2019 SmartWay Barge Carrier Partner Tool:

Technical Documentation

U.S. Version 2.0.18 (Data Year 2018)

EPA-420-B-19-011 | March 2019 | SmartWay Transport Partnership | epa.gov/smartway

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Transportation and Climate Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

EPA-420-B-19-011
March 2019

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1.0 Emission Factors and Associated Activity Inputs

Emission factors form the basis for the emission calculations in the Barge Tool. The Tool uses the latest and most comprehensive emission factors available for marine propulsion and auxiliary engines. The following discusses the data sources used to compile the emission factors used in the Tool, and the fleet characteristic and activity data inputs needed to generate fleet performance metrics.

1.1 AVAILABLE EMISSION FACTORS

Propulsion Engines

CO_2 emissions are calculated using fuel-based factors, expressed in grams per gallon of fuel. Available fuel options include marine distillate (diesel – both low and ultra-low sulfur), biodiesel, and liquefied natural gas (LNG). The Barge Tool uses the same gram/gallon fuel factors for CO_2 that are used in the other carrier tools (Truck, Rail, and Multi-modal), as shown in Table 1. These factors are combined directly with the annual fuel consumption values input into the Tool to estimate mass emissions for propulsion and auxiliary engines. (The fuel consumption inputs are summed across both engine types). The factors for biodiesel are a weighted average of the diesel and B100 factors shown in the table, weighted by the biodiesel blend percentage.

Table 1. CO_2 Factors by Fuel Type*

	g/gal	Source[1]
Diesel	10,180	(i)
Biodiesel (B100)	9,460	(ii)
LNG	4,394	(iii)

* 100% combustion (oxidation) assumed

The Barge Tool uses emission factors expressed in g/kW-hr to estimate NO_x and PM emissions. For marine distillate fuel, the Tool uses EPA emission factors developed to support its recent marine vessel rules. The NO_x and PM_{10} emission factors for main propulsion engines using ultra-low (15 ppm) sulfur distillate fuel are a function of year of manufacture (or rebuild), as well as Engine Class (1 or 2 for tugs/tows), and rated engine power (in kW). These factors, presented in Tables A-1 and A-2 in the Appendix, are combined with estimated engine activity in kW-hrs to estimate mass emissions, as described in Section 2. The PM_{10} factors are multiplied by 0.97 to obtain $PM_{2.5}$ estimates, consistent with the conversion factors used by the EPA NONROAD model.

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[1] i) Fuel economy calculations in 40 C.F.R 600.113 available at http://edocket.access.gpo.gov/cfr_2004/julqtr/pdf/40cfr600.113-93.pdf. Accessed 2-11-19.
ii) Tables IV.A.3-2 and 3-3 in A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1001ZA0.pdf. Accessed 2-11-19.
iii) Assuming 74,720 Btu/gal lower heating value (http://www.afdc.energy.gov/afdc/fuels/properties.html - Accessed 2-11-19.), and 0.059 g/Btu.

NO_x and PM emission factors for biodiesel were based on the findings from an EPA study, A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions (EPA420-P-02-001, October 2002). This study developed regression equations to predict the percentage change in NO_x and PM emission rates relative to conventional diesel fuel, as a function of biodiesel blend percentage, expressed in the following form:

Equation 1

$$\% \text{ change in emissions} = \{\exp[a \times (\text{vol\% biodiesel})] - 1\} \times 100\%$$

Where:

a = 0.0009794 for NO_x, and

a = -0.006384 for PM

For example, the NO_x reduction associated with B20 is calculated as follows

$$[\text{Exp}(0.0009747 \times 20)-1] \times 100 = 1.9\%$$

To obtain the final NO_x emissions the unadjusted NO_x is multiplied by (1-0.019) = 0.991,

Using Equation 1, adjustment factors were developed for biodiesel blends based on the percentage of the biofuel component, and then these adjustment factors were applied to the appropriate conventional diesel emission factors in Appendix A. Ultra-low sulfur diesel fuel (15 ppm sulfur) is assumed as the basis for adjustments.

