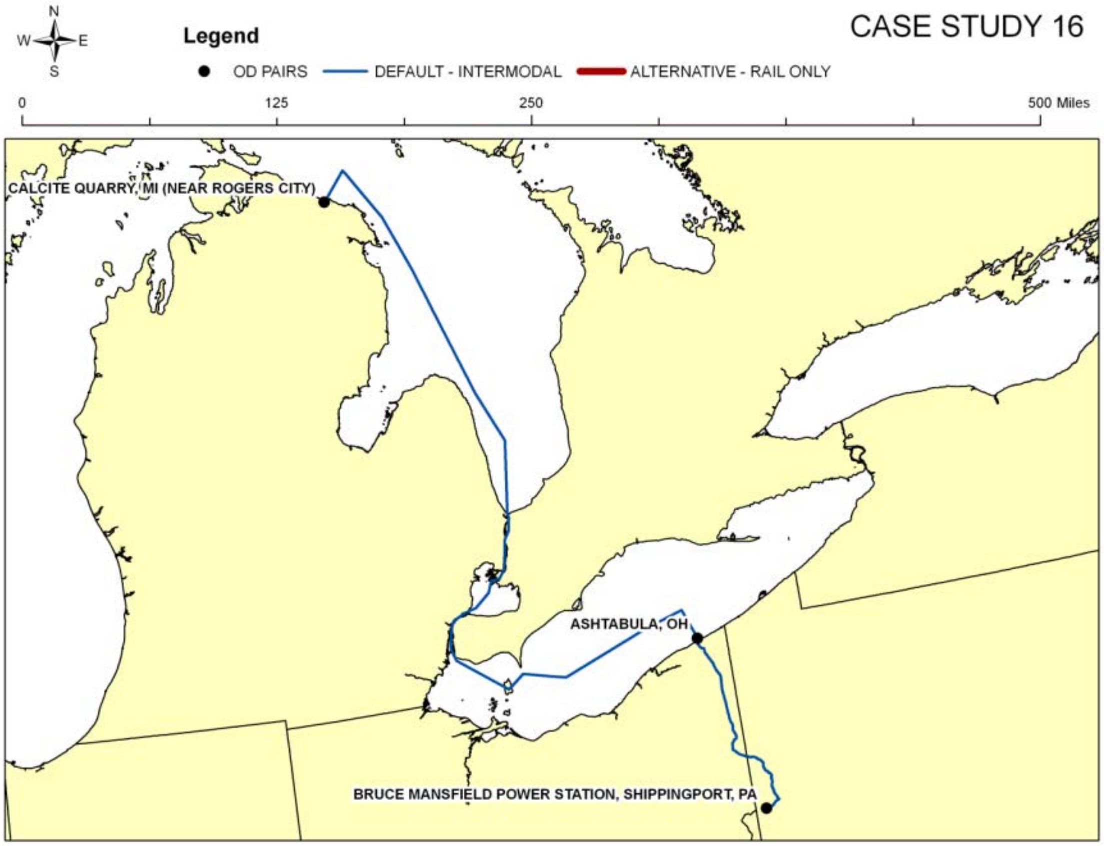
Table 6-6 Estimated Increased Fuel Costs per Vessel per One-Way Trip for Duluth-Superior to Gary, IN

VESSEL NAME	MAIN ENGINE POWER (kW)	VESSEL SPECIFIC RESIDUAL FUEL CONSUMPTION (g/kWh)	OPERATING SPEED (knots)	COST PER TRIP - RESIDUAL FUEL	COST PER TRIP - DISTILLATE FUEL	ESTIMATED INCREASE IN FUEL COST PER TRIP
American Spirit	11,900	231	14	$62,900	$87,200	$24,300
Edwin H. Gott	14,500	231	14	$76,700	$106,300	$29,600

6.2.2 Estimated Trip Cost: Stone from Calcite Quarry, MI to Bruce Mansfield Power Station, OH

This analysis uses Scenario 16 presented in Chapter 2 to estimate the increase in fuel costs an actual vessel may experience when traveling along the water portion of this trip from the port of Roger City, MI to Ashtabula, OH, as shown in Figure 6-3. The two vessels used in the analysis in this section are the 605 foot-long Maumee and the 806 foot-long Hon. James L. Oberstar, both carry stone according to Lloyd's Sea-web database. The analysis in this section estimates the one-way fuel operational cost increase of this vessel route. It should be noted that this analysis is not intended to duplicate the cost analysis contained in the transportation mode shift analysis reported in Chapter 2, which reflects operating costs for a composite vessel as defined in that chapter.

Figure 6-3 Scenario 16: Stone from the Calcite Quarry, MI to Bruce Mansfield Power Station, OH



The actual main engine power installed in the Maumee is just over 2,400 kW while the Hon. James L. Oberstar has over 6,000 kW; the main engine fuel consumption value of 196 g/kWh that was used in Chapter 2 is also used here; as with the previous analysis, the fuel consumption value was adjusted for the difference in energy density associated with the use of distillate fuel. Finally, the operating speed was assumed to be 14 knots for the entire trip also consistent with Scenario 16. These values were input into Equation 6-1 and Equation 6-2 to estimate the amount of fuel used per vessel per one-way trip. Using the same fuel prices as those presented in Chapter 2 ($424 per tonne for residual fuel and $617 per tonne for distillate fuel) we estimate an increase in cost of approximately $2,100 for the Maumee and over $5,100 for the Hon. James L. Oberstar, as shown in below in Table 6-7.

Table 6-7 Estimated Increased Fuel Costs per Vessel per Trip for Rogers City, MI to Ashtabula, OH

Vessel Name	Main Engine Power (KW)	Vessel Specific Residual Fuel Consumption (G/KWH)	Operating Speed (KNOTS)	Cost per trip (Residual Fuel)	Cost per trip (Distillate Fuel)	Estimated Increase in Fuel Cost per Trip
The Maumee	2,416	196	14	$5,400	$7,800	$2,400
Hon. James L. Oberstar	5,995	196	14	$13,300	$18,400	$5,100

6.2.3 Conclusion

The above analysis shows that fuel operating costs on the marine leg of the routes for these scenarios are expected to increase by about 39 percent, which is consistent with the expected increase in price per tonne of fuel.

Appendix 6A

A1 Engineering Costs for Existing Vessels to Accommodate the Use of Lower Sulfur Fuel

A 1.1 Variable Costs to Existing Vessels to Accommodate the Use of Lower Sulfur Fuel

All vessels including both new and existing vessels are required to meet the ECA lower sulfur fuel (LFO) standards beginning in 2015 (with the exception of steamships). This section discusses the vessel costs associated with the ECA standards that may be incurred if additional hardware is required to accommodate the use of lower sulfur fuel in place of heavy-fuel oil (HFO). Costs may include additional distillate fuel storage tanks, an LFO fuel separator, an HFO/LFO blending unit, a 3-way valve, an LFO cooler, filters, a viscosity meter, and various pumps and piping depending on the configuration of the vessel undergoing a retrofit, these costs are presented in Table 6-8.

Table 6-8 Variable Costs Associated with the use of Lower Sulfur Fuel - Existing Vessels

SPEED	**MEDIUM**	**MEDIUM**	**MEDIUM**	**LOW**	**LOW**	**LOW**
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Hardware Cost to Supplier						
Component Costs						
Additional Tanks	$3,400	$5,500	$8,300	$4,600	$6,500	$13,700
LFO Separator	$2,800	$3,300	$3,800	$3,800	$4,200	$4,700
HFO/LFO Blending Unit	$4,200	$4,700	$5,600	$4,700	$5,600	$6,600
3-Way Valve	$950	$1,400	$1,900	$1,400	$1,900	$2,800
LFO Cooler	$2,400	$2,800	$3,300	$2,800	$3,800	$4,700
Filters	$950	$950	$950	$950	$950	$950
Viscosity Meter	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400
Piping/Pumps	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
Total Component Cost	**$18,100**	**$22,100**	**$27,300**	**$21,600**	**$26,400**	**$36,900**
Assembly						
Labor (hours)	480	640	960	640	960	1200
Cost ($23.85/hr)	$11,400	$15,300	$22,900	$15,300	$22,900	$28,600
Overhead @ 40%	$4,600	$6,100	$9,200	$6,100	$9,200	$11,400
Total Assembly Cost	**$16,000**	**$21,400**	**$32,100**	**$21,400**	**$32,100**	**$40,000**
Total Variable Cost	$34,100	$43,400	$59,300	$43,000	$58,400	$77,000
Markup @ 29%	$9,900	$12,600	$17,200	$12,500	$17,000	$22,300
Total Hardware RPE	**$44,000**	**$55,000**	**$76,500**	**$55,500**	**$75,400**	**$99,300**

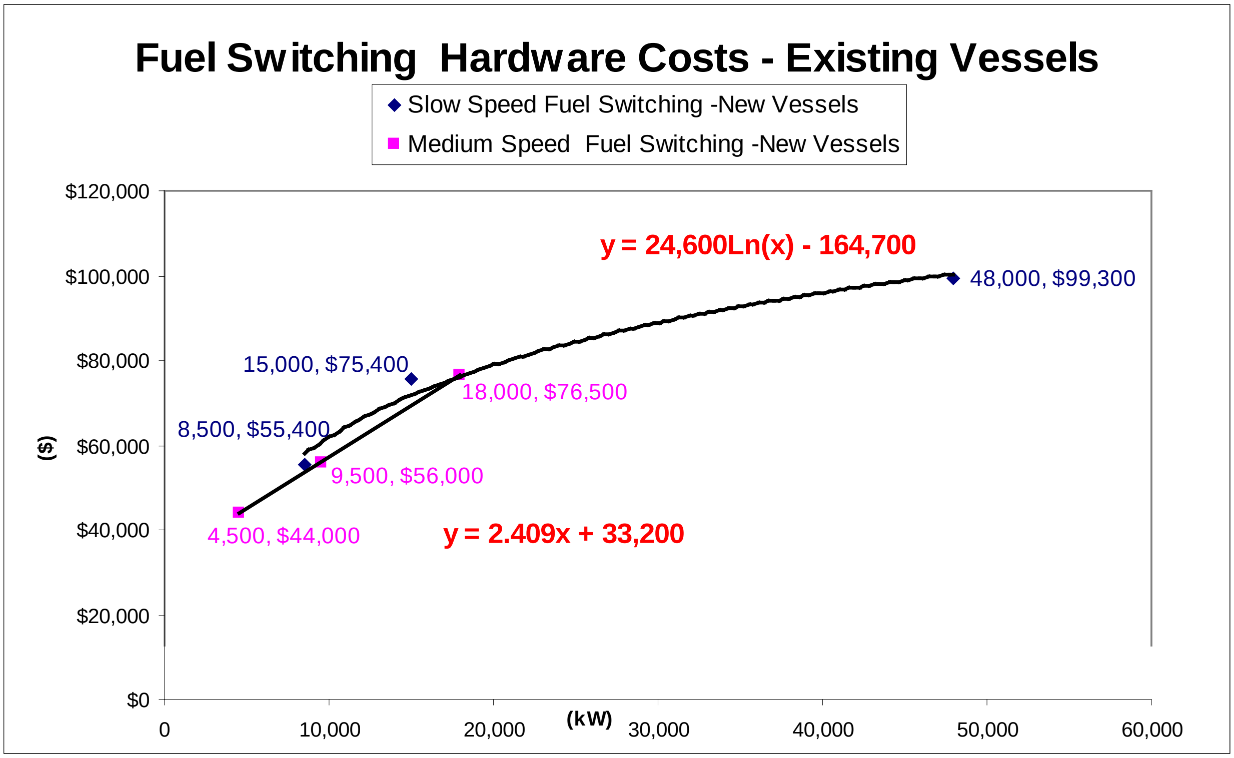
The estimated cost of new fuel tanks is presented here for informational purposes as it is assumed that the Category 3 vessels operating on the Great Lakes would convert their existing heavy-fuel oil tanks over to carry distillate. New distillate tanks are assumed to be constructed of cold rolled steel one mm thick, double walled, and are estimated to carry capacity sufficient for 250 hours of propulsion and auxiliary engine operation. The tank size is based on 250 hours of operation and when estimated to provide fuel for the six different engine configurations used in this analysis tank sizes range from 240 m^3 to nearly 2,000 m^3, these costs are presented in Table 6-9.

Table 6-9 Variable Cost to Associated with Fuel Switching - Extra Tankage

SPEED	**MEDIUM**	**MEDIUM**	**MEDIUM**	**LOW**	**LOW**	**LOW**
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Propulsion						
BSFC (g/kWh)	210	210	210	195	195	195
Load factor	73%	73%	73%	73%	73%	73%
Auxiliary						
Power (kW)	1,000	2,200	4,100	1,900	3,400	10,900
BSFC (g/kWh)	227	227	227	227	227	227
Load factor	31%	31%	31%	31%	31%	31%
Combined						
Fuel Amount (kg)	190,000	401,000	760,000	336,000	592,000	1,896,000
Density (kg/m^3)	960	960	960	960	960	960
Tank Size (m^3)	238	501	950	350	617	1,975
Tank Material (m^3)	0.46	0.75	1.15	0.59	0.87	1.88
Tank Material Cost ($)	$2,500	$4,100	$6,200	$3,200	$4,700	$10,100
Assembly						
Labor (hours)	5	6	7	10	12	15
Cost ($23.85/hr)	$119	$143	$167	$238	$286	$358
Overhead@40%	$48	$57	$67	$95	$114	$143
Total Assembly Cost	$167	$200	$234	$334	$401	$501
Total Variable Cost	$2,600	$4,300	$6,500	$3,500	$5,100	$10,600
Markup @ 29%	$800	$1,200	$1,900	$1,000	$1,500	$3,100
Total Hardware RPE	$3,400	$5,500	$8,400	$4,500	$6,600	$13,700

The costs were developed for each of the six different engine sizes and types used in this analysis. These values were used to develop a curve fit, as presented in Figure 6-4, used to estimate a $/kW equation applicable to other engine sizes and types. As all twelve of the Category 3 Great Lakes vessels are assumed to be powered with medium-speed diesels, the medium speed cost equation was used to project the cost to each vessel.

Figure 6-4 Variable Cost Curve Fit for Fuel Switching Vessels Costs to Existing Vessels



A 1.2 Fixed Engineering Costs to Accommodate the Use of Lower Sulfur Fuel

The fixed costs associated with existing vessels switching to the use of lower sulfur fuel are shown in Table 6-10 and are similar to the costs estimated for new vessels; however, additional research and development is provided to test systems on existing ships.

Table 6-10 Fixed Costs for Fuel Switching Hardware Costs on Existing Vessels

SPEED	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Fixed Costs						
R&D Costs (0.33 year R&D)	$227,040	$227,040	$227,040	$227,040	$227,040	$227,040
Marine Society Approval	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Engines/yr.	40	40	40	40	40	40
Years to recover	5	5	5	5	5	5
Fixed cost/engine	**$1,160**	**$1,160**	**$1,160**	**$1,160**	**$1,160**	**$1,160**

A2 Engineering Costs for Freshly Manufactured Engines

This section describes the projected variable and fixed costs to new engines that may be incurred if a vessel operating on the Great Lakes is repowered with a new Category 3 Tier 2 or Tier 3 engine sometime in the future. The component, tooling, labor and overhead costs are presented here separately for Tier 2 and Tier 3.

A2.2 Engineering Costs for Tier 2 Engines

Tier 2 NO_X standards are roughly 20 percent lower than the existing Tier 1 NO_X standards. To meet these standards, in-cylinder emission control approaches such as electronically controlled high pressure common rail fuel systems, turbocharger optimization, compression ratio changes and electronically controlled exhaust valves could be used.

A 2.2.1 Tier 2 Variable Costs

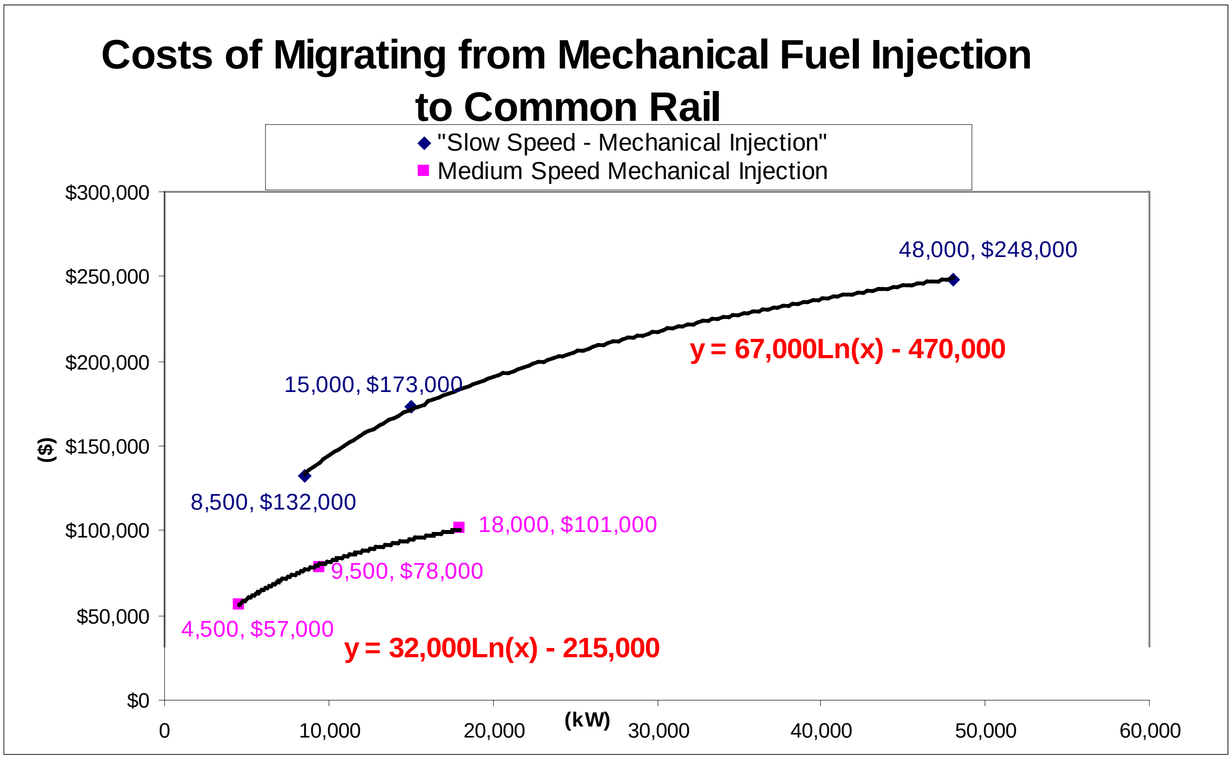
There are no variable costs associated with the Tier 2 engine modifications (such as injection timing and valve timing adjustments, increased compression ratio, and nozzle optimization) as the changes are not expected to require any additional hardware.[10] However, the migration of some engines from mechanical fuel injection (MFI) to common rail fuel systems will require additional hardware including a control unit, common rail accumulators, low and high pressure pumps, injectors and wiring harnesses and we will consider the variable costs associated with these changes as part of the Tier 2 total costs. The cost of the Tier 2 technology presented here was developed using Tier 1 technology as the baseline and assumes that all Great Lakes vessels use mechanical fuel injection. Table 6-11 shows the per engine variable cost estimates for the six engine configurations used in this analysis, and Figure 6-5 shows the cost curve developed from these data points to determine a $/kW equation applicable to other engine sizes.

Table 6-11 Variable Costs for Going from Mechanical Fuel Injection Systems to Common Rail

SPEED	**MEDIUM**	**MEDIUM**	**MEDIUM**	**LOW**	**LOW**	**LOW**
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Hardware Cost to Engine Manufacturer						
Component Costs:						
Electronic Control Unit	$3,500	$3,500	$3,500	$5,000	$5,000	$5,000
Common Rail Accumulators (each)	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
Number of Accumulators	3	6	8	9	12	18
Low Pressure Pump	$2,000	$3,000	$4,000	$2,500	$3,500	$4,500
High Pressure Pump	$3,500	$4,500	$6,000	$4,500	$6,000	$8,000
Modified injectors (each)	$2,500	$2,500	$2,500	$3,500	$3,500	$3,500
Number of injectors	9	12	16	18	24	36
Wiring Harness	$2,500	$2,500	$2,500	$3,000	$3,000	$3,000
Total Component Cost	**$40,000**	**$55,500**	**$72,000**	**$96,000**	**$125,500**	**$182,500**

SPEED	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW
Assembly						
Labor (hours)	120	160	200	200	250	300
Cost ($23.85/hr)	$2,900	$3,800	$4,800	$4,800	$5,900	$7,100
Overhead @ 40%	$1,100	$1,500	$1,900	$1,900	$2,400	$2,900
Total Assembly Cost	**$4,000**	**$5,300**	**$6,700**	**$6,700**	**$8,300**	**$10,000**
Total Variable Cost	**$44,000**	**$60,800**	**$78,700**	**$102,700**	**$133,800**	**$192,500**
Markup @ 29%	$12,800	$17,700	$22,800	$29,800	$38,800	$55,800
Total Hardware RPE	**$56,800**	**$78,500**	**$101,500**	**$132,500**	**$172,600**	**$248,300**

Figure 6-5 Variable Cost Curve-Fit for Mechanically Controlled MFI to Common Rail Fuel Injection Systems



A 2.2.2 Tier 2 Fixed Costs

Tier 2 fixed costs are comprised of those costs associated with engine modifications shown in Table 6-12, and those associated with the migration from mechanical fuel injection to common rail shown in Table 6-13. The engine modification fixed cost estimates include modification of fuel injection timing, increasing the compression ratio, fuel injection nozzle optimization and Miller cycle effects. Retooling cost estimates include cylinder head and piston rod shim modifications to increase compression ratios as well as to accommodate different injection nozzles. Differential costs for new common rail fuel injection systems that replace mechanical fuel injection systems include research and development, and retooling costs include modification of the cylinder head to accommodate the common rail fuel injection systems.

Table 6-12 Fixed Costs Estimated for Tier 2 Engine Modifications

ENGINE SPEED	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Fixed Costs						
R&D Costs (1 year R&D)	$688,000	$688,000	$688,000	$688,000	$688,000	$688,000
Retooling Costs	$750,000	$750,000	$750,000	$1,000,000	$1,000,000	$1,000,000
Marine Society Approval	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Engines/yr.	40	40	40	40	40	40
Years to recover	5	5	5	5	5	5
Fixed cost/engine	**$7,200**	**$7,200**	**$7,200**	**$8,500**	**$8,500**	**$8,500**

Table 6-13 Fixed Costs for Mechanical Fuel Injection to Common Rail Fuel Injection

ENGINE SPEED	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Fixed Costs						
R&D Costs (1 year R&D)	$688,000	$688,000	$688,000	$688,000	$688,000	$688,000
Retooling Costs	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000
Marine Society Approval	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Engines/yr.	40	40	40	40	40	40
Years to recover	5	5	5	5	5	5
Fixed cost/engine	**$8,500**	**$8,500**	**$8,500**	**$8,500**	**$8,500**	**$8,500**

A2.3 Engineering Costs Associated with Tier 3

Tier 3 NO_X standards are approximately 80 percent lower than the existing Tier 1 NO_X standards. To meet these standards, it is expected that selective catalytic reduction (SCR) will be used along with engine modifications. A cost estimate is presented for each of the six engine configurations used in this analysis.

A2.3.1 Tier 3 Variable Costs

The variable costs associated with the use of engine modifications for Tier 3 include the use of two stage turbochargers and electronic valve actuation, and are shown in Table 6-14, Figure 6-6 shows the cost curve used to determine a $/kW equation applicable to other engine sizes and types. The methodology used here to estimate the capacity of the SCR systems is based on the power rating of the propulsion engines only. Auxiliary engine power represents about 20 percent of the total installed power on a vessel; however, it would be unusual to operate both propulsion and auxiliary engines at 100 percent load. Typically, ships operate under full propulsion power only while at sea when the SCR is not operating; when nearing ports the auxiliary engine is operating at high loads while the propulsion engine is operating at very low loads.

Table 6-14 Variable Costs for Engine Modifications Associated with Tier 3

SPEED	**MEDIUM**	**MEDIUM**	**MEDIUM**	**LOW**	**LOW**	**LOW**
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Hardware Costs to the Manufacturer						
Component Costs						
2 Stage Turbochargers (Incremental)	$16,250	$20,900	$46,750	$28,000	$42,000	$61,000
Electronic Intake Valves (each)	$285	$285	$285			
Intake Valves per Cylinder	2	2	2			
Electronic Exhaust Valves (each)	$285	$285	$285	$425	$425	$425
Exhaust Valves per Cylinder	2	2	2	4	4	4
Controller	$3,750	$3,750	$3,750	$3,750	$3,750	$3,750
Wiring	$2,800	$2,800	$2,800	$2,800	$2,800	$2,800
Total Component Cost	**$33,000**	**$41,000**	**$72,000**	**$45,000**	**$62,000**	**$88,000**
Markup @ 29%	$10,000	$12,000	$21,000	$13,000	$18,000	$25,000
Total Hardware RPE	**$43,000**	**$53,000**	**$93,000**	**$58,000**	**$80,000**	**$113,000**

Figure 6-6 Variable Cost Curve-Fit for Engine Modifications Associated with Tier 3

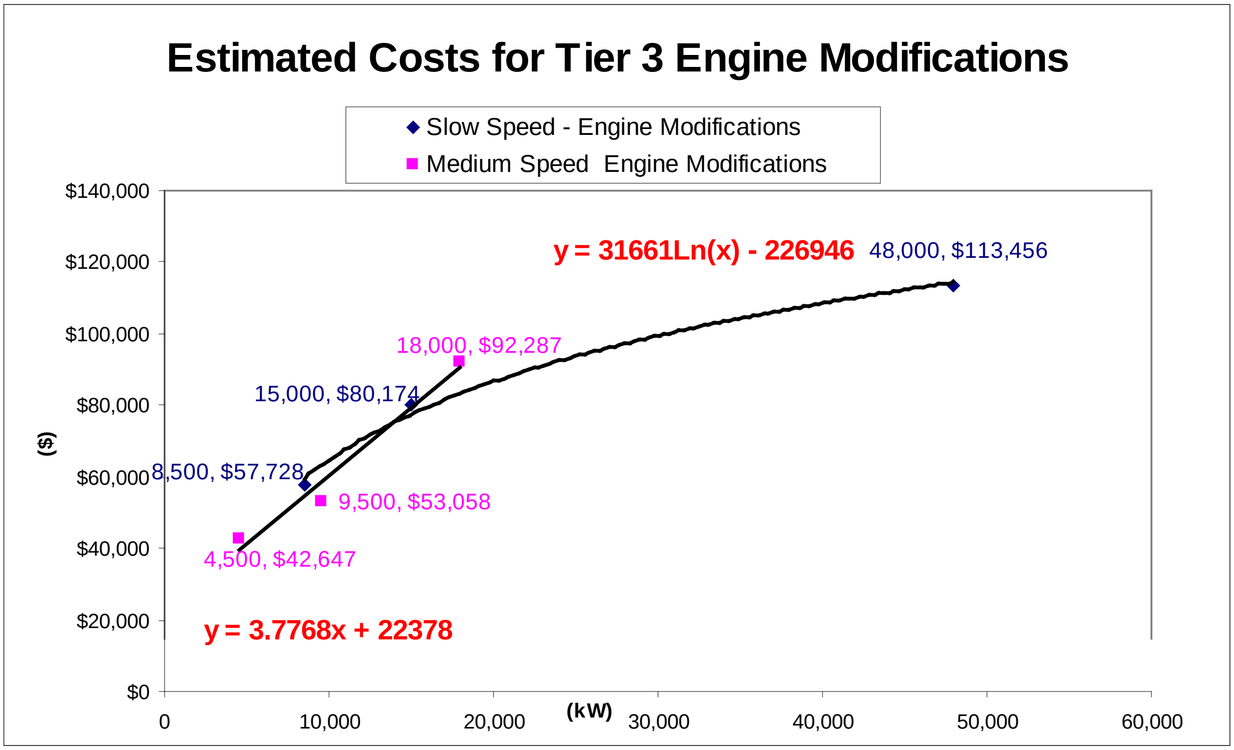


Table 6-15 shows the variable costs associated with the use of SCR, these costs include the urea tank, the reactor, dosage pump, urea injectors, piping, bypass valve, the acoustic horn, a cleaning probe and the control unit and wiring. Detailed costs for the urea tank are shown in Table 6-16 and are based on the storage of urea sufficient for up to 250 hours of normal operation of the SCR. It is envisioned that the urea tank is constructed of 304 stainless steel one mm thick due to the corrosive nature of urea, at a cost of approximately $2,700 per metric ton (tonne).[11]

Figure 6-7 shows the cost curve used to determine a $/kW equation applicable to other engine types and sizes. The total variable hardware costs of Tier 3 estimated here include the fuel injection changes, engine modifications, SCR, and the costs associated with the requirement to test each production engine (§1042.302). We estimate that, on average, this requirement would add a one-time cost of $10,000 for each new engine.

Table 6-15 Variable Costs Associated with the Use of SCR

SPEED	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW
Engine Power (kW)	4,500	9,500	18,000	8,500	15,000	48,000
Cylinders	9	12	16	6	8	12
Liters/cylinder	35	65	95	380	650	1400
Engine Speed (rpm)	650	550	500	130	110	100
Hardware Costs to the Supplier						

Component Costs						
Aqueous Urea Tank	$1,200	$1,900	$2,800	$1,700	$2,400	$4,600
Reactor	$200,000	$295,000	$400,000	$345,000	$560,000	$1,400,000
Dosage Pump	$9,500	$11,300	$13,000	$11,300	$13,000	$15,000
Urea Injectors (each)	$2,400	$2,400	$2,400	$2,400	$2,400	$2,400
Number of Urea Injectors	3	6	8	12	16	24
Piping	$4,700	$5,600	$6,600	$5,600	$7,500	$9,500
Bypass Valve	$4,700	$5,600	$6,600	$5,600	$6,600	$7,500
Acoustic Horn	$9,500	$11,300	$13,000	$11,700	$14,000	$16,400
Cleaning Probe	$575	$575	$575	$700	$700	$700
Control Unit/Wiring	$14,000	$14,000	$14,000	$19,000	$19,000	$19,000
Total Component Cost	**$251,000**	**$360,000**	**$476,000**	**$429,000**	**$662,000**	**$1,530,000**
Assembly						
Labor (hours)	1000	1200	1500	1200	1600	2000
Cost ($23.85/hr)	$23,900	$28,600	$35,800	$28,600	$38,200	$47,700
Overhead @ 40%	$9,500	$11,400	$14,300	$11,400	$15,300	$19,100
Total Assembly Cost	**$33,400**	**$40,000**	**$50,100**	**$40,000**	**$53,500**	**$66,800**
Total Variable Cost	$284,800	$399,700	$525,800	$469,400	$715,000	$1,597,100
Markup @ 29%	$82,600	$115,900	$152,500	$136,100	$207,300	$463,200
Total Hardware RPE	**$367,400**	**$515,600**	**$678,300**	**$605,500**	**$922,300**	**$2,060,300**

Figure 6-7 Variable Cost Curve-Fit for SCR Systems

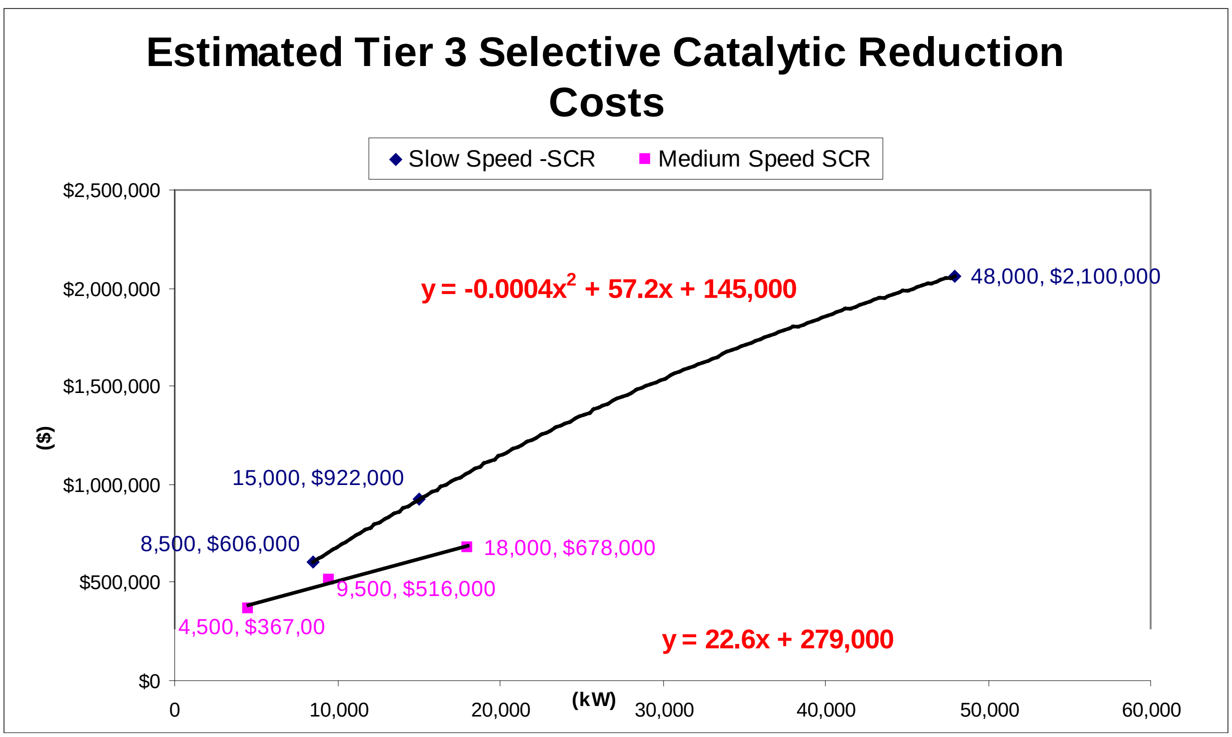


Table 6-16 Variable Costs Associated with the Urea Tanks for use with SCR Systems

SPEED	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Urea Tank Costs						
Urea Amount (kg)	12,910	27,255	51,642	22,645	39,961	127,875
Density (kg/m^3)	1,090	1,090	1,090	1,090	1,090	1,090
Tank Size (m^3)	14	30	57	21	37	117
Tank Material (m^3)	0.04	0.06	0.09	0.05	0.07	0.14
Tank Material Cost ($)	$758	$1,248	$1,909	$977	$1,426	$3,093
Assembly						
Labor (hours)	5	6	7	10	12	15
Cost ($23.85/hr)	$119	$143	$167	$238	$286	$358
Overhead @ 40%	$48	$57	$67	$95	$114	$143
Total Assembly Cost	$167	$200	$234	$334	$401	$501
Total Variable Cost	$925	$1,448	$2,143	$1,310	$1,826	$3,594
Markup @ 29%	$268	$420	$621	$380	$530	$1,042
Total Hardware RPE	$1,194	$1,868	$2,765	$1,690	$2,356	$4,636

A 2.3.2 Tier 3 Fixed Costs

The Tier 3 fixed costs presented here include those associated with the use of SCR, including research and development costs, marine society approval, and retooling for the redesign of the exhaust system to accommodate the SCR unit; the costs are shown in Table 6-17. The migration to common rail from Tier 3 is primarily from electronic fuel injection which includes modification of the cylinder head to accommodate common rail fuel injection systems, these costs are shows in Table 6-18. The fixed costs associated with the migration from mechanical fuel injection to common rail are shown above in Table 6-13. Finally, Tier 3 also includes the fixed costs associated with the engine modifications which include the use of two stage turbochargers and electronic valve actuation; the retooling costs represent turbocharger redesign and valve actuation modifications as shown in Table 6-19.

Table 6-17 Fixed Costs Associated with the use of SCR for Tier 3

ENGINE SPEED	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Fixed Costs						
R&D Costs (1 year R&D)	$1,376,000	$1,376,000	$1,376,000	$1,376,000	$1,376,000	$1,376,000
Retooling Costs	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000
Marine Society Approval	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000

Engines/yr.	40	40	40	40	40	40
Years to recover	5	5	5	5	5	5
Fixed cost/engine	**$16,900**	**$16,900**	**$16,900**	**$16,900**	**$16,900**	**$16,900**

Table 6-18 Fixed Costs Associated with the Migration of Electronic Fuel Injection to Common Rail

ENGINE SPEED	**MEDIUM**	**MEDIUM**	**MEDIUM**	**LOW**	**LOW**	**LOW**
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Fixed Costs						
R&D Costs (0.5 year R&D)	$344,000	$344,000	$344,000	$344,000	$344,000	$344,000
Retooling Costs	$500,000	$500,000	$500,000	$500,000	$500,000	$500,000
Marine Society Approval	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Engines/yr.	40	40	40	40	40	40
Years to recover	5	5	5	5	5	5
Fixed cost/engine	**$4,200**	**$4,200**	**$4,200**	**$4,200**	**$4,200**	**$4,200**

Table 6-19 Fixed Costs Associated with Engine Modifications Used for Tier 3

ENGINE SPEED	**MEDIUM**	**MEDIUM**	**MEDIUM**	**LOW**	**LOW**	**LOW**
Engine Power (kW)	**4,500**	**9,500**	**18,000**	**8,500**	**15,000**	**48,000**
Cylinders	**9**	**12**	**16**	**6**	**8**	**12**
Liters/cylinder	**35**	**65**	**95**	**380**	**650**	**1400**
Engine Speed (rpm)	**650**	**550**	**500**	**130**	**110**	**100**
Fixed Costs						
R&D Costs (1 year R&D)	$688,000	$688,000	$688,000	$688,000	$688,000	$688,000
Retooling Costs	$1,000,000	$1,000,000	$1,000,000	$1,320,000	$1,320,000	$1,320,000
Marine Society Approval	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Engines/yr.	40	40	40	40	40	40
Years to recover	5	5	5	5	5	5
Fixed cost/engine	**$8,500**	**$8,500**	**$8,500**	**$10,000**	**$10,000**	**$10,000**

Chapter 6 References

[1] U.S. EPA, April 30, 2010, Final Rule: Control of Emissions of Air Pollution from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder. Available at: http://www.epa.gov/otaq/oceanvessels.htm

[2] See Tables 7-2 and 7-3 of Chapter 7 of the Category 3 Regulatory Impact Analysis that can be accessed here: http://www.epa.gov/otaq/regs/nonroad/420r09019-chp07.pdf

[3] 2010 Greenwood's Guide to Great Lakes Shipping. Harbor House Publishers, Inc., Boyne City, Michigan.

[4] Lloyd's Sea-Web database of ships, accessed August, 2010 from www.sea-web.com

[5] See comments of the Great Lakes Maritime Task Force, Docket Item EPA-HQ-OAR-2007-0121-0269 at http://www.regulations.gov

[6] Walsh, Gregory M, April, 2008, "Economical heavy fuel oil finding its way into the tugboat industry." Published in issue #112 of the Professional Mariner, available here: http://www.professionalmariner.com/ME2/dirmod.asp?sid=420C4D38DC9C4E3A903315CDDC65AD72&nm=Archives&type=Publishing&mod=Publications%3A%3AArticle&mid=8F3A7027421841978F18BE895F87F791&tier=4&id=F1DFA02472A643369559CCF5F5AC618F

[7] ICF International, "Costs of Emission Reduction Technologies for Category 3 Marine Engines," prepared for the U.S. Environmental Protection Agency, December 2008. EPA Report Number : EPA-420-R-09-008.

[8] See Tables 7-2 and 7-3 of Chapter 7 of the Category 3 Regulatory Impact Analysis that can be accessed here: http://www.epa.gov/otaq/regs/nonroad/420r09019-chp07.pdf

[9] Marine Log, July, 2010, Rand Logistics to Repower Lakes steamship. Available here: http://www.marinelog.com/DOCS/NEWSMMIX/2010jul00271.html

[10] MAN Diesel, "Exhaust Gas Emission Control Today and Tomorrow, August 19, 2008," available at http://www.manbw.com/article_009187.html

[11] See http://www.metalprices.com/FreeSite/metals/stainless_product/product.asp#Tables for 2006.

CHAPTER 7: Industry Characterization

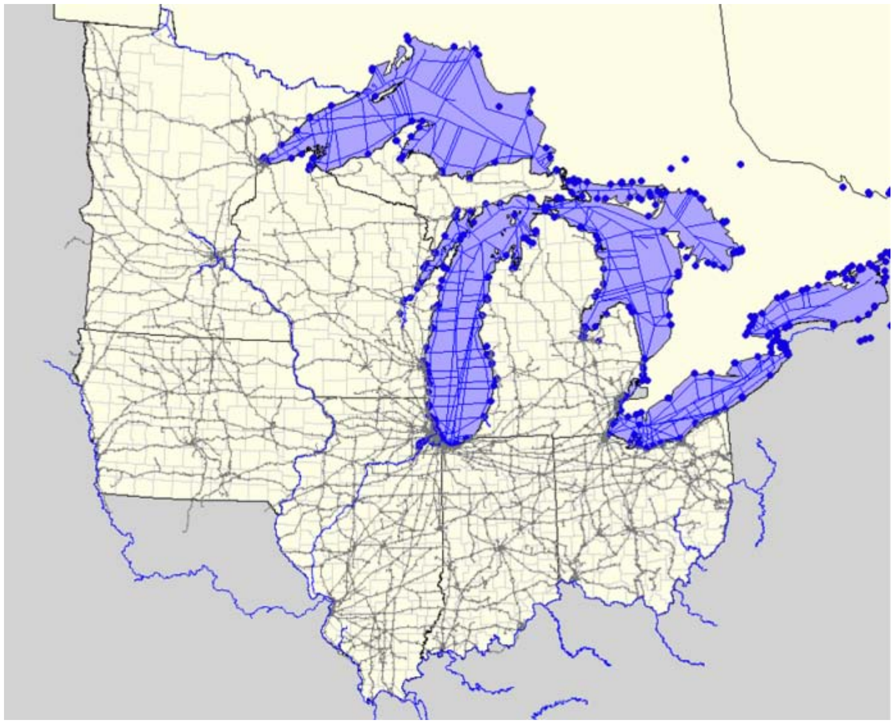
This chapter provides a description of the Great Lakes shipping sector, specifically the ships that are affected by the engine and fuel standards recently finalized in our Category 3 marine rule (75 FR 22896, April 30, 2010). We briefly describe the Great Lakes marine transportation system, the ships operating within that system, the cargoes they carry, and where they take those cargoes.

The primary purpose of this industry characterization is to provide information with respect to those ships on the Great Lakes that will be subject to the Coordinated Strategies. With respect to fuel production and availability, the Great Lakes were included in the fuel sector analysis prepared for the North American ECA application. That analysis can be found on our website, www.epa.gov/otaq/oceanvessels.htm. Additional information on many aspects of the Great Lakes Transportation System can be found in Appendix A to this chapter.

7.1 The Great Lakes Transportation System At-a-Glance

The Great Lakes are an important part of our national and regional transportation system carrying large quantities of raw materials such as iron ore, coal, grain, and crushed stone from the northern and western part of the lakes to places where these resources are used locally, shipped farther inland, or shipped to the rest of the world. Ships are one part of the system, and primarily carry bulk cargo port-to-port. Some of those materials are used at the point of discharge, while others are shipped inland, primarily by rail. Figure 7-1 illustrates the interconnectedness of ship and rail links and shows how Great Lakes shipping is integrated into the region's transportation system.

Figure 7-1 Great Lakes Maritime Information Delivery System - Docks, Waterways and Railroads



Source: Department of Geography and Planning: Center for Geographic Information Sciences and Applied Geographics (GISAG), 2007

According to *Greenwoods Guide to Great Lakes Shipping 2010*, there are about 130 commercial ports and docks on the Great Lakes that can handle shipments of coal, iron ore, and stone; still others handle grain and other bulk goods (the main Great Lakes ports are illustrated in Figure 7-2). These ports and docks range from very large facilities like those in Superior, Wisconsin and Duluth, Minnesota to small docks that may service one plant. In addition to these ports and docks, actual cargo origins and destinations can be located well inland of the Great Lakes. For example, coal can be shipped by rail from Montana to Duluth on Lake Superior and then be transported to power plants on the St. Clair River in Michigan. Similarly, stone can be shipped from mines on the shores of Lake Michigan through Toledo, Ohio, and then shipped by rail to the Ohio River Valley for use in power plant scrubbers.

The amount of cargo annually shipped on the Great Lakes is significant. The data in Table 7-1 show that cargo carried annually on the five Great Lakes themselves, excluding the St. Lawrence River system downstream of Buffalo, amounts to over half of the annual cargo shipments on the Mississippi River system.

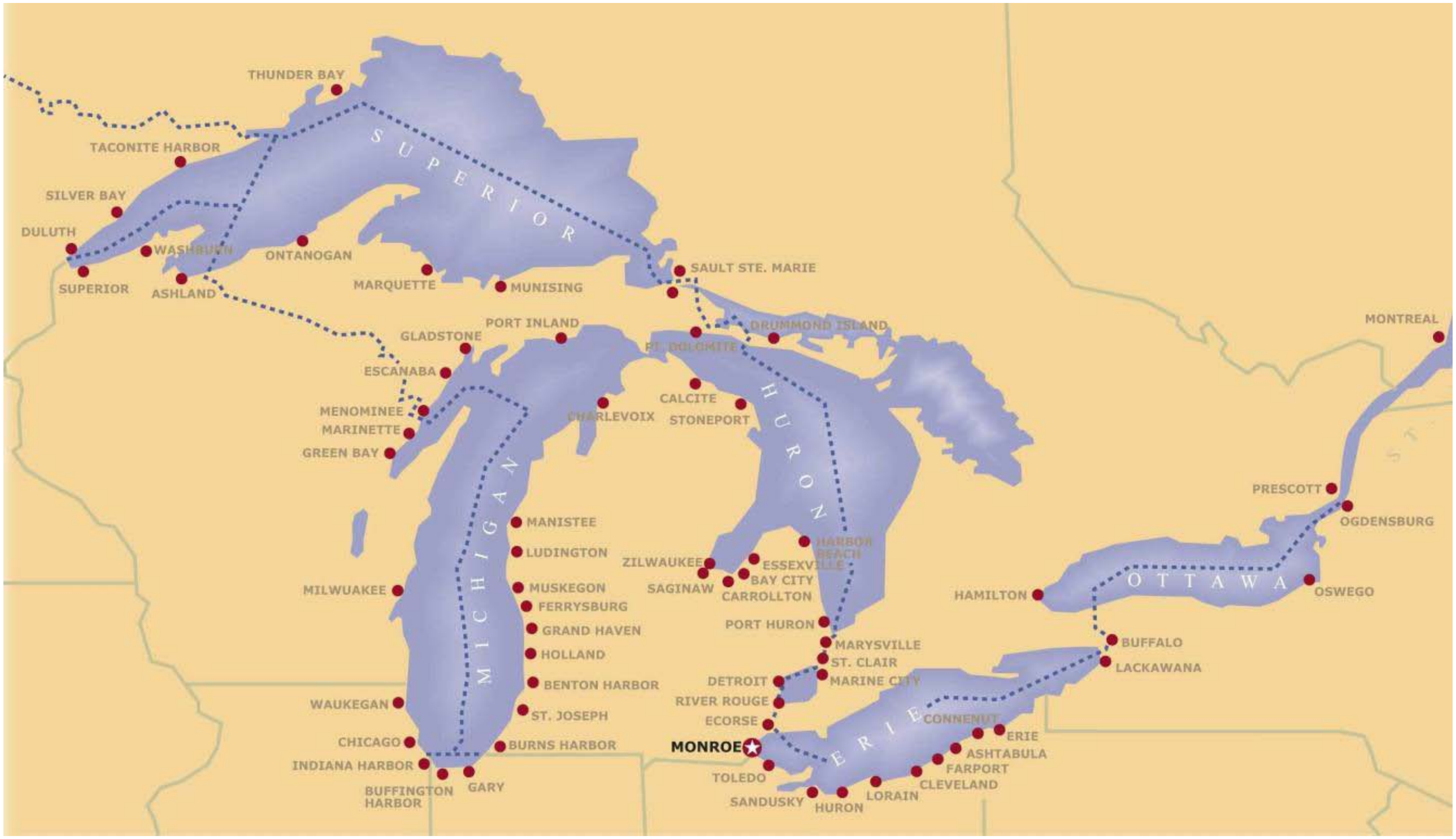
Table 7-1 Annual Shipments, Great Lakes and Mississippi River (million short tons)

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Mississippi River Total	327	317	316	308	313	299	314	313	295
Great Lakes Dry Bulk	177	166	164	155	170	165	170	157	157

[a] A majority of the cargo shipped on the Great Lakes is dry bulk.

Sources: http://www.lcaships.com/TONPAGE.HTM, http://www.shipowners.ca/index.php?page=annual-report-and-statistics, http://www.seaway.ca/en/seaway/facts/traffic/index.html

Figure 7-2 Great Lakes Ports



Source: www.portofmonroe.com/

7.2 Top 10 Great Lakes Ports

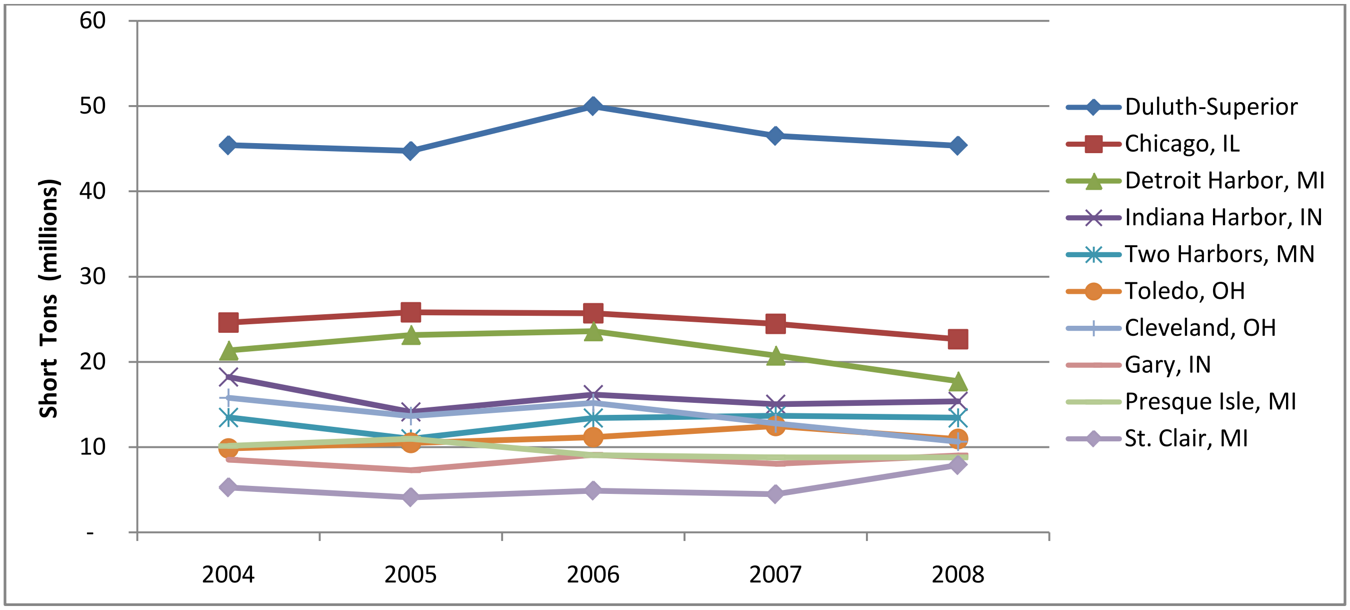
The Army Corps of Engineers keeps track of the amount and type of freight delivered and shipped for 83 ports along the Great Lakes.[1] Of these 83 ports, 12 did not receive any cargo in 2008, and little to no cargo from 2004 through 2007. Of the other 71 ports, Duluth-Superior (Duluth MN, Superior, WI) had the largest quantity of shipments in 2008, more than twice the tonnage of the second largest port, Chicago, IL. All but one of the top ten Great Lakes ports handle primarily coal and iron ore. The exception is Chicago, which handles a wider variety of cargo. The top ten U.S. ports on the Great Lakes in terms of tonnage handled in 2008 are listed Table 7-2, along with their 2008 cargo figures and primary commodity.

Table 7-2 Ten Largest Ports in terms of Tonnage in 2008

PORT	PORT DESCRIPTION	2008 TOTAL TONNAGE RECEIVED AND SHIPPED (SHORT TONS)	PRINCIPAL COMMODITY HANDLED IN TERMS OF TONNAGE	% OF TOTAL TONNAGE HANDLED BY PRINCIPAL COMMODITY
Duluth, MI-Superior, WI	Superior Bay and its tributaries, St. Louis Bay and St. Louis River, and Allouez Bay.	45,341,000	Coal	48%
Chicago, IL	Chicago Harbor, Chicago River, Chicago Sanitary and Ship Canal, Lake Calumet, IL, Calumet Harbor and River, IL and IN.	22,659,000	Coal	22%
Detroit Harbor, MI	U.S. bank of Detroit River from Lake St. Clair to western extreme of Zug Island.	17,752,000	Iron ore	46%
Indiana Harbor, IN	Entire Harbor, Indiana Harbor Canal, including the Calumet River Branch to Columbus Drive Bridge and the Lake George Branch.	15,380,000	Iron ore	76%
Two Harbors, MN	Entire Harbor	13,433,000	Iron ore	100%
Toledo, OH	Channel in Lake Erie and 7 miles in lower Maumee River.	10,955,000	Iron ore	42%
Cleveland, OH	Outer Harbor, Old River and Cuyahoga River from mouth to and including Upper Republic Steel Corp. Dock,	10,637,000	Iron ore	49%
Gary, IN	Entire harbor.	9,030,000	Iron ore	94%
Presque Isle, MI	Entire harbor.	8,808,000	Iron ore	73%
St. Clair, MI	West bank of St. Clair River at St. Clair, MI	7,880,000	Coal	100%

Figure 7-3 shows the tonnages moved by the ten busiest Great Lakes ports from 2004 through 2008. Four of the ten ports have seen declines in tonnage handled since 2004, including the ports of: Detroit, MI; Indiana Harbor; Cleveland, OH; and Presque Isle, MI. All four of these ports handle iron ore as their primary cargo. Overall, the graph shows relatively steady traffic since 2004.

Figure 7-3 Tonnages Moved by the Ten Busiest Great Lakes Ports 2004-2008



7.2.1 Duluth, MN – Superior, WI

The "Twin Ports" of Duluth-Superior combine to represent the largest volume port in the Great Lakes/St. Lawrence Seaway system, it is the second largest dry-bulk port in the U.S., and one of the top 20 ports in the U.S. overall.[2] Duluth-Superior is a multi-modal hub for both domestic and international cargo; industries accommodated at this port include: agriculture, forestry, mining, manufacturing, construction, power generation, and passenger cruising. Located at the head of the Great Lakes, Duluth-Superior functions primarily as a loading port for iron ore mined and processed into taconite from northern Minnesota's Missabe Range, for grain produced in Minnesota and North and South Dakota, and for coal transported via rail from mines in the Powder River Basin of Wyoming and Montana.

The port of Duluth-Superior handles an average of 46 million short tons of cargo and over 1,100 vessel visits each year along its 49 miles of waterfront, supporting about 2,000 local jobs. This port has been designated as Foreign Trade Zone which provides incentives for international shippers as the port looks for opportunities to handle containers in the future. Currently, iron ore and coal account nearly evenly for about 80 percent of the port's total tonnage; nearly 20 million tons of low-sulfur coal from Montana and Wyoming are transferred here for delivery via marine transport to utility and manufacturing plants on the lower Great Lakes. Outbound shipments of grain harvested in the Midwest headed for Europe and Africa account for five to ten percent of the Port's annual tonnage. Inbound shipments of other bulk commodities such as limestone, salt, and cement account for another ten percent. Table 7-3 lists the ten commodities handled most often in the port of Duluth-Superior in 2008; these ten commodities represent over 99 percent of all commodities handled at this port.

Table 7-3 Port of Duluth-Superior: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Coal & Lignite	21,740,637	47.9%
Iron Ore	18,760,970	41.4%
Limestone	2,913,831	6.4%
Wheat	635,286	1.4%
Cement & Concrete	291,797	0.6%
Non-Metallic Mineral NEC (ex. Common Salt)	227,580	0.5%
Animal Feed, Prepared	188,639	0.4%
Oats	175,759	0.4%
Slag	153,740	0.3%
Clay & Other Refractory Minerals	99,635	0.2%
All Commodities	45,341,808	

7.2.2 Chicago, IL

The Port of Chicago is an intermodal facility that also connects barge traffic traveling up from the Gulf of Mexico via the Mississippi River to the Great Lakes.[3] It is the leading ‘general cargo’ port on the Great Lakes, and moves an average of over 26 million tons of natural resources and other goods. The Port of Chicago is near five federal highways and six major railroads as well as a large airport. Facilities include the Iroquois Landing Lakefront Terminus which specializes in intermodal container services and is on a 100-acre parcel with 3,000 linear feet of ship and barge berthing space and a navigational depth of 27 feet. There are also two storage facilities with well over 100,000 sq ft and direct access to rail and truck services. Lake Calumet, part of the Port of Chicago also offers terminals approximately 6 miles inland from Lake Michigan; in addition, Lake Calumet offers 3,000 linear feet of ship and barge berthings and over 315,000 sq ft of shed storage.

The Port of Chicago also includes a Foreign Trade Zone which comprises a 60-mile radius from the city limits of Chicago. It includes 400,000 sq ft of warehouse space and 20 acres of developable land for the storage, handling, processing, manufacturing, and/or assembling of foreign goods. Finally, the Port of Chicago also offers grain and bulk liquid storage capable of holding 14 million bushels and 800,000 barrels respectively. The Port handles a wide variety of goods including: steel, scrap metals, cement, coke, stone, ore, vegetable oil, sugar, and many others, and provides over 3,300 jobs directly related to the Port. Table 7-4 shows the top ten commodities handled by the Port of Chicago in 2008. These ten commodities represent over 79 percent of all tonnage handled at this port.

Table 7-4 Port of Chicago: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Coal & Lignite	4,872,272	22%
Sand & Gravel	2,940,254	13%
Non-Metallic Mineral NEC (ex. Common Salt)	2,335,214	10%
Petroleum Coke	2,331,050	10%
Cement & Concrete	1,326,982	5.9%
Limestone	1,101,997	4.9%
Iron & Steel Scrap	864,939	3.8%
Distillate Fuel Oil	799,123	3.5%
Iron Ore	784,146	3.5%
Pig Iron	649,484	2.9%
All Commodities	22,659,554	

7.2.3 Detroit Harbor, MI

The Port of Detroit services southeast Michigan's busy manufacturing sector, which is still heavily dominated by the automotive industry.[4] The Port also offers rail and trucking services. There are two main companies that depend on this port: Thyssen Krupp and Corus (formerly British Steel). Nearly one-third of the cargo that is handled by the Port is imported by Thyssen for their fabrication plant in Southwest Detroit that serves the automotive industry. The Port is near three main highways and the Ambassador Bridge that crosses to Canada. The Port covers approximately 35 acres with docks over 2,100 feet in length and a depth of 27 feet, and offers 128,000 sq ft of covered storage. The Port supported over 5,800 jobs directly as of 2005, as well as generated over $201 million in tax revenue and over $164 million in business revenue. Table 7-5 shows the top ten commodities handled by the Port of Detroit Harbor in 2008, these ten commodities represent over 96 percent of all tonnage handled at this port.

Table 7-5 Port of Detroit Harbor: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Iron Ore	5,363,333	42%
Limestone	1,964,950	15%
Coal & Lignite	1,844,784	14%
Cement & Concrete	946,072	7.4%
Non-Metallic Mineral NEC (ex. Common Salt)	837,382	6.5%
Asphalt, Tar & Pitch	400,951	3.1%
Petroleum Coke	379,380	3.0%
Slag	270,649	2.1%
Sand & Gravel	193,829	1.5%
Coal Coke	159,308	1.2%
All Commodities	12,836,319	

7.2.4 Indiana Harbor, IN

The Port of Indiana Harbor, shown in Figure 7-4, is on the southwestern shore of Lake Michigan, in East Chicago, Indiana.[5] It is an artificial waterway that connects the Grand Calumet River to Lake Michigan and is made up of two canals: the two kilometer Lake George Branch and the three-kilometer Grand Calumet River Branch. The Port supports a number of companies including ArcelorMittal, and handles cargo such as: iron ore, limestone, coke, steel, gypsum, cement, concrete, and petroleum products as BP has a refinery near this port. Indiana Harbor primarily carries iron ore (over 76 percent), although it handled over one million short tons of limestone in 2008. Table 7-6 shows the top ten commodities, in tons, handled by the Port of Indiana Harbor in 2008. These commodities represent over 98 percent of the total tonnage handled that year.

Figure 7-4 Indiana Harbor, IN

Source: U.S. Army Corps of Engineers

Table 7-6 Port of Indiana Harbor: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Iron Ore	11,738,007	76%
Limestone	1,241,768	8.1%
Slag	595,043	3.9%
Coal Coke	341,815	2.2%
Distillate Fuel Oil	290,778	1.9%
Asphalt, Tar & Pitch	280,244	1.8%
Iron & Steel Plates & Sheets	198,297	1.3%
Gasoline	142,337	0.9%
Petroleum Coke	142,186	0.9%
Aluminum Ore	111,369	0.7%
All Commodities	15,380,630	

7.2.5 Two Harbors, MN

Two Harbors is primarily engaged in loading iron ore and has been doing so for over one hundred and twenty-five years as the first ship to leave this port loaded with iron ore did so in 1884.[6] This Port is located on the north shore of Lake Superior, approximately 27 miles northeast of Duluth, MN.[7] U.S. Steel and Canadian National companies are major stakeholders for this Port. The bulk commodities which pass through this harbor generate over $120 million annually and directly support 2,400 jobs. Since 2004, Two Harbors has handled iron ore almost exclusively as it has made up over 99 percent of the tonnage handled by this port each year. In 2008, Two Harbors only handled two different types of cargo, over 13 million tons of iron ore (short tons) and nearly 60,000 tons of limestone.

7.2.6 Toledo, OH

The Lake Erie port of Toledo, Ohio is a multi-modal transportation hub with heavy rail, highway and air cargo activity as well as its waterborne traffic.[8] Waterborne cargo movement through Toledo involves the U.S.-Canadian interlake trades, coastal trades and the overseas St. Lawrence Seaway trades. Three commodities - coal, iron ore and grain - account for almost 90 percent of the tonnage moved through the port. This Port also has a Foreign Trade Zone and handles over 12 million tons of cargo and 700 vessel calls each year. The Toledo Shipyard is home to one of the only U.S. full service shipyards with graving docks on the lower lakes. Recent property acquisitions by the Port have allowed it to become the largest land mass seaport on the Great Lakes. This port is located at a national crossroads of four railroads including: Norfolk Southern, CSX, Canadian National, and Wheeling & Lake Erie, as well as two transcontinental highways. The Port of Toledo offers four grain terminals with a combined 22 million bushel storage capacity. Table 7-7 shows the top ten commodities in terms of tonnages handled by the Port of Toledo, which represent over 92 percent of the total tonnage handled by this port in 2008.

Table 7-7 Port of Toledo: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Iron Ore	4,574,172	42%
Coal & Lignite	3,031,652	28%
Limestone	564,091	5.1%
Non-Metallic Mineral NEC	368,531	3.4%
Sand & Gravel	363,964	3.3%
Soybeans	276,681	2.5%
Coal Coke	271,964	2.5%
Cement & Concrete	257,454	2.4%
Gasoline	251,595	2.3%
Corn	191,822	1.8%
All Commodities	10,954,686	

7.2.7 Cleveland, OH

The Port of Cleveland handles about 12 million to 16 million metric tons annually of international and interlake cargos with eight international cargo docks and 110 acres of land situated along Lake Erie as well as the 44 acre site of the Cleveland Bulk Terminal facility.[9] It is also home to a number of Great Lakes fleet offices and to the Lake Carriers' Association, which represents the U.S.-flag vessel operators on the Great Lakes. Primary cargoes handled include inbound and outbound steel and heavy machinery. The Cleveland Bulk Terminal features an automated iron ore loader that can move ore at a rate of 5,200 tons per hour. This port supports the Cleveland-Cliffs iron ore pellet supplier, Mittal Steel's mills, and Oglebay Norton Co. that utilize and transport these materials. The Port of Cleveland offers nine berths, 6,500 linear feet of dock space with a depth of 27 feet; in addition they also offered over 300,000 square feet of storage. Table 7-8 shows the top ten commodities in terms of tonnages handled by the Port of Cleveland, which represent over 97 percent of the total tonnage handled by this port in 2008.

Table 7-8 Port of Cleveland: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Iron Ore	5,159,314	49%
Limestone	2,995,005	28%
Non-Metallic Mineral NEC	700,104	6.6%
Cement & Concrete	527,842	5.0%
Sand & Gravel	364,565	3.4%
Iron & Steel Primary Forms	168,094	1.6%
Slag	132,633	1.2%
Asphalt, Tar & Pitch	125,147	1.2%
Iron & Steel Plates & Sheets	107,136	1.0%
Residual Fuel Oil	73,904	0.7%
All Commodities	10,637,330	

7.2.8 Gary, IN

The Port of Gary is operated by the U.S. Steel Corporation where the Gary Works, U.S. Steel's largest manufacturing plant is located on the south shore of Lake Michigan.[10] This port handles commodities such as: coal and petroleum coke, limestone, iron ore, iron and steel scrap, non-ferrous scrap and ores, clay and refractory materials, slag, and iron and steel plates and sheets. In Gary, U.S. Steel makes 7.5 million net tons of raw steel, and also operates three coke batteries with annual production capability of 1.3 million net tons. Table 7-9 shows the top ten commodities in terms of tonnages handled by the Port of Gary, which represent over 99 percent of the total tonnage handled by this port in 2008.

Table 7-9 Port of Gary: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Iron Ore	8,486,695	94%
Limestone	209,603	2.3%
Iron & Steel Plates & Sheets	119,525	1.3%
Slag	68,942	0.8%
Non-Ferrous Scrap	49,172	0.5%
Clay & Refractory Materials	31,221	0.3%
Petroleum Coke	31,191	0.3%
Iron & Steel Scrap	10,673	0.1%
Coal Coke	10,277	0.1%
Primary Iron & Steel	8,537	0.1%
All Commodities	9,030,152	

7.2.9 Presque Isle, MI

The Port of Presque Isle, located in Marquette, MI, was built in 1941 and primarily receives two types of cargo, iron ore and coal; small amounts of limestone are also delivered occasionally.[11] Nearly 73 percent of the Port's cargo is iron ore delivered via railcar from the Upper Peninsula of Michigan. The majority of this iron ore is sent to Algoma Steel in Sault Ste. Marie, Ontario. Table 7-10 shows the three commodities in terms of tonnages handled by the Port of Presque Isle in 2008.

Table 7-10 P ort of Presque Isle: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Iron Ore	6,399,079	73%
Coal & Lignite	2,240,725	25%
Limestone	167,805	2%
All Commodities	8,807,609	

7.2.10 St. Clair, MI

Almost the entire cargo unloaded in St. Clair is coal intended for the Detroit Edison's (DTE) Belle River power plant located on the bank of the St. Clair River on a 2,200 acre site.[12] The Belle River plant produces 1,350 megawatts of power, and is the second largest DTE owned plant. Table 7-11 shows the tonnages by cargo type unloaded in St. Clair in 2008.

Table 7-11 P ort of St. Clair: Top Commodities Handled in 2008 (short tons)

COMMODITY	TONNAGE (short tons)	PERCENTAGE OF ALL TONNAGE
Coal & Lignite	7,880,089	99%
Distillate Fuel Oil	294	<<1%
All Commodities	7,880,383	

7.3 Primary Cargoes Shipped on the Great Lakes

According to the Lake Carriers' Association, the main commodities shipped on the Great Lakes are iron ore, coal, and limestone. These accounted for 38, 25, and 21 percent, respectively, of the dry-bulk commerce on the Great Lakes in 2008.

Table 7-12 Great Lakes Dry-Bulk Commerce, Calendar Years 2004-2008 and 5-year Average (net tons)

	2004	2005	2006	2007	2008	5-Year Average
Iron Ore	62,614,611	58,187,548	59,878,098	58,099,138	59,242,954	59,604,467
Coal	39,936,860	42,706,688	41,878,453	39,260,538	39,790,490	40,696,404
Limestone	40,222,052	37,725,377	38,977,721	34,001,466	32,367,513	36,658,825
Salt	9,239,658	9,255,371	9,726,206	8,892,084	11,425,851	9,707,834
Cement	6,345,674	6,154,834	6,047,303	5,671,762	5,036,915	5,851,297
Grain	11,667,639	11,377,508	13,027,677	11,135,605	9,284,286	11,298,941
Total	170,026,494	165,407,326	1 69,535,458	157,060,593	157,148,009	163,817,768
Source: Lake Carriers' Association (http://www.lcaships.com/SR09-Dry-Bulk%20Commerce%20-%20Text.pdf)						

7.3.1 Coal

As shown in Table 7-12, there were 39,790,490 tons of coal shipped on the Great Lakes in 2008. This figure was slightly down from the five preceding years' average of 40,770,723 tons.[13] This coal goes primarily to power generating plants, steel mills, and paper mills along the coast of the Great Lakes. The paper mills include Cellu Tissue in Menominee, MI;[14] Neenah Paper in Munising, MI;[15] and Georgia-Pacific in Green Bay, WI.[16] In paper mills, coal is used to power boilers. In the paper production process, boilers produce steam both for a turbine and to power steam drives, a substitute for electric motors.[17] Coal is primarily used to power the blast furnace in steel mills, along with being used in the smelting of iron. It also serves as a source of electricity for the steelmaking process and as a source of carbon, which can be used as an energy source and a method of decreasing iron oxide levels during the steelmaking process.[18] The largest use of coal in the Great Lakes region is in power plants to generate electricity. Burning coal heats water until it evaporates into steam. High pressure steam then is routed to spin a turbine attached by a shaft to a generator. The spinning generator then produces electricity.[19] The great majority of this coal comes from two sources: the Powder River Basin, Montana from the west and the Appalachian region from the east. After being mined, the coal is then transported by rail to ports on the Great Lakes; coal from the Powder River Basin is railed to Lake Superior while coal from Appalachia is transported by rail to Lake Erie.[20] From these ports the coal is transported by vessel to lakeside power plants or ports to transfer the cargo. Power plants that aren't located on the water or have a lakeside unloading station will receive their shipments from either truck or rail.

7.3.2 Iron Ore

Iron ore is the most transported commodity on the Great Lakes, the Hon. James L. Oberstar, shown in Figure 7-5 is an example of a ship that carries iron ore. The year 2008 saw 59,242,954 tons of iron ore shipped on the Great Lakes.[21] The final destination of the almost 60 million tons are steel mills. Iron ore is used in the steelmaking process, primarily in the blast furnace to create molten iron, an early step in the production of steel.[22] The iron ore transported on the Great Lakes mainly comes from two iron ranges in the U.S.: the Mesabi Iron Range in the Arrowhead Region of Minnesota, and the Marquette Iron Range in the northern Upper Peninsula of Michigan.[20] Eastern Canada is also a source of iron ore with large mines such as the Wabush Mine in Wabush and other deposits in Newfoundland and Labrador.[23] The Mont-Wright Mining Complex and Fire Lake Mine are located in northeastern Quebec and are owned by ArcelorMittal. As they are about 35 miles away from each other, ore mined at the Fire Lake Mine is transported to the Mont-Wright Mining Complex where the iron ore mined at both facilities are transported by rail to Port-Cartier, Quebec to be shipped to their final destinations.[24,25] The Carol Project, outside of Labrador City in Newfoundland and Labrador, Canada, is an iron ore mining operation just beyond the Quebec border. After it is mined and processed, the iron ore is transported via rail to a year-round port in Sept-Iles, Quebec for shipping.[26]

Figure 7-5 The Hon. James L. Oberstar Heads Downbound at Sault Ste. Marie, MI in July of 2007

Source: Photo taken by and used with permission from Blake Kishler

7.3.3 Stone

There are several different types of stone transported on the Great Lakes, but the dominant type is crushed limestone, 32,367,513 tons of which was transported on the Great Lakes in 2008.[27] Another heavily shipped material is cement with 4,188,457 tons shipped on the Great Lakes in 2008.[28] Other stone-like aggregate products shipped include sand and gravel, with 3,984,434 tons shipped in 2008, and gypsum, with 422,431 tons shipped in 2008.[29] Despite these different types of stone, there are only a few types of companies interested in obtaining it. Limestone can be utilized by cement manufacturers and construction companies as an aggregate along with sand and gravel.[27,29] Cement is also largely used by the construction industry.[28] In addition, limestone is used in the steelmaking process as a filtering material in the blast furnace, specifically for removing sulfur.[30] The power generation industry has found use for limestone's property of reducing sulfur as well. Coal-fired power plants use limestone to control sulfur emissions to comply with environmental standards.[29] Limestone transported in the Great Lakes region is primarily quarried in northeastern Michigan, both in the Lower Peninsula and the Upper Peninsula.[20] Cement is not a raw material and thus not found naturally, but instead produced in plants. It is made from mainly limestone and clay. The two materials are ground, mixed, superheated, and cooled. Then gypsum and other materials are added depending on the type of cement being made.[31] Michigan is the top cement-producing state in the Great Lakes region.[32]

7.3.4 Grain

The lowest quantity of grain transported over the Great Lakes in the last ten years occurred in 2008 reflecting a 31% decrease from the year before as only 7,744,592 tons of grain were transported on the Great Lakes. Part of the reason for this decline is that Canada is shifting its grain trade to the West Coast.[33] From 1998 to 2009, grain shipments from Thunder Bay fell by 47% from 2,059 thousand metric tons to 1,093 thousand metric tons while grain shipments from Canada's Pacific coast rose by over 20% from 15,420 thousand metric tons to 18,716 thousand metric tons.[34,35] This trend in Canadian shipping is attributable to the shift of Canadian grain sales to Asian countries, making shipping from the Pacific coast the most economic option.[36] The companies involved in the grain trade are typically food companies who process and distribute grain and grain products. A large portion of the grain shipments originating in the Great Lakes are exported, with Canada, Western Europe, and Eastern Asia being the main destinations.[37,38] The main domestic targets for grain transported on the Great Lakes are New York and Ohio.[37]

7.3.5 Other Cargoes

The Great Lakes are also used for the transportation of salt, petroleum, vehicles, and people. Salt makes up about 4% of all cargo transported on the Great Lakes. It is mined in Canada and Ohio and shipped mostly to Michigan, Wisconsin, and Illinois. Salt is sold as table salt, used in deicing during the winter, or as a component in other products.[39] Petroleum tankers and barges are an economically efficient way to deliver fuel to some areas on the Great Lakes that need it, since some cities aren't connected to pipelines while others need to supplement their pipeline supply. The use of petroleum tankers is also an effective method to transport fuels that can't be sent through a pipeline due to their makeup.[40] The Great Lakes has eighteen self-powered tankers and twenty-six tanker barges.[41] These forty-four vessels are responsible for all petroleum transportation between the U.S. and Canada.

There are almost fifty car ferries on the Great Lakes, the S.S. Badger based in the Port of Ludington, MI and the M.S. Chi-Cheemaun of Tobermory, Ontario are the two largest ferries operating on the Great Lakes. They are the only ferries on the lakes that have a capacity of over one hundred cars, with capacities of 180 and 138 respectively.[41] The S.S. Badger makes a four-hour trip across Lake Michigan between Ludington, Michigan and Manitowoc, Wisconsin and can carry passenger cars as well as semi trucks and trailers.[42] She serves as a link between the two sections of U.S. Highway 10 on either side of Lake Michigan.[43] The carferries also carry passengers across the Great Lakes.[41]

7.3.6 Short-sea Shipping

There has been more emphasis in recent years on promoting short-sea shipping on the Great Lakes as a way of relieving rail and highway congestion and reduce energy consumption. Short-sea shipping generally involves moving containers and truck trailers (RO-RO) away from highway transportation and toward an intermodal truck-ship-truck route. For example, goods that arrive in east coast ports from all parts of the world would be loaded on smaller container ships and shipped down the St. Lawrence Seaway to Great Lakes ports for distribution in the region.[44] In another example, truck trailers are shipped from Michigan to Wisconsin, across Lake Michigan, to avoid road congestion around Chicago; one study estimates savings on shipping costs of up to 18 percent.[45] In a third example, a study of cargo shipped from Montreal to Cleveland estimates reduced CO_2 emissions and operating costs for truck/ship and truck/rail alternatives to truck only transportation.[46] While short-sea shipping has not yet been implemented on the Great Lakes, this may become a more attractive transportation solution as a result of increasing fuel prices.

7.4 Industries that Use the Cargoes Transported by Great Lakes Shipping

Numerous companies depend on marine transportation to deliver raw materials to their facilities. These industries are crucial for our society, and provide basic products that are used every day. Historically, producers of steel, iron, cement, and electricity located their plants on the Great Lakes because these plants require large amounts of raw materials and water. The Great Lakes provide a low-cost way to transport large quantities of raw materials.[47] Power generation plants, usually need to be located on water and often have coal delivered by water right to the plant. Steel mills have been built on the waterway because it made the transportation of iron ore and other materials needed for steel production easier. Construction is a service performed all over, and the Great Lakes facilitate the movement of aggregate materials that are needed by this industry. The grain industry, utilizes the Great Lakes as the first leg of sending their product overseas. Marine transportation is engrained in each of these industries.

7.4.1 Steel Industry

There are over a dozen steel mills along the coast of the Great Lakes. The steel giants ArcelorMittal and U.S. Steel own eleven such mills between them, with the other mills being owned by AK Steel, Essar Steel, and Severstal.[48,49,50,51,52] ArcelorMittal's four steel mills on the Great Lakes include plants in Burns Harbor, Indiana; Cleveland, Ohio; Indiana Harbor, Indiana;[48] and a Dofasco mill in Hamilton, Ontario.[53] The facilities on the Great Lakes belonging to U.S. Steel include: Mon Valley Works outside of Pittsburgh, Pennsylvania; Gary Works in Gary, Indiana; Midwest Plant in Portage, Indiana; Great Lakes Works just outside of Detroit, Michigan; Lorain Tubular Operations in Lorain, Ohio; Hamilton Works in Hamilton, Ontario; and Lake Erie Works in Nanticoke, Ontario.[49] AK Steel owns a steel mill in Middletown, Ohio.[50] The facility owned by Essar Steel is in Sault St. Marie, Ontario.[51] Severstal owns three mills serviced by the Great Lakes located in Dearborn, Michigan; Warren, Ohio; and Follansbee, West Virginia.[54,55] There is also a facility in Lorain, Ohio owned by Republic Engineered Products.[56]

These integrated steel mills produce several different types of steel products. The major differences between steel bars, strip, plate, and sheet are width and thickness. Sheet steel is thin and flat-rolled. Plate steel is sheet that is wider than eight inches and between a quarter of an inch to over a foot thick. Both plate and sheet steel are produced by further processing slab, the primary type of semi-finished steel. Strip is similar to sheet steel, but often is narrower and of a more uniform thickness.[57] Bars are long pieces of steel rolled from the semi-finished billets. Differing from slabs, billets typically have square width and thickness, whereas slabs vary from being thirty to eighty inches wide and two to ten inches thick.[58] While hot-rolling is the typical method to produce sheet and strip steel, cold-rolling is a method that is also used.[57] Cold-rolled steel is stronger than hot-rolled and is therefore more valuable.[58] Galvanized steel is coated with a layer of zinc.[59] As with all types of coated steel, the zinc acts as an anti-corrosive.[58] Tin mill products are composed of steel with a thin tin layer, used primarily in making cans.[57]

ArcelorMittal's Burns Harbor mill, with about 4,000 employees, produced 1,779 metric kilotons (kt) of hot-rolled steel, 941 metric kt of cold-rolled steel, 358 metric kt of coated-sheet steel, and 442 metric kt of steel plate for a total of 3,520 metric kt in 2009.[60] This same year, ArcelorMittal's plant in Cleveland produced 466 metric kt of hot-rolled steel, 150 metric kt of cold-rolled steel, 142 metric kt of galvanized sheet steel, and 614 metric kt of steel slabs, totaling 1,372 metric kt of steel produced.[61] As of 2009, the facility had between 700 and 850 employees.[62] By comparison, ArcelorMittal's largest American plant in Indiana Harbor had 5,500 employees.[63] In 2009, this plant produced 3,568 metric kt of hot-rolled steel, 1,202 metric kt of cold-rolled steel, 417 metric kt of galvanized steel, and 3,902 metric kt of steel slabs, for a total of 9,143 metric kt.[61] As the national production of steel in the United States in 2009 was 56 million metric tons, ArcelorMittal's Burns Harbor mill was responsible for 6.3 percent of the national output, Cleveland for 1.45 percent, and Indiana Harbor for 16.3 percent.[64] ArcelorMittal's Canadian Dofasco plant had 5,000 employees in 2009 and produced 3,074 metric tons of hot-rolled steel, 2,088 metric kt of cold-rolled steel, 986 metric kt of galvanized steel, and 2,686 kt of steel slabs for a total of about 5, 763,074 metric tons of steel.[65,61] Canada's total steel production was 9,245,310 metric tons, ArcelorMittal's Dofasco mill produced 62.3 percent of Canada's 2009 output.[66]

U.S. Steel's Mon Valley Works just outside of Pittsburgh employs 1,245 people.[67] The Edgar Thomson Plant is the basic steel producer at the Mon Valley Works which employs roughly 643 people.[68,67] Its slab production is the base of the annual steel production of the Mon Valley Works of 2,460 kt.[68,69] In 2009, of about 56 million metric tons of steel produced in the United States, the Mon Valley Works production made up about 4 percent of the national output. In 2009, Gary Works produced 5,379 kt of slabs, sheets, tin mill, and strip mill plate at their facility with about 4,690 employees.[69,67] Gary Works accounted for about 8.7 percent of the national production. At their facility with 2,070 employees, Great Lakes Works produced 473 kt of slabs and sheets in 2009, making up 0.76 percent of the national output.[67,69] For U.S. Steel's Canadian operations in 2009, Hamilton Works, with an employment of about 1,400,[67] produced 564 kt of slabs, sheets, and bars and their Lake Erie Works produced 356 kt of slabs and sheets at a facility with almost 1,100 employees.[69,67] Each of these mills is serviced by a port owned by U.S. Steel except Mon Valley Works.[41]

AK Steel, Essar Steel, Severstal, and Republic Engineered Products own six steel facilities serviced by the Great Lakes between them. AK Steel's mill in Middletown, Ohio produces hot-rolled, cold-rolled, enameled, galvanized, aluminized carbon, and stainless steel.[50] In 2008, Canada's Essar Steel Algoma plant produced 2,121 metric kt of sheet, 594 metric kt of plate, and 17 metric kt of slab, for a total of 2,732 metric kt in that year.[70] Canada's national production in 2008 was 14,845,117 metric tons, meaning that Essar Steel Algoma produced about 18.4 percent of Canada's steel output.[66] Severstal has three plants serviced by the Great Lakes iron ore trade: Severstal Dearborn, Michigan; Severstal Warren, Ohio; and Severstal Wheeling, West Virginia. The Dearborn plant produces hot-rolled, cold-rolled, and galvanized steel[71] while the Warren plant produced hot-rolled and galvanized steel.[72] Essar Steel Algoma and Severstal Dearborn are the only facilities in this group that own their own port.[41]

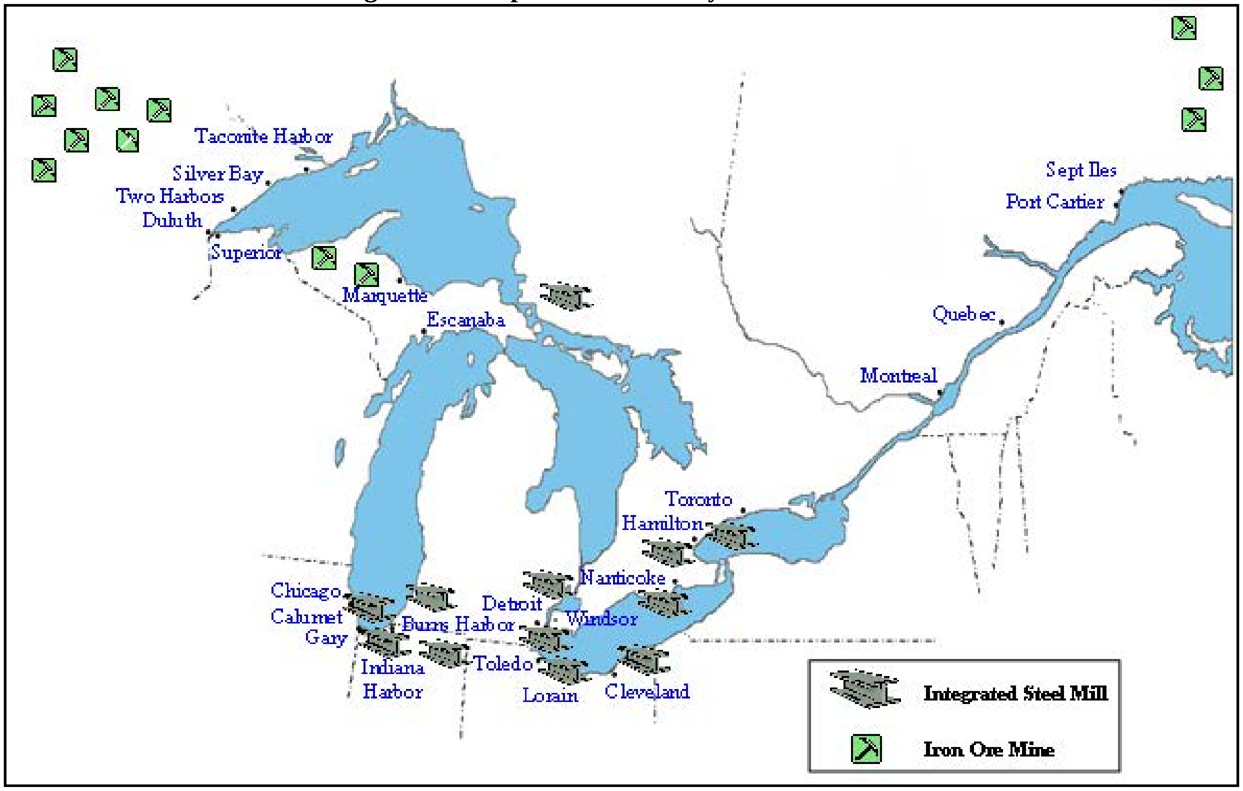
ArcelorMittal's plant at Burns Harbor receives shipments of ore, coal, and limestone by both rail and lake vessel.[73] Besides being serviced by the Burns Harbor port, the plant also receives ore from the Indiana Harbor Belt Railroad and the Gary Railroad Company via Canadian National Rail (CN).[74,75] In Cleveland, ArcelorMittal is located down the Cuyahoga River, past the section navigable by the large lake vessels. To get the ore to the plant, the cargo is often transferred at the Cleveland Bulk Terminal to a smaller ship, able to navigate the river when it gets narrower.[76] ArcelorMittal's Indiana Harbor plant is also serviced by the Indiana Harbor Belt Railroad.[74]

By and large, U.S. Steel's mills are serviced either by ports directly or short line rail lines that are operated by Transtar, a subsidiary of U.S. Steel.[77] For instance, Mon Valley Works is serviced by the Union Railroad Company.[78] In Gary, Indiana, iron ore is received at the west dock. Transtar owns Gary Railway Company, which operates on 63 miles of track, allowing trains to pick up ore shipments at the dock and bring them to the U.S. Steel Gary Works.[79] Similarly to the Gary Railway Company in Gary, Delay Connecting Railroad Company brings iron ore from U.S. Steel's USX dock on the Detroit River to the various facilities in the U.S. Steel Great Lakes Works. It also receives coke shipments from CN and CSX to use in the blast furnaces.[80]

A major source of the iron ore used for steelmaking in the Great Lakes region comes from the Mesabi Range in Minnesota. U.S. Steel, ArcelorMittal, and Essar all have mining operations in the Mesabi Range,[81,82] and therefore have control over how the iron ore gets from the mine to their various mills and production facilities. The Range is serviced by the Duluth, Missabe and Iron Range Railway (DM&IR), which is controlled by CN, which also has tracks that service Chicago, northern Indiana, and the Detroit area.[83] The current state of operations is that the DM&IR brings the iron ore to ports in Duluth and Two Harbors, MN to be shipped to their final destination.[84]

In the winter, Great Lakes navigation is officially out of season from January 15 to March 21. During this time, the Soo Locks, which allow vessels to travel from Lake Superior to the lower Great Lakes, are closed.[85] Because of lock closure, shipments made out of the Duluth, Two Harbors, and Marquette ports cannot make it to the steel mills in the lower Great Lakes region. Instead, iron ore is brought to Escanaba, MI by rail to be shipped to the mills in the lower Great Lakes.[86] This allows the steel mills to continue operating without the need to stockpile large amounts of ore.

Figure 7-6 Map of Steel Industry on Great Lakes



Source: http://outreach.lrh.usace.army.mil/Industries/Iron%20Ore/Iron%20Ore%20GL.htm

7.4.2 Power Generation Industry

Many power plants are located near a body of water, often used as a cooling agent in steam-based electricity generation. As a result of that location, coal is delivered either directly to a power plant or near to it, allowing easy transportation. In the Great Lakes region, DTE and Consumers Energy Company own the big power plants, accounting for about 75% of the electricity generated by power plants serviced by coal-bearing lake vessels. DTE has five plants serviced by the Great Lakes vessel system: Belle River, St. Clair, Harbor Beach, Marysville, and Monroe, all in Michigan. In terms of power generation, Belle River has a capacity of 1,270 MW, St. Clair has a capacity of 1,400 MW, Harbor Beach has a capacity of 103 MW, Marysville has a capacity of 166 MW, and Monroe has a capacity of 3,110 MW.[87] In 2008, the net summer capacity of electricity for the state of Michigan was 30,419 MW: Belle River made up 4.2 % of the state's capacity, St. Clair was 4.6%, Harbor Beach had 0.3%, Marysville accounted for 0.5%, and Monroe 10.2% of Michigan's capacity.[88]

Consumers Energy Company has three power plants on the Great Lakes: the D.E. Karn – J.C. Weadock Complex in Essexville, Michigan;[89] the B.C. Cobb Plant in Muskegon, Michigan;[90] and the J.H. Campbell Complex in Holland, Michigan.[19] The D.E. Karn – J.C. Weadock Complex, with 370 employees has a capacity of 2,101 MW, accounting for 6.9% of Michigan's capacity. However, only four units at the plant are powered by coal, totaling 821 MW or 2.7% of the state's capacity. The other units are powered by natural gas.[89] The B.C. Cobb Plant has a 500 MW capacity, maintaining 1.6% of Michigan's 2008 capacity with 122 employees. This plant has two active coal units and three units powered by natural gas. The two coal units at the B.C. Cobb plant, however, have a capacity of 320 MW, or 1.0% of the state's capacity.[90] The J.H. Campbell Complex, with 310 employees, has a 1,440 MW generating capacity and is responsible for 4.7% of the state's capacity.[19]

NRG Energy has two locations serviced by the Great Lakes, both in the State of New York. They own and operate both the Dunkirk Generating Station in Dunkirk and the Huntley Generating Station in Tonawanda. In 2008, New York had a 38,720 MW capacity of electricity.[88] The Dunkirk plant has 530 MW or 1.4% of the state's capacity and the Huntley plant generates 380 MW, or 1.0% of the state's capacity.[91] WE-Energies also has two locations on the Great Lakes: the Presque Isle Power Plant in Marquette, Michigan[92] which has a generating capacity of 431 MW,[92] or 1.4% of Michigan's capacity, and the Valley Power Plant in Milwaukee, Wisconsin[93] which has a generating capacity of 280 MW,[93] or 1.6% of Wisconsin's capacity. These two companies total 1,621 MW of generating capacity.

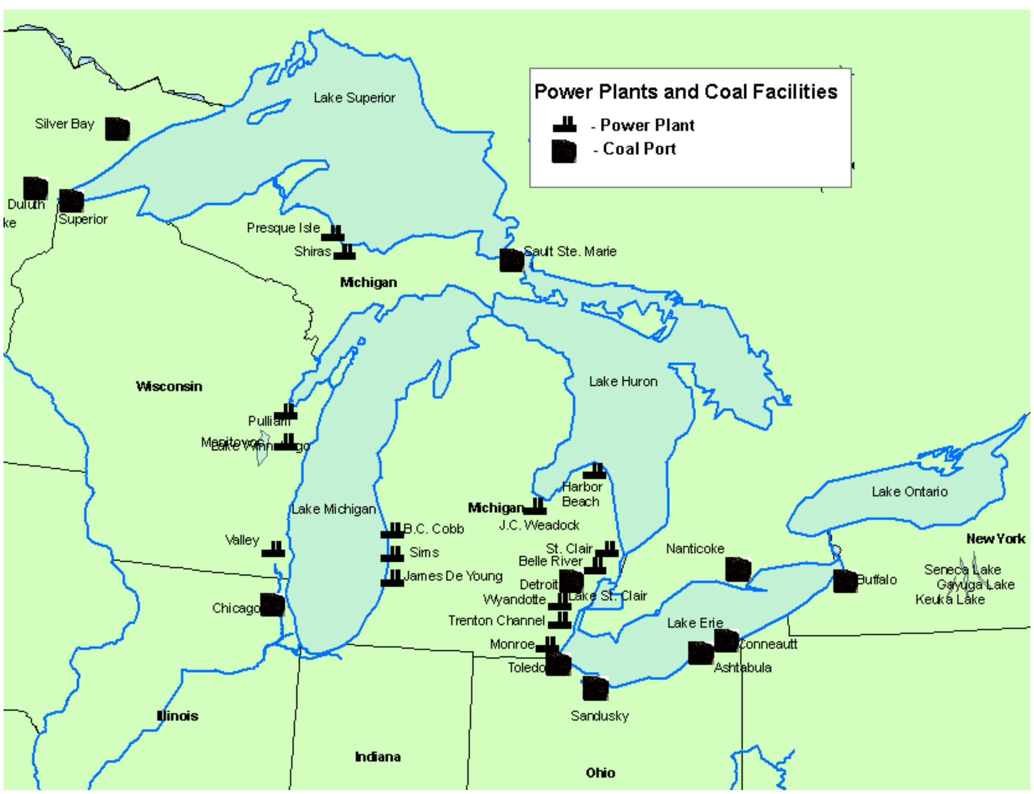
The other coal-fired power plants on the American side of the Great Lakes are smaller operations. Almost all of them are either owned by a municipal government or a local business. Upper Peninsula Power Company operates Escanaba Generating Station, which is owned by the City of Escanaba, Michigan. Its capacity is 26.3 MW,[94] meaning that it contributes 0.09% of the state's electric capacity. T.E.S. Filer City Station is in Filer City, Michigan and has an output of 60 MW,[95] accounting for 0.20% of the state's capacity. The J.B. Sims Generating Station is owned by the Board of Light and Power, Grand Haven, Michigan. It has a capacity of 65 MW[96] and is therefore responsible for 0.21% of the state's electricity capacity. J.P. Pulliam Station in Green Bay, Wisconsin is operated by the Wisconsin Public Service Corp and generates 397 MW,[97] accounting for 2.3% of the annual capacity of Wisconsin. The James De Young Generating Station is owned by the Holland Board of Public Works in Holland, Michigan and is capable of generating 60 MW of electricity,[98] which is roughly 0.20% of the state's capacity. The Manitowoc Public Utilities Power Plant in Manitowoc, Wisconsin has a 79 MW capacity,[99] making up 0.45% of the state's capacity. White Pine Power Plant is a power plant in White Pine, Michigan, outside of Ontonagon. It has a generating capacity of 40 MW[100] which allows it to produce 0.13% of the state's capacity. Minnesota Power's Taconite Harbor Energy Center has a capacity of 200 MW.[101] As Minnesota had a capacity of 14,237 MW of electricity in 2008,[88] the Taconite Harbor Energy Center accounted for about 1.4% of Minnesota's capacity. Also, the Wyandotte Municipal Power Plant in Wyandotte, Michigan has a capacity of 70 MW,[102] 0.23% of the state's capacity. These smaller operations total a capacity of 997.3 MW, less than most of the plants owned by DTE and Consumers Energy Company.

On the Canadian side of the Great Lakes, the two energy companies serviced by Great Lakes transportation industry are New Brunswick Power and Ontario Power Generation. New Brunswick Power's plant in Belledune has a capacity 458 MW.[103] Canada's total electricity capacity in 2007 was 124,720 MW.[104] Using the same principle as the American power plants, the Belledune power plant generates about 0.37% of its nation's annual electricity capacity. Ontario Power Generation has three facilities on the Great Lakes: Lambton Generating Station, Nanticoke Generating Station, and Thunder Bay Generating Station. Thunder Bay Generating Station has 145 employees and can produce 306 MW of electricity,[105] which translates to 0.25% of Canada's annual capacity. The other two stations in Lambton and Nanticoke are each shutting down two generating units in 2010 in an effort to reduce CO_2 emissions and save money. Ontario Power Generation projects a lower demand for electricity and maintains that closing the units will not affect their energy reliability or adequacy. The unit closures will result in a reduction of about 1000 MW generated at each station.[106] Prior to this switch, Lambton's generating capacity was 1,920 MW[107] and Nanticoke's was 3,640 MW.[108] As a result, their new capacities will be about 920 MW (0.7%) and 2,640 MW (2.1%), respectively.

7.4.3 Transportation of Coal to the Power Generation Industry on the Great Lakes

The transportation of coal is quite active on the Great Lakes. Coal is brought to the power plants from two main regions: the Powder River Basin and the Northern Appalachian region. Markets in southern Michigan could be reached by train without having to take a longer trip to get around the Great Lakes. However, markets in Wisconsin, Minnesota, northern Michigan, and Canada would be more difficult to reach with solely rail due to required navigation around the lakes. However, due to emissions regulations, much of the coal used by power plants is at least in some part from the west. Low-sulfur western coal, coming from the Powder River Basin, has seen increased use in recent years.[109] Wisconsin, being the largest shipper of coal in the Great Lakes, ships western coal out of the Superior Midwest Energy Terminal. DTE has an ownership interest in the terminal, which serves DTE and Consumers Energy Company, as well as other power plants. As mentioned previously, those two companies generate about 75% of the electricity generated by the power plants serviced by the Great Lakes. Figure 7-7 maps the major coal port facilities and locations of shore-side power plants in the Great Lakes area.

Figure 7-7 Major Great Lakes Area Coal Port Facilities and U.S. Waterside Power Plants



Source: http://outreach.lrh.usace.army.mil/Industries/Coal/graphics/Great%20Lakes%20Coal%20Ports.bmp

According to the U.S. Army Corps of Engineers, of the 36,471,098 tons of coal transported over the Great Lakes in 2008, 13,960,329 tons of it went to Canada.[110] That's about 37% of the coal transported on the Great Lakes. In an attempt to reduce harmful emissions, Canada is phasing out 33 coal-fired power plants that are considered at the end of their economic lives by 2025, planning to replace them with plants the run on natural gas.[111] As Canada uses less coal, a large piece of the Great Lakes market for coal transportation will decrease. Depending on which plants are closed, coal traffic on the Great Lakes could drop by up to one third.

The Maumee unloads coal at the Menominee Paper Company in Menominee, MI. Source: Taken by and used with permission from Dick Lund, available here: http://www.dlund.20m.com/DMen2008.html

Wisconsin is the state that ships the largest amount of coal on the Great Lakes. This coal comes largely from the Powder River Basin,[110] located in Wyoming and Montana.[112] The sole coal loading port in Wisconsin is the Superior Midwest Energy Terminal,[41] an operation commissioned by DTE to facilitate the transport of low-sulfur coal from the Powder River Basin to the lower Great Lakes.[113] Some of the Superior Midwest Energy Terminal customers include: Consumers Energy Company, DTE, Marquette Board of Light and Power, Minnesota Power, New Brunswick Power, Ontario Power Generation, and WE-Energies.[114]

Of the above power plants, there are several that don't own their own ports. Upper Peninsula Power Company, J.H. Campbell Complex of Consumers Energy Company, J. P. Pulliam Generating Station, Manitowoc Public Utilities Power Plant, and White Pine Power Plant all receive their coal from a dock that they don't own.[41] Consumers Energy Company's D.E. Karn - J.C. Weadock Complex uses about three million tons of coal every year. The coal they use is a blend of eastern coal from West Virginia, Pennsylvania, and Kentucky, and low-sulfur western coal from Wyoming and Montana.[89] Their B.C. Cobb Plant, burning a similar blend, goes through about a million tons of coal annually.[90] The J.H. Campbell Complex, also owned by Consumers Energy Company, has a unit that uses only western coal. The other two units burn a mix of coal from the east and west. In all, the complex burns about five million tons of coal every year.[19] Grand Haven's J.B. Sims Generating Station's source of coal is delivered in twelve shipments by lake vessels every shipping season. The plant uses about 550 tons of coal every day.[96] The J.P. Pulliam Generating Station in Green Bay uses 1.5 million tons of pure western coal every year.[115] Coal is brought to the power plant in Manitowoc usually by lake vessel or rail, although truck is occasionally the mode of transport.[99] WE-Energies has a number of plants including the Presque Isle Power Plant which uses 1.6 million tons of western coal annually, delivered by lake[92], and the Valley Power Plant which uses 2,200 tons of coal every day, also delivered on the lake.[93]

During the winter, additional power is sometimes needed in the Great Lakes region. The power plants that receive shipments of coal can't discontinue running because the lakes freeze. To facilitate the transportation of coal and other commodities on the Great Lakes, the U.S. Coast Guard has several ice breakers they use during the winter. These ice breakers allow the power plants to continue to receive the coal they need to keep running.[116] Of course, plants also stockpile coal for the winter. For example, DTE's St. Clair Power Plant maintains a stockpile of two million tons of coal for the winter.[117] With a combination of increasing storage and continued shipments, power plants are able to continue their production during the winter.