Emission factors were also developed for LNG derived from a variety of data sources including EPA, U.S. Department of Transportation (DOT), Swedish EPA, and the California Energy Commission. The following emission factors were assumed, corresponding to slow-speed engines operating on natural gas.

- 5.084 g NO_x/kW-hr
- 0.075 g PM_{10}/kW-hr

Note that for LNG, emission factors are assumed to be independent of model year and engine size. In addition, as LNG PM emissions are primarily the result of lube oil combustion, the Barge Tool assumes $PM_{2.5}$ emissions equal 97% of PM_{10} emissions, consistent with the conversion used for diesel fuel.

Auxiliary Engines

NO_x and PM emissions associated with diesel auxiliary engine operation are set equal to EPA's nonroad compression engine emission standards, depending on kW and engine model year (see Table 2).[2] Alternative fuels and retrofits are not allowed for auxiliary engines at this time.

[2] See https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf. Accessed 2-11-19.

Table 2. NO_x and PM_{10} Emission Factors (g/kWhr)

Power (kW)	Model Yr Range	NO_x	PM_{10}
< 8	2004 & earlier	10.50	1.00
< 8	2005-2007	7.50	0.80
< 8	2008+	7.50	0.40
8 - <19	2004 & earlier	9.50	0.80
8 - <19	2005-2007	7.50	0.80
8 - <19	2008+	7.50	0.40
19 - <37	2003 & earlier	9.50	0.80
19 - <37	2004-2007	7.50	0.60
19 - <37	2008-2012	7.50	0.30
19 - <37	2013+	4.70	0.03
37 - <56	2003 & earlier	9.20	0.40
37 - <56	2004-2007	7.50	0.40
37 - <56	2008-2012	4.70	0.40
37 - <56	2013+	4.70	0.02
56 - <75	2003 & earlier	9.20	0.40
56 - <75	2004-2007	7.50	0.40
56 - <75	2008-2011	4.70	0.40
56 - <75	2012-2013	4.70	0.02
56 - <75	2014+	0.40	0.02
75 - < 130	2002 & earlier	9.20	0.30
75 - < 130	2003-2006	6.60	0.30
75 - < 130	2007-2011	4.00	0.30
75 - < 130	2012-2013	4.00	0.02
75 - < 130	2014+	0.40	0.02

Power (kW)	Model Yr Range	NO_x	PM_{10}
130 - <225	2002 & earlier	9.20	0.54
130 - <225	2003-2005	6.60	0.20
130 - <225	2006-2010	4.00	0.20
130 - <225	2011-2013	4.00	0.02
130 - <225	2014+	0.40	0.02
225 - <450	2000 & earlier	9.20	0.54
225 - <450	2001-2005	6.60	0.20
225 - <450	2006-2010	4.00	0.20
225 - <450	2011-2013	4.00	0.02
225 - <450	2014+	0.40	0.02
450 - <560	2001 & earlier	9.20	0.54
450 - <560	2002-2005	6.40	0.20
450 - <560	2006-2010	4.00	0.20
450 - <560	2011-2013	4.00	0.02
450 - <560	2014+	0.40	0.02
560 - <900	2005 & earlier	9.20	0.54
560 - <900	2006-2010	6.40	0.20
560 - <900	2011-2014	3.50	0.10
560 - <900	2015+	3.50	0.04
900+	2005 & earlier	9.20	0.54
900+	2006-2010	6.40	0.20
900+	2011-2014	3.50	0.10
900+	2015+	3.50	0.04

APU emissions are calculated by multiplying the appropriate factors from the table above by the kW-hr inputs from the tool, and the default engine load factors for harbor craft APUs.[3]

1.2 ACTIVITY DATA INPUTS

The Barge Tool requires Partners to input vessel and barge characterization and activity data. The input data required to calculate emissions and associated performance metrics include:

- Total number of barges and tugs
- Vessel-specific information –
  - Propulsion engine model/rebuild year
  - EPA Engine Class (1 or 2)

[3] Load factor = 0.56 for Auxiliary engines < 805 HP. From U.S. EPA 2009, Current Methodologies in preparing Mobile Source Port-Related Emission Inventories, Table 3-3.