7.4.4 Construction Industry

The construction industry is unique in many ways. It is seasonal, with most construction taking place in the summer months, usually beginning in the spring and ending in the fall. Also, construction can take place wherever there are roads, making numerous cities and townships potential locations. This is a reason why there are so many ports on the Great Lakes that service construction aggregate. Demand is everywhere for construction companies, so there are numerous companies in the region. Delivering materials closest to the project is ideal, minimizing transportation costs. The large number of ports allow for drop-off close to a particular construction project. Construction's seasonal nature also means there isn't much demand for it during the winter months when the lakes are closed. As no construction aggregate is needed, no alternative transportation is required for the Great Lakes.

In general, limestone is a difficult material to transport. Due to its weight, transportation can be costly when using most forms of freight transportation. When moving large amounts of heavy stones such as limestone, it is usually most economic to transport them to a facility close to the quarry or to use a form of transportation capable of carrying extremely large loads, such as lake vessels.[118] In Michigan, the largest shipper of limestone and other aggregate in the Great Lakes region,[29] there are three active quarries in a region where there used to be over thirty. The area, near the Great Lake coast, includes a quarry at Port Calcite and Presque Isle, the largest limestone quarry in the world.[118] As a result of the costliness of land transportation and location of the quarries, shipping limestone with lake vessels is a commonly preferred method for transporting a widely-used commodity out of such a concentrated area.

The limestone quarries in the northern lower peninsula of Michigan serve as the source of most of the Great Lakes region's limestone. The concentration of these quarries, all near shipping ports, means an effective mode of transportation is important, especially since limestone is such a widely-used commodity. It is also an especially heavy cargo and must be transported in smaller volumes. As a result, a large cargo capacity is ideal in order to carry as much as possible in a single load. Lake vessels can widely distribute such a heavy, commonly used commodity from quarries that are near ports.

The Great Lakes shipping industry services almost forty companies involved in construction or other stone aggregate services. The main companies that drive the industry are: Carmeuse, Essroc, Holcim, Lafarge, Levy, Southwestern Sales Corporation, and St. Marys Cement. Carmeuse has ten locations, focused on limestone and other forms of lime: Buffington, Indiana; Burns Harbor, Indiana; Calcite, Michigan; Chicago, Illinois; Cleveland, Ohio; Detroit, Michigan; Erie, Pennsylvania; Fairport Harbor, Ohio; Port Dolomite, Michigan; and Port Inland, Michigan.[119] Essroc's cement and concrete facilities[120] include Cleveland, Ohio; Essexville, Michigan; Oswego, New York; Picton, Ontario; Rochester, New York; Toronto, Ontario; and Windsor, Ontario.[41] Holcim has a several different types of facilities on the Great Lakes. In Canada, Holcim has an aggregate production plant in Colborne and a concrete plant in Mississauga.[121] In the U.S., Holcim has cement plants in Buffalo, New York and Duluth, Minnesota,[122] and an aggregate facility in Dundee, Michigan.[123] Lafarge, the world leader in cement sales,[124] has nearly thirty terminals on the Great Lakes.[41] Lafarge's largest cement operation in North America is located in Alpena, Michigan. The facility has over 250 employees and produces 2.7 million tons of cement annually.[125] As annual cement production in the United States is just over 100 million tons,[32] this facility accounts for about 2.5% of the national output. There's also a cement plant in Bath, Ontario that has over 110 employees and produces about 3,300 metric tons of cement every day.[126] They also operate a plant in South Chicago that grinds slag, a byproduct of the steelmaking process, into a cement-like substance.[127] Levy has five locations on the Great Lakes, focusing on slag, aggregate, asphalt, and other construction materials: Burns Harbor, Indiana; Detroit, Michigan; Gary, Indiana; Indiana Harbor, Indiana; and Saginaw, Michigan.[128] Southwestern Sales Corporation has docks in five locations in Ontario: Kingsville, Sarnia, Sombra, Tecumseh, and Windsor. They provide limestone-based construction materials to Essex, Lambton, and Chatham-Kent.[129] St. Marys Cement has many terminal locations on the Great Lakes, including: Buffalo, New York; Chicago, Illinois; Cleveland, Ohio; Ferrysburg, Michigan; Green Bay, Wisconsin; Manitowoc, Wisconsin; Milwaukee, Wisconsin; Toledo, Ohio; and Waukegan, Illinois. Its plants on the Great Lakes are in Algoma, Ontario; Bowmanville, Ontario; Charlevoix, Michigan; Detroit, Michigan; Milwaukee, Wisconsin, and Nanticoke, Ontario.[130] Most docks servicing the above facilities are owned by St. Mary's Cement, except for the following plants: Lafarge in Thunder Bay, Ontario; St. Marys Cement in Chicago; Carmeuse in Cleveland, Erie, and Port Dolomite; Essroc in Cleveland; Levy in Gary; Holcim in Mississauga; and Southwestern Sales Corp. in Sombra.[41]

7.4.5 Grain/Agriculture Industry

The Great Lakes are a valuable mode of transportation for the grain industry because of the large portion of exports by the grain industry. In 2008, almost 70% of all grain transported over the Great Lakes was headed for non-U.S. destinations, with about one third of all grain being sent overseas.[37] The Great Lakes and St. Lawrence Seaway provide a convenient avenue for this grain to be taken overseas. Much of the grain is brought from U.S. and Canadian farms by rail to Superior, Wisconsin; Duluth, Minnesota; and Thunder Bay, Ontario for transportation over the Great Lakes. Over 70% of the grain transported over the Great Lakes was shipped from Wisconsin, Minnesota, or Canada.[37]

Domestic grain transport on the Great Lakes is delivered in a different fashion than the grain exported overseas, and is delivered in small amounts, with one vessel often making several smaller stops on the way to a larger unloading point, sometimes a transshipment point for grain being sent overseas.[131] A combination of the large proportion of grain being exported and the practice of dropping off smaller cargoes on the way to a transshipment point leads to a continuation of current practices. Grain cannot be shipped overseas by rail or truck, thus water-based transport remains the most viable option. Lake vessels bringing grain east for transshipment make their trips more efficient by making stops to drop off cargo at grain elevators on the way. As transshipment continues, it makes sense for the domestic cargo deliveries to continue as well.

7.5 Great Lakes Ships

7.5.1 General Characteristics

According to Greenwood's 2010 Guide to Great Lakes Shipping (GWG) there are at least 57 U.S.-flagged freighters, tug-barge combinations, and ferries and 98 Canadian-flagged freighters, tug-barge combinations, and ferries operating on the Great Lakes.[132] These vessels range from small tugboats to ore carriers over 1,000 feet long, and are powered by a wide range of engines ranging from low horse power/high speed Category 1 marine diesel engines to high horsepower/low speed Category 3 marine diesel engines. These ships are flagged in the United States, Canada, and other countries. In addition, there are hundreds of small vessels, ranging from fishing and recreational vessels to dredgers and harborcraft.

One important characteristic of Great Lakes vessels is that they tend to be older than vessels that operate on the oceans. This is because the fresh water of the Great Lakes is not as corrosive as ocean salt water. Several tugboats built in the late 1880s are still in operation on the Great Lakes, although they have been repowered with newer engines. Figure 7-8 shows the oldest Great Lakes freighter in operation, the St. Mary's Challenger, built in 1906, being assisted to port by one of the oldest operating tugboats, the John M. Selvick, built in 1898 and owned by Calumet River Fleeting.

Figure 7-8 The St. Mary's Challenger Arrives at Sturgeon Bay and is Assisted to Port by the John M. Selvick

Source: Photo taken by and used with permission from Blake D. Kishler, taken March 27, 2009 accessed at: www.boatnerd.com

Ships in the Great Lakes fleet are also distinguished by whether they are "salties" or "captive" vessels. Some ships operating on the Great Lakes can navigate the St. Lawrence Seaway and on to the Atlantic Ocean and throughout the world. Vessels that visit the Great Lakes that can also operate on the ocean are called "salties;" these ships typically use residual fuel and will be affected by the application of the ECA fuel requirements to the Great Lakes. Other ships can operate solely on the Great Lakes, and are called "captive" vessels. They are captive due to size restrictions based on their length, width, and draft (i.e. the depth a vessel reaches in the water) that can prevent them from passing through locks in the Great Lakes. For example, for a ship to be able to pass through the St. Lawrence Seaway, it must be no more than 740 feet long, 78 feet wide, while the draft can change yearly depending on water levels. In 2010, for example, the canal opened on March 25, 2010 with a draft of 26 feet 3 inches.[133] The Poe lock in Sault Ste. Marie, is 1,200 feet long and can handle vessels as long as the Paul R. Tregurtha which is 1013.5 feet long, currently the longest vessel operating on the Great Lakes, and therefore titled the "Queen of the Lakes" (see Figure 7-9). Vessels that are built to travel through the Poe lock are considered to be part of the 'captured fleet' of boats on the Great Lakes as they cannot travel through the St. Lawrence Seaway and into the Atlantic Ocean. All foreign vessels that visit the Great Lakes, must be smaller than these thousand foot vessels, known as '1,000-footers' in order to travel through the St. Lawrence Seaway and into the Great Lakes. Of the twelve U.S. flagged C3 vessels, all are captured vessels except for three, the Maumee, the Tug Presque Isle, and the Tug Victory.

Figure 7-9 The "Queen of the Lakes" the Paul R. Tregurtha Heading Downbound at Mission Point

Source: Photograph taken by and used with permission from Dick Lund, available here: http://dlund.20m.com/rbl2.html

7.5.2 Types of Vessels that Operate on the Great Lakes

7.5.2.1 Bulk Freighters

The C3 vessels discussed in this report are bulk freighters, or "lakers." These vessels can carry cargoes such as iron ore, coal, stone, and grain. These vessels are either "self-unloaders" or straight-deck vessels. Straight-deck vessels, such as the Edward L. Ryerson shown below in Figure 7-10, are vessels whose cargo must be removed by cranes or other methods which can take numerous hours to unload. The Edward L. Ryerson is one of only two remaining straight-deck U.S. flagged vessels, and the only one who has operated recently. The other straight decker is the John Sherwin, she is currently out of service pending possible repowering while the Ryerson still uses her original steam engine. The Edward L. Ryerson is the only vessel built in her configuration with a rounded bow, streamlined stainless steel stack, and rounded tapered stern and as such is adored by boat watching fans throughout the Great Lakes and beyond. While the Edward L. Ryerson has not sailed since 2008, she is still considered part of the fleet having received her last 5-year survey in 2006.[A] The straight-deck vessel has not entirely disappeared from Canadian ships and there are still a number of Canadian vessels that are not self-unloaders.

[A] George Wharton, "Great Lakes Fleet Page Vessel Feature – Edward L. Ryerson", accessed at www.boatnerd.com

Figure 7-10 The Edward L. Ryerson on the St. Clair River

Source: Roger LeLievre, on the St. Clair River, accessed at www.boatnerd.com

Most Great Lakes freighters were converted to self-unloaders as early as 1952 as the supply of higher grade iron ore became depleted and steel production turned to the use of taconite pellets. The conversion of straight deckers to self-unloaders continued throughout the early 1980's with conveyor systems that can unload cargo at even an unimproved dock without the assistance of shore-side equipment. Self-unloading systems can transport most free-flowing dry-bulk commodities including: iron ore, coal, limestone, sand, gypsum and grain at rates of up to 10,000 tons per hour.[B] These ships can typically carry up to 70,000 tons of cargo, and have a pivoting boom of up to 280 feet to discharge their cargo to its final destination. Ten of the twelve C3 Lakers are self-unloading (the remaining two vessels are tugboats.)

Ten of the twelve C3 vessels are bulk carriers of two distinct styles based on the location of the pilothouse. Older vessels, such as the Edward L. Ryerson were built with the pilothouse in the front of the ship for better visibility; later ships were built with the pilothouse on the rear to reduce costs and complexity. The difference between the two vessel types can affect the propulsion and drive system designs of these vessels. The use of either a forward or rear pilothouse can affect on the cost to repower and modify a vessel, Figure 7-11 demonstrates the difference between pilothouse locations. The St. Mary's Challenger was built with a forward pilothouse (she is the smaller vessel on the right in the photograph) and the American Century was built with a rearward pilothouse.

[B] See http://www.americansteamship.com/self-unloading-technology.php

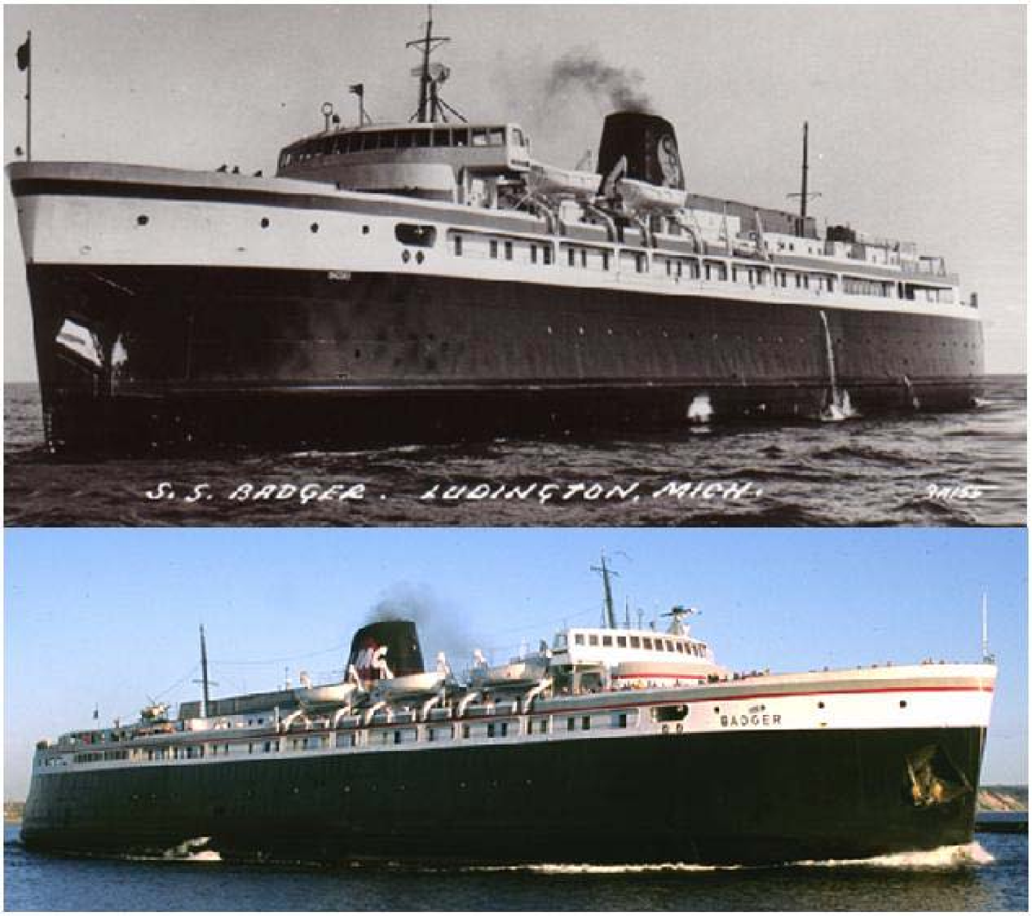
Figure 7-11 The St. Mary's Challenger (Built with a Forward Pilothouse and Pictured on the Right) Spends the Winter in Sturgeon Bay next to the American Century (Equipped with a Rear Pilothouse)

Source: Photograph taken by and used with permission from Dick Lund, available here: http://www.dlund.20m.com/aa_slideshows/SB_040909/sb040909n.html

7.5.2.2 Ferries

Not all freight moving on the Great Lakes consists of raw materials, grain, or finished steel products. While the days of passenger vessels taking travelers on day trips throughout the Great Lakes came to an end in the middle of the twentieth century, there are still passenger and car ferries moving people and freight across the Great Lakes or to various islands. According to the GWG, there are 47 car ferries operating on the Great Lakes, of these, 31 are U.S. flagged, while 16 are Canadian. In general, these ferries range from 13 to 6,991 Gross Registered Tonnage (GRT) and can carry anywhere from 25 to 600 passengers and up to 180 vehicles. The S.S. Badger is the largest U.S. flagged ferry at 4,244 GRT and she is one of two remaining U.S. vessels powered by a Skinner Unaflow four-cylinder steam engine; she was built in 1952 and looks much the same today, as shown in Figure 7-12.

Figure 7-12 The S.S. Badger – Yesterday and Today



Source: www.ssbadger.com/home.aspx

The S.S. Badger is designated as a mechanical engineering landmark by the American Society of Mechanical Engineers, and burns coal to power her steam engines.[134] The S.S. Badger can carry 600 passengers, the most of any ferry on the Great Lakes, as well as 180 automobiles, or tour buses, RVs, motorcycles, and commercial trucks; she also has the most vehicle capacity of any ferry on the Great Lakes. She travels between Ludington, MI and Manitowoc, WI nearly 500 times during her short-season that begins at the end of May and ends the first week of October. Recently, the Badger has assisted in the cause of renewable energy by carrying wind turbine parts across Lake Michigan as they make their way to Altoona, PA to be installed in a new windfarm and become the tallest windmills in the U.S.[135] The smallest ferry working on the Great Lakes, at just 13 GRT, is the Canadian Howe Islander; she can carry 6 cars and up to 25 passengers. With the exception of the Badger, the rest of the ferries working on the Great Lakes are powered by C1 or C2 engines. There are no C3 powered car or passenger ferries working on the Great Lakes.

7.5.2.3 Other Vessels

Other vessels that work on the Great Lakes assist freighters with navigation including: ice breakers, harbor tugs, buoy tenders, and crane barges.

Ice Breakers The U.S. Coast Guard also provides services to the fleet of Great Lakes vessels to increase the length of their work season through the use of ice-breakers. Since, 1944 the icebreaker Mackinaw (WAGB 83) was a familiar winter sight on the Great Lakes. She could break up to 32 inches of ice continuously at 3 knots and break ice up to 11 feet thick by backing and ramming; she was replaced in 2006.[136] The new Mackinaw (WLBB-30) can break up to 30 inches of ice continuously or up to 10 feet of ice. The new Mackinaw also features a 20 ton crane that can assist with the placement and removal of buoys that aid in navigation. She is equipped with two ABB Azipods with electric propulsion drive systems where the propulsion motor is installed inside a pod and coupled directly to a very short propeller shaft to increase maneuverability; the new Mackinaw is powered by two C2 Caterpillar 3612 engines.[137,138]

Tugs and Barges There are a large number of tugboats and barges operating on the Great Lakes, the Presque Isle shown in 7-13 is an example of a C3 tug-barge combination. According to GWG, there are 178 U.S. and 122 Canadian tow and tugboats performing towing and salvage on the Great Lakes. These vessels can range in GRT from 10 to 1,361 tons and are powered by engines ranging in horsepower from 120 hp to 10,200 hp. Of the U.S. flagged tugboats, two are powered by C3 engines, while the remainder are powered by C1 or C2 engines and are not covered here in this report. These vessels can be found pushing or towing one of the 41 U.S. or over 100 Canadian barges in addition to assisting large vessels maneuver into or out of port.

7-13 The Tug-Barge Combination the Presque Isle Clears the Blue Water Bridge in Port Huron, MI

Source: Photo taken by Barant Downs, May 7, 2005.

Barges can carry bulk cargo, be equipped with cranes or excavators, be self-unloaders, floating dry-docks, or serve a number of other purposes. The U.S. barge fleet includes barges that are up to 460 feet long and in some cases, are made out of the former freighters. For example, the barge Lewis J. Kuber began life as the S.S Sparrow Point, a 626 foot steamship launched in 1952, later converted to a self-unloader; renamed the Buckeye, she hauled her last load of coal in December of 2004.[C] In 2006, her rear accommodations, engine room, forward accommodations and wheelhouse were removed and she emerged as a notched, articulated barge, the Lewis J. Kuber, shown whole as the Buckeye, and as the resulting barge being pushed by the tug Olive Moore in Figure 7-14.

Figure 7-14 Example of a Former Freighter Turned Barge: The Lewis J. Kuber Pushed by the Olive Moore

Source: John Meyland, on the St. Clair River, accessed at www.boatnerd.com   Source: Todd Shorkey, on the Saginaw River, Sept. 21, 2006 accessed at www.boatnerd.com

Dredgers

As all Federal harbors on the Great Lakes are located at the mouth of a river or along a coastline using natural or dredged navigation channels, lake and river currents transport sand and silt that can be deposited into the navigation channels making them less deep.[139] The U.S. Army Corps of Engineers is responsible for the construction, maintenance, and operation of Federal river and harbor projects. The Corps of Engineers has regulatory authority for work on structures in navigable waterways under Section 10 of the Rivers and Harbors Acts of 1899 and regulatory authority over the discharge of dredged or fill material into "waters of the United States" a term, which includes wetlands and other valuable aquatic areas.[140] The U.S. Army Corps of Engineers operates crane barges, derrick barges, tugs, and tenders to help maintain waterways; these vessels are all C1 and C2 vessels.

Recreational and Fishing Vessels

While commercial fishing has diminished on the Great Lakes over the past few decades, sport fishing and recreational boating has increased. Nearly five million American and Canadian anglers fish on the Great Lakes each year. The commercial and sport fishing industry on the Great Lakes is collectively valued at more than $4 billion annually and is a blend of native and introduced species.[141] In 2008, the Army Corps of Engineers reported that there were 911,000 recreational boaters on the Great Lakes.[142] Most fishing boats and recreational boats are less

[C] KK Integrated Logistics "Lewis J. Kuber/Olive Moore" accessed at: http://www.kkil.net/lkuber.html than 100 feet long and are powered by Category 1, Category 2 or gasoline engines and are not covered in this report.

7.5.3 U.S. Category 3 Vessels

This section provides information for only those vessels that are affected by the application of the ECA fuel sulfur requirements to the Great Lakes: vessels with Category 3 main propulsion engines. While other vessels may share the same characteristics as the affected Category 3 vessels, they are not included in this report because they are not affected by the Category 3 rule. For example, some bulk carriers may be propelled by smaller Category 2 marine diesel engines. While these may appear to be identical to other bulk carriers that have Category 3 engines, the Category 2 vessels are already required to use low-sulfur fuel (the marine distillate fuel sulfur limit is currently 500 ppm; the phase-in to 15 ppm fuel will be completed in 2014). Similarly, while steamships are an important part of the Great Lakes fleet, they are not included in this report because they are excluded from the ECA fuel sulfur requirements. The St. Mary's Challenger, owned by Port City Tug, hauls cement for the LaFarge Group and is an example of one of the remaining steamships still operating on the Great Lakes. She is one of eight steamships in the Canadian fleet. The U.S. has 13 steamships operating on the Great Lakes.[143,144,D] The twelve U.S. Category 3 ships that operate on the Great Lakes are listed in Table 7-13.

Table 7-13 Twelve Category 3 Vessels Discussed in this Industry Characterization

SHIP NAME	OWNER
American Spirit	American Steamship Company
Hon. James L. Oberstar	Interlake Steamship Company
Edgar B. Speer	Great Lakes Fleet, Inc.
Edwin H. Gott	Great Lakes Fleet, Inc.
James R. Barker	Interlake Steamship Company
Lee A. Tregurtha	Lakes Shipping Company
Maumee	Grand River Navigation
Mesabi Miner	Interlake Steamship Company
Paul R. Tregurtha	Interlake Steamship Company
Presque Isle	Great Lakes Fleet, Inc.
Roger Blough	Great Lakes Fleet, Inc.
Victory	KK Integrated Logistics LLC

This fleet of ships is somewhat different than the fleet described in the report contained in Appendix 2C to Chapter 2 of this report, prepared by ICF and EERA. ICF/EERA reports that there are 12 Category 3 (C3) vessels, 21 Category 2 (C2) vessels, and 15 steamships while the EPA reports that there are 32 C2 vessels and 13 steamships in the U.S. fleet. The fleet numbers presented here are used only in the industry characterization and were not used in Chapter 2 which is route based.

The fleet data is taken from the 2010 Greenwood's Guide and was cross-checked by the EPA with the Lloyd's Sea-web database and shipping company websites wherever possible.[145]

[D] The total of thirteen steamships includes twelve diesel-powered steamships and one coal-fired steamship car ferry.

Further, the EPA did not base the distinction between engine categories on Gross Registered Tons (GRT) or any other similar metric, rather, we checked the bore and stroke of every engine model currently installed in the ships listed in the Greenwood's Guide to determine the category associated with each vessel's main propulsion engine(s). With regard to steamships, the EPA relied on the number of vessels supplied by the Lake Carriers' Association comments submitted in 2009 in response to the C3 Notice of Proposed Rulemaking.[146] While there are other steamships listed in the Greenwood's Guide, some of these do not operate under their own propulsion anymore and are in long-term layup or are used for other purposes. For example, the J.B. Ford owned by Inland Lakes Management is used as a cement silo for excess capacity; we did not include vessels used for storage or in lay-up in our count.

The fleet of twelve U.S.-flagged C3 vessels that ply the Great Lakes is diverse in terms of age, size, and engine power and includes ten self-unloading bulk freighters as well as two tugboats; all twelve vessels are operated on residual fuel. Based on moving cargoes of 70,000 net tons, these vessels can reduce both rail and truck traffic by hauling in one trip, cargoes equivalent to 2,800 trucks, or 700 railcars which would combine to form a train stretching nearly 7 miles.[147] The average age of these twelve vessels is just over 41 years old with no vessels being built after 1981. The oldest vessel is the Maumee, operated by the Grand River Navigation Company. She was launched in 1929 and was initially a steam powered vessel, but was repowered with a Nordberg diesel engine in 1964; she has the lowest installed power of the twelve C3 vessels at just over 2,400 kW. The youngest laker is the Paul R. Tregurtha, she was built in 1981 in Lorain, OH and can carry 68,000 gross tons of taconite pellets, or 71,000 net tons of coal and unloads her cargo with a 260 foot boom in about eight hours; she is owned by the Interlake Steamship Company.[148] The Paul R. Tregurtha was repowered in 2010 with two medium-speed 6-cylinder MAK model 6M43C diesel engines producing approximately 12,000 kW.[149]

The average main engine power of the U.S. C3 fleet is approximately 10,000 kW ranging from the smallest installed power of the Maumee at just over 2,400 kW, to the largest and most powerful U.S.-flagged vessel working on the Great Lakes, the Edwin H. Gott, with just over 14,500 kW. The Edwin H. Gott is owned by Great Lakes Fleet Inc. and was launched in 1978 and carried taconite exclusively from 1979 -1995; she has the largest ore capacity of the C3 fleet, at 74,100 gross tons and has the longest unloading boom at 280 feet.[150]

7-15 The Edwin H. Gott Travels Through the Poe Lock on Engineer's Day in Sault Ste. Marie, MI in June of 2010

Source: Photo taken by and used with permission from Dick Lund, available at: http://www.dlund.20m.com/rbl2.html#Eng

The Edwin Gott is powered by the only Enterprise engines in the C3 Great Lakes fleet; Enterprise was an engine manufacturer that dated back to the late 1800's and was sold to DeLaval in the 1960's. Production of Enterprise diesel engines appears to have stopped in the late 1980's although these engines are still supported by Cameron Compression Systems which owns and operates the Enterprise OEM aftermarket business.[151,152] The Edwin H. Gott is also the only 1,000-footer that was not built by the American Shipbuilding Company in Ohio, rather she was built by Bay Shipbuilding of Sturgeon Bay, WI; they are still in business, but are now a part of the Fincantieri group, headquartered in Italy. The tug-barge Presque Isle, also owned by Great Lakes Fleet Inc. is the only C3 vessel powered by two Mirrlees Blackstone diesel engines producing over 11,000 kW. The Mirrlees Blackstone Company was formed in 1969, was taken over by MAN, and is no longer producing engines. MAN, however, still does provide engine overhaul, refurbishment, and OEM parts for Mirrlees Blackstone engines.[153,154] Table 6-1 lists the propulsion engine manufacturer for each of the twelve C3 Great Lakes vessels.

The average GRT of the twelve C3 vessels is nearly 25,000 tons compared to a less than 16,000 GRT average size for all 55 U.S. flagged freighters and large tugs working on the Great Lakes. The largest vessel in terms of GRT is the Paul R. Tregurtha, while the smallest is the tug Victory. The Victory (see Figure 7-16) with 947 GRT was launched in 1981 for Texaco Marine Services and was purchased by KK Integrated Shipping in 2006 and paired with the barge James L. Kuber, which was made into an articulated barge from the steamship Reserve (launched in 1953); the barge was completed in 2008.[155] The Victory is powered by 2 Krupp-MAK diesel engines that produce nearly 6,000 kW.

Figure 7-16 The Tug Victory - One of Two Category 3 Powered Tugs

Source: Photo taken by and used with permission from Dick Lund April 10, 2008, available here: http://www.dlund.20m.com/index.html

Due to the longevity of vessels working on fresh-water, the hull can outlast the original power-plant and a vessel may be repowered. Of the 57 large U.S.-flagged vessels on the Great Lakes, eight have been repowered since 2000; three of these were repowers to Category 3 vessels. For example, in 2006, the Lee A. Tregurtha, owned by the Lakes Shipping Co. Inc., was repowered with two Rolls Royce Bergen medium-speed diesel engines producing over 6,000 kW. The Lee A. Tregurtha, shown in Figure 7-17, has a long and distinguished career that began with her construction as a World War II tanker in 1942. She served as a tanker in the Atlantic and Pacific oceans including during the invasion of France. She was awarded six campaign medals and two battle stars for her service that are now painted on her pilot house as colored ribbons (see Figure 7-17).

In addition to being repowered, a laker's longevity is increased by the modifications they receive over the years to increase their capabilities, and no finer example of this exists than with the Lee A. Tregurtha.[156] After the war, she was decommissioned and sat idle until the winter of 1959. She was then substantially modified for work on the Great Lakes and changes were made to her structure that include: a 510 foot mid-body cargo section was added and the hull was widened by 7 feet and deepened by 2 feet in 1960, her original midship pilot house and living quarters were moved forward, she received a bow-thruster in 1966, was lengthened another 96 feet in 1976, she was converted to a self-unloader in 1978, received a stern thruster in 1982, and her original steam plant was replaced with a modern diesel plant and she received a controllable pitch propeller system in 2006.

Figure 7-17 The Lee Tregurtha: As She Looks Today, as a World War II Tanker, and Her Campaign Medals

a

b

c

a Source: www.interlake-steamship.com

b Source: U.S. Navy, accessed at: http://www.navsource.org/archives/09/19/19068.htm

c Source: Chris Winters, The Tregurtha's campaign ribbons. Accessed at www.boatnerd.com

The Hon. James L. Oberstar (shown in Figure 7-5) was also repowered when her original steam plant was removed and replaced with two Rolls Royce Bergen diesels engine in 2009 producing approximately 6,300 kW; she is also the fastest C3 laker with a service speed of 15.5 knots. The Hon. James L. Oberstar was built in 1959 by the American Shipbuilding Company and was then one of the longest vessels on the lakes at 710 feet. She also went through numerous changes including being lengthened 96 feet in 1972 and converted into a self-unloader in 1981; she can discharge her 31,000 gross tons of cargo at a rate of 6,000 tons per hour.[157] Table 6-2 shows the characteristics of all twelve U.S.-flagged C3 vessels.

Table 7-14 Characteristics of the U.S.-Flagged Category 3 Powered Fleet

SHIP NAME	GRT	BUILT	SHIP TYPE	POWER (KW)	OVERALL LENGTH	YEAR REPOWERED	ORE CAPACITY (GROSS TONS)
American Spirit	34,600	1978	Self-Unloader	11,900	1004'0"		62,400
Hon. James L. Oberstar	16,300	1959	Self-Unloader	6,300	806'0"	2009	31,000
Edgar B. Speer	34,600	1980	Self-Unloader	14,400	1004'0"		73,700
Edwin H. Gott	36,000	1978	Self-Unloader	14,500	1004'0"		74,100
James R. Barker	34,700	1976	Self-Unloader	11,900	1004'0"		63,300
Lee A. Tregurtha	14,700	1942	Self-Unloader	6,000	826'0"	2006	29,300
Maumee	8,200	1929	Self-Unloader	2,400	604'9"	1964	12,650
Mesabi Miner	34,700	1977	Self-Unloader	11,900	1004'0"		63,300
Paul R. Tregurtha	36,400	1981	Self-Unloader	12,000	1013'6"	2010	68,000
Presque Isle	22,600	1973	Tugboat	11,200	1000'0"		57,500
Roger Blough	22,000	1972	Self-Unloader	11,900	858"		43,900
Victory	950	1981	Tugboat	5,900	140'0"		NA

Some vessels, such as the American Spirit, either came equipped with or were later modified to include bow thrusters that improve maneuverability and reduce docking times by eliminating the need for tug-assistance to port. The American Spirit was launched in 1978 in Lorain, OH, by the American Shipbuilding Company and is powered by 2 Pielstick engines that produce approximately 12,000 kW combined. She is a self-unloader owned by the American Steamship Company and is primarily used for long-haul transport of iron ore pellets.[158]

The James R. Barker, built in 1976 was the first 1,000-foot class vessel constructed entirely on the Great Lakes, where she was built in Lorain, OH by the American Ship Building Company.[159] She is named for the President and Chairman of the Board of the Interlake Steamship Company and is shown in Figure 7-18. The James R. Barker can carry over 63,000 gross tons which is enough material to produce the steel for 16,000 automobiles.[160] She is powered by 2 Pielstick diesel engines that produce approximately 12,000 kW of power.

Figure 7-18 The James R. Barker Heads Downbound at West Pier in the Upper St. Mary's River June 29, 2008

Source: Photo taken by and used with permission from Dick Lund, available here: http://www.dlund.20m.com/images_2008/SOO062908ai.JPG

In addition to carrying products associated with the production of steel, five C3 vessels also carry sand or stone according to Lloyds Sea-web database, including the Roger Blough (see Figure 7-11).[161] The Roger Blough was launched in 1972 by the American Shipbuilding Company, and is the longest traditional (forward pilot house) vessel still working on the Great Lakes. She is powered by 2 Pielstick diesel engines that produce approximately 12,000 kW of power. The Blough has a unique self unloader that is located in the stern section of her hull and can be moved out from either side of the stern, it is 54 feet long and was made to unload directly into a hopper at the ports of Gary, IN, South Chicago, IL, and Conneaut, OH, when steel mills in these areas were flourishing. Today, this special unloading system restricts her ability to unload at other ports, and she was laid up for several years in the 1980's because of this limited capability.[162] Today, however, she is kept busy by the increasing amount of pellets that travel to Duluth via train.

Lloyd's Sea-web database also lists grain capacity for four lakers, indicating that these vessels are capable of carrying grain, including: the Hon. James L. Oberstar, American Spirit, James R. Barker, and the Mesabi Miner. However, there are no available sources indicating any of these vessels have carried grain recently, although the Lake Carrier's Association does note the movement of some grain by U.S. carriers recently, it is unclear which vessels actually move this grain. The Mesabi Miner, like nearly every other 1,000-footer, was built by the American Shipbuilding Company and was launched in 1977, see Figure 7-19. Unlike most other vessels, however, she was not named for a prominent business man; rather she was named in honor of the men and women of Minnesota's Mesabi Iron Range.[163] The Mesabi Miner is powered by two Pielstick diesel engines that produce nearly 12,000 kW of power and can carry over 63,000 gross tons of ore and over 57,000 net tons of coal.

Figure 7-19 The Mesabi Miner Arrives in Marquette, MI in December, 2005.

Source: The Mesabi Miner – Taken by Lee Rowe, Arriving Marquette, MI, Dec, 2005.

Of the twelve C3 vessels and tug-barge combinations, ten have self-unloading booms that are at least 250 feet long, the two ships that do not are the Roger Blough and the Edgar B. Speer, the latter of which has the shortest boom at 52 feet. Similar to the Roger Blough, the Edgar B. Speer's boom is mounted on her stern and restricts her cargo to taconite pellets that can only be unloaded in Gary, IN and Conneaut, IN where the boom can feed directly into a specially designed hopper. The Edgar B. Speer, shown in Figure 7-20, was built by the American Shipbuilding Company in Ohio, and was launched in 1980. She has twenty hatches that lead to five cargo holds and can carry the second largest amount of ore on the Great Lakes at nearly

74,000 gross tons and over 50,000 net tons of coal. The Edgar B. Speer is powered by 2 Pielstick diesel engines that produce the second most power of any C3 U.S.-flagged vessel in the Great Lakes fleet, slightly less than 14,400 kW.

Figure 7-20 The Edgar B. Speer Working in the Winter

Source: http://www.duluthboats.com/shippages/shippic37.html

7.5.4 Canadian Category 3 Vessels

In order to determine how many Canadian vessels are Category 3 vessels, we used the same methodology as for our U.S. study. First, we reviewed the GWG to find the vessels in the fleet, and then researched the bore and stroke for each individual vessel to determine the cylinder displacement, and subsequently what category engine is installed in each ship. We found that there are 68 C3 Canadian-flagged vessels (consistent with the number reported in their comments on the Category 3 rule[164]), 20 C2 vessels, and 8 steamships.[E]

The average age of the 68 Canadian C3 vessels is approximately 30 years, with the newest vessel being built in 2009, compared to the newest U.S.-flagged vessel having been built in 1981. Canada recently restructured its tariff system such that there is no longer a 25 percent tariff on ships over 129 meters long built in foreign countries and imported into Canada, and as a result a number of new ships are being built in China for the Canadian side of the Great Lakes.[F] There are a number of different types of vessels in the Canadian C3 fleet including: 26 self-unloaders, 24 bulk freighters, 15 tankers, and 3 cargo vessels. The size of these vessels ranges from over 5,700 GRT to nearly 24,000 GRT with an average of just over 15,000 GRT. The

[E] Note that these fleet numbers are different from those reported by ICF/EERA in their report contained in Appendix 2C to Chapter 2 (57 C3 and 19 C2 vessels). This discrepancy is not important to this report as these fleet numbers are provided for completeness for this industry characterization. No fleet-wide cost estimates are developed in the analyses contained in this report.

[F] See http://www.fin.gc.ca/n10/10-089-eng.asp reported power of these vessels ranges from just under 2,800 kW to over 11,500 kW with an average power of nearly 6,600 kW. Based on available data, four of the 68 vessels have been repowered, one in 1974, and the other three after 2008.

The St. Lawrence Seaway limits the length of ships to 740 feet, and there are no Canadian ships that are longer than this restricted length in the fleet of 68 vessels; nearly 56 percent of the vessels in this fleet are 740 feet long. The ore capacity ranges from nearly 8,400 gross tons to nearly 38,000 gross tons for the ore-carrying vessels in this fleet. The coal carrying capacity ranges from 8,700 net tons to over 40,000 net tons for those vessels that carry coal. As would be expected, the shorter overall length mandates that these vessels carry less cargo than the U.S. flag ore and coal carriers. Nearly 37 percent of the Canadian C3 vessels carry wheat, sand or stone, corn and rye, barley or oats with capacities ranging from over 7,000 metric tons to over 37,000 metric tons of these commodities.

7.5.5 Salties

There are a number of vessels from countries all over the world that travel across the Atlantic and through the St. Lawrence Seaway to visit the Great Lakes and have done so since the locks opened in 1959. These vessels travel through the 5 Canadian and 2 U.S. locks to reach Lake Ontario, and may continue through another 8 Canadian locks of the Welland Canal to enter Lake Erie and continue on from there to other Great Lakes ports. Since 1959, more than 2.5 billion tonnes of cargo worth an estimated $375 billion have moved to and from Canada, the U.S. and nearly fifty other nations.[165] Nearly 25 percent of the traffic through the Seaway travels to and from overseas ports, especially from Europe, the Middle East, and Africa. Vessels visiting from foreign ports must be small enough to pass through the smaller locks (e.g. no more than 740 feet long) and can therefore easily pass through the Poe Lock in Sault Ste. Marie.

The data presented here on foreign-flagged vessels visiting the Great Lakes comes from the 2009 Seaway Ships.[166] In 2009, 189 different ships visited the Great Lakes from foreign ports, of these most were bulk carriers (39%) followed by general cargo vessels (37%), chemical tankers (23%), and one tanker. The majority of these vessels, (14%) were flying the flag of the Netherlands, Antigua & Barbuda (13%), and Cyprus (11%); while vessels from more than 25 countries visited the Great Lakes. The average GRT of these ships is approximately 12,800, which is less than the U.S. Great Lakes fleet of 16,000 GRT and the Canadian Great Lakes fleet at 15,000 GRT. The smallest ship that visited in terms of length and GRT, the Thor Athos, is less than 291 feet long with a GRT of just over 3,100. The Thor Athos, shown in Figure 7-21, is a general cargo vessel built in 1987 flagged from the Isle of Man; she delivered her cargo to Hamilton, ON during her one visit here in 2009.

Figure 7-21 The Thor Athos. The Smallest Foreign-Flagged Vessel to Visit the Great Lakes in 2009

Source: www.sav-service.com.ua/

The largest vessel in terms of GRT to visit the Great Lakes in 2009 was the Antigua & Barbuda flagged Bluebill. Rated over 37,000 GRT, the Bluebill is owned and managed by Navarone SA; and visited the Great Lakes once in 2009, delivering her cargo to Toronto, ON. The longest foreign-flagged vessel to visit the Great Lakes, the Saguenay, is nearly 730 feet long with just over 22,700 GRT; she is flagged in the Marshall Islands and visited the lakes four times, three months in a row starting in June and one more time in November. The Saguenay is owned by the Canadian Steamship Lines and is one of their straight-deck bulk freighters.

The fleet of foreign-flagged vessels that visited the Great Lakes in 2009 is quite young at an average age of ten years in comparison to both the U.S. and Canadian fleets that are on average 41 and 30 years old respectively. The oldest ship that visited was built in 1980, while over 6 percent of these vessels were sailing their first season in 2009.

More than 70 percent of the vessels visited the Great Lakes only one time in 2009, just over 18 percent visited twice and the rest visited no more than four times. In most cases, vessels that visit multiple times visit the same port each time. Some vessels visit multiple ports during each visit, for example heading to Ashtabula, OH, then Duluth-Superior, MN. Figure 7-22 and Figure 7-23 plot the number of times each port was visited by a foreign-flagged ship in 2009. The port of Duluth-Superior, MN was visited most frequently by foreign-flagged vessels.

Figure 7-22 Number of Visits by Foreign-Flagged Ships to Ports on Lakes: Superior, Michigan, Huron and Erie

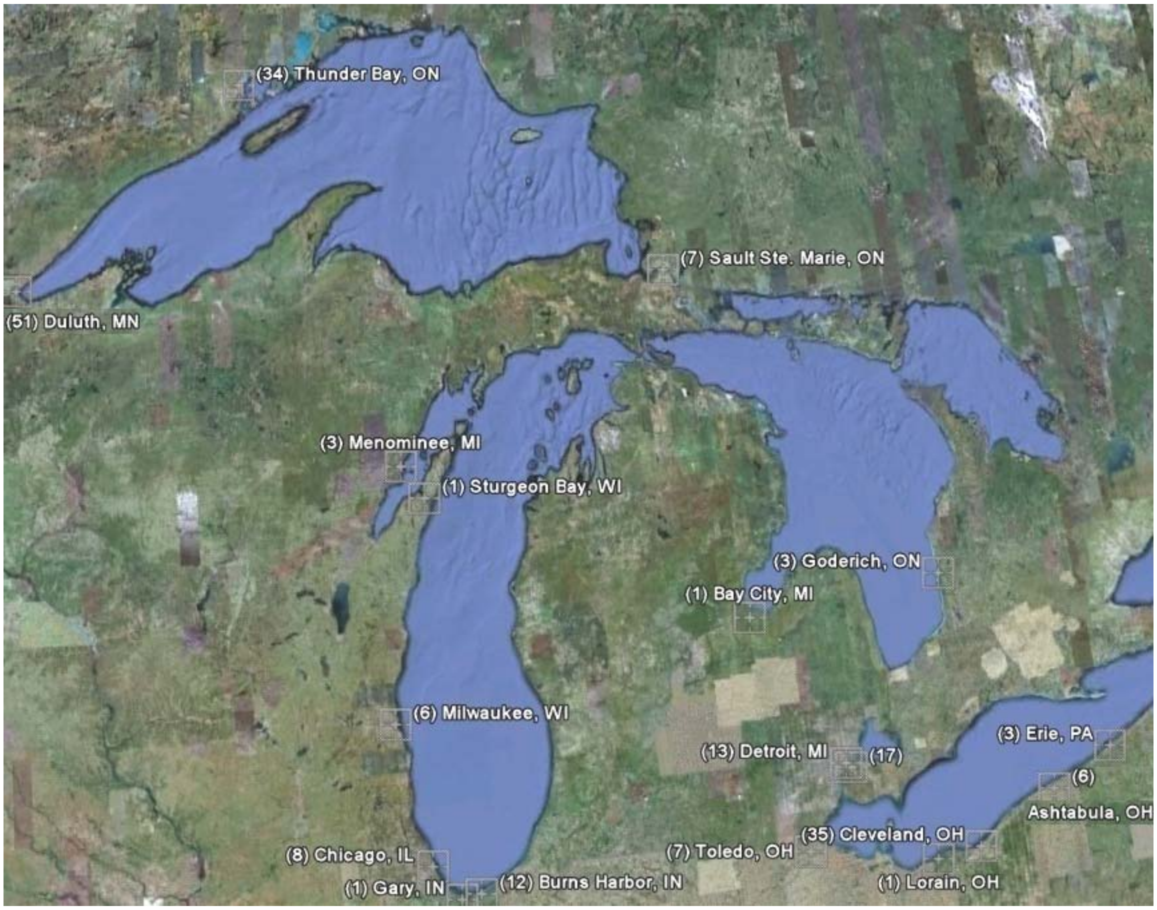
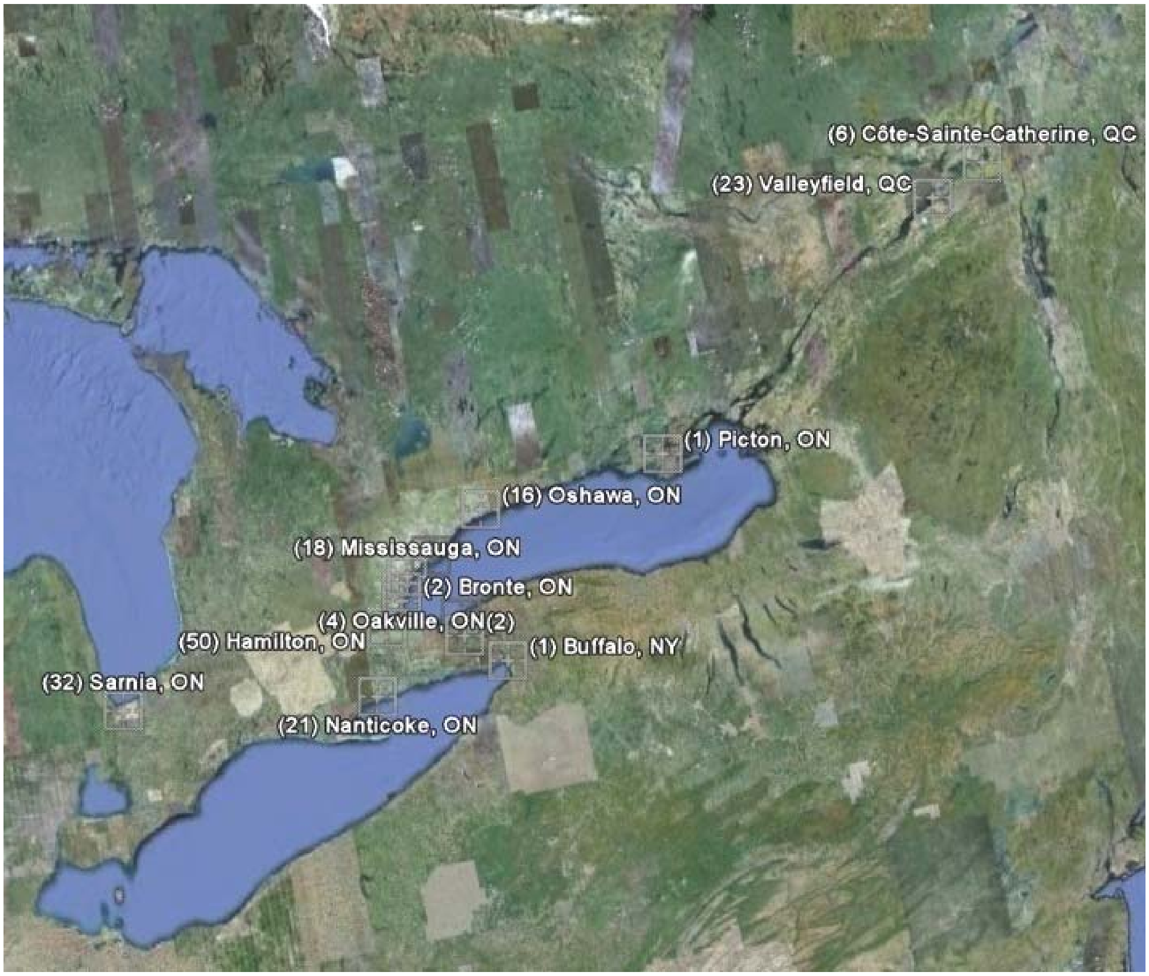


Figure 7-23 Number of Visits by Foreign-Flagged Ships to Ports on Lake Ontario and the St. Lawrence Seaway



In all, there were nearly 400 port visits in the Great Lakes in 2009 to both U.S. and Canadian ports, of these over 65 percent of these visits were to Canadian ports, nearly 20 percent of these visits were to Hamilton, ON. The visits to U.S. ports were primarily to Lake Superior, nearly 37 percent of all foreign-flagged visits to Great Lakes ports were to Duluth, MN.

7.6 Owners Operators of U.S. Category 3 Ships

There are numerous companies that own and operate vessels that work on the Great Lakes, including small businesses that may operate one tugboat, to large companies that send ocean-going vessels to Great Lakes ports. Of these, there are five companies that own and operate the twelve C3 vessels in the U.S. flagged Great Lakes fleet: The American Steamship Company, The Interlake Steamship Company, Great Lakes Fleet, Inc., Grand River Navigation, and KK Integrated Logistics LLC. This section provides a brief overview of these five companies.