- Fuel type (diesel – 15 or 500 ppm, biodiesel, and LNG)
- Retrofit information (technology and/or % NO_x and/or PM reduction, if applicable)
- Annual fuel use (gallons or tons) – Total for propulsion and auxiliary engines
- Vessel towing capacity (tons)[4] – optional input
- Propulsion engine operation
  - # engines (1, 2 or 3)
  - Total rated power (HP or kW – sum if two engines)
  - Hours of operation per year (underway and maneuvering)
- Auxiliary engine operation (for each engine)[5]
  - Engine age
  - Rated power (HP or kW)
  - Hours of operation per year

Barge operation information

- Barge type (hopper, covered cargo, tank, deck, container, other)
- Barge size, by type (150, 175, 195-200 and 250-300 feet in length)
- For each type/size combination:
  - Number
  - Average cargo volume utilization (%) – for each size/type combination
  - Average annual loaded miles per barge (nautical)
  - Average annual empty miles per barge (nautical)
  - Average loaded payload per barge (short tons)

Total annual fleet activity (used for validation – must match totals calculated from barge operation information to within 5%)

- Ton-miles
- Loaded barge-miles
- Unloaded barge-miles

Vessel and barge characterization and activity data are needed for three reasons:

[4] Used to establish upper bound validation limit for total payload ton-mile entries. Not expressed in Bollard Pull since that unit does not uniquely correspond to payload.

[5] **Note** – the Barge Tool assumes all auxiliary engines are diesel powered.

1. To convert the hours of engine operation to kilowatt-hours, it is necessary to know the kilowatt or horsepower rating of the vessel's propulsion and auxiliary engines. Given hours of operation, the Tool can then calculate kilowatt-hours — which is compatible with the available emission factors for both engine types.

2. To classify which regulations the vessel is subject to. EPA engine class is required to identify the correct NO_x and PM emission factors for propulsion engines. Rated power is used to determine the appropriate emission category for auxiliary engines.

3. To combine mass emission estimates with barge-mile and ton-mile activity to develop fleet and company-level performance metrics. (Note, total emissions are also calculated and reported at the vessel-specific level.)

The following section describes how the activity data inputs and the emission factors are combined to generate mass emission estimates and associated performance metrics.

2.0 Emission Estimation

The following sections discuss how emissions are calculated, beginning with selection of emission factors.

2.1 CO_2 CALCULATION

Annual vessel-specific fuel consumption values may be input in the Barge Tool in gallons or tons. Entries in tons are converted to gallons using the following factors:

- Diesel – 284 gallons/ton[6]
- Biodiesel (B100) – 271 gallons/ton[7]
- LNG – 632 gallons/ton[8]

Once all fuel consumption values have been converted to gallons, CO_2 mass emission estimates are calculated for each vessel using the factors shown in Table 1, converted to short tons (1.1023 x 10^{-6} short tons/gram), and summed across vessels to obtain tons of CO_2 per year for the entire vessel fleet.

2.2 NO_X AND PM CALCULATIONS

NO_x and PM are calculated based on kW-hr activity estimates. This approach allows emission calculations to account for the size of the vessel's propulsion engine and the amount of time a vessel spends maneuvering in port and underway. Equation 2 presents the general equation for calculating NO_x and PM emissions for each propulsion engine using diesel fuel.[9]

Equation 2

$$EM_{po} = Pw \times 0.7457 \times Hr_o \times LF_o/100 \times EF_{cyksp} / 1{,}102{,}300$$

Where:

EM_{po}	=	Marine vessel emissions for pollutant (p) and operation (o) (tons/year)
Pw	=	Sum of the power ratings for each of the vessel's propulsion engines (hp or kW) [10]
0.7457	=	Conversion factor from horsepower to kilowatts, if needed (kW/hp - Perry's Chemical Engineer's Handbook)

[6] Iowa State Extension Outreach Ag Decision Maker. http://www.extension.iastate.edu/agdm/wholefarm/html/c6-87.html. Accessed 2-11-19.

[7] For soy-based B100 at 70 degrees F: https://www.nrel.gov/docs/fy09osti/43672.pdf Table D-1. Accessed 2-11-19.

[8] Midwest Energy Solutions. Energy Volume & Weight. http://www.midwestenergysolutions.net/cng-resources/energy-volume-weight. Accessed 2-11-19.

[9] Note: the PM emission factors used in the Barge Tool estimate direct or "primary" PM produced as a result of incomplete combustion. Estimates do not include indirect PM emissions associated with sulfur gas compounds aerosolizing in the atmosphere.

[10] This approach assumes that multiple propulsion engines are of the same type, power, and age, and operate in tandem.

Hr_o	=	Total annual hours of operation for propulsion engines in operating mode o (hr)
LF	=	Load factor for operating mode o - see Table 2 (percentage)
EF_{cykp}	=	Emission factor for operation mode o, engine category c and pollutant p (grams/kW-hr) – see Tables A-1 and A-2
1,102,300	=	Conversion factor from grams to short tons

subscripts -

o	=	Operation (underway or maneuvering)
c	=	EPA Engine Category (1 or 2)
y	=	Year of manufacture
k	=	Kilowatt rating
p	=	Pollutant

If the vessel's power is provided in terms of kilowatts, then the conversion from horsepower to kilowatts is not needed.

The load factors used in the above equations are provided in Table 3 below. These load factors were compiled from a variety of sources and disaggregated into vessel categories used in this project. The data sources include: EPA's *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder* (EPA, 2008); *Commercial Marine Port Inventory Development 2002 and 2005 Inventories* (EPA, 2007b); *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories* (EPA, 2009); and European Commission/Entech study (EC, 2002).

Table 3. Marine Vessel Engine Load Factors (%)

Engine Type	Load Factor (%)	
	Maneuvering	Underway
Propulsion	20	80
Auxiliary	17[11]	

If biodiesel is used, NO_x and PM emissions are calculated assuming ultra-low sulfur diesel fuel as the basis, with the emission factors adjusted according to the fuel blend percentage as described in Section 1.1.

If LNG is used, NO_x and PM emissions are calculated by simply multiplying the g/kW-hr factors presented in Section 1.1 by the effective kW-hrs of operation (hours of use x load factor), summed across operation type (underway and maneuvering).

[11] Average auxiliary engine load factor for cruise operation, from ICF International, Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report, prepared for USEPA, April 2009. Cruise conditions are assumed most prevalent; to the extent that auxiliary engines are also used during maneuvering and hotelling, load factors and emissions will be higher.

2.3 RETROFIT EFFECTIVENESS

The Barge Tool allows the user to select from a variety of propulsion engine retrofit options. Options were only identified for diesel marine engines, and were based on emission adjustment factors developed for EPA's MARKAL model.[12] The reduction factors assumed for each of these control options are presented in Table 4. The Barge Tool only allows the user to specify one retrofit for a given propulsion engine – combinations are not permitted at this time.

Table 4. Diesel Propulsion Engine Retrofit Reduction Factors

Control	Reduction Factor	
	NO_x	PM
Fuel Injection Engine Improvements	0.12	0.12
Selective Catalytic Reduction (SCR)	0.8	0
Common rail	0.1	0.1
Diesel Electric	0.2	0.2
Humid Air Motor (HAM)	0.7	0
Hybrid Engines	0.35	0.35
Diesel Oxidation Catalyst	0	0.2
Lean NO_x Catalyst	0.35	0

Barge Tool users may also specify details and assumed emission reductions for other control measures not listed in the table above, although detailed text descriptions should be provided justifying the use of any alternative factors.