7.6.1 The American Steamship Company

The American Steamship Company (ASC) was founded in Buffalo, NY in 1907, and is headquartered today in Williamsville, NY.[167,168] In 1917, ASC vessels were the first on the Great Lakes to be equipped with radio telegraph sets removed from Navy vessels at the end of World War I. In the 1930's, ASC was the first company on the Great Lakes to convert their bulk freighters into self-unloading vessels. In 1973, ASC was acquired by the General American Transportation Corporation, known as the GATX Corporation of Chicago, and added a number of new vessels to their fleet throughout the 1970's. In 1996, the American Republic, a Category 2 Great Lakes vessel belonging to ASC made history by carrying the Olympic flame on her deck with a specially-built cauldron on her bow; she carried the torch from Detroit, MI to Cleveland, OH on its way to the Olympic Games in Atlanta, GA. In 2002, ASC pooled operations with Oglebay Norton Marine Services under the name of the United Shipping Alliance, however, they terminated this relationship in 2006 and ASC purchased six vessels increasing their fleet to 18 vessels. This fleet of 18 vessels is all self-unloading and ranges in length from 635 feet to 1,000 feet, with carrying capacities ranging from nearly 24,000 to over 80,000 gross tons which can be unloaded at speeds from 7,000 to 10,000 net tons per hour. In 2009, ASC vessels could carry 39 percent of the total industry annual capacity on the Great Lakes, and primarily served electric utilities, followed by the steel industry and construction. In 2009, ASC moved 21 million net tons of cargo which was comprised of 48 percent coal, 39 percent iron ore, 10 percent limestone aggregates, and 3 percent other. Of their 18 vessels, three are steamships and six are thousand-footers.

GATX, ASC's parent company was founded in 1898 as a railcar lessor and today still specializes in railcar leases serving both the North American and European markets with 162,000 train cars; 83 percent of their assets are involved with the rail industry. They also own a fleet of approximately 600 locomotives, and lease these as well as provide maintenance services, engineering, and training to the rail industry, in addition to owning and leasing marine vessels, and other industrial equipment. GATX reaches beyond the Great Lakes and has invested in ocean-going vessels as well and are a part of five joint ventures that involve over 30 of these vessels including: bulk carriers, chemical tankers, LPG carriers, and multi-gas carriers. Their industrial equipment portfolio serves the transportation, mining, and automotive industries. In 2009, GATX had a gross income of $1.15 billion, with assets worth $6.2 billion, while ASC had a gross income of $132.7 million in 2009 down from $271.5 million in 2008.[169]

7.6.2 Interlake Steamship Company, and the Lakes Shipping Company

The Interlake Steamship Company was founded in 1913 through a consolidation of all the vessels formerly managed by Pickands Mather & Company founded in 1883.[170] The Pickands Mather & Company began as a start-up company with an interest in an Upper Michigan iron range land, and a 13/20 interest in a 1,700 ton capacity wooden steamer; their company grew along with the demand for steel during the turn of the century and in 1913, their fleet numbered 39 vessels. In 1927, they commissioned the Str. Harry Coulby which was larger than any other vessel on the Great Lakes at 631 feet long; she was the first to carry more than 16,000 tons of cargo. Over the years, Interlake continued to modernize its fleet adding some newly constructed ships, lengthening, converting and acquiring others. In 1975, the Str. Herbert C. Jackson was the first of three Interlake straight-deck vessels to be converted to self-unloaders.

Between 1976 and 1981, Interlake added three vessels to their fleet: the James R. Barker, Mesabi Miner, and Paul R. Tregurtha which together added 194,600 gross tons to Interlake's total capacity. In 1987, Interlake became a privately held company. In 1989, the three boats left in the Rouge Steel fleet were purchased and organized as the Lakes Shipping Company under the management of the Interlake Shipping Company; these three vessels include: the Lee A. Tregurtha, Str. Kaye E. Barker, and the Str. John Sherwin.

Today, Interlake is headquartered in Richfield, OH. They own and operate nine vessels over 2,000 GRT on the Great Lakes including: three steamships, five vessels powered by C3 engines, and one powered by a C2 engine. In 2010, Interlake was awarded the Midwest Clean Diesel Initiative Leadership Award for repowering three of their vessels with new diesel engines.

7.6.3 Great Lakes Fleet, Inc.

Great Lakes Fleet (GLF) is owned by Canadian National (CN) and operated by the Keystone Shipping Co., based in Duluth, MN.[171] GLF owns a fleet of eight vessels including four steamships and four C3 powered vessels; seven of the vessels are self-unloaders while the eighth is an integrated tug-barge combination, the Presque Isle, which is also self-unloading. The Great Lakes Fleet vessels came from U.S. Steel's Great Lakes fleet which was sold in 2001 to Great Lakes Transportation LLC, a conglomerate of other transportation companies. Great Lakes Transportation was then sold to CN Railway in 2004. In 2009, CN had revenues of over $7.3 billion and employed nearly 22,000 people.[172]

GLF transports dry bulk cargoes, primarily for the U.S. steel industry; their fleet serves both U.S. and Canadian ports. Their ships range from 767 feet to 1,004 feet in length with carrying capacities of 28,400 to 74,500 net tons. Products handled include taconite and natural iron ore mined in the Upper Peninsula of Michigan along the western edge of Lake Superior and shipped to Detroit, Erie, and the lower end of Lake Michigan. They also ship limestone mined along northern Lake Huron and shipped throughout the Great Lakes, coal, petroleum coke, slag, mill scale, taconite pellet screenings, and sand. Great Lakes Fleet vessels have a very distinctive paint scheme, as shown below on the Arthur M. Anderson in Figure 7-24.

Figure 7-24 The Arthur M. Anderson Visiting Duluth, MI in November, 2009

Taken by and used with permission from Andrew Tubesing. Source:
http://www.ee.nmt.edu/~tubesing/personal/boats/boatwatcher.htm

7.6.4 Grand River Navigation

Grand River Navigation (GRN) was acquired by Rand Logistics in 2005 along with Lower Lakes Towing Ltd.[173] GRN is headquartered in Avon Lake, OH with offices in Traverse City, MI, Rand Logistics is headquartered in New York, NY. The Rand fleet is made up of the Lower Lakes fleet of eight Canadian vessels, and the GRN fleet of six vessels which includes 4 self-unloading vessels, and one articulated tug-barge combination that is also a self unloader. These vessels range in length from just over 609 feet to 630 feet with capacities of 12,650 to nearly 20,000 tons. In July, 2010 Rand announced it would repower its last steamship, the S.S. Michipicoten to diesel power during the winter of 2010, similar to the repowering of the Saginaw that they completed in 2008 for an estimated cost of $15 million.[174] For the fiscal year of 2010, Rand announced marine freight revenues (excluding fuel and other surcharges, and outside of charter revenue) was $85.1 million with total sail-days equal to 3,143, down 5 days from 2009.[175]

7.6.5 KK Integrated Logistics LLC

KK Integrated Logistics operates two articulated tug-barge combinations, with one tug, the Victory, powered by a C3 engine. They are headquartered in Menominee, MI with offices in Marinette, Manitowoc, and Green Bay Wisconsin.[176] They offer warehousing, stevedoring, shipping, and trucking. KK Integrated Logistics has two privately owned ports in Menominee, MI and Green Bay, WI with two loading docks at each port and on-site rail access. The port in Menominee was built to serve the wind industry and can store over 13 shipments of windmill towers. Their two articulated tug-barge (ATB) combinations were both purchased as steamships and converted to ATBs in 2006 and 2007 and are both self-unloaders.

Appendices

Appendix 7A

Additional Features of the

Great Lakes Transportation System

This Appendix describes several features of the Great Lakes Transportation network, including seasonal operation constraints, the interface with rail, the impact of cabotage laws, the amount of cargo shipped on the Great Lakes, and Great Lakes waterway routes, including the canal system.

Seasonal Constraints

During the winter, the Great Lakes often experience widespread ice cover typically beginning in mid-December and ending in mid-April, as a result, navigation is restricted. For instance, every year the Soo Locks close from January 15 to March 25.[177] This severely restricts shipping in the Great Lakes as the Soo Locks provide the only point of access from Lake Superior to both Lake Michigan and Lake Huron. The U.S. Coast Guard operates the icebreaker Mackinaw on the Great Lakes to enable ships to pass through the ice while the Locks are open; however, cargoes are not shipped during the month of February and in some cases during the month of January.[178]

Interface with Other Modes of Transportation

The Great Lakes serve as an effective and convenient mode of transportation, especially for raw commodities. However, the origins and destinations of these materials are not always located directly on the lakes. As a result, the method to get these materials from their source to their endpoint is often intermodal transportation. For example, much of the coal transported on the Great Lakes comes from either the Powder River Basin in Montana or the Appalachian region. Neither of these coal deposits is adjacent to the Great Lakes and therefore neither has a mine on the shores of the Great Lakes. While power plants are often located near water in order to maintain a steady stream of cold water for their power generation, steel mills don't have the same requirement. Coal that goes to steel mills, along with iron ore and limestone, usually must travel by rail to get to the final destination. Both the origins and destinations of iron ore, stone, and grain aren't always on the shores of the Great Lakes and therefore require more than one mode of transportation to get to the endpoint. For example, the Mesabi Iron Range serves as the main source of iron ore for Great Lakes industry. Canadian National (CN) owns Duluth, Missabe, & Iron Range line, which services the iron range.[179] This line also runs to Duluth, Minnesota, where CN owns the ore loading dock. [180,41] The ore would then be loaded on a lake vessel for transport to any number of steel mills on the Great Lakes, most of which have ore docks at their facilities.

Cabotage Laws (U.S., Canada)

Domestic waterborne transportation is safe, reliable, efficient and an established mainstay of America's national transport system. The domestic shipping operations of the American merchant marines provide essential services to 41 states reaching 90 percent of the national population. This form of surface transportation handles a combined total of over 1.1 billion short tons of cargo, which is about 23 percent of the ton-miles of all domestic surface transportation traffic. Domestic waterborne transportation contributes $7.7 billion to the gross domestic product annually in the form of freight revenue.

To encourage a strong U.S. merchant marine for both national defense and economic security, the nation's domestic waterborne commerce is reserved for vessels built in the United States, owned and crewed by American citizens, and registered under the American flag.[181,] U.S. laws governing the domestic transportation of passengers and cargo by water are generally known as the Jones Act, named after Senator Wesley Jones (R-WA), the sponsor of the Merchant Marine Act of 1920. The Jones Act continues to be the foundation for America's domestic shipping policy.

The Jones Act (46 U.S.C. 883, 19CFR 4.80 and 4.80b) requires that merchandise being transported by water between U.S. points must travel in U.S.-built and U.S.-citizen owned vessels that are documented by the U.S. Coast Guard for such carriage. The U.S. Customs Service has direct responsibility for enforcing the provisions of the Jones Act and is statutorily limited to granting waivers from the Act only in the interest of national defense or for a vessel in distress.

The Canadian equivalent of the Jones Act that establishes laws regarding domestic commercial marine activity is known as the "Coasting Trade Act." It includes the transportation of goods and passengers between Canadian points as well as any other commercial marine activity in Canadian waters. The Coasting Trade Act supports domestic marine interests in a similar manner as the U.S. Jones Act by reserving the coastal trade of Canada to Canadian-flagged ships, with some exemptions.[182]

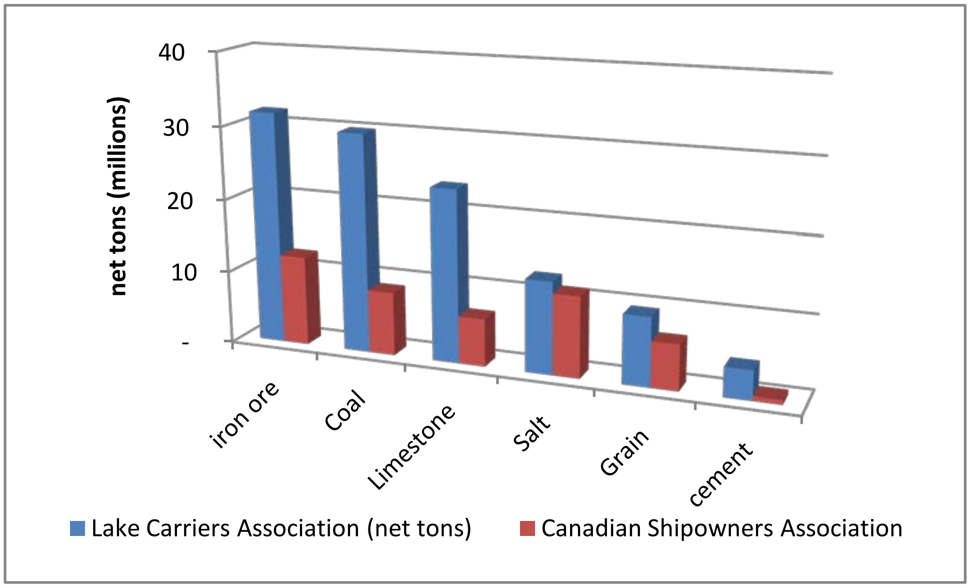
Foreign-flagged vessels entering the Great Lakes through the St. Lawrence Seaway can deliver and take out cargoes at any port for export. The Jones Act, for example, only prevents these ships from picking up and subsequently delivering cargo within the U.S.

How Much Cargo is Moved on the Great Lakes

The Lake Carriers' Association (LCA) represents eighteen operators of U.S.-flagged vessels that operate on the Great Lakes. Similarly, the Canadian Shipowners' Association (CSA) represents owners and operators of Canadian-flagged vessels in Canada. These two associations report the tonnages moved by their respective members each year. In 2009, LCA reported that their members moved over 111 million net tons of dry bulk tonnage; while CSA reported that their members moved over 51 million net tons.[G] Figure 7A-1 shows the dry-bulk tonnages

[G] The LCA only reports tonnages for dry bulk cargoes including: iron ore, coal, limestone, salt, cement, and grain while the CSA reports dry bulk tonnages for the following cargos: coke, general cargo, gypsum, misc. bulk, and potash. In addition, the CSA also reports tanker cargos. In order to compare the dry bulk results here, the remaining moved by type of cargo reported moved by the LCA and the CSA in 2009. The difference in the amount of cargo between U.S. and Canadian vessels in part can be explained by the length and capacity of the vessels operating on the lakes.

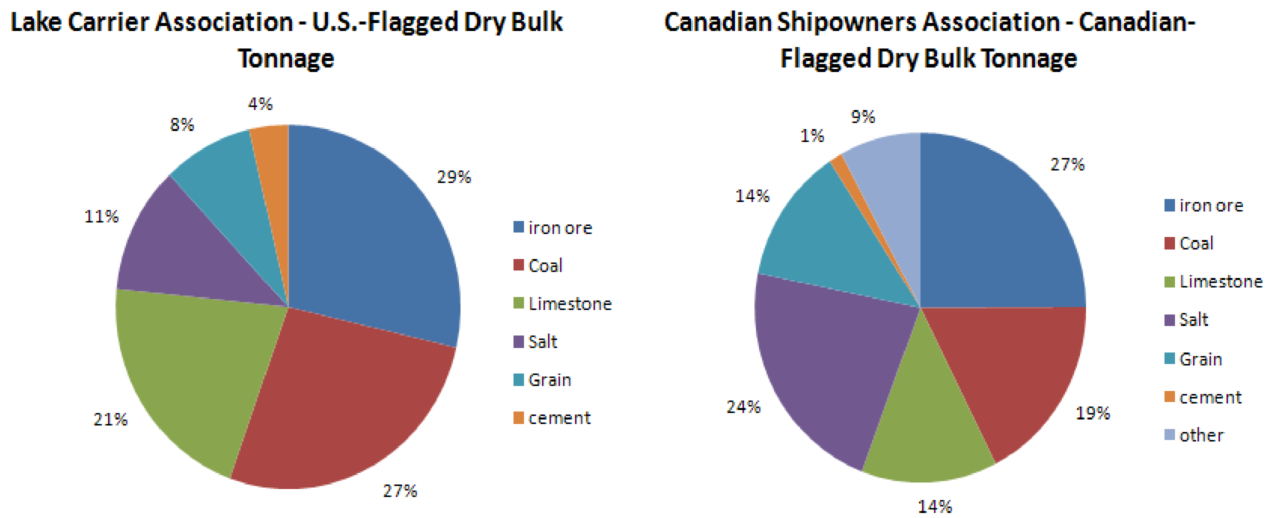
Figure 7A-1 U.S. and Canadian Dry Bulk Tonnage in 2009 from LCA and CSA



In terms of what type of dry-bulk tonnage makes up the majority of this category of cargo, both the LCA and the CSA report that ships mainly move iron ore, although the CSA reports that their vessels move more salt then coal, while the LCA reports that coal is the second-most moved cargo in 2009. The total amount of coal moved on the Great Lakes as reported by LCA or nearly 30 million net tons, or approximately 3.4 percent of the amount of coal moved by rail in the U.S. which according to the American Association of Railroads (AAR) was over 878 million tons in 2009.[183] Coal is the most frequently moved cargo by railroads comprising over 45 of all moved tonnage in 2009. In terms of metallic ores, LCA reports that U.S.-flagged vessels moved approximately 32 million tons of iron ore in 2009, while the AAR reports that in 2009 nearly 60 million tons of metallic ores were moved by rail. Figure 7A-2 highlights how important the iron ore, coal, and limestone cargos are to the Great Lakes fleet of vessels, both in the U.S. and in Canada.

categories of CSA cargos were totaled as “Other” and are included in the dry bulk totals presented in this analysis. Note that the 51.4 million net tons reported moved in 2009 by CSA also includes 6.6 million tons of tanker products.

Figure 7A-2 Dry-Bulk Tonnages Moved on the Great Lakes in 2009



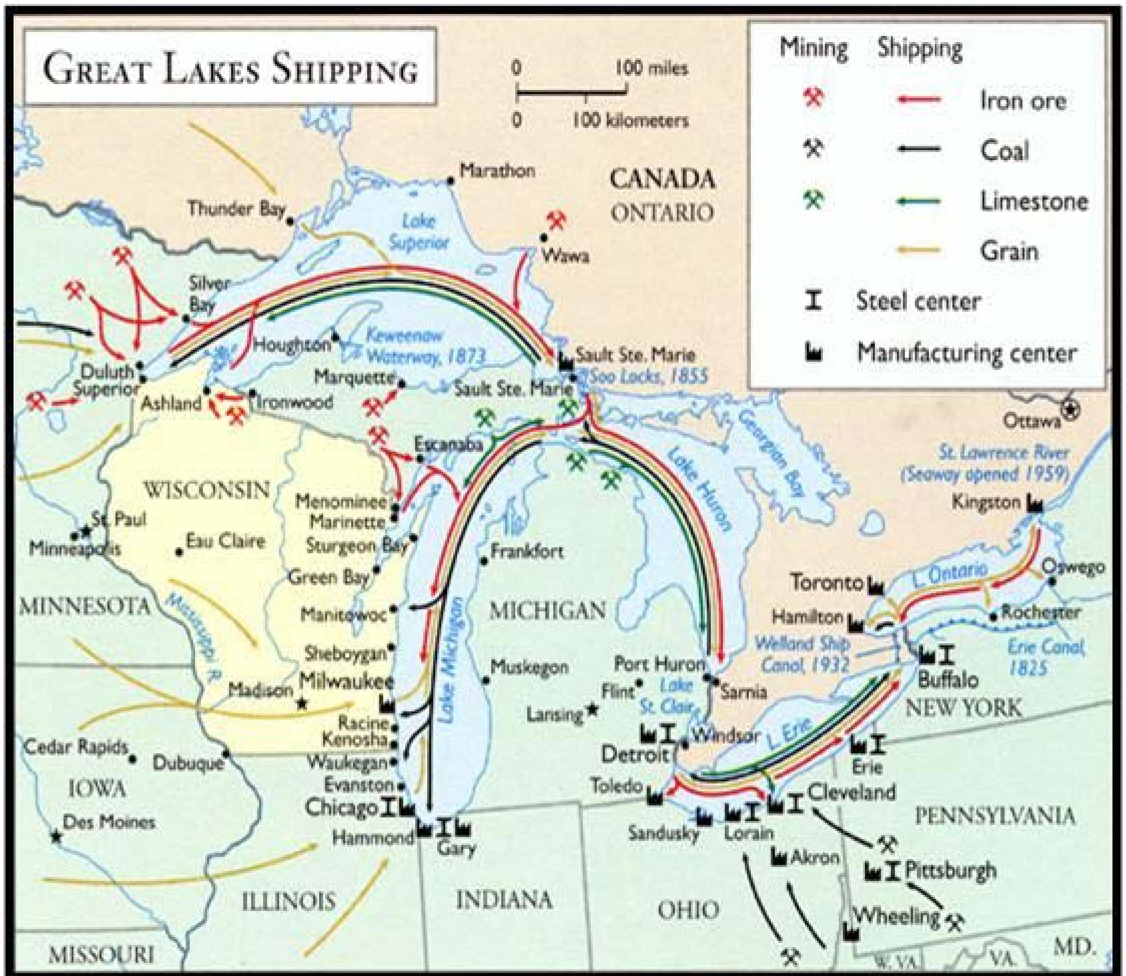
Great Lakes Shipping Routes

Shipping routes on the Great Lakes are dictated by the nature of the cargo and backhaul being carried by each vessel. More specifically, the location of iron ore, coal mines, and stone quarries dictated, in the late 1800's, where ports would be built and what they would handle. These old ports are still in use today, and the characteristics of these ports continue to set limits on the size and type of vessel that can be used on a route (draft limitations; loading and unloading equipment).

For example, iron ore is the most common cargo shipped across the Great Lakes due to the fact that major iron ore mines are located close to Lake Superior and the lower St. Lawrence River.[184] Vessels collect ore at these locations and deliver them to the steel mills located primarily at the southern ends of Lakes Michigan and Erie. In this case, mining in the Mesabi Range led to the establishment of the ports of Duluth-Superior as early as 1892,[185] and steel mills were located in Illinois, Indiana, and Ohio to take advantage of ship transportation and abundant supplies of water. Similarly, coal traffic through Lakes Superior, Michigan, Huron, and Erie has largely been driven by the availability of low sulfur coal from the Powder River Basin. Limestone has seen an increase in demand as it aids in the reduction of sulfur emissions through the use of scrubbers from coal-burning industries.

Figure 7A-3 shows the origins of the main commodities shipped on the Great Lakes and the routes they typically operate.

Figure 7A-3 Shipping Routes Along the Great Lakes by Commodity



Source: Army Corps of Engineers, "Great Lakes Navigation System Five-Year Development Plan."[186]

Waterways

There are a number of lakes, rivers, and locks that make up the navigable waterways of the Great Lakes region which empties into the Atlantic Ocean.[187] The Great Lakes include: Lake Huron, Lake Ontario, Lake Michigan, Lake Erie, and Lake Superior; they are connected by three main rivers: the St. Clair River, St. Mary's River, Detroit River, and are connected to the Atlantic Ocean via the St. Lawrence River. The lakes are the largest system of fresh, surface water on earth, containing nearly 21 percent of the world supply.[188] They contain approximately 5,500 cubic miles of water and cover an area of nearly 94,000 square miles.[189] Ships travelling from the Atlantic Ocean can reach the western edge of Lake Superior in 8.5 sailing days. Despite their large size, however, the Great Lakes are sensitive to the effects of a wide range of pollutants. The sources of pollution include the runoff of soils and farm chemicals from agricultural lands, the waste from cities, discharges from industrial activity such as ship emissions and leachate from disposal sites. The large surface area of the lakes also makes them vulnerable to direct atmospheric pollutants that fall with rain or snow and as dust on the lake surface.[190] Outflows from the Great Lakes are relatively small (less than 1 percent per year) in comparison with the total volume of water. Pollutants that enter the lakes - whether by direct discharge along the shores, through tributaries, from land use or from the atmosphere - are retained in the system and become more concentrated with time. Also, pollutants remain in the system because of resuspension (or mixing back into the water) of sediment and cycling through biological food chains.

Figure 7A-4 The Great Lakes Waterways

Lake Superior is the coldest, deepest, and largest of all the Great Lakes; it is 350 miles long and 160 miles wide and in terms of volume could hold all of the other Great Lakes and three more Lake Erie's combined; the average depth is 483 feet with a maximum depth of 1,330 feet. Due to its large size and small outflow, it has a retention time of 191 years.[191] Lake Superior is an estimated 183.5 meters above sea level, while both Lake Huron and Lake Michigan are 176.3 meters above sea level. The Soo Locks lead vessels from Lake Superior to the St. Mary's River on their way to Lake Huron and Lake Michigan. Lake Huron is the widest lake of the five at 183 miles wide and is 206 miles in length; it also offers the most shoreline of the lakes at over 3,800 miles. Lake Michigan and Lake Huron are connected directly at the Straits of Mackinac. Lake Michigan is the second largest Great Lake in terms of volume, and the second longest after Superior at 307 miles and is 118 miles wide; it is the only lake that lies entirely within the U.S. border. The southern shore of Lake Michigan is one of the most heavily urbanized areas of all the lakes, and includes Milwaukee, WI, and Chicago, IL.

Vessels traveling to Cleveland, OH, for example, from Chicago would go through the Straits of Mackinac and under the Mackinac Bridge and into Lake Huron, and then into the St. Clair River through Lake St. Clair and through the Detroit River to arrive in Lake Erie. Lake

Erie is slightly lower than Lake Huron, at 174.3 m above sea level, and is the most biologically productive of the Great Lakes.[192] Lake Erie is also the smallest of the lakes by volume it is 241 miles long and 57 miles wide and is the shallowest of all the lakes with an average depth of 62 feet. From Lake Erie, vessels must go through the Welland Canal to pass through the nearly 100 meter drop between these two bodies of water. Lake Ontario is approximately 75 m above sea level, and although slightly smaller than Lake Erie in terms of area, Lake Ontario is much deeper with an average depth of 283 feet and a maximum depth of 802 feet. Lake Ontario is 193 miles long and 53 miles wide. The U.S. shoreline is less urbanized than the Canadian side of Lake Ontario which includes the industrial areas of Toronto and Hamilton. Finally, vessels heading to the Atlantic Ocean will have to pass through the Montreal/Lake Ontario sections of locks and the St. Lawrence Seaway which is nearly 2,340 miles long.[193]

The Soo Locks

Located on the St. Mary's River in Sault Ste. Marie, MI the Soo Locks connect Lake Superior to the lower lakes. The Soo Locks consist of two canals and four locks. The Poe Lock is the newest lock, built in 1968, and is 110 feet wide and 1200 feet long. The MacArthur Lock was built in 1943 and is 80 feet wide and 800 feet long. The remaining two locks, the Davis and the Sabine were built prior to 1920 and are currently closed. In 2008, over 72 million tons of cargo valued at over $3.2 billion passed through the Soo Locks, 62 percent of which was iron ore. The Army Corps of Engineers maintains and operates the locks, and is evaluating the replacement of the Davis and Sabine locks with a single lock that would be 110 feet wide and 1,200 feet long. Congress authorized the replacement of this lock in the Water Resource Development Act of 1986, and groundbreaking ceremonies have occurred, however, whether or not there will be funding for the entire project is not clear.[194]

7A -5 The Edgar B. Speer Travels Through the Poe Lock in Sault Ste. Marie with Approximately 30" of Clearance per Side.

Source: Photo taken by and used with permission from Dick Lund, available here: http://www.dlund.20m.com/custom5.html

Welland Canal

The Welland Canal consists of a series of eight locks that provide over 326 feet of lift and leads ships through 27 miles of channels and locks.[195] The locks limit the size of ships that can pass through the entire Seaway and enter the Great Lakes; ships must be no more than 740 feet long, 78 feet wide, the draft can change yearly depending on water levels. In 2010, the canal opened on March 25, 2010 with a draft of 26 feet 3 inches.[196] Vessels transiting through this waterway are typically either freighters or tug/barge combinations that travel exclusively on the Great Lakes, or are ocean-going vessels. The large Great Lakes freighters typically carry iron ore from the Quebec Labrador mining area to the steel mills that are located in the Great Lakes. These same vessels may also carry grain to ports along the lower St. Lawrence River that will be loaded aboard ocean-going vessels for shipment overseas.

Figure 7A--6 Locks 4, 5, and 6 of the Welland Canal

Source: St. Lawrence Seaway Management Corporation

The development, operation, and maintenance of the Seaway are under the joint control of the St. Lawrence Development Corporation, a corporate agency of the U.S., and the St. Lawrence Seaway Management Corporation of Canada (SLSMC). The U.S. Corporation headquarters is in Washington, D.C., and the operational field headquarters is in Massena, N.Y. The Canadian Corporation headquarters is in Cornwall, Ont., with field offices in Cornwall, St. Lambert, and St. Catherines. The SLSMC operates and manages the assets of the St. Lawrence Seaway for the Canadian Government under a long-term agreement with Transport Canada. The SLSMC oversees the transit of over 4,000 vessels each year through the Seaway during their season that typically goes from late March to late December.

Ships up to 78 feet wide enter the 80 foot wide lock, remain under their own power, and are tied up as large steel gates close and the lock either fills or empties via gravity flow. The amount of water used to fill a lock can vary, depending on the size of the lock, but is generally upwards of 15 million gallons which can flow in and fill the lock in approximately 15 minutes. Typically, the total lock transit time can be at least 30 minutes, which includes the vessel approach, mooring, etc. The total estimated time it takes to travel through the entire Welland Canal is 8-12 hours depending on traffic.

Figure 7A-7 The Edward L. Ryerson Passing Through Lock 2 of the Welland canal

Source: St. Lawrence Seaway Management Corporation

The Lake Ontario/Montreal Canal System of the St. Lawrence Seaway

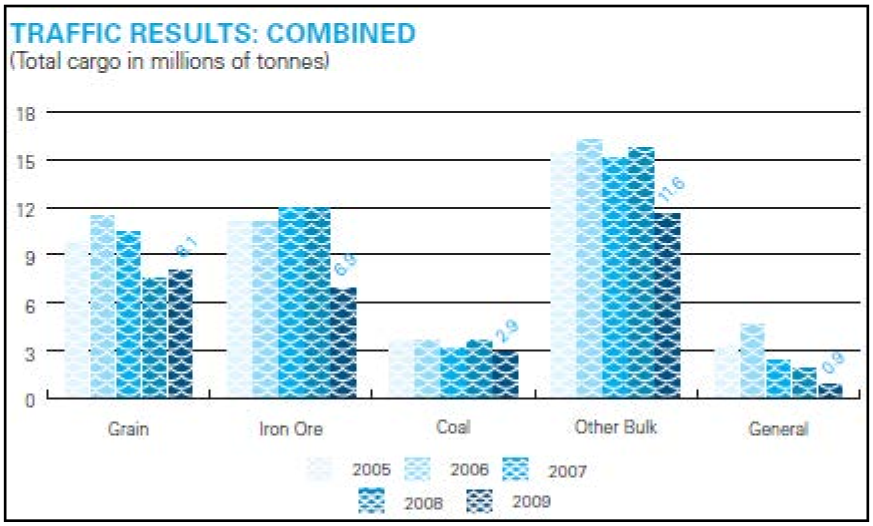
The St. Lawrence Seaway is a nearly 2,340 mile stretch of navigable waters and locks connecting the Atlantic Ocean to the Great Lakes and in addition to the Welland Canal, it also includes the Montreal/Lake Ontario section that is comprised of a series of seven locks.[197] The Montreal/Lake Ontario section of the St. Lawrence Seaway allows vessels to navigate between Lake Ontario and the lower St. Lawrence River. Dominant commodities moved in this waterway are: iron ore, coal, limestone, grain, cement, and general cargo such as iron products and heavy machinery. The first set of locks heading from the Great Lakes to the Atlantic Ocean is the Iroquois lock that provides between 0.6 and 1.8 m of lift, depending on the water height of Lake Ontario. The other locks include: two U.S. locks the Snell and Eisenhower, the Lower and Upper Beauharnois, Côte Ste. Catherine, and the: St. Lambert locks. Figure 7A-8 shows the major ports along the Great Lakes and the St. Lawrence Seaway. It is estimated to take seventeen hours to travel through the locks of the upper St. Lawrence Seaway.

Figure 7A-8 Ports of the Great Lakes and the St. Lawrence Seaway

Source: http://www.media-seaway.com/seaway_handbook/flash-tour-en/tour-e.html

In 2009, the Seaway celebrated its 50th year of operation while the current Welland Canal is approaching its 80th year in operation. Tonnage in 2009 dropped to levels not seen since the early 1960s, and was down nearly 25 percent from 2008 levels or 30.7 million tonnes, with more tonnage passing through the Welland Canal than the Montreal/Lake Ontario section.[198] The drop in production in the steel industry had a significant effect on the decrease in tonnage in the 2009/2010 season, with shipments of iron ore falling nearly 58 percent to just over 5 million tonnes through the Montreal/Lake Ontario section and a drop of over 34 percent to 2.7 million tonnes through the Welland Canal.

Figure 7A-9 Tonnage of Freight by Type Moved Through the St. Lawrence Seaway



Source: 2009/2010 Seaway Annual Report

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CHAPTER 8: Response to Peer Review Comments

This EPA report has undergone peer review pursuant to EPA's *Science Policy Council Peer Review Handbook*, 3rd edition (*Peer Review Handbook*).[A] The peer review was facilitated by RTI International. The three reviewers were Dr. Michael Belzer of Wayne State University, Dr. Bradley Hull of John Carroll University, and Mr. James Kruse of the Texas Transportation Institute.

Appendix 8A to this chapter contains peer review comments and responses that are not addressed in the above chapters of this document, and is included here for completeness purposes; it was not part of the draft document that underwent peer review. In addition to writing our responses, EPA retained the original contractor who conducted the mode shift study, EERA, to prepare responses to certain of the comments pertaining to their contractor report, contained in Chapter 2, Appendix 2C. While most mode-shift related comments have been addressed directly in Appendix 2C, EERA also produced a separate document for addressing certain comments, and this is attached as Appendix 8B.

Finally, the documentation of the peer review process and summary of its findings are found in the technical memorandum titled "Peer Review of EPA's 'Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping' Study," included as Appendix 8C.

8.1 Overview

The reviewers were charged to review and provide comments on: 1) the clarity of the presentation; 2) the overall approach and methodology; 3) the appropriateness of the datasets and other inputs; 4) the data analyses conducted; and 5) appropriateness of the conclusions. The reviewers were asked to focus their review on the first three chapters of this report.

All three reviewers provided supportive comments as well as suggestions for improvements. The reviewers generally found the EPA report to be comprehensive and well written. Overall, reviewers concurred with the selected methodology.

8.2 Comments Not Addressed Specifically

Where practical, responses to comments from peer reviewers have been incorporated into the body of this report, in the sections to which the comments were directed. Reviewers also made several suggestions for straightforward editorial revisions, such as use of unit labels for numbers and consistent use of terms. Unless noted otherwise, these were all accepted and resulted in changes to the report that may not be highlighted within the context of the narrative.

In addition, some substantive comments warrant responses that don't fit into the narrative. These have been collected and are presented with their responses in Appendix 8A.

[A] These guidelines can be found at http://www.epa.gov/peerreview/. Further, the Office of Management and Budget's (OMB's) Information Quality Bulletin for Peer Review and Preamble (found in the EPA's *Peer Review Handbook*, Appendix B) contains provisions for conducting peer reviews across federal agencies and may serve as an overview of EPA's peer review process and principles.

Appendices

Appendix 8A

EPA Responses to Peer Review Comments on 'Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping'

In this appendix, EPA provides responses to the substantive comments offered by reviewers that did not fit easily into the narrative of the report, and that are not addressed by the EERA work in Appendices 2C or 8B.

8A.1. Ships' Contribution to Air Pollution

Commenter	Comment
Hull	Demonstrate that ships are a major contributor to sulfur problems in the Great Lakes/St. Lawrence region. Your study hasn't done that in a convincing way. Convince the audience. Provide a chart that shows ship emissions versus sulfur emissions from all the other polluters: trucks, railroads, automobiles, and manufacturers in the Great Lakes area. Convince the audience that adopting MDO will have a significant positive impact on the Great Lakes environment. Demonstrate that despite the fact that a large percentage of ship emissions occur in unpopulated areas, ships are major polluters in populated areas compared with shore based emissions sources.
Hull	At the beginning of Chapter 1, make the case that marine emissions are a big problem in the Great Lakes and St. Lawrence. This is the reason for having a C3 ruling in the first place. Present statistics showing that the Great Lakes are a non-attainment region and establish that marine emissions are a considerable percentage of those emissions. Add a table comparing the emissions from ships, trucks, railroads, automobiles, and factories showing the relative contribution of each to our densely populated region.
Hull	Page 1-4: Please document the degree to which ships contribute to the air quality in the region, compared with other emissions sources. From a novice's point of view, the Midwest economy is depressed, and shipping is considerably off, so with few ships there will be few air emissions. Also, I would imagine that trucks, rail, and factories contribute a much greater share than do ships. If possible it would be useful to document this.

<u>EPA Response</u>:

EPA performed an extensive analysis of the environmental need for the new Category 3 engine standards and fuel sulfur limits as part of our Category 3 rule.

We estimate that in 2009 Category 3 engines contributed about 10 percent of national mobile source emissions of nitrogen oxides (NO_X), about 24 percent of national mobile source diesel $PM_{2.5}$ emissions (with $PM_{2.5}$ referring to particles with a nominal mean aerodynamic diameter less than or equal to 2.5 µm), and about 80 percent of national mobile source emissions of sulfur oxides (SO_X). Without new controls, we anticipate the contribution of Category 3 engines to national emission inventories to increase to about 24 percent, 34 percent, and 93 percent of mobile source NO_X, $PM_{2.5}$, and SO_X emissions, respectively in 2020, growing to 40 percent, 48 percent, and 95 percent respectively in 2030.

The inventory, air quality and benefits analyses developed for our for Category 3 rule were developed on a national basis. In response to comments on our Category 3 rule proposal (see Section 1.5.1), we also prepared a memorandum to the docket discussing the inventory impacts and the benefits and costs of the applying the Coordinated Strategy to the Great Lakes region in response to comments on our proposal.[1] Chapters 4, 5 and 6 of this report expand on that analysis.

We estimate that Great Lakes vessels will account for about 1.5 percent of uncontrolled national emissions of Category 3 marine for each of NO_X, $PM_{2.5}$ and SO_X emissions in 2020.[B] If Category 3 engines on the Great Lakes were to remain uncontrolled after the Category 3 requirements for engines and fuels go into place, these percentages would increase to 2.3 percent, 10 percent, and 26 percent for NO_X, $PM_{2.5}$, and SO_X emissions, respectively.

With regard to human health and welfare impacts, we are able to use the air quality modeling performed for the national rule to estimate air quality and benefits impacts of the application of the ECA fuel sulfur requirements for the six states bordering the Great Lakes: IL, IN, MI, MN, OH, and WI. The results of the disaggregation of national to regional benefits are contained in Section 5.5 of this report. This analysis shows that the monetized $PM_{2.5}$ human health and welfare benefits that would accrue to these six Great Lakes states in 2030 from applying the ECA fuel controls in the Great Lakes are expected to be between $1.5 and $3.7 billion, compared to total projected costs of about $0.05 billion.

8A.2. Scope of Analysis; U.S. Jurisdiction

Commenter	Comment
Hull	Page 1-8: North American ECA: Ships transiting the Seaway will travel many more miles with the North American ECA than will ships travelling from, say, Europe to an East Coast port. Thus the ruling will fall more heavily on Seaway transits than any other part of the North American ECA – true or false? If true, then the main cost increases will be the ships that are either captive to the Great Lakes or FF ships that transit the Seaway. Thus, both types of ships should be reviewed.
Hull	Clarify whether the Seaway between Montreal and the mouth of the mouth of the St Lawrence River (a 500 mile long leg which exclusively runs through Canada), will require 100% MDO. I assume that this section of the River will continue to use HFO. Here is why: Montreal aggressively competes with US East Coast Ports to handle imports/exports for the US Midwest. Since the St Lawrence River downstream of Montreal runs exclusively through Canada, the many miles of using 100% MDO would negatively impact Montreal's competitive position – an undesirable result from a Canadian point of view. I encourage you to address the issue and state what you feel is the most likely assumption, so that readers can better understand the areas of impact of the C3 Ruling. (As a parenthetical comment, both the Montreal and US East Coast port routes to Midwestern cities involve overland, high emissions truck/rail legs. The lowest emission route is all-water through the Seaway and the Great Lakes to Midwestern cities. Thus, it is important to protect the all-water route).

[B] The emission inventories for Great Lakes Category 3 vessels are set out in Table 4-2 of Chapter 4. As explained in Section 4.6, the estimated inventories do not include emissions from Jones Act vessels; when the inventories are adjusted, Great Lakes inventories are about 3 percent of the national inventories for these pollutants.

Commenter	Comment
Hull	Please state the jurisdiction of the C3 Rule more clearly. I assume that the C3 Rule legally covers all ships travelling through or loading/unloading in US waters. If so, please state that. Due to the more-than-a-dozen border crossings, I assume that it de facto covers all ships travelling through Canadian waters in the Great Lakes as well. If so, please state that too.
Hull	Explain how the US EPA standards can apply to the Canadian Great Lakes ships of Table 1-3. I think that EPA standards would apply to US waters, and that EPA standards would be applied to Canadian ships because of the many boundary crossings they must make.
Hull	Are the sulfur limits imposed on the Great Lakes/Seaway by EPA any stricter than those planned by the Canadians, or those planned for the US East Coast ports? Do the sulfur limits apply downstream of Montreal? What parts of the Lakes and St. Lawrence River are impacted?
Hull	With only 8 Category Three US Flagged Vessels, 57 Category Three Canadian Flagged Vessels, and numerous Category Three Foreign Flagged Vessels, the impact of the EPA ruling will fall mainly on Canadian and Foreign Flagged ships. Will the Canadian and Foreign Flagged ships require engine modifications too?

EPA Response:

The broad geographic area included in this study includes the five Great Lakes and the St. Lawrence Seaway. As explained elsewhere in this report, the transportation mode shift analysis, and therefore the actual area of shipping activity studied, is scenario specific. Sixteen O/D pairs were selected; vessel operating costs were estimated based on currently-used HFO and ECA-compliant distillate fuel. Then, freight rates were adjusted to reflect the increase in fuel operating costs. Operating costs were estimated for the entire trip, and are based on the assumption that the ECA fuel requirements are applied uniformly on the U.S. and Canadian sides of the Great Lakes.

As a result, in some scenarios activity may be limited to a small portion of one of the Great Lakes; for others, activity may reach from the western edges of the Great Lakes to the eastern limit of the St. Lawrence Seaway. There are 3 scenarios that include extensive operation on the St. Lawrence Seaway: Scenarios 6, 9, and 10. In addition, the supplemental analysis for the steel sector contained in Section 3.2.4 of Chapter 3 discusses the impacts on a foreign vessel transiting both the coastal and the Great Lakes St. Lawrence Seaway portions of the North American ECA.

Pursuant to MARPOL Annex VI, the ECA fuel sulfur limits apply to any ship, regardless of flag operating in a designated ECA. We clarify that these requirements apply to vessels operating in U.S. internal waters, including the U.S. portions of the Great Lakes, through our recent rulemaking under the Act to Prevent Pollution from Ships (see 40 CFR 1043). Therefore, the ECA fuel requirements apply on all U.S. portions of the Great Lakes and St. Lawrence Seaway.

The Canadian program to implement the North American ECA is still under development. To simplify the analysis, we apply the fuel operating costs associated with the ECA controls to the Canadian side of the lakes for those scenarios that contain operation in areas under Canadian jurisdiction. As a result, this approach is conservative. To the extent that Canada adopts a different approach with respect to the application of the ECA requirements to the Great Lakes, ship owners may have more flexibility in their compliance strategies. They may be able to use a combination of strategies that provide least-cost compliance with the fuel requirements on the relevant parts of the Great Lakes St. Lawrence System. For example, if a ship installs an exhaust gas cleaning system (scrubber) it may be possible to run it at different intensities on the U.S. and Canadian sides of the lakes. Note that such an option may not be available for ships operating on the St. Clair and Detroit Rivers between Lake Erie and Lake Huron due to the narrow shipping channel on these rivers and the frequent cross-overs between U.S. and Canada. This would require ships either to use compliant fuel for the entire length of that journey or leave any on/off technology "on."

It is difficult to say whether the fuel sulfur requirements will fall mainly on Canadian and foreign vessels. As explained in Chapter 1, while the Canadian fleet may be larger numerically than the U.S. fleet, the U.S. fleet is larger in terms of total tonnage and it carries more cargo.

8A.3. Steamship Applicability

Commenter	Comment
Hull	With steam engines being excluded from the ruling, is it likely that they will be more heavily used by ship owners so that they can avoid retrofitting Category Three vessels? Please confirm that steamships are PERMANENTLY excluded from the ruling or list any conditions attached.
Hull	Page 1-11: Please reconcile the following two seemingly contradictory sentences: 1) "…we excluded Great lakes steamships from the ECA fuel sulfur requirements." 2) "..allows Great Lakes shippers to petition EPA for a temporary exemption from the 2015 fuel standards, which can encourage repowering steam engines to……" Are steamships excluded permanently from the sulfur standards, or only until 2015?
Hull	I thought that steamships were permanently exempted from the ruling. The text indicates that a fuel waiver is available only until January 2015. Which is true? Please clarify.

EPA Response:

These comments refer to different parts of our compliance program with respect to internal waters (see 40 CFR 1043.95).

The special Great Lakes provisions contained in our Category 3 rule consists of three provisions: the exclusion of Great Lakes steamships from the ECA fuel standards; a general fuel availability waiver for to the 10,000 ppm fuel sulfur limit that is available for non-steamship Great Lakes Category 3 ships, and an economic hardship waiver.

With regard to the steamship provision, Great Lakes steamships are excluded from the ECA fuel standards. This exclusion is available for vessels propelled by steam turbine engines or reciprocating steam engines, provided they were operated within the Great Lakes before October 30, 2009 and continue to operate exclusively within the Great Lakes. This exclusion does not expire.

The fuel availability waiver applies to fuel meeting the 10,000 ppm fuel sulfur limit and is available to Category 3 Great Lakes vessels that are not covered by the steamship exclusion. The 10,000 ppm ECA fuel sulfur limit begins to apply on the Great Lakes when the North American ECA goes into effect, in August 2012, and continues until the more stringent 1,000 ppm ECA fuel sulfur limit goes into effect January 1, 2015. The Great Lakes fuel waiver is available if marine residual fuel meeting the 10,000 ppm sulfur limit is not available. Under this provision, it will not be a violation of our standards for a Great Lakes vessel operator to purchase and use marine residual fuel with sulfur content above 10,000 ppm provided the fuel purchased is the lowest sulfur marine residual fuel available at the port. There are some reporting requirements for this waiver.

With regard to the economic hardship waiver, this provision was included in the program to provide Great Lakes shippers a temporary exemption from the 2015 fuel sulfur standards. This waiver is not automatic; the ship owner must apply to EPA. As part of that application, the ship owner must show that despite taking all reasonable business, technical, and economic steps to comply with the fuel sulfur requirements, the burden of compliance costs would create a serious economic hardship for the company. The Agency will evaluate each application on a case-by-case basis, which must be submitted by January 1, 2014.

Finally, the ability of fleet owners to favor steamships over diesel ships depends mostly on how steamships are currently used and whether they can be used more intensely. The impact of such a change on freight rates, which is the focus of this study, is unclear. However, given the higher fuel costs of steamships and their small share of Great Lakes cargo capacity (15 percent of the number of vessels, 12.5 percent of tonnage; see Table 1-4 in Chapter 1) it is reasonable to ignore these potential effects in this study.

8A.4. Fuel Availability and Fuel Price

Commenter	Comment
Hull	Do sufficient quantities of MDO exist to support the C3 ruling? I assume so, but did not see this question addressed or analyzed in detail. This point should be cleared up to further establish the feasibility of the C3 Rule.
Hull	Page 2-15: You quote that MDO is expected to be 45.5% more expensive than HFO. Is that figure in $/ton for both MDO and HFO? How does the btu content of MDO compare with HFO? What is the comparison in $/BTU? I would think that the cost per BTU would be a more valid comparison of MDO and HFO.
Belzer	2-14: I wonder if they aren't using a per-barrel oil price that is too low to be "normal"? Using the 2007 price has the disadvantage of capturing a non-random point in time rather than a trend, and I would suggest an averaging or trend-based method across ten years or so.
Kruse	I don't see where the document addresses the concern the shareholders expressed regarding a potential spike in the price of the 0.1% sulfur fuel if there is a limited supply in the Great Lakes region when implementation begins.

EPA Response:

The availability of ECA-compliant marine fuel was discussed extensively in our Category 3 rulemaking and is not the subject of this study. See C3 Marine Diesel Rule, Final Regulatory Impact Analysis, Chapter 5, Engineering Cost Estimates, Section 5.6.4.3.4 Overall Increases Due to Fuel Switching and Desulfurization. See also the Summary and Analysis of Comments on the C3 rule, Section 4.5, Fuel Availability.

The fuel prices used in this study are described in Section 2.5.3.1 and are based on 2007 fuel prices reported by the U.S. Energy Information Administration (EIA) in the Annual Energy Outlook (AE) for 2010. Fuel prices for 2007 are used rather than projected fuel prices because freight rates are based in part on current fuel prices, not projected fuel prices for many years in the future.[C] These fuel prices are adjusted for the Great Lakes market (10 percent adjustment; see Section 2.6.3). Using a price based on a trend (e.g., 2000-2007), as suggested by the peer reviewer, would result in a lower price given the historic low price of HFO ($150-$175/ton for 2000-2005).

While fuel prices have increased over the last month or so due to instability in the Middle East, these price increases are not incorporated in the study. This is because it is not possible to anticipate any long-term market impacts particularly with regard to prices in 2015. In addition, oil price increase will affect the price of MDO for both marine and the land-based alternative, and therefore an increase in market prices is not expected to substantially affect the overall findings of this study. The analysis is based on the price differential between HFO and MDO, and historic price data suggest that the long-term differential between these fuels has been fairly constant outside periods of market adjustment. Finally, as noted by Belzer, "As the price of oil goes up, the greater efficiency of using the marine mode might provoke shift of freight to marine over rail; this would happen at the extremes of price when the cost of fuel is so great that it begins to trump the cost of intermodal handling needed to shift as much to marine as possible. This, however, would not change the conclusions of the analysis because it would drive freight toward, not away from the marine mode; it would not favor truck or even rail." In addition, Belzer notes "as long as fuel prices rise, systematic shifts likely will favor maritime over rail and rail over truck, so a low price probably leaves a very conservative result in this case."

[C] The prices for 2008 were not used due to the perturbations in the global fuel market that occurred in that year, and data for 2009 were not available.

8A.5. Scenario Selection

Commenter	Comment
Hull	Page 2-7: How did the EPA identify the stakeholders who provided the 50 O/D pairs? Who were the stakeholders? How did you winnow the list down to the 16 winners? Please provide a list of stakeholders either in the text or in an appendix. If the stakeholder list is confidential, please characterize them to the extent reasonable. The readers would like to know who was involved.
Belzer	2-7: As discussed above, this report does not clearly specify the basis on which the EPA chose the sixteen routes among the fifty routes provided to them by stakeholders. Except generally for an attempt to incorporate all four broad commodity groups, the basis for the selection of these particular sixteen O/D pairs is never explained. The choices are not random, which normally would be preferred.

EPA Response:

Section 2.4 of Chapter 2 of this report contains an expanded description of the method we used to select the 16 O/D pairs included in the study. As noted in that section, we solicited input from industry stakeholders both directly and through the primary trade organizations with respect to shipping routes that are at risk for transportation mode shift as a result of the fuel requirements contained in our Category 3 rule. We received suggestions for about 50 O/D pairs; we selected 16 and shared them with stakeholders asking them if they would like to replace any of the O/D pairs with a different route. We received no adverse comments on our selection.

Chapter 2, Appendix 2B has been modified to include the list of stakeholders who attended the June 10, 2010 EPA workshop. The invitation to that workshop was sent to a broad group including environmental organizations, a variety of industry stakeholders, states and port authorities, and individual citizens who had participated in our C3 rulemaking process. That list is not confidential but is too lengthy to repeat here. However, all comments made on the C3 rule are publically available at www.regulations.gov under Docket ID number EPA-HQ-OAR-2007-0121.

These 16 O/D pairs are not a random selection of possible Great Lakes shipping routes or of the 50 suggested O/D pairs. They were selected from the set of about fifty at-risk routes based on cargo type and geographic factors. As a result, these at-risk O/D pairs may not be typical and the amount of cargo shipped to these destinations may be only a small portion of total Great Lakes cargo in any one year. However, if fuel price increases of the magnitude expected from switching to ECA-compliant fuel on the Great Lakes do not indicate a transportation mode shift on these at-risk routes, where the price difference between the marine and the all-rail alternative is close enough to be of concern to stakeholders, then transportation mode shift on other routes without such price pressures would not likely be indicated. In his comments, Dr. Belzer notes that "EPA selected these cases systematically in an attempt to fairly represent a cross-section of trips about which the private sector was concerned. One might also be concerned, however, that the EPA selected these cases systematically to identify O/D pairs that would least likely to trigger the shifts. While the critique can be made, it is a thin reed because the results so strongly refute the contention that transportation mode shift, source shift, and production shift would occur from the higher fuel cost. The only case studied that might support this contention is the odd case in which coal travels almost as far on rail in the rail diversion case as in the default case, and unique circumstances must allow this route choice in the first place."

8A.6. Transportation Mode Shift – Methodology; Validation

Commenter	Comment
Hull	If you proceed with this analysis I urge you to add a validation step in which you select some of the sixteen origin/destination pairs, meet with the relevant stakeholder, and delve into details of the actual movements.
Hull	Since the EERA model is theoretical and actual routes and rates may differ, I would encourage a final validation of the model by selecting a subset of the sixteen scenarios and interviewing shippers/carriers for their input and perspective.
Hull	In Scenario 2, were the mine and paper mill stakeholders approached to try to better understand the situation? I think this might be a valuable way of validating the modeling approach, since the modeling approach did not seem to work. I recommend that you get into the details of Scenario 2 and talk with the shippers and carriers to find an explanation. Without such explanation, the result casts doubt on the results of the other Scenarios.
Hull	Scenario 2's Base Case looks crazy. I recommend that it be researched further. Why would anyone use a ship in this case? Does the base case reflect an actual movement? Is it possible that Georgia Pacific cant unload rail cars? Is the actual rail route the same as the one that the model chose? Is there an equity ownership involved?

EPA Response:

EPA validated the scenarios by sharing all of the data inputs used in the transportation mode shift analysis with stakeholders prior to performing the analysis described in Chapter 2. This includes the description of the transportation routes for the ship route and the all-rail alternative; the characteristics of the vessel carrying the cargo, and cargo transfer costs. All comments received were used to adjust the scenarios. While EPA solicited input on actual industry freight rates, stakeholders were unwilling to share this information with us as this is confidential business information and because these rates may vary not only by route but by freight customer.

Therefore, while a validation exercise with actual using facilities might be interesting, the main result of such a step would be simply to revise the characteristics of the scenarios.

The comments with respect to Scenario 2 are in reference to the results for that scenario as reported in the contractor report contained in Appendix 2C, which suggest that the route-based freight rate for the all rail alternative is less than both the Base Case or ECA Case freight rates.

The trade route that makes up Scenario 2 was recommended by a stakeholder who described it as coal from South Chicago to Green Bay that originates as western bituminous coal from, for example, Colorado. This stakeholder further specified that the coal is delivered to a paper mill in Green Bay. At the time the scenario was defined, we did not have details about the specific characteristics of the facility and we designed the route to be consistent with the other scenarios: transportation of coal from the mine head to the using facility. The scenario as specified was shared with all stakeholders and we received no adverse comment on its particulars.

The contrary modeling results for this scenario reported in Appendix 2C led EPA to perform additional research with regard to this facility. The information obtained by EPA indicates that, due to quality specifications for the coal used by this facility, the western bituminous coal used in this paper mill is blended with other coal to obtain the product needed.[2,3] The blended coal is frequently obtained from a source in South Chicago, where the KCBX Terminal can store up to one million net tons of coal on site and can blend up to three coals for a customer. Consequently, EPA believes this case was mis-specified.

We did not remodel this scenario based on a new definition of the route. We do not have the information needed to remodel, particularly with regard to the relevant freight rates for the Baseline Case and for the All-Rail Alternative. For example, Dr. Belzer noted that "[i]t is also possible that the route through South Chicago is inexpensive because trains handle so much volume from Elk Creek to South Chicago that the ton-mile cost is lower via that combined rail/marine route than via the direct rail route." In addition, it is unclear how the scenario should be modeled, to ensure consistency with the other scenarios. To be consistent, it would be necessary to include transportation costs from the coal mine; however, it is not clear how this could be done, particularly with respect to the cost of transporting coal from the terminal in Chicago to the facility in Green Bay. Specifically, we do not have a mechanism to allocate the transportation cost from the mine head(s) to the total route scenario. This question could be important because this facility also receives coal by ship from Sandusky and Ashtabula, Ohio, and vessels operating from those facilities are also required to use ECA-compliant fuel. For the reasons stated here and in Chapter 2, it is not possible for this study to assess the potential for transportation mode shift impacts for this route.

8A.7. Source Shift Analysis: Stone Scenarios

Commenter	Comment
Kruse	I have strong concerns about the methodology used for crushed stone. On page 3-3, the next-to-last paragraph states "It also does not examine the reason why the purchasing facility uses stone originating at a much longer distance, requiring ship transportation, when stone from local quarries may be available." The existence of this situation in the "real world" invalidates the methodology used in the document. Users are importing stone from great distances for a reason. To simply expand the "competitive radius" as the basis of the analysis ignores this consideration. If the stone is being imported from a specific quarry, then the inclusion of quarries producing similar quality/grade stone needs to be evaluated rather than just looking at quarries generically.

EPA Response:

EPA used the methodology used by the Canadian Shipowners' Association in their 2009 study (see Section 1.6.3.2 in Chapter 1), which also does not consider the grade of stone at the different quarries. See response under 8A.7.2 for more about stone quality.

8.A.7.1 Qualitative Comparisons

Commenter	Comment
Kruse	The conclusions were appropriate and justified, taking into account the data sources and inputs employed for the analysis. There were just two instances, where I felt the conclusions needed to be shored up. On pages 3-5 and 3-6 statements are made to the effect that “the increase is not substantial compared to the number of quarries already located within the radius.” This is a subjective statement that needs to be validated with numbers/data.

EPA Response:

The analysis is based on the change in the competitive radius around the stone using facility, and considers the number of quarries within the original radius and a revised radius that reflects the increase in ship transportation costs. There are two ways to evaluate the impacts of an increase in the competitive radius. The first is to consider the number of additional quarries that are included in the expanded radius. Referring to the maps in Chapter 3, it is clear that for Scenarios 13, 14, and 16, the number is small when compared to the number of quarries within the distance. A count of the quarries for Scenario 15 reveals that approximately 2 more quarries are added to the competitive radius, which is an addition of about 22 percent.

The second way to evaluate the impact of an increase in the competitive radius is to examine increase in the distance from the using facility. We performed this analysis for the four stone scenarios and added it to Chapter 3. For all four scenarios, this increase is very small, 11 miles for Scenario 13, 10 miles for Scenario 14, 15 miles for Scenario 15, and 13 miles for Scenario 16. In fact, it is possible that quarries located within such a marginal extra distance can already compete with the quarries within the base case competitive radius. For example, in Scenario 15 (stone to American Crystal Sugar Company, MN) about 2 additional quarries would be drawn into the market. However, given the increase in round-trip distance of only 15 miles, those quarries may be considered competitive with the existing quarries even without the increase in ship freight rates. The additional 15 miles would increase the fuel costs per trip by about 3 percent, and total operating costs by about 1 percent. Averaged over miles in the original competitive radius, the increase in fuel costs is about $0.06/gallon/trip, which is well within the fluctuation of diesel fuel prices. Therefore, including these quarries in the revised competitive radius does not significantly change the competitive nature of this market. Table 8A-1 presents the results of this analysis for the other three stone scenarios, with similar results.

Table 8A-1 Stone Scenario; Fuel Costs Associated with Increase in Competitive Distance

	Scenario 13	Scenario 14	Scenario 15	Scenario 16
Transport price 1 truckload	$468	$383	$518	$280
Fuel costs for 1 truckload	$188	$154	$208	$113
Increased mileage round trip	11	10	15	13
Additional fuel for longer trip (gal)	2.2	2.0	3.0	2.7
Increased fuel costs for longer trip	$4.50	$3.98	$6.05	$5.36
Increased in base fuel costs ($/gal)	$0.05	$0.05	$0.06	$0.10
% increase in fuel costs for longer trip	2.4%	2.6%	2.9%	4.8%
% increase in total costs for longer trip	1.0%	1.0%	1.2%	1.9%

8.A.7.2 Data Assumptions

Commenter	Comment
Kruse	In Chapter 3, is the assumption of a truck load of 43 short tons valid if the quarry is located in the United States?
Kruse	I have strong concerns about the methodology used for crushed stone. On page 3-3, the next-to-last paragraph states "It also does not examine the reason why the purchasing facility uses stone originating at a much longer distance, requiring ship transportation, when stone from local quarries may be available." The existence of this situation in the "real world" invalidates the methodology used in the document. Users are importing stone from great distances for a reason. To simply expand the "competitive radius" as the basis of the analysis ignores this consideration. If the stone is being imported from a specific quarry, then the inclusion of quarries producing similar quality/grade stone needs to be evaluated rather than just looking at quarries generically.
Hull	I felt the crushed stone analysis was quite good though it needs a review of its underlying data sources.
Hull	Section 3.1: Source Shift (Crushed Stone): I assume that power plants run a combination of trucked and ship/railed stone? Michigan's high calcium carbonate and low bond work index seems to be valuable because of its chemical properties for use in scrubbers. Further I assume that a ton of Michigan stone, because of its unique chemical properties, must replace more than one ton of locally quarried stone. If this is true then we would want to encourage the use of long distance Michigan stone to reduce the number of truckloads of lower grade local stone.
Hull	Stone shift analysis is stated as problematic, even by the authors, due to factors not included in the analysis. I happen to like the analysis a lot, but it makes several simplifying assumptions which need to be examined and validated, such as the use of theoretical transport costs from origin to destination, the assumption that highways are "straight line", that Michigan specialty stone replaces local quarry stone on a ton for ton basis, and that heavy trucks are allowed on US highways. These assumptions need to be reviewed, but found the analysis otherwise very interesting.
Hull	The study states that the analysis is problematic because of factors not included, as listed in the last paragraph on Page 3-8. Still further, the shift analysis hinges on theoretical rail/water cost figures. Despite all that I think this is a very interesting approach.

<u>EPA Response</u>:

The discussion in the last paragraph on page 3-8 is a discussion of the Canadian Shipowners' Study, not the EPA study. We corrected the text to clarify this.

We performed an analysis of the emissions impacts of the shift; see Section 3.3 of Chapter 3. Dr. Hull is correct that the analysis relies on the rail/water freight rates reported in Chapter 2. This is appropriate as the intent of the study was to estimate the impact on freight rates of an increase in fuel costs associated with the application of the ECA on the Great Lakes.

To respond to the comments about truck size and distance to the quarry, we performed three sensitivity analyses, with respect to the size of the truck load, the truck freight rate, and the truck route. These results are reported in Table 3-4 of Chapter 3. This analysis shows that a smaller delivery load (20 tons instead of 43 tons per truck), a more expensive truck freight rate ($20/ton), or a less direct route between a local quarry and the using facility (represented by an increase of diversions along the truck route by 10 percent) all reduce the competitive radius around the using facility. However, for each of the sensitivity analyses, the change in competitive radius remains about the same, less than 10 miles, and is not large enough to change the competitive nature of the relevant market.

EPA received comments during our rulemaking process that the quality of Michigan stone makes it "attractive to power plants and manufacturers far inland as it contains a high percentage of calcium carbonate (over 97 percent) that scrubs more SO_2 with less stone."[D] However, we did not conduct a sensitivity analysis with regard to additional tons needed to compensate for the quality of stone, because the amount of additional tonnage is not known and may vary by facility. It is possible that some power plants have choices in the quality of scrubber stone used to achieve the required sulfur dioxide emissions limits. Customers choose stone based on many factors, including the power demands on the pumping system of circulating the reagent slurry in the correct ratio to the flue gas flow (need more power for higher liquid to gas ratio with lower calcium content), as well as tolerances for variations in pH to minimize unacceptable scaling or corrosion.

EPA assumed that all identified quarries within the selected competitive radius are potentially equally competitive. The effect of considering only those quarries that can provide stone with a given calcium content, for example, would be a decrease in the total number of truly competitive quarries. It is beyond the scope of this analysis to investigate the tolerances of the using facilities or the quality of limestone at each mapped quarry. Qualitatively, if the total number of truly competitive quarries were reduced, then the number of additional quarries becoming competitive due to the ECA fuel prices could be a higher proportion of the total.

8A.8. Air Emissions Comments

Commenter	Comment
Hull	Further, if a shift from rail/water to truck occurs, the emissions consequences of this shift should be calculated and be included in the analysis.
Hull	If the Bruce Mansfield Power Station is expected to see a partial modal shift, we should find out if the increased emissions of the additional trucks offset the emissions savings of the C3 ruling. Also, if the Power Station is outfitted to unload cars with few emissions, a conversion to truck may increase them. It wouldn't hurt to talk directly with the Station about their supply sources to validate your analysis.
Hull	In the scenarios, does a switch from the Base Case Route to an All Rail route involve more emissions at destination? That is, for example, does a power plant emit more when it unloads rail cars or a ship? If this is true, is this factored in anywhere?

EPA Response:

EPA has estimated the emissions consequences of both a shift from the base water/rail route to an all-truck route (Scenarios 13-16) and a shift to an all-rail route (Scenarios 1-5, 7-12). Although the transportation analyses indicate that neither type of shift is likely, the potential

[D] See comments of the Great Lakes Maritime Task Force. EPA-HQ-OAR-2007-0121-0269. See also discussion in Chapter 7 of this report, page 7-56.

emissions impacts are described in Section 3.3 of the report. Further, Section 3.3 has been revised to incorporate responses to the above comments.

As explained in Section 3.3, the emissions analysis does not include emissions from loading and unloading operations. We focused on the transportation emissions from the main propulsion engines. Consistent with the methodology of the transportation analyses, which excluded the costs of the first loading at the origin and final unloading at the destination, the effects of those initial and final transfers have been deemed outside the scope of this analysis.

To include all transfer emissions would entail quantifying not only the emissions from material handling equipment operated at origin and destination, but also emissions at the intermediate transfer points, the additional engine idling emissions as well as the fugitive dust PM emissions during cargo transfer.

Looking at the scenarios, there were seven where the alternate case assumed the same mode as the base case at the origin (first leg of journey was by rail for both cases); four scenarios where the final leg of the journey used the same mode under the alternate case as the base case (product delivered to end user by rail for both cases), and three scenarios where the intermediate number of transfer points along the journey did not change with mode (uni-modal under base and alternate cases).

As noted in Section 3.3.1, EPA does not have specific information indicating whether the land-based material transfer emissions rates are greater or less than the vessel-based loading/unloading emissions rates. For the scenarios where there is either a higher number of intermediate transfer points under the base case, or an increase in use of land-based transfer equipment as well as engine idling at either the origin or destination, or both, the total trip-based emissions could either be greater or less when including all material handling emissions. If these all-inclusive trip-based emissions were less under the alternate case, then this analysis may understate the emissions benefits of any possible mode shift. If they were greater, then the adverse emissions impacts of any mode shift, should it occur, may be underestimated.

One could also imagine that any increased truck or rail traffic could lead to more congestion-related vehicle emissions, and that both a rail and a truck alternative could have the effect of shifting the source of the emissions closer to some population centers.

Section 2.4.2.4 describes how we validated the stone scenario routes. Our sources indicate that the sugar factory and one of the two power plants have rail access, and both power plants can receive stone from river barges.

8A.9. Production Shift: Electricity and Steel

8.A.9.1 Cost of Production

Commenter	Comment
Hull	Section 3.2: Production shift (Steel and Electric): Low cost steel and electricity producers typically run at capacity, while high cost producers expand or contract their production to meet the ups and downs of demand. By increasing the transportation cost of the inputs, we put the Great Lakes producers into the higher cost category, and as such they may lose production at times to the lower cost producers. This is probably a difficult concept to quantify. The classic example of such a potential shift is the new Thyssen-Krupp steel mill in Mobile. Thyssen has water access to the Midwest for its steel through the Tennessee-Tombigbee Waterway, and would like compete with the Midwest producers. As a new state of the art facility, they are high volume, low cost producer. Thus, perhaps the Great Lakes producer does not go out of business, but he will likely lose some business at the edge of his/her marketing area to companies such as Thyssen-Krupp

EPA Response:

As Dr. Hull notes, it would be difficult to quantify whether the additional transportation costs would place Great Lakes steel producers into the higher cost category. This would likely require an in-depth analysis of steel producing facilities near the Ohio and Mississippi rivers and southern Ontario and Quebec. Nevertheless, it is unlikely that a production cost increase of the magnitude expected by the application of the ECA requirement to the Great Lakes would put Great Lakes steel producers in the high cost category. Although the freight rate in terms of cost per cargo-ton is estimated to increase by up to 16.6 percent, it should be remembered that the transportation of iron ore is only one input to the cost of making steel, and the impacts of the increase in transportation costs in terms of steel industry revenues is estimated to be about 0.10 percent. As illustrated in Figure 3-4 of Chapter 3, steel price fluctuations have been larger than the estimated increase for iron ore transportation costs.

8.A.9.2 Coal Movements for Electric Sector / Revenues

Commenter	Comment
Hull	Section 3.2.2: Impact on Great Lakes Sector: The Rosebud Mine is used for the lower and upper bound scenario and applied to electrical generation for the entire Lakes region. This is certainly a conservative assumption, since lots of the coal used does not even move by water, and some electricity is not generated by hydroelectric rather than coal. You might mention this in the text. Further in your analysis, you relate the transport cost increase to reduced electricity revenues. How do you calculate this inverse relationship? Is it a price elasticity argument?

EPA Response:

We made the notation in the text with respect to coal movement by rail and hydroelectric generation.

The analysis is not related to reduced electricity revenues. Rather, we attempt to put the increase in transportation costs in context by comparing them to revenues in this sector. The increase in freight rates for coal transportation is estimated to be about 0.5 percent, which is less than the fluctuation in retail prices for electricity for the Great Lakes region, as illustrated in Table 3-5 of Chapter 3.

8.A.9.3 Coal Transport Costs

Commenter	Comment
Hull	Your argument in the last paragraph of Page 3-10 is difficult to follow. Please explain more fully how you separate the transport cost from the EIA figures. My understanding is that you use average figure for mine costs in East North Central, and subtract it from the "delivered coal cost." Also, once you have subtracted the transport component, you must have to back out the percentage trucked and direct railed. Finally in using your baseline case freight rate, you are using the Rosebud Mine as indicative of the Midwest industry. I somehow am not understanding your argument or I am overthinking it. Please clarify for me and for others. It would be helpful if you would add some columns to Table 3-4 so that one could more easily follow your argument. Also, in the table you distinguish between public utilities versus independent power generators – but you don't distinguish between them in the text. Please expand this section

EPA Response:

We included additional explanatory text in Chapter 3 and revised Table 3-4.

The EIA regional data for the electricity sector reports only delivered coal cost; it does not provide separate data for coal cost at the mine and coal shipping cost. Therefore, to perform this analysis we used EIA reported 2008 U.S. national average coal cost at the mine to approximate coal cost at the mine for the Great Lakes region. Using this method, shipping costs would be about 39 percent to 45 percent of "delivered coal cost," and increasing in shipping costs by about 1.2 percent to 4.47 percent would be equivalent to increasing "delivered coal cost" by about 0.47 percent to 2 percent. It should be noted that this increase in "delivered coal cost" does not back out the other transport component such as the percentage trucked and direct railed, since we do not have this information.

8.A.9.4 Elasticity

Commenter	Comment
Hull	The argument is compelling but not complete in that you show that the MDO cost increase is a small percentage of revenues. However, as a percent of transport cost it can be between 8.5-16.6% for iron ore and 1.2-4.5% for coal. A company is quite capable of changing their shipping decisions based on such percentage increases in cost (especially for the iron ore percentages). A company's shipping decisions are typically designed around minimizing manufacturing and transport costs. Revenues are calculated separately. If a steel company has no choice it may have to pay the difference, but the steel manufacturing decision may result in producing a bit less at the now-higher-cost Great Lakes plant and more at another plant.

EPA Response:

It is difficult to predict what a particular company would do in response to a freight rate increase for iron ore or coal of the magnitude estimated by this study. As we illustrated in Chapter 3, the impacts are expected to be small both in terms of industry revenues and historic price variations for electricity and steel. In addition, while it may be the case that a company may change shipping decisions based on increases in freight rates of this magnitude, there may also be many reasons why such a change may not be feasible, including the use of established supply chains and infrastructure, making it more reasonable for the company to pass on the costs instead of incurring the costs associated with changing these established ways of doing business.

In addition, Dr. Belzer notes that "the small increased price for steel would be absorbed in down-market competition, so you are correct to conclude that it's negligible. Commenting also on the table, and repeating what has been said above, for all these commodities except perhaps stone, the marginal increase in cost for the transportation service will be swamped by the rising costs of the commodity globally."

8.A.9.5 Coal Movements for Steel

Commenter	Comment
Hull	My understanding is that Great Lakes coal movements are almost exclusively destined for power plants and almost none is used in steel production (steel companies usually use coke with is rail supplied). There are a few exceptions, like the Rouge steel plant in Detroit which occasionally received a shipload of metallurgical coal, but there aren't many. Your table in this section seems to indicate that Great Lakes ships DO consume coal delivered by Great Lakes ships. This should be changed.

EPA Response:

We removed coal from the steel analysis.

8.A.9.6 Steel Raw Material Costs

Commenter	Comment
Kruse	What is the basis for the assumption that 80% of the delivered iron ore cost is the "iron ore cost at the mine"?

EPA Response:

Without having specific freight rate and cargo data from stakeholders it is difficult to say with certainty what portion of the price of delivered ore is the cost of iron ore at the mine. However, the USGS reports the value at the mine ($/metric ton) of iron ore in the United States has varied between $37.92 and $70.43 for the years 2004 through 2007[4]. Using our estimated base case total freight rate, we estimate that shipping costs would vary between about 6 percent and 30 percent of the total price of iron ore. Therefore, 20 percent is a mid-range value. This is a conservative estimate given the higher value of iron ore at the mine in recent years.

8A.10. Production Shift: Supplemental Steel Analysis

8A.10.1 Quotas

Commenter	Comment
Kruse	Would steel import quotas have an effect on this analysis? If so, that should be analyzed.

EPA Response:

To the extent steel quotas keep steel prices - and therefore steel revenues - high, then the impact of steel quotas on the analysis would result in the fuel cost increase being relatively smaller than for a market with competitive steel prices. It should be noted, however, that the analysis takes the market as given and does not try to separate out the impacts of steel quotas on the results.

8A.10.2 Linear Flow Model

Commenter	Comment
Hull	I encourage the EPA to consider the following approach to the steel industry analysis: develop a linear program that models the mills on the Great Lakes and elsewhere and optimizes flows from mills to market. Next, perform a sensitivity analysis on the water transport costs to determine the extent to which MDO usage shifts steel manufacturing away from the Great Lakes to other steel centers. I am concerned that increased MDO costs might result in global steel companies shifting production (to greater or lesser degree) from Great Lakes mills to their other mills. With the depressed state of the “rust belt” we don’t want to lose any more jobs.

EPA Response:

This study was performed in response to comments on our Category 3 marine rule. As summarized in Chapter 1 of this study and in the Summary and Analysis of Comments document prepared for our final rule[5], Great Lakes stakeholders expressed concern that the application of the ECA fuel requirements to the Great Lakes would lead to transportation mode shift and result in increased emissions in the Great Lakes region. Stakeholders were also concerned that an increase in transportation costs would result in steel and electrical production moving out of the Great Lakes region.

In support of our final rule we performed an analysis of the impact of increased transportation costs associated with the ECA for steel that is manufactured in Indiana Harbor (IN) and for use in Detroit (MI).[6] With respect to steel, the increased cost for transporting iron ore and limestone to Indiana Harbor was compared to steel imported from Europe. The analysis showed that the additional fuel costs associated with using ECA-compliant fuel are smaller than the cost of importing steel to Detroit, either through the St. Lawrence Seaway or by rail from an East Coast port. Chapter 3 of this study expands on that analysis and shows the impact of higher fuel operating costs associated with transporting iron ore in the Great Lakes using ECA compliant fuel is small, about 0.1 percent of sector revenues. This is less than the annual fluctuation in steel prices.

We did not use a general equilibrium model in this analysis, or a linear flow mode. Available general equilibrium models typically estimate impacts across an economy as a whole and are not constructed in a way that would allow analysis of specific transportation links or examination of the extent to which the raw materials and goods currently transported by one mode (ship) would shift to another (rail or truck). It would also not be feasible to construct a model for the purpose of this study as these models also require a great deal of data and information for potentially hundreds of submarkets.

While a linear flow model would be more targeted to the steel industry, it would also require a great deal of information about steel production and use through the Great Lakes region, the relationship between producers of raw material inputs, steel producers, and steel user for the entire country, as well as detailed information on exports and imports. However, given that transportation costs for iron ore are only one part of the cost of iron ore, which is only one input into the steel making process, we determined that developing a full-scale model of this economic sector was not necessary, particularly given the small estimated impact on iron ore freight rates (8.5% to 16.7%, depending on the scenario). This increase on its own is unlikely to cause steel production to shift out of the Great Lakes region, especially given the cost of creating or modifying steel production facilities in other locations (assuming there is enough excess capacity available to cover all the steel production in one or all Great Lakes steel mills), the cost of developing new supply chains and infrastructure, and the cost of transporting steel to manufacturers in the Great Lakes region who use it as an input.

8A.10.3 Consideration of Steel Coil/Grain Movements

Commenter	Comment
Hull	A further factor to include in your steel industry analysis: Steel imports from Northern Europe to the Midwest are highly dependent on grain backhauls (steel ships need a grain backhaul to justify the inbound steel movement). To the extent that MDO usage reduces the availability of grain backhauls while simultaneously increasing the cost of steel fronthauls, steel movements into the Great Lakes become less economic. Eliminating the steel coil imports weakens the steel industry, because the European made steel coils are purchased for specialty uses.
Hull	6. Impact of global marketplace is not included in the study, but should be included because it is the “growth business” of the Seaway. The Great Lakes has a significant quantity of captive business with iron ore, limestone, crushed stone, coal, and internal grain movement. However, these businesses have been on the decline since before 1990, and any growth for the Great Lakes/Seaway will necessarily come from increased import/export. Currently grain is exported (significant quantities this fall!), and steel coils/slabs have been imported for the past 50 years (using FedNav, Polsteam, and Wagenborg – none of whom is included in the study). Further, moves are afoot to deliver international containers to the Great Lakes (the Ports of Cleveland, Toledo, Erie/Conneaut, Ashtabula are all studying this, and Great Lakes Feeder Lines, McKeil Marine, and Wagenborg are interested carriers). Since this would create a significant number of jobs in the depressed “rust belt” and since this business would take trucks off the road, I believe that it should be included in the study. Here are three components that should be included:

Commenter	Comment
	a. Grain from the Midwest is shipped abroad via three main routes – by ship through the Great Lakes/St Lawrence, by rail to the US West Coast for loading to China, and by river barge down the Mississippi for export from New Orleans. My understanding is that the route chosen is highly dependent on transport rates, and small rate changes can have a major impact on choice of route. Would a requirement to burn MDO both ways on the 2000+ mile journey have a significant negative impact on the amount of grain routed through the Great Lakes? Page 7-26 of the study states that 70% of grain on the Great Lakes is destined for export, so this is an important case to be considered in the body of the report. Grain is an important export and should be explicitly analyzed. b. Steel coils are imported into the Great Lakes in the following manner. A breakbulk ship (typically FedNav, Polsteam, or Wagenborg) loads steel coils in Northern Europe for a variety of Great Lakes customers. The ship then crosses the Atlantic and transits the Seaway to discharge partial cargos at Cleveland, Detroit, and Burns Harbor. When finished discharging, the ship picks up a grain backhaul and returns to Europe. Two issues need to be addressed: i. If use of 100% MDO on the entire Great Lakes/Seaway route has a significant negative impact on availability of grain backhauls, will steel coil imports become uneconomic? ii. If the use of 100% MDO makes the (fronthaul) delivery of steel coils through the Seaway less economic, steel coils will likely be diverted to the East Coast ports for an overland rail/truck leg to Midwestern customers. (this is an alternative Midwestern route used by steel companies) In this case, the system generates more emissions from rail/truck. This alternate route is also considerably more expensive (that's why the all-water route to the Midwest is preferred) which then reduces the viability of the existing Midwestern steel companies.
Hull	I believe that you should include a category for imported steel coils/slabs in addition to coal, iron ore, crushed rock, and grain, because there are an appreciable number of steel coils imported into the Midwest from Northern Europe by ship. This would involve a breakbulk ship delivering steel coils from Northern Europe to the steel companies in Cleveland/Detroit/Burns Harbor, typically using a three port discharge, with a grain backhaul. This breakbulk ship voyage should be compared with another similar voyage to the East Coast for delivery to the same destinations by rail. Midwestern steel companies use both routes. I am concerned that the need to utilize MDO for the entire Seaway voyage will eliminate the Seaway route in favor of the water/rail route (which increases emissions and cost).
Hull	I think the steel issue is one of extent, rather than one of relocating. A large, global steel company faces a worldwide demand and meets it with least cost. Thus if one of the steel mills owned by the global company experiences an increase in its transport cost to market, that mill will manufacture less, and another lower cost steel mill located elsewhere will manufacture more. Thus, a GL transport price increase would likely reduce the shipments "somewhat" rather than result in an immediate relocation. The amount of the reduction is often measured by a linear program.
Hull	FedNav (Canadian flag and FF ship operator), Polsteam (Polish flag), and Wagenborg (Dutch flag) are breakbulk operators who operate a significant number of vessels between the Great Lakes and abroad. FedNav also operates within the Great Lakes. FedNav, in particular is a major ship operator headquartered in Montreal. They should be included in Table 14 and in the analysis. These are "salties" that bring steel coils into the Seaway and export grain.

EPA Response:

This report was not intended to look at the impact of the application of the ECA program to the steel industry; it was intended to look at the impacts of the program on Great Lakes shipping. We looked at the four main cargoes transported on the Great Lakes: Iron ore, coal, crushed stone, and grain.

We did not look at the impacts of this program on specific industrial sectors in the Great Lakes region. Our analysis of production shift was intended to examine the fuel cost increase expected from the application of the ECA to Great Lakes Shipping in comparison with total revenues for specific sectors to explore whether these freight rate increases are large enough to have a significant impact on the industrial sector, as measured by revenues. That analysis shows that the expected transportation cost increase as a percent of sector revenues is within historic price variations and therefore no production shift is indicated.

We also included a supplemental analysis with respect to imported steel because stakeholders were concerned that the additional transportation costs on the Great Lakes would shift steel production offshore. Our analysis shows this is unlikely because the increase in transportation costs for steel inputs on the Great Lakes is less than the increase for transporting a ton of steel through the North American ECA and Great Lakes St. Lawrence Seaway (see Table 3-7 of Chapter 3).

This supplemental steel analysis only considers ship traffic in one direction and assumes that the vessels will perform useful work on the return voyages (i.e., there is a backhaul; one peer reviewer (Hull) indicated that the backhaul for steel coils is typically grain. If we were to assume no backhaul for either the domestic or the imported steel case, this would increase the estimated transportation costs but the increase would apply to both cases proportionally and therefore no production shift would be expected. If we were to assume a backhaul for the imported steel but no backhaul for the domestic steel, this would increase the estimated transportation cost for the domestic case but a production shift would still not be expected. Since the empty backhaul would consume less fuel (due to the lighter load), the transportation cost increase for the round-trip domestic case would be less than double the one-way case and therefore the price impacts for the domestic case still would be less than the imported steel case with a backhaul.

While the analysis was not intended to examine the imported steel coil market specifically, it suggests that even if the fuel costs for the entire ECA trip, inbound and outbound, were placed on the imported steel, this would represent an increase of approximately 0.6 percent in the cost of a ton of steel. This increase is still low compared to price fluctuations for the entire steel industry. Also, because steel transportation costs are only one element of total input costs for goods produced using steel, this is not likely to have a large impact on steel consumers, especially those that use higher-priced specialty steel.

Finally, grain backhauls on these routes between North America and Europe are a discount on shipping costs in that they allow the ship owner to generate revenue on the return voyage. These grains backhauls to Europe are not expected to cease because these backhauls reduce the costs of the return trip in that they generate revenue that an empty backhaul would not.

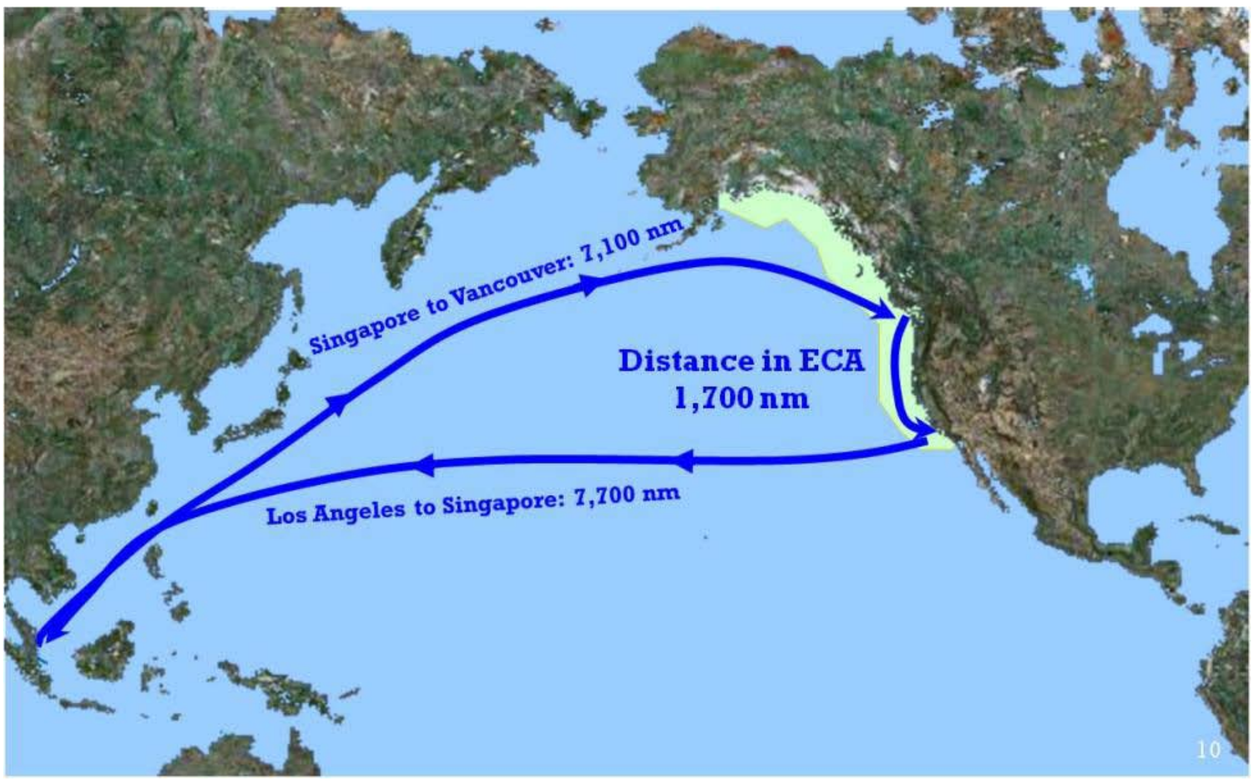
8A.10.4 Trans-Pacific Routes

Commenter	Comment
Hull	Page 3-15: The statement is made that a trip from Asia to LA can involve 1700 miles of North American ECA transit. How can that be? I thought that the NA ECA extended to 200 miles offshore only. If such a route exists, is it likely that that captain would take it when he can burn HFO for only 200 miles?

EPA Response:

While the Pacific region of the North American ECA is not the subject of this study, Figure 8A-1 illustrates the distance between Asia and Los Angeles through the ECA. Our Category 3 rule contains a discussion of the routes taken by ships in this area, based on ship traffic densities (see Chapter 3 of the RIA, Figure 3-3 and associated text).

Figure 8A-1 North American ECA Pacific Route



Source: EPA

8A.10.5 Steel Costs

Commenter	Comment
Hull	Page 3-17: Please check the fuel cost increased for the imported steel case. It seems to me that if imported steel moves through the North American ECA, all the way (1500 miles or so) down the St Lawrence and into the Great Lakes, that utilizing MDO at a 40% or so premium above HFO would significantly increase the transport cost. However, the figures on Table 3-7 do not reflect this, if true.

EPA Response:

The calculations contained in Table 3-7 are based on the fuel prices in the Category 3 rule RIA (not the newer adjusted Great Lakes fuel prices) and are based on the following logic. The Great Lakes Maritime Task Force indicates that a ship can move 607 ton miles per gallon of fuel. Based on a density of 270 gallons per metric ton, this yields about 164,000 ton miles per metric tonne of fuel. At a price increase of $322 per metric tonne, we get a baseline fuel cost of roughly $0.0020 per ton-mile. A 40% increase on this is $0.0008 per ton-mile, which compares well with $0.0009 per ton-mile contained in Table 3-7.

This calculation does not take into account differences in density and energy content of the two fuels. When these are considered, the estimate decreases to about $0.0007 per ton-mile.

When the analysis is performed with the adjusted fuel prices for the Great Lakes ($424/tonne for HFO and $617/tonne for distillate), this results in an estimated increase of $0.0010 per ton-mile.

In summary, the estimated cost increase in Table 3-7 is a little overstated because it did not account for the differences in energy content between HFO and distillate fuel. However, using the updated Great Lakes fuel costs, the estimated cost per ton-mile increases slightly compared to what was reported in Table 3-7.

8A.11. Impacts of Fuel Sulfur Controls on Emerging Markets - Containers

Commenter	Comment
Hull	In addition to the two pronged approach described above, I feel strongly that the EPA should add a third prong: the impact of MDO usage on the potential all-water imports and exports through the Great Lakes/St Lawrence – this is potentially a significant growth industry for the Great Lakes. Here is the business opportunity for Midwestern cities located near the Great Lakes: The St Lawrence Seaway lies geographically on a straight line between the Midwest (large consuming population and industrial heartland), and Rotterdam/Antwerp (two of the largest world ports). This route has been cost effectively used by the steel industry for the past 50 years for importing steel coils from Northern Europe, but it is rarely used for general merchandise. (I will discuss the reasons with you if you wish) Based on the minimum mileage character of this straight line and the low cost of all-water transport, this route could benefit a host of imports/exports. As such, it is widely recognized as a potential growth business. Great Lakes ports, shippers, and carriers are studying ways to initiate service.

Commenter	Comment
	This is a MAJOR OPPORTUNITY for the EPA to reduce emissions in the Midwest and East Coast: As a large manufacturing and consuming region, the Midwest imports and exports considerable quantities between Midwestern cities and Europe. The routes currently used, though, require an overland leg by rail or truck (generating major emissions) between the Midwest and either Montreal or US East Coast ports, and then a waterborne leg between Montreal or East Coast ports and Rotterdam/Antwerp/Europe. If imports/exports were channeled through the all-water route, we would reduce emissions in the Midwest and East Coast, save transport costs, and take trucks off the roads. This would have a significant positive impact both to the Great Lakes as well as the East Coast environment. The Rhine River is an excellent example of such a working system, because the Rhine handles much of Europe's commerce, reducing overland journeys through Europe by truck and rail, and significantly reducing emissions throughout Europe. Relevance to the current EPA study: Montreal successfully competes with the US East Coast ports for deliveries to the Midwest, and approximately half of Montreal's imports are destined for the US Midwest. Many Great Lakes ports, shippers and water carriers are evaluating the all water service to Europe described above. (few such services exist and I would be happy to discuss this further with you). Will the higher cost of MDO discourage the development of these many opportunities, giving further advantage to the high emissions overland routes to East Coast ports and Montreal? In summary, with the internal Great Lakes industries in decline, we should encourage growth of new business opportunities, such as import/export – especially since this growth simultaneously cleans up the environment. The C3 study should address this topic.
Hull	The EERA study addresses the impact of 100% MDO on internal Great Lake movements. With the Great Lakes industries on the decline, the study needs to consider the global marketplace and present and potential import/export opportunities, which is, after all the growth opportunity for Great Lakes as well as the rest of the economy.
Hull	6. Impact of global marketplace is not included in the study, but should be included because it is the "growth business" of the Seaway. The Great Lakes has a significant quantity of captive business with iron ore, limestone, crushed stone, coal, and internal grain movement. However, these businesses have been on the decline since before 1990, and any growth for the Great Lakes/Seaway will necessarily come from increased import/export. Currently grain is exported (significant quantities this fall!), and steel coils/slabs have been imported for the past 50 years (using FedNav, Polsteam, and Wagenborg – none of whom is included in the study). Further, moves are afoot to deliver international containers to the Great Lakes (the Ports of Cleveland, Toledo, Erie/Conneaut, Ashtabula are all studying this, and Great Lakes Feeder Lines, McKeil Marine, and Wagenborg are interested carriers). Since this would create a significant number of jobs in the depressed "rust belt" and since this business would take trucks off the road, I believe that it should be included in the study. Here are three components that should be included: [Grain and steel coils; see response to Production Shift: Supplemental Analysis, above]

Commenter	Comment
	c. Containers: Containerships transit the Seaway as far as Montreal. At that point, the containers are transloaded to truck and rail for delivery to Canadian and US customers. The truck/rail movements generate high emissions. My understanding is that approximately half of the containers are delivered to the US. At present there are several moves afoot to extend container deliveries into the Great Lakes by water, possibly directly from Europe or by transloading containers to feeder ships or barges in Montreal or Halifax (the Ports of Cleveland, Toledo, Erie/Conneaut, and Oswego are the interested ports and Wagenborg, Great Lakes Feeder Lines, and McKeil Marine are interested carriers). Such a service would reduce SOX, NOX, and particulate emissions because it would replace rail and truck deliveries from Montreal and the East Coast. Would the 100% MDO ruling make this opportunity uneconomic?
Belzer	1-4: I am skeptical that the Great Lakes waterways would be an economically acceptable routing for intermodal short-sea container shipping. No container ships have been built for the Great Lakes and they probably could not hold more than two hundred containers, so this would only work for bulk shipments by container. No container ports exist on the Great Lakes. Containers more likely will travel by rail.
Hull	I would like to ask the author a further question … to deliver breakbulk material such as steel (but of any type), what will be the increased cost of Seaway transit to cities such as Cleveland, Toledo, Detroit, and Burns Harbor. I believe that this question is quite important, specifically because there are many attempts to deliver international containers directly into the Great Lakes ports from Europe, rather than delivering them through New York/Phila/Baltimore with an overland freight leg. I am concerned that a large marine fuel cost increase on the Seaway might delay this shift to waterborne deliveries, and would like to understand the potential incremental cost per ton of cargo.
Hull	The study only includes the 16 identified captive Great Lakes cases, but does not include import/export along the Seaway.

EPA Response:

Two peer reviewers, Hull and Belzer, commented on the impacts of the ECA fuel controls on the emerging market of container shipping on the Great Lakes. Dr. Hull raises concerns about the impact of the ECA fuel sulfur limits on the potential for container shipping in the Great Lakes region. He notes that not only will this emerging market provide important economic opportunities for the region, but it will also help reduce air emissions by using more efficient ship transportation. Dr. Belzer, on the other hand, is less optimistic about the future for container shipping on the Great Lakes. He is skeptical, he notes, because "no container ships have been built for the Great Lakes and they probably could not hold more than two hundred containers, so this would only work for bulk shipments by container. No container ports exist on the Great Lakes. Containers more likely will travel by rail."

Taken together, these two comments illustrate why it would not be possible for EPA to perform analysis on this market sector that does not currently exist.

The Great Lakes container market, both direct container shipments from Europe and short-sea container shipments from East Coast ports, has been the subject of analysis since the 1970s. While there had been container traffic on the Great Lakes in the earlier part of the 1970s, changes in container ship sizes subsequently made them unable to access the Great Lakes. As a result, containers enter the United States through East Coast ports and are transported to the Great Lakes region via rail.

More recent analysis of the container market suggests that there are important constraints that would need to be resolved for the Great Lakes container market to resume. Constraints raised most recently by stakeholders at a meeting held by MARAD in the context of their Ship Revitalization Study[E] include the seasonality limits of Great Lakes shipping, lack of port infrastructure, ship loading restrictions due to lack of dredging in key areas, bottlenecks at locks and rivers, lack of attention to the shipping transportation network by state transportation boards, and the competitive advantage given to railroads through various subsidies. These are all serious infrastructure limitations that are unaffected by ship fuel costs. Other stakeholders noted that it is quicker to transport containers by rail from East Coast ports than it would be for containers to go through the St. Lawrence Seaway to the Great Lake ports and therefore the Great Lakes St. Lawrence Seaway route may be efficient only to the extent that there are bottlenecks at East Coast ports or for containers that are oversized or overweight.

In summary, there are serious infrastructure constraints for container shipping on the Great Lakes, and it is unlikely that applying the ECA fuel sulfur limits to the Great Lakes will affect the impacts of those constraints.

Finally, it should be noted that the fuel sulfur limit for distillate fuel sold for use in locomotive engines and in marine engines with per cylinder displacement less than 30 liters was reduced to 500 ppm in 2007, with a further reduction to 15 ppm to be phased in by 2014. Thus, these alternative transportation modes must use fuel that is much more environmentally protective than the fuel used by Category 3 vessels.

8A.12. Other Comments

8A.12.1 Grain Exports

Commenter	Comment
Hull	70% of grain on the Great Lakes is destined for export, so this is an important case to be considered in the body of the report Grain exports: Grain from the Midwest gets exported either through the Great Lakes, the Mississippi River, or the West Coast depending on market prices and transport cost. Adding cost to Great Lakes route will tilt the flow toward the other two routes to a degree. Can you quantify this? How much additional cost will be added and/or how much MDO versus HFO will be burned on the inbound and outbound voyages? (with 70% of grain on the Great Lakes destined for export, this is an important case)

<u>EPA Response</u>:

As noted in our response for the supplemental steel analysis, this report was not intended to look at the impact of the application of the ECA program to the grain industry, including exports. It

[E] Meeting held in Cleveland, Ohio, on February 15, 2011. More information about the MARAD Ship Revitalization Study can be found at http://gcaptain.com/great-lakes-shipping-revitalization?19640.

was intended to look at the impacts of the program on Great Lakes shipping. We looked at the four main cargoes transported on the Great Lakes: Iron ore, coal, crushed stone, and grain. With respect to grain, we considered grain transported from western locations on the Great Lakes to users on the Great Lakes (Scenarios 11 and 12), and to Baie Comeau where it is stored in silos awaiting export.

Our response for the supplemental steel analysis discusses the implications of the program for grain backhauls associated with steel coil imports. See response in section 8A.10.3, above.

8A.12.2 Retrofitting

Commenter	Comment
Hull	With Category Three US Flagged Vessels using HFO, all will require retrofitting. Is the technology available currently to allow a changeover? The information on Page 13 indicates that the US Flagged vessels are quite large, so can the changeover present a problem?

In the majority of vessels which operate on residual fuel, marine distillate fuel is still used for operation during routine maintenance, prior to and immediately after engine shut-down, or in emergencies. Certain changes will need to be made to the engine's fuel system with respect to injectors, fuel pumps, and fuel lines. Chapter 4 of Regulatory Impact Analysis prepared for our Category 3 marine diesel rule contains a discussion of the changes that may be needed.

8A.12.3 Stakeholder Participation

Commenter	Comment
Hull	Algoma Central and CSL Group are the Canadian Flag operators who have the lions share of Category Three ships. Have they issued a position to the study?

EPA Response:

All stakeholders were invited to participate in the development of this study. The Canadian Shipowners' Association was involved in all steps of this study. However, neither Algoma Central nor CSL Group commented directly on our Category 3 marine rule or directly participated in this analysis.

Chapter 8 References

[1] Samulski, Michael. Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder – Information in Support of Applying Emission Control Area (ECA) Requirements to the Great Lakes Region. EPA-HQ-OAR-2007-0586. December 15, 2009.

[2] *Power Magazine*, "Burning PRB Coal," October 2003, explaining why coal blending is necessary for many existing boilers, available at http://www.prbcoals.com/pdf/PRBCoalInformation/Power-Oct03-PRBCoal.pdf.

[3] Telephone call between L. Steele of EPA and K. Graves of Georgia-Pacific, May 12, 2011, concerning coal sourcing activities.

[4] See http://minerals.usgs.gov/minerals/pubs/commodity/iron_ore/myb1-2008-feore.pdf

[5] EPA (December, 2009) Summary and Analysis of Comments: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder. Chapter 10. EPA420-R-01-019 A copy of this document can be found at http://www.epa.gov/otaq/regs/nonroad/marine/ci/420r09015.pdf

[6] Samulski, Michael. Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder – Information in Support of Applying Emission Control Area (ECA) Requirements to the Great Lakes Region. EPA-HQ-OAR-2007-0586. December 15, 2009.

Appendix 8B

EERA Responses to Peer Review Comments on 'Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping'

In this appendix, EPA's contractor, Energy and Environmental Research Associates, LLC, provides responses to the substantive comments offered by reviewers. In addition, their final contract report, included as Appendix 2C to this report, has been revised in response to comments.

EERA's Response to Reviewers' Comments on Appendix 2A: Analysis of Impacts of Category 3 Marine Rule on Great Lakes Shipping

6 April 2011

Comment 1

Summarized Comment:
In four scenarios, there is no all-rail alternative considered, but the document does not explain why at this point. In the results section, the document states, "It was determined that *xxxx* is not serviceable by rail. Therefore an All-Rail Alternative Route does not exist". The justification needs to be included on pages 53, 55, 57, and 59 as well. (Kruse)

Contractor Response:
Language indicating why a no-rail alternative exists for Scenarios 6, 13, 14, 15, and 16 has been added to the appropriate sections under *Chapter 4: Scenario Description and Input Assumptions*. Generally, the language states that, "After reviewing the rail network in the GIFT model and through discussions with stakeholders and experts, it was determined that no rail service exists at [appropriate origin of the route]; therefore, no All Rail Alternative Route exists."

Comment 2

Summarized Comment:
How did EPA (or its contractor) derive the assumed propulsion powers? (Kruse)

Contractor Response:
We have added language under *Vessel Main Engine Horsepower* to reinforce that our choices for main engine horsepower values were made after considering hp values for actual Great Lakes ships of 1000, 770, and 625 foot vessels carrying coal, iron ore, grain, and stone.

Comment 3

Summarized Comment:
What is the basis or source for the statement on engine specific fuel oil consumption?(Kruse)
How were fuel consumption rates calculated for the ships? (Hull 18)

Contractor Response:
We added language under *Vessel Main Engine Specific Fuel Oil Consumption* in order to clarify how main engine specific fuel oil consumption was chosen for each vessel modeled.

Comment 4

Summarized Comment:
The current Great Lakes basin profile is for 2008. Table 13 should be updated. (Kruse 25)

Contractor Response:
We have updated Table 13 to reflect the 2008 Great Lakes Basin Profile. We found that only Iron ore/Steel Products changed substantially. Coal had no change.

Comment 5

Summarized Comment:
The sources should be stated for the following assumptions used to develop Table 16: Auxiliary Engine power, Auxiliary Engine Load Factor in Port, and Rail Energy Intensity. (Kruse 25)

Contractor Response:
We have included Footnote F from page 3-22 of the main EPA report as a note under Table 16 to indicate the source of the rail energy intensity variable. We have also added the *Auxiliary Engine Horsepower and Load Factor* section under *Description of Input Assumption Sources* to address auxiliary engine power and auxiliary engine load factor in port.

Comment 6

Summarized Comment:
Why is it assumed that the vessel will be loaded to 85% of its capacity? Since this assumption directly affects the unit freight cost, it is important to justify it. (Kruse)

Contractor Response:
We have added language to the *Assumed Cargo Load* section of the report expanding our explanation of why we chose a maximum assumed cargo load of 85%.

Comment 7

Summarized Comment:
The Corps' Port and Waterway Facilities data were used to obtain the depth of each port. I don't know about the Great Lakes, but for the Inland Waterway System, these data are highly unreliable. Again, since available depth directly affects the unit freight cost, I would suggest some kind of "truthing" of these depths. (Kruse)

Contractor Response:
We added language under *Port Depth Limit* to clarify that the USACE data is modified by observed vessel drafts and therefore are "ground-truthed."

Comment 8

Summarized Comment:
According to what the document says on 2A-16 and what the carriers state, vessels that carry iron ore can also carry grain. (Kruse)

Contractor Response:
We have added language to *Bulk Cargo Capacity* and *Nature of Backhauls in Great Lakes Freight Transportation* to clarify that the Canadian-flagged grain vessels sometimes backhaul iron ore.

Comment 9

Summarized Comment:
In the body of the text please distinguish between "rates" and "costs." (Hull)

Contractor Response:
We took care to standardize our terminology and edited the *Calculating the Total Route Costs for the All-Rail Alternative Route* to read *Calculating the Total Route **Freight Rate** for the All-Rail Alternative Route*. We similarly edited the title and variable descriptions of *Equation 11* and changed one column in Table 76 and Table 78 from "All-Rail Scenario Rail Rate" to "All-Rail Scenario Rail **Freight** Rate." Lastly, the column headings and title of Table 77 have been completely re-worked for consistency.

Comment 10

Summarized Comment:
Are the underlying rates/costs provided by Dager rates or are they costs? Please explain what you mean by freight rates. I think that you are building up the ship, rail and handling costs and adding some percentage of profit. Is this true? If the analysis is based on value of service, how is this estimated (rail and ship rates are contractual and not published) and what is the information source? Railroads set their rates based on negotiations, using "differential pricing" or a "value of service approach." Their freight rates often differ widely from their costs. Rates would be more accurate but extremely difficult to accomplish with accuracy. Much better definition of his data set is required. Your analysis expects the reader to accept the rail rates you are publishing – so you need to provide backup as to how you arrived at them. (Hull)

Contractor Response:
In order to clarify that the freight rates used in the report for rail and ship are indeed rates and not costs, we have added two new sections (*Marine Vessel Freight Rate* and *Rail Freight Rate)* to the report under *Description of Input Assumptions Sources*. These sections describe in detail how marine vessel and rail freight rates were estimated. We also added language to *Total Transfer Costs for Default Scenario Route* to better explain how intermodal transfer costs were estimated.

<u>Comment 11</u>

<u>Summarized Comment:</u>
Other parts of the report state that there are 12 Category Three US Flag Ships, as opposed to the 8 referred to on this page. My understanding is that there are 12. (Hull)

<u>Contractor Response:</u>
We have confirmed that there are indeed 12 US-flag C3 vessels operating on the Great Lakes. We found that two steamships and one C2 vessel were repowered with C3 engines. Also, one C3 US-flag vessel and one US-flag steamship were previously unreported. We have updated *Chapter 2: Great Lakes Vessel Fleet Characterization* and Table 1 to reflect this change as shown below. We have also edited Tables 2, 3, 4, 5, 6, 7, 9, 10, 12, and 14 since they are affected by changes in the number of Category 3 and Category 2 US-flag vessels.

<u>Comment 12</u>

<u>Summarized Comment:</u>
The study refers to cost function modeling (which is cost-of-service, as opposed to value-of-service). Does the analysis strictly compare costs of two alternatives or does it compare rates? If the analysis is cost of service, what component costs are included and what was the source of the information? All cost components should be explicitly enumerated in the text. For Great Lakes ships, if the study includes cost-of-service, it should include the cost of laying the ships up during winter, which will increase their costs. It must also include factors such as tug costs which will be required to position ships alongside docks, lock fees, pilotage fees which can be quite high, etc. (Hull)

<u>Contractor Response:</u>
The cost-function that is referred to in the report is an activity-based fuel cost model that we use to calculate the incremental freight rate increase from the Base Case to the MDO case due to the use of ECA-compliant fuel (i.e. MDO). Our analysis compares the total freight rates of the MDO Case to those of the All-Rail Alternative Route. These rates include marine vessel freight rates, cargo transfer costs, and rail freight rates as discussed in our response to Comment 10. A complete description of how we calculate MDO Case freight rate is presented in *Chapter 3: Methodology* in Appendix 2A of the EPA report.

<u>Comment 13</u>

<u>Summarized Comment:</u>
The reference in Chapter 2 to the assumption of no backhauls in the study is not prominent enough. The commenters were unclear about this assumption. (Hull & Belzer)

<u>Contractor Response:</u>
We have added language under *Nature of Backhauls in Great Lakes Freight Transportation* to address this comment and clarify why we chose to assume no backhauls.

Comment 14

Summarized Comment:
Most of the cases modeled involve US Port/US Port movement. These require US Flagged vessels which are large. Does the ship analysis in this study account for this fact, or is it using generic Category Three ship figures? (Hull)

Contractor Response:
We want to clarify that the vessels used in the analysis are based upon the characteristics of the Great Lakes Vessel fleet but do not represent a particular vessel. Rather, the vessels modeled are considered to be a representative vessel of a length, cargo capacity, and power that could transport the specified commodity along each route examined in the report. We have added language to *Vessel Length* in order to address this comment.

Comment 15

Summarized Comment:
It would be wise to verify that the Algoma facility included in the analysis does have the facility to receive iron ore by rail. Regarding the CSA study, "The authors specify that iron ore and coal were not examined because for infrastructure and other reasons they are not vulnerable. . . the steel mills examined do not have rail alternatives." (report p 1-22/1-23) (Kruse)

Contractor Response:
The Geospatial Intermodal Freight Transport (GIFT) model was used in our analysis. This model uses geographic information system (GIS) data from Transport Canada for the location of Canadian rail lines. The geospatial location of the Algoma facility suggests that there is a possibility for a rail connection. Additionally, we verified the existence of rail lines in close proximity to the Algoma facility using Google Earth. Therefore, Scenario 5 in the analysis provides a comparison of the total freight rate comparison between the *Default Scenario Route* and an *All-Rail Alternative Route* that we believe is plausible.

Comment 16

Summarized Comment:
Please confirm that there is a rail ferry across the St. Lawrence River to Baie Comeau, QC. I have never heard of such! What are the sensitivities considered? (Hull)

Contractor Response:
There is a rail ferry that links Baie Comeau, QC to Matane, QC across the St. Lawrence River. The ferry has a capacity of twenty-six 50 foot rail cars. The name of the ferry is the Georges-Alexandre-Lebel Rail Ferry. The source of these data is the City of Baie Comeau, QC website available at:
http://www.ville.baie-comeau.qc.ca/en/investing/services/rail-port_complex/

Comment 17

Summarized Comment:
Please check the rail routes for feasibility: are they heavily travelled trunkline routes, and do they involve multiple railroads? Railroads often don't use the shortest route. Railroads try to shift traffic to their most heavily used lines for economies of scale, density, and service. The rate and route also depends on how many railroads are involved and their individual routes – railroads all want to achieve long haul economics and may avoid a least cost routing that might extend over multiple railroads. A route with more than two carriers is rare. (Hull)

Contractor Response:
The GIFT model is a GIS-based tool developed by the Rochester Institute of Technology and the University of Delaware that combines the US and Canadian road, rail, and water transportation networks to create an intermodal network. GIFT is an optimization model and can solve a route from origin to destination based on user-defined objectives including least-time, least distance, least-economic cost, least-CO_2, least PM_{10}, etc. For the all-rail alternative routes, we solved for the "least-distance" while staying on active rail lines (mainly Class I rail lines). In our analysis, we calculated the all-rail alternative route freight rate by multiplying the total distance (in miles) by the per-mile freight rate ($/mi). Our analysis cannot ensure that only one rail company was used. However, our analysis gives the least possible distance from origin to destination along active rail lines. For our purposes, the least-distance all-rail route is also the least expensive. If we had focused on using only one or two rail companies, the route may have been longer, resulting in an increased total freight rate.

To address Dr. Hull's comment directly, the question about heavily travelled trunkline routes is interesting but was (a) not contained within the scope of our study and (b) not necessary in the analysis of the least-distance route. We did not come across data about travel frequency along these trunkline routes. We are aware that the Class I railroads have shared agreements for segments of the national railway network and we understand that Class I rail operators may dominantly operate its own equipment on other sections of the network; there may be a number of rail line owners represented along our route.

Additional EPA Comment
Please provide a description of the GIFT model to be included in Chapter 2 of the EPA report and Appendix 2A.

Contractor Response:
We provide the following description of the GIFT model and how it is used in the report and have included it in the *Introduction* section of Appendix 2A of the EPA report:

This study uses the Geospatial Intermodal Freight Transport (GIFT) model, discussed in detail in Winebrake et al. (2008) and Comer et al. (2010), to display maps of the Default Scenario Route and All-Rail Alternative Route. Additionally, the GIFT model is used to calculate the distance (in miles) from origin to destination for the All-Rail Alternative Route as well as the distance traveled by rail for the rail portion of the Default Scenario Route, if any, by solving for the "least-distance" route along active rail lines. The GIFT model is a GIS-based tool developed by the Rochester Institute of Technology and the University of Delaware that combines the US and Canadian road, rail, and water transportation networks through intermodal transfer facilities to create an intermodal network. The GIFT model can solve a route from origin to destination based on user-defined objectives including least-time, least distance, least-economic cost, least-energy, and least-emissions (including carbon dioxide [CO_2], carbon monoxide [CO], oxides of nitrogen [NO_x], sulfur oxides [SO_x], particulate matter [PM_{10}], and volatile organic compounds [VOCs]). For this study, we utilize GIFT's visualization and least-distance optimization capabilities.

Appendix 8C

Peer Review of EPA's 'Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping' Study

Peer Review of EPA's "Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping" Study

Work Assignment 3-05
(RTI 005)

Technical Memorandum

Prepared for

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EPA Contract Number EP-C-08-008

RTI Project Number 0211577.004.005

January 2011

Technical Memorandum on Peer Review of EPA's "Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping" Study

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Memorandum

TO: Lauren Steele, (Environmental Engineer) U.S. Environmental Protection Agency, Office of Transportation and Air Quality (OTAQ)

FROM: Alex Rogozhin, RTI International.

DATE: January 28, 2011.

SUBJECT: Peer-Review of EPA's "Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping" Study

1. Background

The U.S. Environmental Protection Agency's (EPA's) Office of Transportation and Air Quality recently finalized regulations addressing emissions from Category 3 marine diesel engines and their fuels (the C3 Marine Rule, 83 FR 22896, April 30, 2010). That rule contains EPA's coordinated strategy to address these emissions through a combination of national and international actions. As EPA developed the C3 Marine Rule, stakeholders from the Great Lakes shipping industry expressed their concerns that the proposed program, particularly the fuel sulfur limits, would lead to higher operating costs for ships operating on the Great Lakes. They further commented that this would lead to a transportation mode shift away from ships and toward trucks or rail, with concerns that the result could actually be an increase in emissions—the opposite of what EPA sought to accomplish. They also indicated that the increased operating costs could lead to a source shift for the crushed stone market and a production shift for steel manufacturing, which would also adversely affect Great Lakes shipping.

EPA did not change its final rule with regard to applying the C3 marine engine standards and fuel sulfur limits to the Great Lakes. In response to the comments, EPA performed an analysis of the economic impact of the C3 Marine Rule on Great Lakes shipping ("Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping," called "the EPA Report"). The EPA Report includes an analysis of transportation mode shift analysis, performed by ICF International and Energy and Environmental Research Associates, LLC (EERA), and source shift and production shift analyses performed by EPA. EPA submitted the Report for peer review, seeking the reviewers' expert opinion on the methodologies employed and analyses presented in the report and whether the impacts and effects described reflect a solid understanding of the effects of the C3 Marine Rule on Great Lakes shipping. RTI International facilitated this peer review, and this memorandum contains a summary of the peer review results as well as documentation of the peer-review process.

2. Description of the Peer-Review Process

EPA's Office of Transportation and Air Quality contacted RTI in October 2010 to facilitate the peer review of the EPA Report titled "Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping." EPA provided RTI a non-comprehensive list of subject matter experts from academia and the public sector (Appendix A of the performance work statement, WA 2-05), and this served as a starting point from which RTI assembled the list of subject matter experts. Even though EPA provided a non-comprehensive list of subject matter experts, the final list of 16 potential reviewers was compiled by RTI without consultation with EPA. To ensure that the work would be completed in a timely manner, RTI contacted the potential reviewers within a week of submitting the work plan and determined whether each expert would be able to review the study during the period of performance. RTI selected three independent (as defined in Sections 1.2.6 and 1.2.7 of EPA's *Peer Review Handbook*) subject matter experts based on the following criteria in order of importance: 1) expertise in subject matter, 2) diversity of backgrounds of the reviewers as a group, and 3) availability to perform the review in the stipulated time frame. When one of the initially selected reviewers later declined to participate, RTI selected an alternate reviewer from the list of 16 potential subject matter experts. To make the review process as credible as possible, RTI did not consult EPA in selecting the final reviewers.

The selected reviewers possess a range of expertise in maritime operations, transportation planning and logistics, economic analysis, environmental issues, and the effect of transportation on economic development. Appendix A of this technical memorandum provides the resumes obtained from the selected reviewers. The selected reviewers have sufficient knowledge in: 1) economics, 2) water transportation, 3) transportation logistics, and 4) regulation analysis to evaluate the three methodologies (mode-shift analysis, source shift analysis, and production shift analysis) used in the EPA Report.

RTI provided each of the reviewers with a copy of the EPA Report. The reviewers were also given a set of charge questions prepared by the EPA as well as several supporting documents (the list of additional documents provided to the reviewers is available in Appendix F). The note along with the set of charge questions sent from RTI to the reviewers is included in Appendix B of this memorandum.

After 3 weeks of the review process, a telephone conference call was organized between EPA, the reviewers, and RTI. The purpose of the telephone conference was to provide an opportunity for the reviewers to discuss any questions or concerns regarding the review material and the expected deliverables. Some of the questions addressed in this process are included in Appendix C of this memorandum. Additionally, one of the reviewers had further questions regarding the study. A second telephone conference was held between EPA, the reviewer, and RTI with the purpose to address those questions. The telephone conference was documented, and the log of the conference was later shared with the other reviewers. The log of the second conference call is included in Appendix C.

RTI received the review reports from the reviewers and forwarded the reports to EPA by the requested date. The review reports included the responses to the charge questions and any additional comments or recommendations. From each reviewer, RTI obtained a cover letter that stated the reviewer's name, the name and address of his/her organization, the documents that were received and reviewed by the reviewer, and a statement of any real or perceived conflict(s) of interest. These cover letters and the review reports are included in Appendices D and E of this memorandum.

3. Summary of the Peer-Review Comments

The EPA Report consists of seven chapters and various appendices. The reviewers were asked to comment on the report as a whole but to focus on Chapters 2, 3, and the Appendices to those chapters. Chapter 2 contains the analysis of the potential for transportation mode shift on the Great Lakes as a result of compliance with the Category 3 rule. Chapter 3 contains the analysis of the potential for source shift and production shifts, as well as the emission impacts of transportation mode shift, were it to occur. The remainder of the EPA Report consists of general information about EPA's marine emissions control program (Chapter 1) as well as information specific to the Great Lakes with regard to estimated emission inventories (Chapter 4), estimated air quality impacts and human health and welfare benefits associated with the Category 3 rule (Chapter 5), estimated compliance costs for Category 3 ships on the Great Lakes (Chapter 6), and an industry characterization (Chapter 7).

With regard to Chapters 2 and 3, the reviewers were asked to focus their reviews primarily on the following issues raised by charge questions: 1) clarity of the presentation, 2) the overall approach and methodology, 3) appropriateness of the datasets and other inputs, 4) the data analyses conducted, and 5) appropriateness of the conclusions. Reviewers organized their review reports by first addressing each of the five issues mentioned above, and then providing a list of page-by-page comments. This memorandum provides a summary of the comments received from the three reviewers: Dr. Michael Belzer (Wayne State University), Dr. Bradley Hull (John Carroll University), and Mr. James Kruse (Texas Transportation Institute).

This memorandum is structured as follows: Section 3.1 provides an overview of all the peer-review reports, Section 3.2 summarizes comments on clarity and presentation of the EPA Report, Section 3.3 summarizes comments on the overall approach and methodology, Section 3.4

summarizes comments on the appropriateness of the datasets and other inputs, Section 3.5 summarizes comments on the data analyses conducted, Section 3.6 summarizes comments on appropriateness of the conclusions, and Section 3.7 summarizes any other comments provided by reviewers. Interested readers should refer to Appendix E for the full text of the comments.

3.1 Overview of the Reviewers' Comments

The reviewers found the EPA Report to be comprehensive and well substantiated. With respect to *clarity of presentation*, the reviewers generally noted that the EPA Report is well written and easy to follow.

With respect to *methodology*, the reviewers commented that the methodology chosen is appropriate but had some suggestions about some of the methodology assumptions. One of the reviewers suggested improving mode shift analysis by addressing the impacts of a global trade on three commodities (grain, steel coils, and containers). Another reviewer suggested that a cost-benefit analysis would have been sufficient to justify environmental action.

Reviewers' most substantive critique was of the *inputs* to the analysis. All reviewers emphasized the need for better documentation of some of the inputs and further explanation of how several other inputs were derived.

While the reviewers commented that the *conclusions* drawn from the study were appropriate, they suggested providing further evidence and explanation for some of them. One reviewer suggested validating the applicability of the assumptions in the real world by discussing inputs, analysis, and conclusions of a subset of 16 selected scenarios with the stakeholders.

3.2 Clarity of the Presentation

The reviewers generally noted that the EPA Report is well written and easy to follow. The reviewers provided suggestions to improve overall readability and clarity to a general audience. Some of their suggestions are summarized in this section.

Dr. Belzer suggested changing wording and clarifying several passages in Chapter 3. For example, he suggested attributing the argument about a negligible increase in price of commodities (except stone) to "down-market competition" in the last paragraph on page 3-13. He also recommended providing a reference for an assumption that "marine carriers have empty backhauls" in the first paragraph on page 3-20. Finally, Dr. Belzer suggested portraying marine emissions in Table 3-9 on page 3-20 in the manner similar to locomotive emissions in Table 3-11 on page 3-22. He explained that it seems that locomotive and marine emission calculations are in different denominations, and that makes it hard for a reader to compare the two.

Dr. Hull suggested stating clearly early in the EPA Report that the study addresses sulfur limits only, because readers might question why only sulfur limits are addressed in the EPA Report, while the report also includes details on NO_x and particulate matter. He proposed clarifying the jurisdiction of the C3 Marine Rule, and suggested adding a convincing argument that ships are among the major contributors to sulfur pollution in the Great Lakes/St. Lawrence region (he suggested providing a table that lists sulfur emissions from ships, trucks, railroads, automobiles, and manufacturers in the Great Lakes). He added that readers need to be convinced that even though a majority of marine emissions take place in unpopulated areas, populated areas are affected as well.

Dr. Hull also suggested clarifying "whether the Seaway between Montreal and the mouth of the St. Lawrence River will require 100% MDO" and requested to perform a due diligence analysis to determine whether sufficient quantities of MDO exist to support the C3 Marine Rule. Finally, he suggested distinguishing clearly between the terms "rates" and "costs" throughout the entire report.

Mr. Kruse mentioned that it would be helpful to standardize the units of measures for tons, as terms such as "tonnes," "tons," "metric tons," and "short tons" are used throughout the report. He suggested spelling out acronyms when they are introduced in the report for the first time, such as "BAU" on page 1-12. He recommended providing explanation for the statement "the analysis does not consider the transportation of the grain from the farm to the silo" on page 2-9. Mr. Kruse also suggested stating the fact that in some cases the origin/destination points are not serviceable by rail in the beginning Appendix A to Chapter 2 versus, as it stands now, at the end of the report in the results section. Mr. Kruse commented that the following two statements were important and suggested adding them to the executive summary: 1) "The purpose of this study is to examine whether an increase in fuel costs for Great Lakes shipping could lead to transportation mode shift" on page 2-6, and 2) an explanation of how the freight comparison was conducted on page 2-16.

3.3 Overall Approach and Methodology

Overall reviewers concurred with the selected methodology. With respect to the origin/destination pairs, Dr. Belzer raised a concern that the 16 routes that were used in the analysis were not randomly selected from about 50 cases suggested by the industry. He mentioned that one potentially could assume that EPA selected "the cases with [the] least likelihood of modal shift." However, Dr. Belzer argued that since 50 cases were proposed by the industry that in general objects to the C3 Marine Rule, all 50 cases were likely to "support [the] contention that these shifts would occur." Dr. Belzer commented that "due to overwhelming evidence, repudiating the notion that modal shift would occur, it is unlikely that random selection would have yielded much different results;" and he further mentioned that if there is any bias, it is likely to be on the conservative (higher cost) side. Dr. Belzer stated that it appears that EPA "selected these cases systematically in an attempt to fairly represent a cross-section of trips about which the private sector was concerned."

The other two reviewers suggested that clarifications are necessary for some of the methodology assumptions. Dr. Hull suggested a clarification on whether the rail routes used in the analysis are "heavily traveled trunk-line routes" and whether they involve multiple railroads. He explained that though the shortest routes are appealing, railroads might choose longer, even circuitous routes to preserve the long haul to gain the economies of scale and to not have to share the revenue with another railroad by having to use another railroad for part of the way. Dr. Hull further suggested explaining whether the routes were calculated based on "cost of service" or "value of service" and specifying which components were included or providing a clear definition of the calculation method. In his review report, Dr. Hull described both approaches, and noted that in real life railroads use a "value of service" rather than "cost of service" approach.

Mr. Kruse commented that "the approach of looking at origin/destination pairs that stakeholders thought might be affected was excellent." He also mentioned that based on historical cargo flows, the "commodities that were chosen were appropriate," and "the involvement of stakeholders was accurate and meaningful." The fact that backhauls were considered to be empty, in Mr. Kruse's opinion, was an assumption on the conservative (higher cost) side. Finally, Mr. Kruse commented, the analysis followed "an appropriate trade-off between accuracy and the level of effort."

With regard to stone shipments, two reviewers suggested that some additional clarification is needed. Mr. Kruse recommended further studying and providing an explanation as to why some facilities used stone originating at a much longer distance, requiring ship transportation, when stone from local quarries may be available. Dr. Belzer noted that "if the higher cost of fuel causes customers to source their products more nearby, then the products must be close enough substitutes that they should not travel such distances in the first place. In other words, if close substitutes do not shift closer then society must be subsidizing excessive freight transport distance, which would be a bad public policy because the economics of the move would not pay the full cost." Dr. Belzer also suggested EPA to consider quantitatively validating the otherwise subjective statement about the stone analysis, that "the increase in number of quarries is not substantial compared to the number of quarries already located within this radius" on pages 3-5 and 3-6.

3.4 Appropriateness of Databases and Other Inputs

All three reviewers agreed on the need to explain how certain inputs for the analysis were derived. Some of the key suggestions are presented in this section.

Dr. Belzer commented that datasets appear to be acceptable by both EPA and the industry, and seem as most appropriate for this analysis. Dr. Belzer suggested using an average (or trend) price of marine fuel rather than single year price, because "using the 2007 price has a disadvantage of capturing non-random point in time, rather than a trend." He also made a similar comment about diesel fuel price for trucks and suggested using a long-term trend price. However, he noted that using a lower price results in a "very conservative" estimate in the analysis.

Dr. Belzer also mentioned that it would be helpful to study a coal-supply route from the paper mill in Green Bay, Wisconsin (mentioned in Chapter 2); he suspected that the transfer cost would not make viable a long part-rail/part-marine route. However, the route through South Chicago might be inexpensive because of volume of cargo handled thus making the ton-mile cost lower for a combined rail/marine route versus an all-rail route.

Dr. Hull sought clarifications on the rate/cost inputs provided for the analysis by Chrisman Dager. He reiterated that it should be stated clearly whether these inputs are in terms of "cost of service" or "value of service." If the inputs are in terms of cost of service, it should be explicitly noted what components were included and what the source of the information was. If the inputs are in terms of value of service, it should be noted how they were estimated and what the source of the information was.

Mr. Kruse suggested providing a source for the specific engine marine fuel oil consumption, and how the assumed propulsion power was derived. He also suggested the following:

- updating the Great Lakes basin profile with more recent data (if available) in Chapter 2, Appendix A, Table 13;
- stating the sources for following variables: Auxiliary Engine Power, Auxiliary Engine Load Factor in Port, and Rail Energy Intensity in Chapter 2, Appendix A, Table 16;
- justifying the assumption that a vessel would be loaded to 85% of its capacity (this assumption directly affects unit freight costs) in Appendix A;
- verifying the depth of ports located on the Great Lakes (this assumption also directly affects unit freight costs); in Mr. Kruse's experience, the Corps of Engineers' Port and Waterway Facilities data are not reliable for an inland waterway system;

- verifying the truck load assumption of 43 short tons, if the quarry is located in the United States; and
- verifying the assumption that the Algoma facility included in the analysis does have the ability to receive iron ore by rail, and providing the source of the assumption that "80% of the delivered iron ore costs, is the iron ore cost at the mine."

3.5 Data Analysis Conducted

In general, all reviewers agreed that transportation mode shift, source shift, and production shift analyses performed were straightforward, appropriate, and adequate. Dr. Belzer commented that the mode, shift, and production analyses were appropriate. Dr. Hull commented that the analysis was straightforward and particularly the crushed stone analysis was "quite good, though it would still benefit from a review of the underlying data sources." Dr. Hull commented that the coal analysis could have been more thorough and the steel and supplementary analyses should be revised to incorporate a global perspective.

More specifically, Dr. Hull made the following comments with regard to stone, coal, steel, and supplementary portions of the mode shift analysis:

- *Stone*: Several simplifying assumptions were made and need to be validated. These assumptions include the use of theoretical transportation cost from origin to destination, the assumption that highways were a "straight line," the fact that Michigan specialty stone replaces local quarry stone ton for ton, and the fact that heavy trucks are allowed on highways.
- *Coal*: The explanation of this portion of the analysis was rather confusing, and could benefit from further explanation in simpler terms.
- *Steel*: Since steel is a vital industry in the Midwest, it can benefit from an expanded analysis. One of the assumptions made in the analysis is that coal supplied to Great Lakes by marine route is used in steel production, while in reality it is almost always used by power plants.
- *Supplementary*: This portion of the analysis is generally compelling, but requires adding grain backhauls and a wider (worldwide) marketplace.

Mr. Kruse thought the analysis was "appropriate and adequate" with the exception of concern why some facilities do not use stone from local quarries (See Section 3.3, above).

3.6 Appropriateness of the Conclusion

In general, the reviewers commented that the conclusions drawn in the EPA Report were appropriate. Dr. Belzer commented that conclusions were adequate based on the information that was analyzed, and that cost increases due to a fuel change would be lost in the noise of price changes and would not cause the shifts in question.

Dr. Hull suggested that EPA expand on the report, commenting that “with the Great Lakes industries on the decline, the study needs to consider the global marketplace and present potential import/export opportunities.” Also, since the EERA model is theoretical, and the assumptions may differ from the actual routes and rates, Dr. Hull encouraged a final validation of the model by gaining stakeholders’ input and perspective about a subset of 16 selected origin/destination routes. Dr. Hull also noted that in reality the railroads and marine operators price their services based on value of service, and even though the analysis shows that no modal shift will occur, the higher priced marine fuel can result in “less business overall, as manufacturers shift production away from the Great Lakes toward lower cost supply sources.”

Mr. Kruse thought the conclusions were appropriate and justified given the data sources and inputs used in the analysis.

3.7 Other Comments

In addition to the comments on the charge questions, the reviewers also provided other suggestions and comments, which are summarized in this section.

Dr. Belzer commented that even though transportation mode shift, source shift, and production shift analyses are of a concern in the EPA Report, from an economic and environmental standpoint “these shifts would be entirely acceptable and in many cases more efficient,” especially considering that the societal benefits in this case exceed costs by anywhere between 30:1 and 100:1. Dr. Belzer suggested that these impacts can be examined through the use of a broad type of macroeconomic model, such as that incorporated in REMI and IMPLAN would be adequate to perform a full cost-benefit analysis. Dr. Belzer also commented that truck and locomotive industries already endure the costs of switching to low-sulfur fuel that resulted from higher fuel prices and restrictions. He argued that actions to preserve air quality should affect all transportation modes. Thus, if maritime sector were not required to comply with cleaner fuel regulations, the society “risks subsidizing marine sector over others, contributing to economic inefficiency and social inequity.”

Dr. Hull urged EPA to include in the analysis the impact of the global marketplace on three commodities in the Great Lakes region:

- *Grain*: Grain from the Midwest is shipped via three main routes: by ship through the Great Lakes/St. Lawrence, by rail to the U.S. West Coast for loading on ships to China, and by river barge down the Mississippi River for export from New Orleans. These routes likely depend on transportation rates, and small rate changes might have major impacts on the choice of route. As stated on p.7-26, almost 70% of grain shipments on the Great Lakes are destined for export, so this might be a commodity that should be analyzed explicitly.

- *Steel Coils*: Break-bulk ships (typically operated by FedNav, Polstream, and Wagenborg) export steel coils from Northern Europe by crossing the Atlantic, transiting the Seaway, and discharging partial cargos at Cleveland, Detroit, and Burns Harbor. These ships are then loaded with grain on the backhaul trip to Europe. Thus, it is important to address whether requiring a use of low-sulfur fuel would: 1) make deliveries of steel coils on their way to the Unites States through the Seaway less economically attractive, shifting it to East Coast ports for an overland rail/truck route, and potentially causing more emissions from rail/trucks and 2) make backhaul deliveries of grain less available, thus making delivery of steel coils less economically attractive, and causing the routes to shift inland, causing higher emissions from rail/trucks.

- *Containers*: Containerships transit the Seaway as far as Montreal and then are loaded on trucks and rail for delivery, with approximately half of the containers going to Canada and half going to the United States. Currently, plans are underway to extend container deliveries into the Great Lakes by water, directly through Europe or by loading containers on feeder ships or barges in Montreal or Halifax (the ports of Cleveland, Toledo, Erie/Conneaut, and Oswego are the interested ports and Wagenborg, Great Lakes Feeder Lines, and McKeil Marine are the interested carriers). If realized, these plans would lower SO_x, NO_x, and particulate emissions by replacing rail and truck deliveries from Montreal and the East Coast. It is important to study whether requiring use of low-sulfur fuel would make these plans less economically attractive.

Mr. Kruse mentioned that one facet that is missing from the analysis is the concept of equity, i.e. placing low-sulfur fuel requirements on the truck and locomotive industries but not on the marine would represent an indirect subsidy to the marine industry.

Appendix A: Resumes of Selected Reviewers

MICHAEL H. BELZER, PhD
Wayne State University
College of Liberal Arts and Sciences
656 W Kirby, 2074 Faculty/Administration Bldg.
Detroit, MI 48202
(313) 577- 3345
michael.h.belzer@wayne.edu

BIOGRAPHICAL SUMMARY:

Michael H. Belzer is Associate Professor in the Department of Economics of the College of Liberal Arts and Sciences at Wayne State University. He also is Associate Director of the Alfred P. Sloan Foundation's Trucking Industry Program, one of more than twenty Sloan Industry Centers. The Trucking Industry Program focuses on trucking industry operations, regulation, industrial organization, and industrial relations, and Dr. Belzer directs its Trucking Industry Benchmarking Program. He serves as Chair of the Transportation Research Board Committee on Trucking Industry Research, as a member of the Freight Systems Executive Board, and as a member of the Committee on Freight Economics and Regulation as well as a member of the Truck and Bus Safety Committee. Additional current interests include labor policy, industrial organization, and the role of transportation in economic development.

DEPARTMENT/COLLEGE:

Department of Economics, College of Liberal Arts and Sciences

Departmental web page: http://www.clas.wayne.edu/unit-faculty-detail.asp?FacultyID=595

PRESENT RANK & DATE OF RANK:

Associate Professor, since September 1, 2000.

WSU APPOINTMENT HISTORY:

Year Appointed/Rank: September 1, 2000, as Associate Professor

Tenured in 2004 as Associate Professor of Urban and Labor Studies in the College of Urban, Labor, and Metropolitan Affairs (CULMA)

With closure of CULMA on September 30, 2005, tenure granted in Department of Interdisciplinary Studies, College of Liberal Arts and Sciences

With dissolution of the Department of Interdisciplinary Studies on September 30, 2007, tenure granted in Department of Economics, College of Liberal Arts and Sciences

Academic Director, Master of Arts in Industrial Relations Program
September 1, 2000 – October 15, 2003

EDUCATION:

Baccalaureate: A.B. College of Arts and Sciences, Cornell University, 1972

Graduate: M.S. Graduate School, Cornell University, 1990 (Ithaca, NY)
Ph.D. Graduate School, Cornell University, 1993 (Ithaca, NY)
(Studied at New York State School of Industrial and Labor Relations)

Major: Collective Bargaining, Labor Law, and Labor History

Minors: City and Regional Planning/ Human Resource Studies/ Research Methods

SELECTED PUBLICATIONS:

Book Chapters:

1. "Labor and Human Resources in the Freight Industry." A chapter in *Intermodal Freight Transportation*, Lester Hoel, Genevieve Giuliano, and Michael Meyer, editors. Publisher: Eno Transportation Foundation, Inc. Forthcoming.
2. "The Next Move: Metropolitan Regions and the Transformation of the Freight Transport and Distribution System." With Susan Christopherson. In *Urban and Regional Policy and Its Effects*, edited by Nancy Pindus, Howard Wial, and Harold Wolman. Brookings Institution Press. 2009.
3. "The Effects of Trucking Firm Financial Performance on Safety Outcomes." With Marta S. Rocha and Daniel A. Rodriguez. In *Transportation Labor Issues and Regulatory Reform*. James H. Peoples and Wayne K. Talley eds. Research in Transportation Economic Series. Rotterdam, The Netherlands: Elsevier Science Publishers, 2004, pp. 35-55.

Peer-Reviewed Journal Articles Published:

1. "Environmental determinants of obesity-associated morbidity risks for truckers." International Journal of Workplace Health Management. With Yorghos Apostolopoulos, Sevil Sönmez, and Mona M Shattell, In press.
2. "Worksite-Induced Morbidities Among Truck Drivers in North America: A Comprehensive Literature Review." With Yorghos Apostolopoulos, Sevil Sönmez, and Mona M. Shattell. *American Association of Occupational Health Nurses [AAOHN] Journal*. Vol. 58, No. 7, 2010: pp. 285-96.
3. "Empirical Evidence of Toll Road Traffic Diversion and Implications for Highway Infrastructure Privatization." With Peter F. Swan. *Public Works Management & Policy*, Vol.14, No. 4 (April 2010): pp 351-73.

BRADLEY HULL, PhD
Associate Professor and Reid Chair
Department of Management, Marketing, and Logistics
John Carroll University
University Heights OH 44118
(216) 397-4182
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LOGISTICS MANAGEMENT EXPERT with well-developed management skills and proven ability to control costs, maximize service levels and build profitable national and international logistics operations.

- Recognized as a leader in oil/chemical industry logistics and strategic planning issues.
- Creative problem solver, known for ability to creatively overcome obstacles and develop innovative solutions for difficult logistics problems.
- Highly effective in utilizing logistics to enhance marketability of company assets.
- Broad base of industry contacts and an up-to-date knowledge of market conditions.

Core Competencies:

Supply Chain Management	Operations Management	Operations Planning
Distribution Management	Operations Research	Carrier Selection / Negotiation
Emergency /Haz-Mat Response	Fleet Management	Total Quality Management
Inventory Management	Customer Service	Warehouse Management

BIOGRAPHICAL SUMMARY

1. Previously employed by British Petroleum for 28 years in a wide variety of logistics and supply chain positions. In these positions I stored and delivered chemicals, petroleum, and petroleum products, both domestically and internationally by rail, truck, barge, pipe, and ship.

2. For the past 11 years I have been a professor at John Carroll University where I research transportation topics and teach courses in logistics and operations management. More recently, I also worked on a part-time basis for the Port of Cleveland developing new business. In addition, I was hired by NEOTEC (Northeast Ohio Trade and Economic Consortium) to perform the "Northeast Ohio Logistics Infrastructure Study" which can be found at www.neohiotransportationupdate.com or www.neotec.org.

3. I hosted three seminars on campus in the past year. Each was attended by more than 250 business people. The first was titled "The Great Lakes/St Lawrence Marine Highway, Fitting the Pieces Together," and the second was titled "Northeast Ohio Logistics Infrastructure." The recent August 30th seminar is the second annual "Fitting the Pieces Together" seminar. These seminars have led directly to decisions to 1) expand rail access to the Port of Cleveland, 2) reexamine the feasibility of a cross lake ferry, and 3) reexamine the feasibility of a Cleveland/Montreal scheduled waterborne service.

4. Through my efforts, John Carroll University has been accepted a member of the Great Lakes Maritime Research Institute and the Great Lakes Coalition.

Professional Profile

Education

University of Pennsylvania, BS in Mathematics
Stanford University, MS in Operations Research
Case Western Reserve University, PhD in Operations Research

Experience

JOHN CARROLL UNIVERSITY - Cleveland, Ohio

Associate Professor of Management (2007-present)

Teach undergraduate and MBA courses in Logistics, Transportation, Operations Management, MIS

Assistant Professor of Management Information Systems (1999-2007)
Teach undergraduate and MBA courses in MIS, ERP Systems, Operations Management, and Logistics

BP OIL COMPANY - Cleveland, Ohio

Logistics Expert (1997-1999)

Functioned as logistics expert, supporting operations such as Refinery Supply, Alaskan Trading, International Oil Trading, Exploration, Terminals and Chemicals. Develop flexible, cost-effective distribution channels for BP's business units.

- Developed new crude oil and finished product supply routes, when BP sold one refinery and greatly modified another. Logistics expenditures exceed $150,000,000 per year.
- Persuaded BP to spend $1million to improve a terminal, resulting in $2million/year savings, and a partnering offer, due to its newfound logistics potential. *Completed similar projects at other terminals.*
- Identified and resolved a persistent crude oil contamination problem. $2 million annual savings.
- Avoided a "last minute" sale of $9 million worth of crude oil (in transit to one of our refineries during a fire). Identified unique method of supplying the burned refinery with intermediate feedstocks.
- Published monthly "*Pipeline News*" newsletter for three years.
- Provided consulting services to the Canadian government.

Alaskan Oil Logistics Mgr. – Lower 48 and Panama (1988-1997)

Managed $100,000,000-$300,000,000 in annual logistics expenditures. Managed the flow of Alaskan Oil to mid-continent markets along a 12,000 mile long supply chain (via crude oil tanker deliveries through Panama and four cross country pipeline networks). Responsibilities included: tanker and pipeline scheduling, inventory management, customer service, new account development, and quality control. Managed BP's operations at four crude oil terminals.

- Increased customer base by 25%, cut inventories by 25%, and cut transportation costs by 20%.
- Customer deliveries 99% on time and within specification.
- Developed 10-15 new customers for Alaskan crude in the mid-continent.
- Extended our marketing area by utilizing uniques modes of transportation.
- Successfully avoided many "last minute" sales of crude oil, during multiple logistics disruptions
- Increased BP's market share by helping competitors find low cost routes to other markets.

BP OIL COMPANY AND BP PIPE LINE COMPANY - Cleveland, Ohio

Logistics Consultant / Mgr. Computer Resources (1986-1988)

Provided logistics consulting services; developed multiple crude supply routes for BP's five refineries.

- Resolved a 10-year raw materials bottleneck at BP's New Orleans refinery.
- Developed access routes from BP's Los Angeles supply hub to four independent LA refiners.
- Developed the ***first*** use of laptop computers for pipelines (software was sold to Exxon).

BP CHEMICALS - Lima and Cleveland, Ohio

Director of Logistics (1978-1985)

Managed $100,000,000 in annual logistics expenditures. Coordinated the distribution of 20 product lines. Assumed responsibility for planning and day-to-day operations (i.e., transportation, storage, fleet management, private trucking, emergency response, export and hazardous materials regulation). Utilized multiple transportation modes, including rail, truck, barge, pipeline and ship. Directed activities of more than 100 trucking companies, a fleet of 1000 rail cars, 15 tractor-trailers, and 30 storage facilities.

- Supervised and directed a staff of 30, and managed a $12,000,000 budget.
- Coordinated daily shipping operations (from order entry through physical delivery), and achieved a 99% on-time performance; additionally responsible for emergency response to hazardous situations.
- Managed a 1000 rail car fleet in the U.S. and a 30-car rail fleet in Europe.
- Planned and negotiated rates and service commitments with tank car suppliers, railroads, trucking companies, barge lines and ocean carriers.
- Negotiated warehousing facilities for chemicals in the U.S. and Europe.
- Successfully implemented logistics innovations that improved system performance.

SOHIO - Cleveland, Ohio

Management Science Specialist (1973-1977)

Developed linear programs and computer simulations for a wide variety of logistics issues critical to the company's growth and success. Served as member of six-person team ($500,000,000 project) that selected a crude oil tanker fleet, developed supertanker port, and identified market for Alaskan oil following development of the Alaskan oil field.

OTHER EXPERIENCE (1986-1999)

Lecturer - John Carroll and other local Universities. Teach evening MBA courses in Operations Research and Operations Management (part-time)

Selected Publications

Hull, B., "Supply Chain Mythology", submitted to the Decision Sciences Journal

Hull, B., "Northeast Ohio Logistics Infrastructure Study." Sponsored by NEOTEC, January 2010, www.neohiotransportationupdate.com.

Hull, B., "Frankincense and Myrrh – the Oldest Global Supply Chain?" *Journal of Macromarketing*, Vol. 28, No. 3, 2008, pp. 275-289.

Hull, B., "Have Supply (Driven) Chains Been Forgotten?," International Journal of Logistics Management, 16.2 (2005): 218-36.

Hull, B., "Oil Pipeline Markets and Operations," Journal of the Transportation Research Forum, 44.2 (2005): 111-25. [2] (Fall Issue).

Hull, B., "The Role of Elasticity in Supply Chain Performance", *International Journal of Production Economics*, Vol. 98, Issue 3, Dec. 2005, pp. 301-314

Grenci, R. and B. Hull, "New Dog, Old Tricks: ERP and the Systems Development Life Cycle", *Journal of Information Systems Education*, Vol. 15, No. 3, (Fall 2004), pp. 277-287.

Hull, B. "A Structure for Supply Chain Information Flows and its Application to the Alaskan Crude Oil Supply Chain", *Logistics Information Management*, 15,1,2002.

Ten editions of *Pipeline News*, a pipeline industry newsletter, which I wrote and distributed to 100+ colleagues and customers.

Hull, B., "How to Make a Logistics Partnership Work", *Transportation and Distribution*, June 1989.

Hull, B., TE Moroni, DL West, "Automating Liquid Line Shipping Documentation." *Pipeline Industry*, May 1987.

Hull, B., TE Moroni, GE Shetler, DL West, "Automating Flow of Pipeline Shipments Documentation," *Proceedings of the American Petroleum Institute Conference*, April 1986.

Hull, B., TE Moroni, DL West, "Adapting Small Computers to Pipelines," *PipelineDigest,* October 1986.

Hull, B., "Two Algorithms for Matroids", *Discrete Mathematics*, Vol. 13, No 2, October 1975.

C. JAMES KRUSE
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Houston, TX 77024
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j-kruse@ttimail.tamu.edu

BIOGRAPHICAL SUMMARY

Mr. Kruse is the Director of the Center for Ports and Waterways at the Texas Transportation Institute (TTI). He is responsible for identifying research and extension needs in the port community and mobilizing resources to meet those needs.

He served in a senior executive capacity for nine years at the Port of Brownsville (1988-1997), Texas (eight years as port director), where he led a successful effort to acquire a Presidential Permit for an international bridge. Following his service at the Port of Brownsville, Mr. Kruse worked as a Regional Program Manager for Foster Wheeler Environmental's Ports Harbors & Waterways Program and assisted on port-related projects around the country.

Mr. Kruse has acquired a strong transportation planning background, having served on numerous local, state, and national boards and task forces. He was an active participant in the development of long range plans for a seaport and airport in South Texas, he has worked on statewide issues in Texas, he has participated in border transportation organizations, and he has assisted ports from Corpus Christi to New York with planning and environmental issues. Mr. Kruse is bilingual (Spanish/English) and has worked on a number of projects in the Latin American region.

EDUCATION

MS, International Business and Human Resources, Houston Baptist University, 2000.
MBA, Accounting and Finance, University of Kansas, 1977.
B.A., Business Administration, Mid-America Nazarene University, 1975.

RELEVANT EXPERIENCE

Texas Transportation Institute, Center for Ports & Waterways (2002 – Present). Director, Center for Ports and Waterways

As Director of the Center for Ports & Waterways, primary focus is on acquiring research contracts for the organization and directing that research.

- Technical Analyst: Provided technical assistance to Puerto Rico Sea Grant Program in evaluating issues raised by the Environmental Impact Statement for the proposed Port of the Americas
- Technical Analyst: Prepared comments for Port of Chicago regarding land use options
- Organizer: Organized the 2004, 2006, and 2008 Texas Ports and Waterways Conference co-hosted by Sea Grant and the Center for Ports and Waterways

- Research Analyst: Gathered information on Liquefied Natural Gas import terminals and presented to Sea Grant agents and state legislators from various states
- Investigator: *Panama Canal Dry–Bulk Market Segment Peer Review* (Research funded by Panama Canal Authority, 2003)
- Principal Investigator: *Analysis of Start-up Cross-Gulf Shipping Activities with Mexico Since 1990: Problems and Opportunities* (Research funded by Southwest Region University Transportation Center, 2004)
- Principal Investigator: *Effect of Security Requirements on Port Infrastructure Development and Funding* (Research funded by Southwest Region University Transportation Center, 2005)
- Principal Investigator: *Analysis Of U.S.-Mexico Border Trade Targets For Short Sea Shipping* (Research funded by Gulf Ports Association of the Americas, 2006)
- Principal Investigator: *Container on Barge Market Analysis – Task 1* (Research funded by private industry, 2006)
- Principal Investigator: *Environmental Impacts of Modal Transportation Study-Phase I*, (Research funded by Maritime Administration, 2006)
- Principal Investigator: *The Value of Texas Seaports in an Environment of Increasing Global Trade (Research funded by Texas Department of Transportation)* – (Research funded by Texas Department of Transportation, 2007)
- Principal Investigator: *A Modal Comparison of Domestic Freight Transportation Effects on the General Public* (Research funded by US Maritime Administration and National Waterways Foundation, 2007)
- Principal Investigator: *Short Sea Shipping Initiatives and the Impacts on the Texas Transportation System* (Research funded by Texas Department of Transportation, 2007)
- Investigator: *Study for the Development of a National Competitiveness Pact* (Research funded by Secretariat of Communications and Transportation, Mexico, 2008)
- Principal Investigator: *An Analysis of Harbor Master Positions in Cargo Ports* (Research funded by Port of Houston Authority, 2008)
- Principal Investigator: *Lock And Dam Non-Navigation Beneficiary Study* (Research funded by National Waterways Foundation, 2008)
- Principal Investigator: *Development of Potential Policies and Incentives to Encourage Movement of Containerized Freight on Texas Inland Waterways* (Research funded by Texas Department of Transportation, 2008)
- Investigator: *Emerging Trade Corridors and Texas Transportation Planning* (Research funded by Texas Department of Transportation, 2009)
- Investigator: *Protecting Waterways from Encroachment* (Research funded by Texas Department of Transportation, 2010)
- Principal Investigator: *North American Marine Highway Operations* (Research funded by National Cooperative Freight Research Program, Transportation Research Board, 2010)
- Principal Investigator: *Transportation Rate Analysis For The Gulf Intracoastal Waterway – West* (Research funded by the US Army Corps of Engineers, 2010)
- Principal Investigator: *Modal Comparison of Greenhouse Gas Emissions* (Research funded by the National Waterways Foundation, 2009)
- Principal Investigator: *Metropolitan Planning Organization (MPO) Maritime Information Needs Study,* (Research funded by Marine Highways Cooperative Program, 2010)

- Principal Investigator: *Analysis of the Effects of Lack of Channel Maintenance Dredging* (Research funded by Port of Houston Authority , 2010)
- Principal Investigator: *Update to "A Modal Comparison of Domestic Freight Transportation Effects on the General Public"* (Research funded by National Waterways Foundation—Research in Progress)
- Principal Investigator: *Transportation Rates & Closure Response Research - Calcasieu Lock* (Research funded the U.S. Army Corps of Engineers—Research in Progress)
- Active Memberships:
    1. Transportation Research Board Committee on Ports and Channels
    2. Transportation Research Board Committee on Marine Environment
    3. Transportation Research Board Committee on Inland Waterways
    4. Harbors, Navigation and Environment Committee, American Association of Port Authorities
    5. Texas Ports Association
    6. Houston-Galveston Area Maritime Security Committee

***Foster Wheeler Environmental Corporation, (1997–2002*). Regional Program Manager, Ports, Harbors & Waterways Program**

Project Manager- *Gulf Intracoastal Canal Association, Verification Analysis of Economic Impact of Lower Laguna Madre Reach of GIWW*, 2002.

Project Manager- *BP Refinery (Amoco Oil) Navigation Project Permit and Development Assistance (Texas City)*, 2001-2002.

- Business Development Lead & Project Team Member- *Maine Department of Transportation Dredging Management Action Plan*, 2001.
- Project Manager- *Port of Texas City Disposal Area Management Plan, Phase II*, 2001.
- Task Manager- *Port Authority of New York & New Jersey, Analysis of Opportunities and Issues for Nearshore Fills for Terminal Expansion*, 2000.
- Project Manager- *Port of Houston Authority, Administrative and Oversight Assistance with Alexander Island Spill Cleanup*, 1999-2000.
- Project Manager- *Port of Texas City Disposal Area Management Plan, Phase I*, 1999.
- Project Manager- *Port of Corpus Christi, Assumption of Maintenance Analysis, Rincon Canal System*, 1998.
- Project Manager- *Port of Pascagoula (MS), Project Management for Dredging and Infrastructure Improvements*, 1997-1999.

In addition to his project activities, Mr. Kruse was the regional Business Development Manager for Ports, Harbors, & Waterways opportunities, and assisted on many proposals both nationwide and in foreign countries.

***Port of Brownsville, TX, (1988 – 1997)*. General Manager & Port Director**

As Port Director, served in a wide variety of functional areas:

- Was appointed by Gov. Ann Richards to Texas/Mexico Authority
- Supervised planning, design, and implementation of $100 million in improvements to the Port facilities

- Engaged in extensive public relations efforts including newspapers, radio, TV, magazines, seminars, speaking engagements, and special campaigns
- Re-evaluated and redesigned organizational structure, producing new job descriptions, procedures, and policies
- Wrote the Port's long range plan
- Worked extensively with business leaders and State and Federal Government officials in U.S. and Mexico on legislative and economic development matters

Major project activities included:

- Project Manager- *Permitting and Project Development for New International Bridge Crossing between Brownsville, TX and Matamoros, Tamaulipas, Mexico,* 1990-1997.
- Project Coordinator- *Channel Deepening Project, Brownsville, TX,* 1989-1995.
- Project Coordinator- *Mexico Intracoastal Waterway, Analysis and Relations with Mexican Government,* 1993-1997.
- Project Manager- *Acquisition and Installation of Drydock for Port of Brownsville, TX,* 1994-1996.
- Project Oversight- Provided project oversight for railroad relocation, new dock construction, and rehabilitation and reconstruction of docks and roads for the shrimping industry.
- Legislative: Testified before a number of U.S. Congressional Committees and Texas legislative committees on a variety of issues.

During tenure at Port of Brownsville, served on the following Boards/Committees:

- Texas Border Transportation Technical Advisory Committee (TxDOT)
- Economic Development Subcommittee of the Statewide Transportation Plan Committee for development of the 1994 Texas Transportation Plan (Texas Department of Transportation)
- American Association of Port Authorities, Board of Directors
- Gulf Ports Association of the Americas
- Long Range Plan Committee for Brownsville/South Padre Island International Airport
- Long Range Plan Committee for Brownsville Navigation District

***Arthur Andersen & Co., (1977-1980),* Senior Analyst, Management Information Consulting Division**

Designed, installed, and revised several accounting systems for use in oil and gas industry in Texas and Mexico. Worked one and one-half years in Mexico City (1978-1980) on project for Petroleos Mexicanos (PEMEX).

SELECTED PUBLICATIONS

J. Mileski, R. Thrailkill, K. Haupt, J.J. Lane, W.T. McMullen, J. Gunn, C.J. Kruse, D.H. Bierling, L.E. Olson, J. Huang, P.-. Lorente. Protecting Waterways from Encroachment. 0-6225-S. Texas Transportation Institute, College Station, TX. 2010.

J. Mileski, W.T. McMullen, R. Thrailkill, J. Gunn, K. Haupt, C.J. Kruse, J.J. Lane, D.H. Bierling. Recommendations and Guidelines on Shoreline Development and Hazards to Navigation. 0-6225-P1. Texas Transportation Institute, College Station, TX. December 2010.

J. Mileski, R. Thrailkill, K. Haupt, J.J. Lane, W.T. McMullen, J. Gunn, C.J. Kruse, D.H. Bierling, L.E. Olson, J. Huang, P.-. Lorente. Analysis and Recommendations on Protecting Waterways from Encroachment. 0-6225-1. Texas Transportation Institute, College Station, TX. August 2010.

C.J. Kruse, C.A. Morgan, N. Hutson. Potential Policies and Incentives to Encourage Movement of Containerized Freight on Texas Inland Waterways. 0-5937-1. Texas Transportation Institute, College Station, TX. March 2009.

C.J. Kruse, N. Hutson, C.A. Morgan. Guidebook: Potential Policies and Incentives to Encourage Movement of Containerized Freight on Texas Waterways. 0-5937-P1. Texas Transportation Institute, College Station, TX. February 2009.

C.J. Kruse, J.C. Villa, D.H. Bierling, M.S. Terra, N. Hutson. Short Sea Shipping Initiatives and the Impacts on the Texas Transportation System. PSR. 0-5695-S. Texas Transportation Institute, College Station, TX. 2007.

C.J. Kruse, J.C. Villa, D.H. Bierling, M.S. Terra, N. Hutson. Short Sea Shipping Initiatives and the Impacts on the Texas Transportation System: Technical Report. SWUTC. 0-5695-1. Southwest Region University Transportation Center, Texas Transportation Institute. December 2007.

C.J. Kruse, A.A. Protopapa, L.E. Olson, D.H. Bierling. A Modal Comparison of Domestic Freight Transportation Effects on General Public: Final Report. TTI-2007-5. Texas Transportation Institute, College Station, TX. December 2007.

C.J. Kruse, J.C. Villa, D.H. Bierling, J.M. Solari-Terra, P.-. Lorente. Container on Barge Market Analysis - Task 1. April 2006.

Appendix B: Charge Questions

Memorandum

TO: Michael H. Belzer, PhD (Wayne State University)
Bradley Hull, PhD (John Carroll University)
James Kruse (Texas A&M University)

FROM: Alex V. Rogozhin (RTI)

CC: Dileep K. Birur (RTI); Michael P. Gallaher (RTI); Lauren Steele (EPA)

DATE: December 1, 2010

SUBJECT: Charge Questions for Peer Review of Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping.

Thank you for agreeing to review the enclosed report, "Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping."

EPA's Office of Transportation and Air Quality recently finalized regulations addressing emissions from Category 3 marine diesel engines and their fuels (the C3 Marine Rule, 83 FR 22896, April 30, 2010). This rule contains EPA's coordinated strategy to address these emissions through a combination of national and international actions. As EPA developed the C3 Marine Rule, stakeholders from the Great Lakes shipping industry expressed their concerns that the proposed program, particularly the fuel sulfur limits, would lead to higher operating costs for ships operating on the Great Lakes. They indicated that this would lead to a transportation mode shift away from ships and toward trucks or rail, which could increase emissions overall by moving to less efficient ground transportation. . They also indicated that the increased operating costs could affect the market for crushed stone, leading users to change their source from stone transported from the upper Great Lakes to local quarries. In addition, there was concern about a possible production shift for steel manufacturing and electricity generation, which would also adversely affect the Great Lakes shipping sector. Although EPA did not change its final rule with regard to applying the engine standards and fuel sulfur limits to the Great Lakes, EPA included several provisions to address these concerns and indicated that it would perform an economic impact analysis of the rule on Great Lakes shipping. The attached report contains that analysis. We are submitting this document to you for a peer review of the methodology, and the validity of the data and assumptions that go into it.

EPA has provided direction and charge questions for this review and these are included below. A teleconference call will also be arranged so that EPA can respond to questions from individual reviewers on the material that was provided for review. The completed review reports are to be furnished to RTI by January 12, 2011.

<u>Elements to be addressed in the Charge to the Reviewers of the Report on "Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping."</u>

The report looks at three aspects of EPA's recent Category 3 marine rule raised by stakeholders with respect to the application of stringent fuel sulfur limits to ships that operate on the Great Lakes. Specifically, the report examines whether higher fuel costs associated with switching from heavy-fuel oil to distillate fuel will result in transportation mode shift, source shift, or production shift.

Three separate methodologies are used for the analyses. The transportation mode shift was performed by ICF Int'l. with EERA, and uses a route-based approach. The source shift analysis was performed by EPA and uses a competitive radius approach. Finally, the production shift was performed by EPA and uses a retail revenue approach.

The report also contains information on EPA's estimated emission inventories (Chapter 4), air quality impacts and human health and welfare benefits (Chapter 5), costs (Chapter 6), and industry characterization (Chapter 7). However, these chapters are included in the report for information purposes only and we are not asking you to review them.

We request that your review primarily focus on: 1) clarity of the presentation, 2) the overall approach and methodology, 3) appropriateness of the datasets and other inputs, 4) the data analyses conducted, and 5) appropriateness of the conclusions. For this review, no independent data analysis is required, nor is it required that you duplicate the results. The appendices to several chapters of the report contain detailed information about the analysis, including contractor reports where relevant. You may need to review and comment on these appendices as part of the peer review of the report, especially Appendix 2A, which is the final project report from EERA and ICF.

In your comments, you should distinguish between recommendations for clearly defined improvements that can be readily made based on data reasonably available to EPA, versus improvements that are more exploratory or dependent on data not available to EPA. The comments should be sufficiently detailed to allow a thorough understanding by EPA or other parties familiar with the work.

Your comments should be provided as an enclosure to a cover letter that clearly states your name, the name and address of your organization, what material was reviewed, a summary of your expertise and qualifications, and a statement that you have no real or perceived conflicts of interest. Please also enclose an email with your comments in MS Word, or a format that can be imported into MS Word. The comments should be sent in care of Alex Rogozhin to the E-mail: avr@rti.org.

This study is in response to an EPA rulemaking on this subject. Therefore, EPA will make the report and your comments available in the Public Docket for the rule.

We would appreciate your not providing the peer review materials or your comments to anyone else until EPA makes them public. We would also like to receive the results of this review in the shortest time frame possible, preferably within four weeks of your receipt of this request. If you have any questions about what is required in order to complete this review, or if you find you need additional background material, please contact Alex Rogozhin by phone (919-541-6335) or e-mail [avr@rti.org]. If you have any questions about the EPA peer review process itself, please direct them to Ms. Ruth Schenk of EPA by phone (734-214-4017) or e-mail [schenk.ruth@epa.gov]

You will be paid a flat fee of $5,000 for this peer review. This fee was calculated based on an estimated 50 hours of review time at a rate of $100 per hour. In your cover letter please indicate the number of hours spent on the review; spending fewer or more hours than our estimate will not affect the fee paid for this work, but will help us improve our future budget estimates.

Appendix C: Questions and Answers Provided During the Review Process

Conference Call # 1:

Reviewers provided EPA with a list of questions that directed EPA's presentation, and were addressed on the conference call. Reviewers were given an opportunity to ask additional questions during the conference call.

Participants:

Reviewers:	Michael H. Belzer, PhD (Wayne State University); Bradley Hull, PhD (John Carroll University); James Kruse (Texas A&M University)
EPA:	Lauren Steele, Jean-Marie Revelt
RTI:	Alex Rogozhin

Questions from Dr. Brad Hull

General Questions:

1. In the Great Lakes area, what percent of the emissions are caused by ships? I ask this because, being a depressed economy, there doesn't seem to be much Great Lakes shipping.
2. Please confirm that the EPA C3 requirements are the same as those stated in the last paragraph on page 12 of the executive summary. Why didn't EPA make its ruling directly rather than through an amendment to MARPOL Annex VI?
3. How do the MARPOL Annex VI limits compare with those proposed for the North American ECA? Are they more stringent for the Great Lakes?
4. Canada must have emissions limits for Canadian Flag vessels. How do their limits compare with the existing US requirements and proposed EPA C3 requirements?
5. Does the technology presently exist to achieve these proposed standards?
6. Could I read some of the stakeholder comments, such as Lake Carriers and Canadian Shipowners? I would like to understand their viewpoint as I review the EPA study.
7. The foreign flag shipping industry does not have an organization like Lake Carriers or Canadian Shipowners. How will the C3 requirements impact international movements of foreign flag ships?

Comparison of the Great Lakes versus other US waterways:

1. How do the EPA C3 requirements compare with those required on the Mississippi/Illinois/Ohio river system? Do the vessels on those rivers utilize C2 or C3 engines?
2. Are the same EPA C3 requirements being applied to domestic US Flag shipping requirements on the East, West, and Gulf Coasts of the US?

Who uses C3 engines? :

My understanding is that the Great Lakes freighters that stay within the Great Lakes operate with C3 engines.

1. Do Great Lakes barge operators use C3 engines – or do they use C2?
2. Do Great Lakes towing companies use C3 engines – or do they use C2?
3. Do the cross-lake ferries use C3 engines? (I assume that Badger does, but is it the only one?)
4. Do oceangoing vessels that transit the Seaway/Great Lakes have C3 engines – or do they use C2? Here I am referring to Seawaymax or smaller vessels that carry steel slabs and coils from Europe to the Great Lakes, grain ships, and breakbulk ships that move project cargo.

Understanding the EPA C3 requirements from a vessel perspective:

1. Do the EPA C3 requirements apply only to US Flag ships? Do Canadian and foreign flag vessels fall under these requirements?
2. Will the EPA C3 requirements be enforced on Canadian and/or foreign flag ships in US Great Lakes waters or US Great Lakes ports?
3. Are the EPA C3 requirements more or less stringent than Canadian requirements? What are the Canadian requirements?
4. The Canadian Shipowners Association is listed as a stakeholder. Why is this, if the EPA ruling only pertains to US Flag ships? What is the expected impact on Canadian ship-owners?

Economic Arguments:

1. What is the expected percentage wise increase that C3 requirements will add to shipping costs?
2. The executive summary concludes that reducing C3 emissions should not impact volumes moving on the Great Lakes, and should not displace them to rail or truck (which would cause more emissions). However, by paying higher fuel costs will the crushed stone (and the other Great Lakes products) less profitable the increased fuel costs to their customers. That is, in economic terms, how much will demand for Great Lakes products be reduced when the fuel price increases? Is this a major or minor point?
   My understanding is that for commodities like crushed stone, potash, etc, that transportation costs are a significant percentage of the sales price. In particular, years ago, when I used to move potash from Saskatchewan to the Midwest by rail, that the rail rates were 40% of the sales price of the potash! If this is the case with crushed stone, coal, and the other Great Lakes commodities, might not this phenomenon reduce the overall demand for the product?
3. Could the new C3 standards result in a shift to Canadian sources for crushed stone or coal? After all, US shipping prices would increase relative to Canadian?
4. Any impact on steel movements? Or other breakbulk movements?

5. Why does the list of 16 at risk moves include some cross-lake movements. (Cross-lake movements can utilize foreign flag ships). Might not a cross-lake movement presently being made by a US Flag ship, switch to a Canadian flag ship?

Questions from Mr. James Kruse

General Questions:

1. Does an analysis of the economic dampening effect of an increase in cost without an increase in productivity or service levels need to be performed?
2. A parallel question: There may not be a mode shift, but will businesses continue to consume the same amount of product if the cost rises? In other words, instead of a shift, what if there is a reduction in economic activity?
3. How were individual vessel fuel consumption patterns determined?
4. Chapter 6 seems to indicate that we are only talking about modifying 12 ships. Is that correct?

Conference Call # 2:

Log of January 7, 2011 telephone conversation between RTI (Alex Rogozhin), EPA (Lauren Steele, Jean-Marie Revelt), and Dr. Bradley Hull

1) Q: Are steamships excluded? Do they run on heavy fuel? Can they run on residual fuel? Are there any that run on coal?

   A: Steamships are exempt from ECA fuel sulfur requirements on the Great Lakes. There are no freighters with steam power from coal operating on the Great Lakes.[1] Steamships on the Great Lakes do run on heavy fuel (aka residual). Steamships were exempted from the ECA fuel requirements after the industry raised safety concerns that may arise from the use of distillate fuel in these boilers, which were designed to use residual fuel.

2) Q: Are steamships used on the same trade routes on Great Lakes as diesel ships?

   A: Yes, steamships operate on the same trade routes on the Great Lakes as diesel ships.

3) Q: Are steamships more expensive to operate on Great Lakes?

   A: EPA did not attempt to study the operating costs of steamships operating on the Great Lakes because they are exempt from the ECA fuel sulfur requirements on the Great Lakes.

4) Q: Are C2/C3 diesel ships required to comply with regulation if retrofitted, are steamships required to comply if retrofitted?

   A: EPA does not require any vessel, including steamships, to be repowered. However, if an owner decides to repower a steamship, the replacement diesel engines would be required to comply with EPA's replacement engine requirements (have to meet current tier standards or demonstrate why this is not possible).

5) Q: Are steamships exempt from ECA sulfur requirements until 2015 (or 2014) or indefinitely?

   A: Existing steamships that operate on the Great Lakes are exempt from the ECA fuel sulfur requirements indefinitely.

6) Q: I recall seeing different numbers of US flagged ships mentioned in the report (some parts 8, some parts 12), what is the correct number of US flagged ships operating in Great Lakes?

[1] It was not mentioned on the Jan 7 call but there is a steam-powered car ferry that burns coal, the S.S. Badger, operating on the Lakes.

A: To our understanding, the correct number is 12. Different parts of the report were written by different authors and contractors, and some might have reviewed outdated literature. Please flag the discrepancies if you see them.

7) Q: Did the study considered US flagged vessels only?

   A: The Study was meant to be "flag neutral," in that the analysis looks at the impact of an increase in fuel costs for a type of vessel operating on a particular route. The flag of the ship was not taken into consideration. The ECA fuel sulfur requirements are expected to have similar impacts on similar vessels regardless of flag. Canadian flagship operators were a part of EPA's outreach process to stakeholders.

8) Q: Study only considers sulfur standards, the NO_x standards would be affected by retrofitting, correct?

   A: Yes, the study considers only the impacts of the ECA fuel requirements on the Great Lakes. The study does not consider the ECA NO_x requirements because new ships are added to the Great Lakes fleet only rarely.

9) Q: What is meant by "BAU" on page 1-12 of the report.

   A: BAU stands for "Business as Usual."

10) Q: Sulfur limits are only supposed to be imposed in US waters (NA ECA), are some of Canadian waters considered NA ECA?

    A: NA ECA are defined in an amendment to ANNEX VI, which defines the outer limit of the area. In the C3 rule, EPA clarified that the ECA applies to US internal waters, including waters adjacent or emptying into the ECA and the U.S. portion of the Great Lakes. EPA's study assumes vessels use ECA fuel on the entirety of the Great Lakes. However, it is up to the Canadian Government to determine how the ECA requirements will apply on their side of the Great Lakes.

11) Q: In what part of Chapter 2 does EPA identify stakeholders?

    A: Stakeholders are identified in an Appendix to Chapter 2. EPA invited a wide group of stakeholders to a workshop on the Great Lakes study, consisting of all those individuals and groups that were on EPA's public outreach list from the Category 3 marine diesel engine rule, the loco/marine rule, and other marine-related actions. Only a small subset of that invitational list participated in the workshop, however. Nevertheless, the main marine trade associations participated, as well as many ship owners and purchasers of marine transportation services. EPA will provide Appendix 2B and the workshop attendee list to RTI for sharing with the peer reviewers.

12) Q: How was the rail-route chosen in a GIFT model?

    A: Rail-route was chosen based on shortest distance between the origin and destination points.

13) Q: How were the GIFT model input costs (such as freight rates) calculated?

A: Key inputs, such as freight rates, transfer costs and port conditions, were obtained by contractors who performed the analysis, Corbett and Winebrake, from Chrisman Dager, a transportation expert consulted during the study. Fuel prices were EPA-specified.

14) Q: How were the routes for Great Lakes study developed?

A: The selection of baseline routes is described in Section 2.4 of the Study. Stakeholders identified origin/destination pairs for at-risk routes. EPA selected 16 O/D pairs and provided additional details with respect to actual sites. After sharing this final list with stakeholders, EPA provided this list to the Contractor, who developed the exact routes using the GIFT model, by maximizing the use of the Great Lakes over the route. The alternative all-rail route was determined by minimizing the distance between the origin and destination. Corbett and Winebrake performed due diligence, such as making sure that rails exist and operational for the routes identified for rail transportation scenarios.

15) Q: There is a route, originating in Europe, shipping steel coils, which are later dropped off at Cleveland and Detroit. The ships then get loaded with grain, and head back to Europe. The shipping is done by FedNav located in Canada. This route can be alternated by shipping cargo to NYC, and then distributing to mainland by rail. Is there a specific reason this route is not added?

A: No, this route was not identified to EPA by the stakeholders through the process described above in Q14 and Section 2.4. The reviewer should feel free to add this to his comments.

Appendix D: Cover Letters

WAYNE STATE UNIVERSITY

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Lauren Steele
U.S. Environmental Protection Agency
Office of Transportation and Air Quality
2000 Traverwood Dr.
Ann Arbor, MI 48105

January 12, 2011

Greetings:

The documents that I received from EPA (or RTI International) were a letter containing the charge questions and the study report by ICF International and Energy and Environmental Research Associates, LLC.

I reviewed all of the documents that I received in developing my expert opinion as contained in the “Peer Review, *Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping*” submitted on December 1, 2010.

I have provided a brief bio along with this report, as requested in the Charge Letter.

I declare that there are no real or perceived conflicts of interest concerning my involvement in this review for the U.S. Environmental Protection Agency.

I have worked approximately 50 hours on this report.

Best regards,

Reviewer Michael H. Belzer

Bradley Z Hull PhD
Associate Professor and Reid Chair
Department of Management, Marketing, and Logistics
John Carroll University
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Peer Review of **"ECONOMIC IMPACTS OF THE CATEGORY 3 MARINE RULE ON GREAT LAKES SHIPPING,"** Assessment and Standards Division, Office of Transportation and Air Quality, US Environmental Protection Agency

Bradley Hull's background for this peer review process:

1. Professor at John Carroll University for the past 12 years, teaching/researching logistics and supply chain courses/issues.
2. University of Pennsylvania (BA in Mathematics), Stanford University (MS in Operations Research), and Case Western Reserve University (PhD in Operations Research)
3. During a previous career at British Petroleum, I developed mathematical models of logistics systems. These models included linear programming models for oil and chemicals movements, mixed integer programming models for ship and pipeline scheduling, and several computer simulations of the Alaskan crude oil supply chain.
4. At British Petroleum, I was a logistics/supply chain manager (in a variety of positions) during most of my 28 year tenure. For BP Chemicals, I managed freight expenditures of $200 million per year and for BP Oil I managed freight expenditures that were greater. I have managed rail and truck movements, a fleet of 2000 rail tank cars, operated tows on the Mississippi and the Gulf Coast, shipped potash on the Great Lakes, moved a lot of Alaskan and other crude oils by ship and pipeline both internationally and in the US, stored and moved chemicals through Europe and Asia as well as domestically, and started a private trucking company. I have extensive experience both operating logistics systems and negotiating rates with carriers.
5. I have a strong interest in the transportation infrastructure of the Great Lakes/St Lawrence, and completed a year-long project "Northeast Ohio Logistics Infrastructure" in late 2009 for NEOTEC (Northeast Ohio Trade and Economic Consortium).
6. I consulted for the Port of Cleveland for over a year to help them develop new waterborne business on the Great Lakes.
7. I have hosted three conferences on the John Carroll University campus in the past two years – two of which were titled "Great Lakes St Lawrence Marine Highway – Fitting the Pieces Together" (which had a water focus) and one titled "Northeast Ohio Transport Infrastructure Study" (which had a rail focus). The conferences brought together many stakeholders (shippers, carriers, ports, and government officials) of the Great Lakes and Northeast Ohio to generate business opportunities.

I have no real or perceived conflicts of Interest. I grew up on the Great Lakes and I just want the best of all things for the Great Lakes and our environment. I sincerely thank you for the opportunity to comment. I spent approximately 150 hours to prepare this review.

To: **Lauren Steele**
U.S. Environmental Protection Agency
Office of Transportation and Air Quality
2000 Traverwood Dr.
Ann Arbor, MI 48105

From: **C. James Kruse**
Texas Transportation Institute
Texas A&M University System
701 N. Post Oak, Suite 430
Houston, TX 77024
Email: j-kruse@ttimail.tamu.edu

January 12, 2011

Dear Ms. Steele:

The documents that I received from EPA (via RTI International) were a letter containing the charge questions and the study report by ICF International and Energy and Environmental Research Associates, LLC. I reviewed all of the documents that I received in developing my expert opinion as contained in the "Peer Review, Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping" submitted on December 1, 2010.

I declare that there are no real or perceived conflicts of interest concerning my involvement in this review for the U.S. Environmental Protection Agency.

I spent approximately 40 hours while performing this review.

Best regards,

C. James Kruse
Director, Center for Ports & Waterways
Texas Transportation Institute

Appendix E: Review Reports

Review-1 by: Dr. Michael Belzer.

Peer Review, Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping

Dr. Michael H. Belzer

Wayne State University and Sound Science, Inc.
January 5, 2011

My overall impression of the assessment is that it is comprehensive and exhaustive and generally very well executed. From an economic perspective, it should not even be necessary to prove that transportation mode shift, source shift, and production shift would not occur. That is, a benefit/cost analysis would seek to demonstrate that the policy has a net benefit to society and this report shows that it achieves this benefit.[2] For the purpose required in this evaluation – to determine whether transportation mode shift, source shift, and production shift would occur – it meets the standard quite clearly. According to the text on page 1-7, the benefits exceed the costs by between 30:1 and 100:1.

To be very specific, benefit/cost analysis would determine whether the full benefit of the policy would exceed the full cost. If the higher cost of fuel resulted in a net cost that exceeded the health and climatological benefit of reduced environmental pollution, then there might be an issue. However, I have been informed by the EPA that the health effects of higher pollution due to lower grade fuels, and the costs of those effects, are not contested; that is, the amount of health risk and the cost of that risk is not in dispute. I do not see reference to climate-change issues in the chapters under review: Executive Summary and Chapters 1 through 3, inclusive.

With respect to mode, source, and production shifts, from the economic perspective, if the higher cost of fuel causes customers to source their products more nearby, then the products must be close enough substitutes that they should not travel such distances in the first place. In other words, if close substitutes do not shift closer then society must be subsidizing excessive freight transport distance, which would be bad public policy because the economics of the move would not pay the full cost. The researchers find that even those shifts do not occur, so the case is moot. Especially whether the product is iron ore or Michigan stone that is high in calcium carbonate, the product is sufficiently unique that it does not provoke a shift.

Incidentally, the paper makes reference to a possible disintermediation between raw iron ore and scrap steel. From my understanding of the steel industry, steel mills that use iron ore generally do not use scrap, and vice versa. That is, scrap mills generally do not require the resources that basic steel requires so they can be built farther from iron ore sources anyway. I do not believe that basic steel uses scrap either, so their incentives to relocate are even smaller than the report suggests.

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[2] See Committee for Study of Public Policy for Surface Freight Transportation. 1996. *Paying Our Way: Estimating Marginal Social Costs of Freight Transportation*. Washington, DC: Transportation Research Board of the National Research Council; National Academies Press.

1) Clarity of the presentation
The executive summary and introductory chapter lay out the problem clearly. Chapters 2 and 3 get more complex, but it still is clearly written with few exceptions. For those who wish to get into the underlying methodology, which was not required for this review, the extensive appendix, which is the report written by the EERA consultants, amply documents the processes.

2) The overall approach and methodology
One might quibble with the sampling design for the sixteen cases because they were not drawn at random from among the possible cases, but these cases were selected from among the 50 cases suggested by those who had objected to the rule and who were concerned that these shifts would occur, so the selection process was biased conservatively at the outset. That is, since the cases were provide by the stakeholder community as possible instances in which these shifts would occur, we would expect that evidence would tend to support the contention that shifts would occur. They did not.

These cases had been recommended by the private sector objectors because it would have been impossible for the EPA to identify the population of all possible routings. However, at least one and perhaps two of the cases chosen were not apropos of the study because either alternative routes just did not exist or the short route leg on the Great Lakes suggested something else was going on. This could suggest that perhaps the EPA should have selected the sixteen cases they chose at random from the 50 cases available to them, but the chance of having been chosen would have been one in three, reducing the likely validity from the random draw. With the results so strongly repudiating the notion that the shifts would occur, it is unlikely that the selection used would have yielded much different results from a random draw.

It appears that the EPA selected these cases systematically in an attempt to fairly represent a cross-section of trips about which the private sector was concerned. One might also be concerned, however, that the EPA selected these cases systematically to identify O/D pairs that would least likely to trigger the shifts. While the critique can be made, it is a thin reed because the results so strongly refute the contention that transportation mode shift, source shift, and production shift would occur from the higher fuel cost. The only case studied that might support this contention is the odd case in which coal travels almost as far on rail in the rail diversion case as in the default case, and unique circumstances must allow this route choice in the first place. I discuss this below.

3) Appropriateness of the datasets and other inputs
The datasets used appear to be accepted by both the EPA and the shipping community. They appear to be the most appropriate ones for this situation. The data and methods appear to have consensual agreement.

4) The data analyses conducted
The first analysis determined whether mode shifts would occur. There is no evidence to support this contention. Researchers are correct to conclude that the increment of higher cost due to the fuel change is so small that it is lost in the noise of price changes. Indeed, the cost of some of these raw materials, most notably iron ore, coal, and grain, have increased dramatically just in the last year because of global demand for raw materials such as iron ore and coal, and weather-related pressure on grain prices due to the drought and fires in Russia in 2010. US public policy

that subsidizes corn production for ethanol has driven up grain prices even further. The additional fraction of a percent of cost for cleaner fuel is a very small increment – one that by itself would not be noticed in final price because other factors, such as the foregoing, put much greater pressure on price. The recent flooding in Queensland may have a greater impact on commodity prices than the cost of lower sulfur more refined fuel.

5) Appropriateness of the conclusions.
The conclusions drawn are appropriate based on the information analyzed. There is no question that cost increases due to this fuel will not cause the feared shifts.

Detailed comments, by page and section.

1-4: I am skeptical that the Great Lakes waterways would be an economically acceptable routing for intermodal short-sea container shipping. No container ships have been built for the Great Lakes and they probably could not hold more than two hundred containers, so this would only work for bulk shipments by container. No container ports exist on the Great Lakes. Containers more likely will travel by rail.[3]

On pages 1-14 through 1-25 the authors present an annotated literature review. The review is critical and evaluates the relevant previous studies. However, they uncritically report in section 1.7.1.1 the MNDot 1991 study having a purpose to "demonstrate"… that policy decisions …can have important human health and welfare impacts". That study should have been "evaluation", not "demonstration", but that's not the problem of the authors of the present study.

On page 1-16 they review the MARAD 2006 study that evaluates short-sea shipping on the Great Lakes. This evaluation is sketchy and the fact that this shift has not happened, even as fuel price spikes made truck transport much more disadvantageous, suggests they may still have it wrong. I would suggest that the shift will be from truck to rail before it ever gets to short-sea shipping. The cost of time is significant and rail is much faster. I do not know if this study reviewed the Thomchick et al. study cited here.

1-24: In paragraphs 2 and 3 on this page, the report repeatedly refers to "realistic" and "normal" prices for fuel. I think it is difficult to forecast pricing and define normality in fuel pricing. Yes, fuel prices jumped far out of the norm by the summer of 2008, but the high fuel prices were speculatively driven and contributed to the ensuing recession. Fuel prices may have been unrealistically low before that point and may be starting to approach those 2008 levels as developing countries' demand for fuel continues to rise in spite of the recession in the industrially developed countries.[4] I would suggest using an objective standard based on a trend analysis of real historical prices and live with the consequences.

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[3] Thomchick, Evelyn A., Gary L. Gittings, John C. Spychalski, and Christopher M. Cassano. 2003. Analysis of the Great Lakes/St. Lawrence River Navigation System's Role in U.S. Ocean Container Trade: Pennsylvania Transportation Institute. www.mautc.psu.edu/docs/PSU-2002-04.pdf

[4] See Pfeifer, Sylvia. "Oil price 'enters danger zone'". *Financial Times USA*. Wednesday, January 5, 2011, page 1. This story highlights the fact that crude oil at this time is nearing $100/barrel, even during a time of great global economic uncertainty.

1-25: The authors are correct to argue that “monetized health benefits are most likely significantly underestimated.” This is the hardest measure to develop. However, it is important also to emphasize that fuel prices and restrictions affecting air quality affects all modes, including truck and rail, which already have borne the cost of shifting to low-sulfur fuel. If the maritime sector were not required to use clean fuel, we might risk subsidizing that sector over the others, contributing to economic inefficiency and social inequity.

2-2: It would have been helpful if the researchers had attempted to find out the coal-supply route from the paper mill in Green Bay. Perhaps this was not within their scope or authority, but I suspect that the transfer costs in time and money would not make it worthwhile to make the long part-rail/part-ship route. It also is possible that the route through South Chicago is inexpensive because trains handle so much volume from Elk Creek to South Chicago that the ton-mile cost is lower via that combined rail/marine route than via the direct rail route.

2-6: The broadest type of economic model, a macroeconomic model such as that incorporated in REMI and IMPLAN, would be the best to do a full benefit/cost analysis. This was not required for this particular study and thus it was not necessary to incur the additional cost, as mode, production, and source shifts were in question in this case.

2-7: As discussed above, this report does not clearly specify the basis on which the EPA chose the sixteen routes among the fifty routes provided to them by stakeholders. Except generally for an attempt to incorporate all four broad commodity groups, the basis for the selection of these particular sixteen O/D pairs is never explained. The choices are not random, which normally would be preferred.

2-8: Did the EPA try to determine the specifics underlying the O/D pairs as discussed in Table 2-2? It would take some digging and investigation, along with cooperation, to determine what is going on for each case.

2-14: I wonder if they aren’t using a per-barrel oil price that is too low to be “normal”? Using the 2007 price has the disadvantage of capturing a non-random point in time rather than a trend, and I would suggest an averaging or trend-based method across ten years or so.

2-15: With respect to last full paragraph in 2.6.3, I think that though the tradeoffs in fuel prices between marine and land-based distillate probably would remain constant, as stated in this section, but the tradeoff between the two might not be linear. As the price of oil goes up, the greater efficiency of using the marine mode might provoke shift of freight to marine over rail; this would happen at the extremes of price when the cost of fuel is so great that it begins to trump the cost of intermodal handling needed to shift as much to marine as possible. This, however, would not change the conclusions of the analysis because it would drive freight toward, not away from the marine mode; it would not favor truck or even rail.

While developed countries continue to have stagnant growth, many developing countries, especially in Asia, are experiencing rapid growth in demand for oil.

3-1: While I understand that mode, source, and production shift is the issue to be addressed here, from the economics and environmental perspective, these shifts are entirely acceptable and in many cases more efficient. In fact, if for some commodities the price of movement may be too great to support the move, and the sale and movement of the commodity would be foregone. From an economic perspective, this is an appropriate outcome. No matter what moon rocks are worth, the cost of obtaining them is prohibitively high for commercial purposes.

3-4: The current cost of diesel fuel is around $3/gallon, plus taxes, and as noted above, many analysts anticipate it will continue to rise even in the short term despite global economic uncertainty.[5] This just emphasizes the value of using a long-term price trend on which to base estimates. However, as long as fuel prices rise, systematic shifts likely will favor maritime over rail and rail over truck, so a low price probably leaves a very conservative result in this case.

3-13: Very technical clarification in first full paragraph. I would say "iron and steel sector" instead of "this sector". Last full paragraph comment: the small increased price for steel would be absorbed in down-market competition, so you are correct to conclude that it's negligible. Commenting also on the table, and repeating what has been said above, for all these commodities except perhaps stone, the marginal increase in cost for the transportation service will be swamped by the rising costs of the commodity globally.

3-18: Regarding the first paragraph and repeating what I discussed above, the markets for iron-ore-based production and scrap-based production are different. I am pretty certain that the crossover is negligible.

3-20: Top of page, last sentence in paragraph, refers to assumption that marine carriers have empty backhauls. I haven't seen a reference to this before. Is this verifiable?

3-22, Table 3-11: It would be helpful if vessel emissions could be portrayed and measured the same way as this. Seems like the calculations are in different denominators and a translation must exist for this. It is hard for a reader to make the judgment without it.

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[5] Pfeifer, Sylvia. 2011. "Oil price 'enters danger zone'". *Financial Times* (USA), Wednesday, January 05, 1.

Review-2 by: Dr. Bradley Hull.

Bradley Z Hull PhD

Associate Professor and Reid Chair
Department of Management, Marketing, and Logistics

John Carroll University

Peer Review of **"ECONOMIC IMPACTS OF THE CATEGORY 3 MARINE RULE ON GREAT LAKES SHIPPING,"** Assessment and Standards Division, Office of Transportation and Air Quality, US Environmental Protection Agency

GENERAL COMMENTS ON THE STRUCTURE OF THE ANALYSIS

The study takes a two pronged approach to the HFO/MDO issue. First, it develops a cost comparison of all-rail versus rail/water routes for sixteen origin destination pairs. The goal is to establish that a switch from HFO to MDO will not result in a significant modal shift to rail. While the results of the analysis strongly suggests this result, it is not conclusive. A stronger argument is required. Here is why: The study utilizes a shortest route all-rail route for the origin/destination pairs, and also utilizes a cost based (I think) approach to compare the all-rail versus rail/water alternatives. In reality, railroads often don't use the shortest route, and don't use cost based methods to calculate their rates. Rather, they calculate their freight rates based on "differential pricing" methods (charging what the market will bear). In fact, railroads are famously known for using differential pricing to compete for waterborne traffic. Thus, though the analysis strongly indicates minimal modal shift to rail, the reality could be different. If you proceed with this analysis I urge you to add a validation step in which you select some of the sixteen origin/destination pairs, meet with the relevant stakeholder, and delve into details of the actual movements.

The second prong of this two pronged approach is important and necessary because it addresses the wider issue of industry competition – taking the study beyond the bounds of strictly modal competition. It takes a Great Lakes perspective of the steel, stone, coal, and power generation industries and evaluates the impact of the higher priced MDO on the ability of these industries to compete. Overall, I feel that each of the industry analyses can be improved (later in the document you will see detailed comments on each), and that more work needs to be done. The analysis should further include a look beyond the Great Lakes especially for the steel industry, due to its global nature.

I encourage the EPA to consider the following approach to the steel industry analysis: develop a linear program that models the mills on the Great Lakes and elsewhere and optimizes flows from mills to market. Next, perform a sensitivity analysis on the water transport costs to determine the extent to which MDO usage shifts steel manufacturing away from the Great Lakes to other steel centers. (The petroleum industry uses similar models to direct flows of crude oil from multiple origins through multiple waterborne and pipeline routes, to multiple refineries. It uses similar models to optimally route refined products from refineries to markets – I developed and worked with several of these models at BP). I am concerned that increased MDO costs might result in global steel companies shifting production (to greater or lesser degree) from Great Lakes mills to their other mills. With the depressed state of the "rust belt" we don't want to lose any more jobs.

A further factor to include in your steel industry analysis: Steel imports from Northern Europe to the Midwest are highly dependent on grain backhauls (steel ships need a grain backhaul to justify the inbound steel movement). To the extent that MDO usage reduces the availability of grain backhauls while simultaneously increasing the cost of steel fronthauls, steel movements into the Great Lakes become less economic. Eliminating the steel coil imports weakens the steel industry, because the European made steel coils are purchased for specialty uses.

In addition to the two pronged approach described above, I feel strongly that the EPA should add a third prong: the impact of MDO usage on the potential all-water imports and exports through the Great Lakes/St Lawrence – this is potentially a significant growth industry for the Great Lakes.

Here is the business opportunity for Midwestern cities located near the Great Lakes: The St Lawrence Seaway lies geographically on a straight line between the Midwest (large consuming population and industrial heartland), and Rotterdam/Antwerp (two of the largest world ports). This route has been cost effectively used by the steel industry for the past 50 years for importing steel coils from Northern Europe, but it is rarely used for general merchandise. (I will discuss the reasons with you if you wish) Based on the minimum mileage character of this straight line and the low cost of all-water transport, this route could benefit a host of imports/exports. As such, it is widely recognized as a potential growth business. Great Lakes ports, shippers, and carriers are studying ways to initiate service.

This is a MAJOR OPPORTUNITY for the EPA to reduce emissions in the Midwest and East Coast: As a large manufacturing and consuming region, the Midwest imports and exports considerable quantities between Midwestern cities and Europe. The routes currently used, though, require an overland leg by rail or truck (generating major emissions) between the Midwest and either Montreal or US East Coast ports, and then a waterborne leg between Montreal or East Coast ports and Rotterdam/Antwerp/Europe. If imports/exports were channeled through the all-water route, we would reduce emissions in the Midwest and East Coast, save transport costs, and take trucks off the roads. This would have a significant positive impact both to the Great Lakes as well as the East Coast environment. The Rhine River is an excellent example of such a working system, because the Rhine handles much of Europe's commerce, reducing overland journeys through Europe by truck and rail, and significantly reducing emissions throughout Europe.

Relevance to the current EPA study: Montreal successfully competes with the US East Coast ports for deliveries to the Midwest, and approximately half of Montreal's imports are destined for the US Midwest. Many Great Lakes ports, shippers and water carriers are evaluating the all water service to Europe described above. (few such services exist and I would be happy to discuss this further with you). Will the higher cost of MDO discourage the development of these many opportunities, giving further advantage to the high emissions overland routes to East Coast ports and Montreal?

In summary, with the internal Great Lakes industries in decline, we should encourage growth of new business opportunities, such as import/export – especially since this growth simultaneously cleans up the environment. The C3 study should address this topic.

RESPONSES TO THE CHARGE QUESTIONS PLUS ONE MORE

1. Clarity of the Presentation: The study is well written, but I have a few suggestions for "framing the problem," especially in the opening pages, to enhance its clarity for a general audience.
    a. State clearly that the study addresses Sulfur limits. In reading the study it took me awhile to understand this, because the study includes details on NOX and Particulates. My understanding now is that NOX and Particulates standards were previously justified and ruling has been made – they are secondary to Sulfur for this study. In my initial reading, I had felt that the NOX and Particulate limits were a subject of the analysis as well, and I wondered why the analysis was on sulfur only.
    b. Demonstrate that ships are a major contributor to sulfur problems in the Great Lakes/St. Lawrence region. Your study hasn't done that in a convincing way. Convince the audience. Provide a chart that shows ship emissions versus sulfur emissions from all the other polluters: trucks, railroads, automobiles, and manufacturers in the Great Lakes area. Convince the audience that adopting MDO will have a significant positive impact on the Great Lakes environment. Demonstrate that despite the fact that a large percentage of ship emissions occur in unpopulated areas, ships are major polluters in populated areas compared with shore based emissions sources.
    c. Clarify whether the Seaway between Montreal and the mouth of the mouth of the St Lawrence River (a 500 mile long leg which exclusively runs through Canada), will require 100% MDO. I assume that this section of the River will continue to use HFO. Here is why: Montreal aggressively competes with US East Coast Ports to handle imports/exports for the US Midwest. Since the St Lawrence River downstream of Montreal runs exclusively through Canada, the many miles of using 100% MDO would negatively impact Montreal's competitive position – an undesirable result from a Canadian point of view. I encourage you to address the issue and state what you feel is the most likely assumption, so that readers can better understand the areas of impact of the C3 Ruling. (As a parenthetical comment, both the Montreal and US East Coast port routes to Midwestern cities involve overland, high emissions truck/rail legs. The lowest emission route is all-water through the Seaway and the Great Lakes to Midwestern cities. Thus, it is important to protect the all-water route)
    d. Please state the jurisdiction of the C3 Rule more clearly. I assume that the C3 Rule legally covers all ships travelling through or loading/unloading in US waters. If so, please state that. Due to the more-than-a-dozen border crossings, I assume that it de facto covers all ships travelling through Canadian waters in the Great Lakes as well. If so, please state that too.
    e. Do sufficient quantities of MDO exist to support the C3 ruling? I assume so, but did not see this question addressed or analyzed in detail. This point should be cleared up to further establish the feasibility of the C3 Rule (and having worked in the petroleum industry I can offer some suggestions if you wish).
    f. In the body of the text please distinguish between "rates" and "costs." Your use of these terms was confusing at times and they seem to be used interchangeably. I am fairly certain that your analysis compares the costs of all-rail, versus the costs of rail/water transport. Unless you are adding a profit margin to these figures, please continue to refer to them as costs rather than as rates. This confused me

since railroads set their rates based on negotiations, using "differential pricing" or a "value of service approach." (in fact, this is the method by which they famously compete with water transport) Their freight rates can and often differ widely from their costs.

More clearly defining the scope of the issues and the jurisdiction of the C3 Rule on the first pages adds clarity to the remainder of the presentation. Also, clarity is enhanced in the body of the text through items e and f above.

2. The overall approach and methodology need further clarification:
   a. The EERA approach compares a minimum distance all-rail route with a minimum distance rail/water route. The rail routes are calculated using a model of existing rail tracks. Please check these routes for feasibility: are they heavily travelled trunkline routes, and do they involve multiple railroads? This is important since the routes are theoretically calculated rather than based on knowledge of actual routes being used.

      While the shortest route is appealing, railroads often don't use the shortest route. Railroads want a long haul to gain economies of scale, and the long haul may not be the shortest, and may even be circuitous. In fact I have seen railroads utilize extremely circuitous routes just so they can preserve the long haul instead of having to share revenues by incorporating a second railroad. Also, railroads try to shift traffic to their most heavily used lines for economies of scale, density, and service. These heavily used lines may detract from the shortest route approach as well.
   b. Are the routes from "item a" above evaluated on a "cost of service" or "value of service" basis? (I think that you are using "cost of service" but please clarify) A more clear definition of the calculation method and components is required. "Cost of service" builds up costs from the component operating costs of railroads and ships. It would include such factors as cost of cost of the train operating costs, winter layup for ships, tugs, lock fees, and pilot fees in calculating an overall voyage cost. Value of service would compare existing freight rates (which are very difficult to find due to their proprietary nature), and competitive positions of the railroads. Cost of service seems more appropriate for theoretically calculated routes. The EERA study uses rate/cost information from Chrisman Dager. It is important to understand the source of his information and whether it is cost or rate based. See references to Dager in part 3 below and on my comments about the EERA report. Further documentation of Dager's technique and information source is needed. It would be good if his input figures could be included in an appendix.
   c. Railroads use "value of service" or "differential pricing" to value their services. In fact, on the Great Lakes and Mississippi River systems, they are known for drastically reducing their rates to attract business away from the water. This issue should also be addressed in the analysis*, and it puts the entire concept of "cost of service" pricing in question for this analysis.*

3. Appropriateness of the of the datasets and other inputs:
   a. Dager provided many of the underlying rates/costs for the analysis. Are they rates or are they costs? If the analysis is cost of service, what component costs are

included and what was the source of the information? There are many such costs for both railroads and ships. For ships on the Great Lakes, costs include, US Flag hire cost, US crew cost, pilot fees, tug charges, lock delays on the Seaway, wintertime layup costs, and many more. Costs should be explicitly enumerated in the text. Similarly, if the analysis is based on value of service, how is this estimated (rail and ship rates are contractual and not published) and what is the information source (actual rates are very difficult to find)? Much better definition of his data set is required.

4. The data analyses conducted:
    a. The EERA study provides a straightforward analysis of the Dager information.
    b. Regarding the stone, coal, and steel analyses of Chapter 3, I would like a more thorough analysis done for coal, I felt the crushed stone analysis was quite good though it needs a review of its underlying data sources, and that the steel analysis and supplementary analysis needs to be revised to incorporate a more global perspective.

5. Appropriateness of the conclusions:
    a. The EERA study addresses the impact of 100% MDO on internal Great Lake movements. With the Great Lakes industries on the decline, the study needs to consider the global marketplace and present and potential import/export opportunities, which is, after all the growth opportunity for Great Lakes as well as the rest of the economy.
    b. Since the EERA model is theoretical and actual routes and rates may differ, I would encourage a final validation of the model by selecting a subset of the sixteen scenarios and interviewing shippers/carriers for their input and perspective.
    c. The EERA study is suggestive but not conclusive. First the all-rail versus rail/water comparison is based on a cost model that may or may not be followed in the real world. Railroads and ship price their services on value of service instead of cost of service. This is especially true when they compete for waterborne business. Regardless of the fact that the EERA cases show that Great Lakes ships can absorb the increased cost of MDO without significant modal shift, the higher priced MDO can still result in less business overall, as manufacturers shift production away from the Great Lakes toward lower cost supply sources.
    d. The stone, coal, and steel analyses of Chapter 3 are also not conclusive.
        i. Stone shift analysis is stated as problematic, even by the authors, due to factors not included in the analysis. I happen to like the analysis a lot, but it makes several simplifying assumptions which need to be examined and validated, such as the use of theoretical transport costs from origin to destination, the assumption that highways are "straight line", that Michigan specialty stone replaces local quarry stone on a ton for ton basis, and that heavy trucks are allowed on US highways. These assumptions need to be reviewed, but found the analysis otherwise very interesting.

ii. Coal power is explained in a confusing way and the argument needs to be expanded. I spent a lot of time reading it, and would like the work done more explained further in more simple terms.
iii. I would like to see an expanded analysis of the steel industry since steel is so vital to the Midwest. The first discussion of steel assumes that water supplied coal is used in steel production, when in reality, the coal delivered by Great Lakes ships almost always goes to power plants. The supplementary analysis is more compelling but needs to factor in the need for grain backhauls and a wider marketplace. Also with the additional MDO costs added to limestone and iron ore movements along with additional MDO costs for steel imports and grain backhauls, it seems conceptually that the combined effect would be a significant negative for the competitiveness of the steel industry, vis a vis the steel industry elsewhere.

6. Impact of global marketplace is not included in the study, but should be included because it is the "growth business" of the Seaway. The Great Lakes has a significant quantity of captive business with iron ore, limestone, crushed stone, coal, and internal grain movement. However, these businesses have been on the decline since before 1990, and any growth for the Great Lakes/Seaway will necessarily come from increased import/export. Currently grain is exported (significant quantities this fall!), and steel coils/slabs have been imported for the past 50 years (using FedNav, Polsteam, and Wagenborg – none of whom is included in the study). Further, moves are afoot to deliver international containers to the Great Lakes (the Ports of Cleveland, Toledo, Erie/Conneaut, Ashtabula are all studying this, and Great Lakes Feeder Lines, McKeil Marine, and Wagenborg are interested carriers). Since this would create a significant number of jobs in the depressed "rust belt" and since this business would take trucks off the road, I believe that it should be included in the study. Here are three components that should be included:
    a. Grain: Grain from the Midwest is shipped abroad via three main routes – by ship through the Great Lakes/St Lawrence, by rail to the US West Coast for loading to China, and by river barge down the Mississippi for export from New Orleans. My understanding is that the route chosen is highly dependent on transport rates, and small rate changes can have a major impact on choice of route. Would a requirement to burn MDO both ways on the 2000+ mile journey have a significant negative impact on the amount of grain routed through the Great Lakes? Page 7-26 of the study states that 70% of grain on the Great Lakes is destined for export, so this is an important case to be considered in the body of the report. Grain is an important export and should be explicitly analyzed.
    b. Steel Coils: Steel coils are imported into the Great Lakes in the following manner. A breakbulk ship (typically FedNav, Polsteam, or Wagenborg) loads steel coils in Northern Europe for a variety of Great Lakes customers. The ship then crosses the Atlantic and transits the Seaway to discharge partial cargos at Cleveland, Detroit, and Burns Harbor. When finished discharging, the ship picks up a grain backhaul and returns to Europe. Two issues need to be addressed:

i. If use of 100% MDO on the entire Great Lakes/Seaway route has a significant negative impact on availability of grain backhauls, will steel coil imports become uneconomic?
ii. If the use of 100% MDO makes the (fronthaul) delivery of steel coils through the Seaway less economic, steel coils will likely be diverted to the East Coast ports for an overland rail/truck leg to Midwestern customers. (this is an alternative Midwestern route used by steel companies) In this case, the system generates more emissions from rail/truck. This alternate route is also considerably more expensive (that's why the all-water route to the Midwest is preferred) which then reduces the viability of the existing Midwestern steel companies.

c. Containers: Containerships transit the Seaway as far as Montreal. At that point, the containers are transloaded to truck and rail for delivery to Canadian and US customers. The truck/rail movements generate high emissions. My understanding is that approximately half of the containers are delivered to the US. At present there are several moves afoot to extend container deliveries into the Great Lakes by water, possibly directly from Europe or by transloading containers to feeder ships or barges in Montreal or Halifax (the Ports of Cleveland, Toledo, Erie/Conneaut, and Oswego are the interested ports and Wagenborg, Great Lakes Feeder Lines, and McKeil Marine are interested carriers). Such a service would reduce SOX, NOX, and particulate emissions because it would replace rail and truck deliveries from Montreal and the East Coast. Would the 100% MDO ruling make this opportunity uneconomic?

DETAILED COMMENTS

The numerous comments below are listed page by page. I boldfaced some of the more important comments for emphasis.

Executive Summary

Page 10: Define "Category 3" engines in the text, rather than in a footnote, since the study is about them.
Page 13: I thought that steamships were permanently exempted from the ruling. The text indicates that a fuel waiver is available only until January 2015. Which is true? Please clarify.
Page 16: Provide more information on which stakeholders were consulted. Stakeholder buy-in is critical. This section only lists Lake Carriers Assn. and Canadian Shipowners Assn. That isn't a lot of stakeholders. A full list should be included in the body of the study or in an Appendix. If the full list is confidential, you should try to characterize the list as best you can.

Chapter 1

At the beginning of Chapter 1, make the case that marine emissions are a big problem in the Great Lakes and St. Lawrence. This is the reason for having a C3 ruling in the first place. Present statistics showing that the Great Lakes are a non-attainment region and establish that marine emissions are a considerable percentage of those emissions. Add a table comparing the emissions from ships, trucks, railroads, automobiles, and factories showing the relative contribution of each to our densely populated region.

Page 1-4: Please document the degree to which ships contribute to the air quality in the region, compared with other emissions sources. From a novice's point of view, the Midwest economy is depressed, and shipping is considerably off, so with few ships there will be few air emissions. Also, I would imagine that trucks, rail, and factories contribute a much greater share than do ships. If possible it would be useful to document this.

Page 1-5: Explain how the US EPA standards can apply to the Canadian Great Lakes ships of Table 1-3. I think that EPA standards would apply to US waters, and that EPA standards would be applied to Canadian ships because of the many boundary crossings they must make.

Page 1-5: The study looks only at sulfur standards in fuel and yet engine changes must be made to accommodate reductions in particulates and NOX. Please explain the relevance of NOX and particulates to this particular study, and explain why the cost of engine changes is not incorporated in the analysis.

Page 1-6: Ocean going salties "carry only a small share of cargo on the Great Lakes." They are very important though because they represent the growth business for the Seaway, so it is important to consider them in the analysis. Elsewhere in this document I am recommending that you evaluate the steel movements of salties. Also there are a considerable number of "salties" that bring containers as far down the Seaway as Montreal and there are studies that show that extending their reach to the Great Lakes is economic. Thus, it is important to determine whether this ruling will have a significant negative impact on these growth opportunities for the Seaway.

Page 1-7: With steam engines being excluded from the ruling, is it likely that they will be more heavily used by ship owners so that they can avoid retrofitting Category Three vessels?

Page 1-7: Please confirm that steamships are PERMANENTLY excluded from the ruling or list any conditions attached.

Page 1-8: North American ECA: Ships transiting the Seaway will travel many more miles with the North American ECA than will ships travelling from, say, Europe to an East Coast port. Thus the ruling will fall more heavily on Seaway transits than any other part of the North American ECA – true or false?
If true, then the main cost increases will be the ships that are either captive to the Great Lakes or FF ships that transit the Seaway. Thus, both types of ships should be reviewed.

Page 1-9: Add a bullet point describing the Seaway and Great Lakes components of the North American ECA. (you have bullet points for the other NA ECA components).

Page 1-9: In the summary, or earlier in the text, please be sure to explain how a US EPA ruling becomes incumbent on Canadian and Foreign Flag carriers. Are they included due to the fact that they travel through US waters? Are they included only if they unload at a US port? Are they included because it would be too complicated to track all the boundary crossings?

Page 1-11: Please reconcile the following two seemingly contradictory sentences:

1) "…we excluded Great lakes steamships from the ECA fuel sulfur requirements."
2) "..allows Great Lakes shippers to petition EPA for a temporary exemption from the 2015 fuel standards, which can encourage repowering steam engines to……"

Are steamships excluded permanently from the sulfur standards, or only until 2015?

Page 1-12: Please define "BAU" (business as usual) for the general audience.

The remaining pages of the chapter are quite interesting summaries of other studies. I think this is good to put your study in context, and very useful. I only have one comment on them below:

Page 1-22/23: I think the steel issue is one of extent, rather than one of relocating. A large, global steel company faces a worldwide demand and meets it with least cost. Thus if one of the steel mills owned by the global company experiences an increase in its transport cost to market, that mill will manufacture less, and another lower cost steel mill located elsewhere will manufacture more. Thus, a GL transport price increase would likely reduce the shipments "somewhat" rather than result in an immediate relocation. The amount of the reduction is often measured by a linear program.

Chapter 2 ***General (and important) Comment on Chapter 2*****:** I believe that you should include a category for imported steel coils/slabs in addition to coal, iron ore, crushed rock, and grain, because there are an appreciable number of steel coils imported into the Midwest from Northern Europe by ship. (I can fill you in on more details). This would involve a breakbulk ship delivering steel coils from Northern Europe to the steel companies in Cleveland/Detroit/Burns Harbor, typically using a three port discharge, with a grain backhaul. This breakbulk ship voyage should be compared with another similar voyage to the East Coast for delivery to the same destinations by rail. Midwestern steel companies use both routes. I am concerned that the need to utilize MDO for the entire Seaway voyage will eliminate the Seaway route in favor of the water/rail route (which increases emissions and cost).

Page 2-2: Category Three ships must undergo modifications as well as fuel change. I believe the modification costs were not included in the analysis. What would be the impact if these were included?

Page 2-2: In Scenario 2, were the mine and paper mill stakeholders approached to try to better understand the situation? I think this might be a valuable way of validating the modeling approach, since the modeling approach did not seem to work. I recommend that you get into the details of Scenario 2 and talk with the shippers and carriers to find an explanation. Without such explanation, the result casts doubt on the results of the other Scenarios.

Page 2-5: Are the sulfur limits imposed on the Great Lakes/Seaway by EPA any stricter than those planned by the Canadians, or those planned for the US East Coast ports? Do the sulfur limits apply downstream of Montreal? What parts of the Lakes and St. Lawrence River are impacted?

Page 2-6: (IMPORTANT) Since the conversion to run MDO instead of HFO in Category Three ships is inexpensive, these costs can be effectively ignored. You should make this point in the analysis, as well as document it, because as you discuss modal shift, I kept wondering why you did not include the fixed costs of conversion

Page 2-6: By "flag neutral" I assume that the EPA requirements will be required of all US, Canadian, and Foreign Flag ships operating in US waters in the Great Lakes St Lawrence Seaway System. Correct?

Page 2-7: How did the EPA identify the stakeholders who provided the 50 O/D pairs? Who were the stakeholders? How did you winnow the list down to the 16 winners? Please provide a list of stakeholders either in the text or in an appendix. If the stakeholder list is confidential, please characterize them to the extent reasonable. The readers would like to know who was involved.

Page 2-10: I am concerned at the use of the GIFT model to calculate an optimal all rail route. This is because railroads negotiate rates based on "value of service approach" or "differential pricing." This is charging what the market will bear, rather than a straight mileage times dollars per mile calculation. The rate and route also depends on how many railroads are involved and their individual routes – railroads all want to achieve long haul economics and as such may avoid a least cost routing that might extend over multiple railroads.

Page 2-13: The study refers to cost function modeling (which is cost-of-service, as opposed to value-of-service). Does the analysis strictly compare costs of two alternatives or does it compare rates? Rates would be more accurate but extremely difficult to accomplish with accuracy.

Page 2-14: I disagree with Section 2.6.2. I think that since the rail routes used are calculated a model, that we can't provide detail about the specific types of services. These calculated rail rates are critical to the results of the analysis. You should expand this one paragraph section to describ how you calculate the rail rates. Your analysis expects the reader to accept the rail rates you are publishing – so you need to provide backup as to how you arrived at them.

Page 2-14: For Great Lakes ships, if the study includes cost-of-service, it should include the cost of laying the ships up during winter, which will increase their costs. It must also include factors such as tug costs which will be required to position ships alongside docks, lock fees, pilotage fees which can be quite high, etc.

Page 2-15: You quote that MDO is expected to be 45.5% more expensive than HFO. Is that figure in $/ton for both MDO and HFO? How does the btu content of MDO compare with HFO? What is the comparison in $/BTU? I would think that the cost per BTU would be a more valid comparison of MDO and HFO.

Page 2-15: Please explain what you mean by freight rates. I think that you are building up the ship, rail and handling costs and adding some percentage of profit. Is this true?

Page 2-15: If this is a buildup of costs, then please provide a list of the component costs. For ships there are some costs unique to the Great Lakes that need to be included, such as winter layup cost, tug costs, pilot costs (which can be quite expensive), the high US Flag costs for maintenance and ops, and tolls – along with the more usual costs. Were these costs included?

Chapter 2, Appendix A

Overall Comment: Chrisman Dager's input is crucial to the analysis, and also undocumented. Please document his input and how he arrived at it.

Page 7: The study only includes the 16 identified captive Great Lakes cases, but does not include import/export along the Seaway. Also, no cost of converting engines to handle MDO is included. If the conversion cost is high it should be included in the analysis, otherwise the authors should establish that they are too small to bother with (as I think is the case).

Page 10: Other parts of the report state that there are 12 Category Three US Flag Ships, as opposed to the 8 referred to on this page. My understanding is that there are 12. With only 8 Category Three US Flagged Vessels, 57 Category Three Canadian Flagged Vessels, and numerous Category Three Foreign Flagged Vessels, the impact of the EPA ruling will fall mainly on Canadian and Foreign Flagged ships. Will the Canadian and Foreign Flagged ships require engine modifications too?

Page 12: With Category Three US Flagged Vessels using HFO, all will require retrofitting. Is the technology available currently to allow a changeover? The information on Page 13 indicates that the US Flagged vessels are quite large, so can the changeover present a problem?

Page 16: The no backhaul assumption can make shipping more expensive than the reality with backhauls.

Page 17: FedNav (Canadian flag and FF ship operator), Polsteam (Polish flag), and Wagenborg (Dutch flag) are breakbulk operators who operate a significant number of vessels between the Great Lakes and abroad. FedNav also operates within the Great Lakes. FedNav, in particular is a major ship operator headquartered in Montreal. They should be included in Table 14 and in the analysis. These are "salties" that bring steel coils into the Seaway and export grain.

Page 17: Algoma Central and CSL Group are the Canadian Flag operators who have the lions share of Category Three ships. Have they issued a position to the study?

Page 18: Most of the cases modeled involve US Port/US Port movement. These require one of the 8 (US Flagged vessels above, and the study indicates, these vessels are large. Does the ship analysis in this study account for this fact, or is it using generic Category Three ship figures? Also, with steamships being exempted, one might expect a shift from using US Flag Category Three ships to more fully utilizing steamships,

Page 19: Who is Chrisman Dager? He is providing the rail rates for the analysis and we don't know how he gets them? Does he build them up on a cost plus basis, or does he use knowledge of the existing rate structure, or some other method?

Pages 19-22: **I believe that Chrisman Dager provided figures for** FR_{BC} $DTM_{dsr\ rail}$ TC_{dsr} *and* $DTM_{all\ rail}$**. These figures are critical to the results of the analysis and their source and values should be documented.**

Pages 19-22: In calculating the at-sea fuel cost, what size ship is used? More generally, the rail freight is calculated as a $/ton figure times miles travelled, and the ship freight rates were provided by Chrisman Dager. Who provided the rail costs and how were these rail/ship freight figures estimated? If the ship rates were calculated on a cost of service basis, how were the old US Flag ships valued?

Sailing on the Seaway/Great Lakes differs from East Coast sailing, in that the speed limits are lower, there are several lock fees, wintertime layup costs, costs of US crews and ships, tug fees, and pilotage fees are an issue. I understand that pilotage fees can cost $10,000 per day for foreign flag ships. Are these factors included in the analysis? If so, then they are factored in through the Dager analysis.

For the base case rail route in the scenarios, how do the routes chosen by the model compare with those actually used?

Page 23: Of the 16 cases, 12 require a US Flag ship. Are these ship moves presently being made by a steamship (exempted from the study) or one of the US Flagged Category Three ships? If the moves are steamship moves, shouldn't they be removed from the study? Are the remaining 4 cases handled by a Canadian Flag ship?

Page 26: How were fuel consumption rates calculated for the ships?

Page 26-29: It is nice to see that careful thought was put into the ship selection for each Origin/Destination pair.

Pages 24-29: in the Description of Input Assumption Sources please add a paragraph on how rail rates were calculate and another paragraph for ship rates.

Page 27-28: Rail distances. Railroads prefer one-line-hauls. If the movement is from a mine served b a single railroad, the origin carrier will want the long haul to achieve economies of scale. For this reason, rail movements are not necessarily the shortest distance route (and can be quite circuitous), especially if the shortest route involves two or more railroads. I would be curious to know if the model used selected a route with three or more railroads – since a route with more than two carriers is rare.

Pages 29-94
In the scenarios, I assume that the Base Case Route is the one that is actually used. Is this true, or are either the rail or ship portion generated by the Hawker model?
In the scenarios, does a switch from the Base Case Route to an All Rail route involve more emissions at destination? That is, for example, does a power plant emit more when it unloads rail cars or a ship? If this is true, is this factored in anywhere?
Scenario 2's Base Case looks crazy. I recommend that it be researched further. Why would anyone use a ship in this case? Does the base case reflect an actual movement? Is it possible that Georgia Pacific cant unload rail cars? Is the actual rail route the same as the one that the model chose? Is there an equity ownership involved?

Page 97: Please confirm that there is a rail ferry across the St. Lawrence River to Baie Comeau, QC. I have never heard of such! What are the sensitivities considered?

Chapter 2, Appendix B

Stakeholders were approached at Marine Community Day, an Ann Arbor workshop, the Canadian Shipowner's Association, and Lake Carrier's Association. These were likely representatives of the water carriers as opposed to representatives of the coal, stone, iron ore, and grain industries. Were stakeholders from these industries also included in the analysis? Please describe the stakeholders in the study.

Chapter 3

Section 3.1: **Source Shift (Crushed Stone):** I assume that power plants run a combination of trucked and ship/railed stone? Michigan's high calcium carbonate and low bond work index seems to be valuable because of its chemical properties for use in scrubbers.

Further I assume that a ton of Michigan stone, because of its unique chemical properties, must replace more than one ton of locally quarried stone. If this is true then we would want to encourage the use of long distance Michigan stone to reduce the number of truckloads of lower grade local stone. I suggest that someone from the stone industry (or one of the power plants under discussion) answer this question.

Section 3.1.2: Based on the reading and a subsequent phone call with the EPA here is my understanding of the method utilized: I believe that we start with the EERA model-calculated water/rail cost from the Michigan origin to a power plant, and then for this cost we draw a circle around the power plant to represent a competitive truck radius. This identifies the truck completion. We then look at expanding the truck radius by the extra ship MDO expenditure. As a result, the analysis is strongly dependent on the initial rail and ship cost figures provided by Dager (see my Chapter 2 remarks). The source of Dager's figures needs to be documented.

Water/rail deliveries versus truck deliveries of crushed stone:

1. **On Page 3-4, the analysis assumes oversized trucks with 43 ton cargos, rather than the 20 ton cargos allowed on Ohio's and Pennsylvania's roads (Pennsylvania's weight limit may even be lower than 20 tons). Is this a valid assumption?**
2. The study indicates that "anecdotal evidence suggests that truck rates may be higher, at $20 per short ton more" than their analysis uses. This large discrepancy should be reconciled.

If the Bruce Mansfield Power Station is expected to see a partial modal shift, we should find out if the increased emissions of the additional trucks offset the emissions savings of the C3 ruling. Also, if the Power Station is outfitted to unload cars with few emissions, a conversion to truck may increase them. It wouldn't hurt to talk directly with the Station about their supply sources to validate your analysis.

The study states that the analysis is problematic because of factors not included, as listed in the last paragraph on Page 3-8. Further, if a shift from rail/water to truck occurs, the emissions consequences of this shift should be calculated and be included in the analysis. Still further, the shift analysis hinges on theoretical rail/water cost figures. Despite all that I think this is a very interesting approach.

Section 3.2: Production shift (Steel and Electric): Low cost steel and electricity producers typically run at capacity, while high cost producers expand or contract their production to meet the ups and downs of demand. By increasing the transportation cost of the inputs, we put the Great Lakes producers into the higher cost category, and as such they may lose production at times to the lower cost producers. This is probably a difficult concept to quantify. The classic example of such a potential shift is the new Thyssen-Krupp steel mill in Mobile. Thyssen has water access to the Midwest for its steel through the Tennessee-Tombigbee Waterway, and would like compete with the Midwest producers. As a new state of the art facility, they are high volume, low cost producer. Thus, perhaps the Great Lakes producer does not go out of business, but he will likely lose some business at the edge of his/her marketing area to companies such as Thyssen-Krupp.

Section 3.2.2: Impact on Great Lakes Sector: The Rosebud Mine is used for the lower and upper bound scenario and applied to electrical generation for the entire Lakes region. This is certainly a conservative assumption, since lots of the coal used does not even move by water, and some electricity is not generated by hydroelectric rather than coal. You might mention this in the text. Further in your analysis, you relate the transport cost increase to reduced electricity revenues. How do you calculate this inverse relationship? Is it a price elasticity argument?

Your argument in the last paragraph of Page 3-10 is difficult to follow. Please explain more fully how you separate the transport cost from the EIA figures. My understanding is that you use average figure for mine costs in East North Central, and subtract it from the "delivered coal cost." Also, once you have subtracted the transport component, you must have to back out the percentage trucked and direct railed. Finally in using your baseline case freight rate, you are using the Rosebud Mine as indicative of the Midwest industry. I somehow am not understanding your argument or I am overthinking it. Please clarify for me and for others. It would be helpful if you would add some columns to Table 3-4 so that one could more easily follow your argument. Also, in the table you distinguish between public utilities versus independent power generators – but you don't distinguish between them in the text. Please expand this section.

Section 3.2.3: Impact on Steel: I encourage you to add another row in Table 3-6 immediately above "transp cost increase % revenue" with the $100.2 billion steel revenue figure. This would add clarity for people like me who like to reproduce the answers.

The argument is compelling but not complete in that you show that the MDO cost increase is a small percentage of revenues. However, as a percent of transport cost it can be between 8.5-16.6% for iron ore and 1.2-4.5% for coal. A company is quite capable of changing their shipping decisions based on such percentage increases in cost (especially for the iron ore percentages). A company's shipping decisions are typically designed around minimizing manufacturing and transport costs. Revenues are calculated separately. If a steel company has no choice it may have to pay the difference, but the steel manufacturing decision may result in producing a bit less at the now-higher-cost Great Lakes plant and more at another plant.

My understanding is that Great Lakes coal movements are almost exclusively destined for power plants and almost none is used in steel production (steel companies usually use coke with is rail supplied). There are a few exceptions, like the Rouge steel plant in Detroit which occasionally received a shipload of metallurgical coal, but there aren't many. Your table in this section seems to indicate that Great Lakes ships DO consume coal delivered by Great Lakes ships. This should be changed.

Section 3.2.4 Steel Production Shift: A Supplemental Analysis: The analysis in this section is both thought provoking and well done. I would like to ask the author a further question: An appreciable quantity of imported steel coils enters the Great Lakes from Europe. The steel coils are typically carried by FedNav, Polsteam, or Wagenborg. When these ships arrive in the Great Lakes, they discharge partial cargos at Cleveland, Detroit and Burns Harbor. After this, they pick up a grain backhaul and return to Europe (typically). This is a very cost effective movement that has been popular for the past 50 years! Competing for this business is a second movement from Europe. This second movement involves the same ships (or larger ships due to Seaway limitations) delivering coils to the Philadelphia/New York area, where they are offloaded and shipped into the Ohio/Pennsylvania area by rail.

The question for the author is: to deliver breakbulk material such as steel (but of any type), what will be the increased cost of Seaway transit to cities such as Cleveland, Toledo, Detroit, and Burns Harbor. I believe that this question is quite important, specifically because there are many attempts to deliver international containers directly into the Great Lakes ports from Europe, rather than delivering them through New York/Phila/Baltimore with an overland freight leg. I am concerned that a large marine fuel cost increase on the Seaway might delay this shift to waterborne deliveries, and would like to understand the potential incremental cost per ton of cargo.

Page 3-15: The statement is made that a trip from Asia to to LA can involve 1700 miles of North American ECA transit. How can that be? I thought that the NA ECA extended to 200 miles offshore only. If such a route exists, is it likely that that captain would take it when he can burn HFO for only 200 miles?

Page 3-17: Please check the fuel cost increased for the imported steel case. It seems to me that if imported steel moves through the North American ECA, all the way (1500 miles or so) down the St Lawrence and into the Great Lakes, that utilizing MDO at a 40% or so premium above HFO would significantly increase the transport cost. However, the figures on Table 3-7 do not reflect this, if true.

Page 3-17: Truth is stranger than fiction. Steel does move by water to East coast ports and then by rail to the Midwest. Norfolk Southern RR has a yard in Philadelphia dedicated to such moves.

Chapter 6

Page 6-1: Is it possible that we would refit a Category Three ship with a Tier 2 OR a Tier 3 engine?

Page 6-2: hardware costs of fuel switch are $42k-$71k!!! So little!! Say this at the beginning of the study, so that a reader does not feel that you overlooked what they may think of as a major fixed investment cost!

Page 6-8: Category Three ships do not need to be repowered under the ruling – only for company reasons, such as the existing power unit outliving the hull of the ship. This comment is important and should be more prominent in the beginning of the study.

Page 6-8: The repowering costs mentioned above are up to $600,000 in addition to an engine replacement. Thus, they are extremely high. Does this pertain to steamships too, and will this contribute to them being retired?

Page 6-9: Seasonal layups are not included in the freight costs, but would likely be included in the actual freight rates charged to customers.

Page 6-11: PLEASE EXPLAIN THIS PAGE – WHERE DO THE STATS COME FROM?

Page 6-12: IN THE TABLE, ARE THE COLUMNS DIFFERENT SHIPS?

Chapter 7

Page 7-26: 70% of grain on the Great Lakes is destined for export, so this is an important case to be considered in the body of the report

Grain exports: Grain from the Midwest gets exported either through the Great Lakes, the Mississippi River, or the West Coast depending on market prices and transport cost. Adding cost to Great Lakes route will tilt the flow toward the other two routes to a degree. Can you quantify this? How much additional cost will be added and/or how much MDO versus HFO will be burned on the inbound and outbound voyages? (with 70% of grain on the Great Lakes destined for export, this is an important case)

Page 7-54: Please site the specific document from which you obtained Figure 7A-3.

Review-3 by: Mr. James Kruse.

PEER REVIEW

ECONOMIC IMPACTS OF THE CATEGORY 3 MARINE RULE ON GREAT LAKES SHIPPING
Reviewer: C. James Kruse, Texas Transportation Institute

In preparing these comments, I reviewed four documents:

- Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping, Chapters 1, 2, and 3
- Comment Letter from Canadian Shipowners Association, dated September 25, 2009
- Study of Potential Mode Shift Associated with ECA Regulations In the Great Lakes, August 2009
- EPA's Emission Control Program: Great Lakes Shipping, PowerPoint presentation dated February 11, 2010

I also participated in a conference call on December 21, 2010, that included a representative of RTI International, several representatives of the Environmental Protection Agency (EPA), and the other peer reviewers.

In reviewing the document, I focused on methodology, assumptions, and data sources. I did not attempt to do any grammatical or editing reviews, nor did I attempt to verify that computations were correct or that stated values were accurately imported from their sources.

For the most part, I found the document to be comprehensive and well-substantiated. Exceptions are noted in the attached comments. One facet of the analysis that is missing is the concept of equity. If ultra-low sulfur fuel requirements are being placed on trucks and locomotives, but not on marine engines, this would represent an indirect subsidy to marine. While the road to implementation may be markedly different, the requirements should represent a level playing field to the degree possible.

The charge letter requested that peer reviewers focus on 5 issues. These are addressed in the following paragraphs.

1. **Clarity of presentation**
   By and large, the presentation is fairly easy to follow. There are a few things that could be done to improve clarity and readability:
   - It would be helpful to standardize the units of measures for tons. Specifically, the document uses "tonnes", "tons", "metric tons", and short "tons" (to name a few). Either the same "type" of ton should be used throughout the document or the unit of measure should be explicit each time any variant of "ton" is used.
   - There are a lot of missing words and extraneous words. Correcting these editorial problems will help.

- On page 1-7, paragraph 5, the reference to “Section 1.1.4 below” doesn’t make sense. This is already section 1.4.2.
- On page 1-8, the document says “the level of fuels used in an ECA will decrease from 15,000 ppm to 10,000 in 2010”. We are already past 2010. Should it say “decreased” instead of “will decrease”?
- On page 1-9, the document states that France was instrumental in getting the North American ECA approved. Should it be Mexico? Omitted?
- Acronyms need to be spelled out at first usage. For example, on page 1-12, paragraph 1, what does “BAU” stand for?
- On page 1-22, paragraph 1, “go does” should be “goes down”.
- On page 2-6, the document states that “The purpose of this study is to examine whether an increase in fuel costs for Great Lakes shipping could lead to transportation mode shift”. This is extremely important in evaluating the analysis. I think this should be highlighted in the Executive Summary and at several points throughout the document.
- On page 2-9, the document states that “the analysis does not consider the transportation of the grain from the farm to the silo”, but does not state why. Although the reason may seem obvious, some explanation should be given.
- There are two issues with paragraph 1 on page 2-14: (1) The term “net tons” needs to be explicitly defined. (2) In three instances in this paragraph, the document states that the vessel weighs a certain amount. This is not true. It appears that the author intends to refer to “deadweight tonnage”, which is the weight of cargo, fuel, stores, and crews that the vessel can accommodate at its maximum load line—not the weight of the vessel. This needs to be clarified.
- On page 2-16, there is an excellent description of how the freight comparison was conducted. It might be useful to mention this in a couple of other places (e.g., executive summary), but not critical.
- In four scenarios shown in Chapter 2, Appendix A, there is no all-rail alternative considered, but the document does not explain why at this point. In the results section, the document states, “It was determined that *xxxx* is not serviceable by rail. Therefore an All-Rail Alternative Route does not exist”. The justification needs to be included on pages 53, 55, 57, and 59 as well.
- What is the unit of measure for costs In Table 3-6? Is it millions of dollars?

2. The overall approach and methodology

The approach of looking at origin/destination pairs that stakeholders thought might be affected is excellent. Given historical cargo flows, it also appears that the commodities that were chosen were appropriate. The involvement of stakeholders seems to be adequate and meaningful. Finally, there was an appropriate trade-off between accuracy and level of effort. My specific concerns about methodology are the following;

- In the CSA study dated August 2009, the authors state that “Transportation costs while an important factor in determining ore sourcing are often subordinate to considerations of ore quality, mine ownership, long-term contracts, and overall corporate benefit”. This should be noted in EPA’s analysis of the iron ore trade.
- In the document I reviewed, the analysis assumes that each voyage will have a revenue-generating backhaul. I have received a notice that backhauls were

considered to be empty in the analysis. If so, I do not have a problem with backhauls, as empty backhauls will state the worst expected case.

- I agree that focusing on the 2015 sulfur limit is the way to go.
- I have strong concerns about the methodology used for crushed stone. On page 3-3, the next-to-last paragraph states "It also does not examine the reason why the purchasing facility uses stone originating at a much longer distance, requiring ship transportation, when stone from local quarries may be available." The existence of this situation in the "real world" invalidates the methodology used in the document. Users are importing stone from great distances for a reason. To simply expand the "competitive radius" as the basis of the analysis ignores this consideration. If the stone is being imported from a specific quarry, then the inclusion of quarries producing similar quality/grade stone needs to be evaluated rather than just looking at quarries generically.
- Would steel import quotas have an effect on this analysis? If so, that should be analyzed.
- I don't see where the document addresses the concern the shareholders expressed regarding a potential spike in the price of the 0.1% sulfur fuel if there is a limited supply in the Great Lakes region when implementation begins.

3. Appropriateness of the datasets and other inputs

- In the CSA study, it was noted that neither Ontario steel mill has the facility to receive coal by rail. It would be wise to verify that the Algoma facility included in the analysis does have the facility to receive iron ore by rail.
- What is the basis or source for the statement on engine specific fuel oil consumption? How did EPA (or its contractor) derive the assumed propulsion powers?
- The source for the assumption on rail energy intensity needs to be stated.
- The current Great Lakes basin profile is for 2008. Table 13 in Appendix A should be updated.
- The sources should be stated for the following assumptions used to develop Table 16 in Appendix A: Auxiliary Engine power, Auxiliary Engine Load Factor in Port, and Rail Energy Intensity.
- In Appendix A, why is it assumed that the vessel will be loaded to 85% of its capacity? Since this assumption directly affects the unit freight cost, it is important to justify it.
- The Corps' Port and Waterway Facilities data were used to obtain the depth of each port. I don't know about the Great Lakes, but for the Inland Waterway System, these data are highly unreliable. Again, since available depth directly affects the unit freight cost, I would suggest some kind of "truthing" of these depths.
- In Chapter 3, is the assumption of a truck load of 43 short tons valid if the quarry is located in the United States?
- What is the basis for the assumption that 80% of the delivered iron ore cost is the "iron ore cost at the mine"?

4. **Data analyses conducted**
   With the exception of the concern regarding stone quarry analysis noted above, I found the analyses to be appropriate and adequate. I have no further items of concern in this area.

5. **Appropriateness of the conclusions**
   The conclusions were appropriate and justified, taking into account the data sources and inputs employed for the analysis. There were just two instances, where I felt the conclusions needed to be shored up. On pages 3-5 and 3-6 statements are made to the effect that "the increase is not substantial compared to the number of quarries already located within the radius." This is a subjective statement that needs to be validated with numbers/data.

My comments are attached in tabular format. They are arranged in the order in which the underlying paragraphs in the document are presented—not in order of importance. The items I consider to be of greater importance have an asterisk ("*") below the page number.

LISTING OF COMMENTS REGARDING ECONOMIC IMPACTS OF THE CATEGORY 3 MARINE RULE ON GREAT LAKES SHIPPING

Page	Paragraph	Comment
General		It would be helpful to standardize the units of measures for tons. Specifically, the document uses "tonnes", "tons", "metric tons", and short "tons" (to name a few). Either the same "type" of ton should be used throughout the document or the unit of measure should be explicit each time any variant of "ton" is used.
General		There are a lot of missing words and extraneous words.
General		The involvement of stakeholders seems to be adequate and meaningful.
General		I don't see where the document addresses the concern the shareholders expressed regarding a potential spike in the price of the 0.1% sulfur fuel if there is a limited supply in the Great Lakes region when implementation begins.
General		In the CSA study dated August 2009, the authors state that "Transportation costs while an important factor in determining ore sourcing are often subordinate to considerations of ore quality, mine ownership, long-term contracts, and overall corporate benefit". This should be noted in EPA's analysis of the iron ore trade.
General		In the same CSA study, it was noted that neither Ontario steel mill has the facility to receive coal by rail. It would be wise to verify that it does have the facility to receive iron ore by rail.
1-7	5	The reference to "Section 1.1.4 below" doesn't make sense. This is already section 1.4.2.
1-8	2	The document says "the level of fuels used in an ECA will decrease from 15,000 ppm to 10,000 in 2010". We are already past 2010. Should it say "decreased" instead of "will decrease"?

Page	Paragraph	Comment
1-9	0	The document states that France was instrumental in getting the North American ECA approved. Should it be Mexico? Omitted?
1-12	0	At the end of the paragraph, should probably use "metric ton" instead of "tonne". (See general comments).
1-12	1	What does "BAU" stand for? Please write it out.
1-22	1	"go does" should be "goes down".
2-5	2	I agree that focusing on the 2015 sulfur limit is the way to go.
2-6 *	3	The document states that "The purpose of this study is to examine whether an increase in fuel costs for Great Lakes shipping could lead to transportation mode shift". This is extremely important in evaluating the analysis. I think this should be highlighted in the Executive Summary and at several points throughout the document.
2-9 *	1	The document states that "the analysis does not consider the transportation of the grain from the farm to the silo", but does not state why. Although it may seem obvious why, some explanation should be given.
2-14	1	There are two issues with this paragraph: (1) The term "net tons" needs to be explicitly defined. (2) In three instances in this paragraph, the document states that the vessel weighs a certain amount. This is not true. It appears that the author intends to refer to "deadweight tonnage", which is the weight of cargo, fuel, stores, and crews that the vessel can accommodate at its maximum load line—not the weight of the vessel. This needs to be clarified.
2-14 *	2 & 3	What is the basis or source for the statement on engine specific fuel oil consumption? How did EPA (or its contractor) derive the assumed propulsion powers?
2-14 *	4	The source for the assumption on rail energy intensity needs to be stated.
2-16	1	This is an excellent description of how the freight comparison was conducted. It might be useful to mention this in a couple of other places (e.g., executive summary), but not critical.
2A-13	1	According to what the document says on 2A-16 and what the carriers state, vessels that carry iron ore can also carry grain.
2A-15	Table 13	The current Great Lakes basin profile is for 2008. The table should be updated.
2A-24 *	Table 16	The sources should be stated for the following assumptions: Auxiliary Engine power, Auxiliary Engine Load Factor in Port, and Rail Energy Intensity.
2A-26 *	2	Source for specific fuel oil consumption parameters?
2A-26 *	5	Why is it assumed that the vessel will be loaded to 85% of its capacity? Since this assumption directly affects the unit freight cost, it is important to justify it.

Page	Paragraph	Comment
2A-27 *	4	The Corps' Port and Waterway Facilities data were used to obtain the depth of each port. I don't know about the Great Lakes, but for the Inland Waterway System, these data are highly unreliable. Again, since available depth directly affects the unit freight cost, I would suggest some kind of "truthing" of these depths.
2A-53, 55, 57, & 59		In four scenarios, there is no all-rail alternative considered, but the document does not explain why at this point. In the results section, the document states, "It was determined that xxxx is not serviceable by rail. Therefore an All-Rail Alternative Route does not exist". The justification needs to be included on pages 53, 55, 57, and 59 as well.
3-2 ff **		I have strong concerns about the methodology used for crushed stone. On page 3-3, the next-to-last paragraph states "It also does not examine the reason why the purchasing facility uses stone originating at a much longer distance, requiring ship transportation, when stone from local quarries may be available." The existence of this situation in the "real world" invalidates the methodology used in the document. Users are importing stone from great distances for a reason. To simply expand the "competitive radius" as the basis of the analysis ignores this consideration. If the stone is being imported from a specific quarry, then the inclusion of quarries producing similar quality/grade stone needs to be evaluated rather than just looking at quarries generically.
3-4	2	Is the assumption of a load of 43 short tons valid if the quarry is located in the United States?
3-5	2	The last sentence states, "…the increase is not substantial compared to the number of quarries already located within the radius." "Not substantial" is subjective. I suggest including some numbers here.
3-6	1	See previous comment.
3-9	3	Would steel import quotas have an effect on this analysis? If so, that should be examined here.
3-12	4	What is the basis for the assumption that 80% of the delivered iron ore cost is the "iron ore cost at the mine"?
3-13	Table 3-6	What is the unit of measure for costs? Is it millions of dollars?

Appendix F: Additional Documents Provided to the Reviewers

List of Additional Documents Provided to the Reviewers

1) U.S. EPA Appendix 2B "Stakeholder Interactions" to Chapter 2 of the EPA "Economic Impacts of the Category 3 Marine Rule on Great Lakes Shipping" (June 10, 2010);
2) Stakeholder "Attendee List" (June 10, 2010);
3) U.S. EPA Marine Control Program: "Marine Community Day Presentation" (February 11, 2010) [Available in Appendix F of this memorandum];
4) "Comments of the Canadian Shipowners Association on the United States Environmental Protection Agency's proposed rulemaking entitled "Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder" (September 25, 2010 EPA-HQ-OAR-2007-0121);
5) Research and Traffic Group "Study of Potential Mode Shift Associated with ECA Regulations In the Great Lakes" (August, 2009);
6) U.S. EPA "Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder – Information in Support of Applying Emission Control Area (ECA) Requirements to the Great Lakes Region" (December 15, 2009 EPA-HQ-OAR-2007-0121-0586);
7) U.S. EPA "Summary and Analysis of Comments: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder" (December, 2009 EPA-420-R-09-015).

EPA's Emission Control Program: Great Lakes Shipping

Marine Community Day
February 11, 2010

Byron Bunker
U.S. Environmental
Protection Agency

Overview

- Summary of Marine Engine, Fuel Programs
- Congressional Direction
- Great Lakes Provisions
- Great Lakes Study

2

EPA's Marine Program

- Comprehensive program - marine engines and fuels
- Coordinated strategy
  - Clean Air Act
  - MARPOL Annex VI
  - Emission Control Area Designation
    - ECA designation expected to be adopted at IMO March 2010

3

Marine Diesel Engines

- NOx, PM
- 2008 Loco/Marine Rule
  - New Category 1 and 2 engines
  - Reman Category 2 engines
- 2009 Rule/MARPOL Annex VI Amendments
  - New engines >130 kW
  - Existing Category 3 engines

4

Marine Fuels

- Sulfur and PM

- Fuels produced, distributed in US (CAA program)
  - 15 ppm distillate by 2014
    - 2004 Clean Air Nonroad Diesel Rule
  - 1,000 ppm ECA fuel by 2015
    - 2009 Category 3 Marine Rule

- Fuels used in North American ECA (ECA program)
  - 10,000 ppm by 2012
  - 1,000 ppm by 2015


U.S./Canada ECA Proposal
Greenland
(Denmark)
Alaska (U.S.)
Canada
Saint-Pierre
& Miquelon
United States (48 states)
Bahamas
Mexico
Hawaii (U.S.)
70°
60°
50°
40°
30°
20°
160°
140°
120°
100°
80°
60°
6

Result: Reduced Ship Emissions

- NOx Controls
  - ~ 80% NOx reduction new vessels (2016)

- PM and SOx Controls
  - ~95% SOx reduction
  - ~85% PM reduction

- Shipping will be efficient and clean!

7

Human Health & Welfare Benefits: Category 3 Rule

- 2030 estimated benefits are between $110 and $280 billion
- By 2030, program expected to prevent:
  - Between 13,000 and 32,000 PM-related premature deaths
  - Between 220 and 980 ozone-related premature deaths
  - Up to 1,500,000 work days lost
  - Up to 10,000,000 minor restricted-activity days
- Estimated annual costs are much smaller: $3.1 billion

8

Human Health & Welfare Benefits: 2008 Loco/Marine Rule

- 2030 estimated benefits are between $9 and $11 billion

- By 2030, program expected to prevent:
  - 1,100 PM-related premature deaths
  - 280 ozone-related premature deaths
  - 120,000 work days lost
  - 1,100,000 minor restricted-activity days

- Estimated costs are much smaller: $740 million

Great Lakes Shipping

- U.S. ship owners and Great Lakes industry associations contributed to our marine actions
  - 2003 Tier 1 Rule
  - 2004 Locomotive and Marine Rule
  - 2007 Ship ANPRM

- Environment Canada, Transport Canada, and Canadian ship owners also participated

Great Lakes Vessels

- Lakers: ECA fuel sulfur requirements on the Great Lakes will –
  - Put steamships out of use –distillate fuel causes safety concerns
  - Increase operating costs, leading to significant modal shifts to rail or truck

- Result will be emissions <u>increase</u>, from rail and truck

11

Direction from Congress

- 2010 Appropriations Bill (HR9226, the Department of Interior, Environment, and Related Agencies Appropriates Act, 2010)
- EPA directed to exclude Great Lakes steamships from fuel sulfur standards
- Bill Report: EPA should include 2 waivers (fuel availability, economic hardship), do study)

12

FRM Provisions for Lakers

- 40 CFR 1043.95
- Steamships excluded from fuel requirements
- Diesel ships: compliance waived for 10,000 ppm fuel if that fuel is not available - but owner must purchase the next cleanest fuel available
- Serious economic hardship provision
- Canadian vessels are also eligible – Annex VI Compliance on the Lakes

13

Great Lakes Economic Study

- What are the impacts of fuel sulfur requirements on Great Lakes shipping?
- How do we evaluate this question?
  - Methodology
  - Data needs
- Developing stakeholder process to carry out this study
- Assessing existing methodologies

14

Additional Information

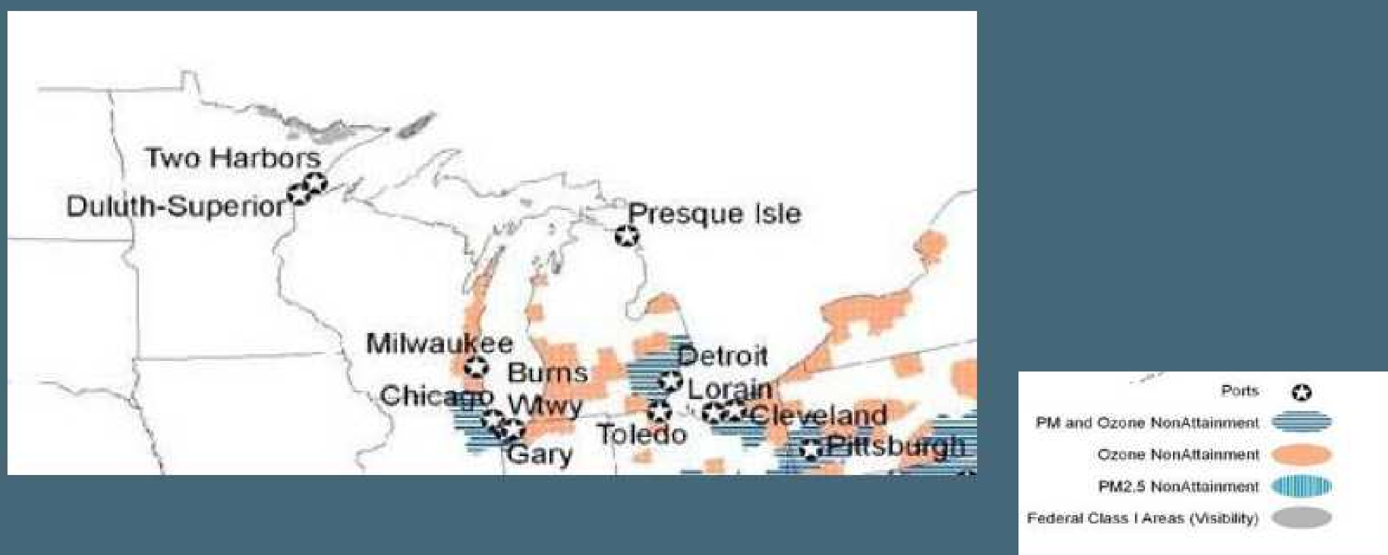
- 2009 Category 3 Marine Rule and North American ECA
  - www.epa.gov/otaq/oceanvessels.htm
- 2008 Loco/Marine Rule
  - www.epa.gov/otaq/marine.htm
- General Marine Program Contact
  - Jean-Marie Revelt
  - U.S. Environmental Protection Agency
  - Revelt.Jean-Marie@epa.gov
  - (734) 214-4822

Appendix

Impacts of Great Lakes Vessels on U.S. Air Quality

Great Lakes Ports and Nonattainment Areas

- Great Lakes shipping about 1.5% of the emissions and fuel consumption in the U.S., but their impacts are localized on the Lakes



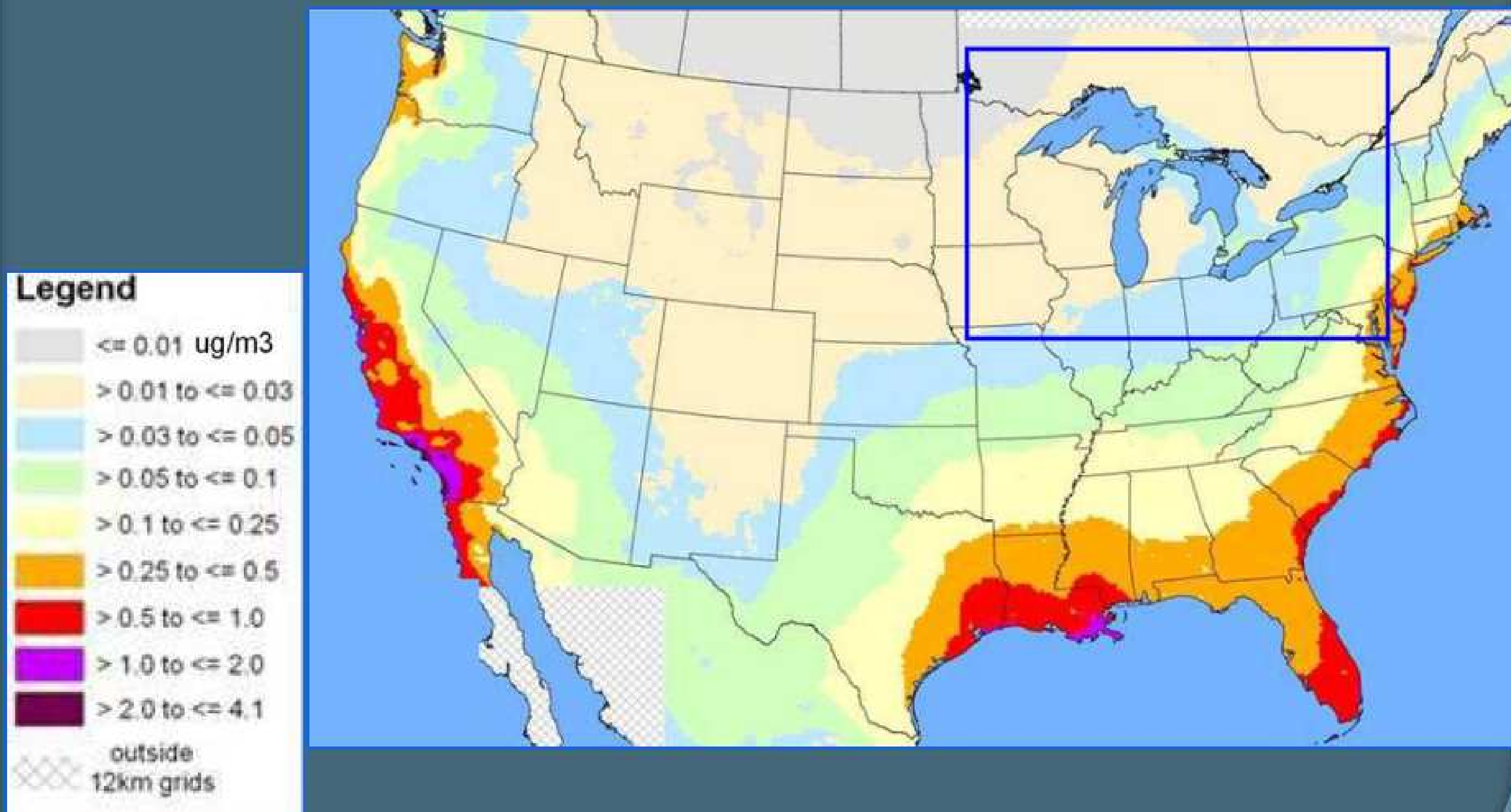
17

Great Lake Vessel Contribution

- About 1.7% of the PM benefits of Category 3 engine and fuel controls in the U.S. are achieved in 6 Great Lake states (IN, IL, MI, MN, OH, WI)
  - PA and NY not included because they also border Atlantic Ocean
- Estimated benefits of controls on Lakers is –
  - $1.5-3.7 billion in benefits v. $0.05 billion in costs
  - In comparison, the total benefit of Category 3 marine rule in 2030, for the full U.S. ECA, is $110-$260 billion, with $3.1 billion in costs, for similar benefit-to-cost ratio

18

2020 Potential PM2.5 Reductions



19