If retrofit Information has been entered for a vessel, the NO_x and PM emissions calculated above are adjusted by the factors shown in Table 4.[13] For example, a 20% reduction in PM emissions associated with a diesel oxidation catalyst would require an adjustment factor of 1 – 0.2 (0.8) to be applied to the calculated PM values.

Finally, NO_x and PM emissions are summed across all vessels and source types (propulsion and auxiliary) to obtain fleet and company-level mass emission estimates.

[12] Eastern Research Group, "MARKAL Marine Methodology", prepared for Dr. Cynthia Gage, US EPA, December 30, 2010.

[13] The Barge Tool assumes that retrofits are only applied to main propulsion engines, not auxiliary engines.

3.0 Performance Metrics

The Barge Tool is designed to apply the calculated emissions to a variety of operational parameters. This provides performance metrics that are used as a reference point to evaluate a Partner's environmental performance relative to other SmartWay Partners across different transportation modes. In this way the metrics presented here are made comparable to the metrics used in the other carrier tools.

For these comparisons to be most precise, it may be necessary to group the data into comparable operating characteristic bins to ensure that similar operations are being compared. For example, open-water barge operations may need to be considered separately from river barge operations because these vessels and their activities are very different. For this reason the Barge Tool collects a variety of vessel and barge characteristic information that may be used to differentiate barge operations in the future.

The following summarizes how the Barge Tool performance metrics are calculated for a given pollutant. Note: all distances are reported in nautical miles.[14]

3.1 GRAMS PER BARGE-MILE

Equation 3

grams / (loaded + unloaded barge-miles - from Total Fleet Activity entry)

3.2 GRAMS PER LOADED BARGE-MILE

Equation 4

grams / (loaded barge-miles - from Total Fleet Activity entry)

3.3 GRAMS PER TON-MILE

Equation 5

grams / (total ton-miles - from Total Fleet Activity entry)

[14] 1 nautical mile = 1.15 statute miles.

3.4 FLEET AVERAGE CALCULATIONS

The Barge Tool calculates fleet-level average payloads for use in the SmartWay Carrier Data File. In order to calculate average payload the Tool first calculates total ton-miles for each row on the Barge Operations screen as follows:

Row-Level ton-miles = Average Payload Value * Avg Loaded Miles * Number of Barges

Next, the Tool sums the row-level ton-miles as well as the total barge miles (Avg Loaded Miles * Number of Barges) across all rows. The tool then divides the summed ton-miles by the summed total miles to obtain the fleet average payload.

3.5 PUBLIC DISCLOSURE REPORTS

The Barge Tool now provides a report summarizing Scope 1 emissions for public disclosure purposes. Mass emissions are presented in metric tonnes for CO_2 (biogenic and non-biogenic), NO_x, and PM[15] for all fleets. Biogenic CO_2 emissions estimates are assumed to equal 2 percent of total CO_2 emissions, as per U.S. requirements for biomass-based diesel from the EPA Renewable Fuel Standard program final volume requirements.[16]

[15] Emissions from CH_4, N_2O, HFC's, PFC's, SF_6 and NF_3 have been deemed immaterial, comprising less than 5% of overall GHG emissions and are therefore EXCLUDED for reporting purposes.

[16] As stated in the Final Rule (Table I.B.7-1 – see https://www.gpo.gov/fdsys/pkg/FR-2017-12-12/pdf/2017-26426.pdf), the volume requirements for biomass-based diesel in 2018 is 1.74%, rounded to equal 2% for calculation purposes. The percentage will be updated annually in the Tool.

4.0 Data Validation

The Barge Tool employs limited validation to ensure the consistency of Partner data inputs. Cross-validation of barge and ton-mile inputs are conducted on the Barge Operations screen. These checks ensure that the values entered in the Fleet Totals section of the screen for total ton-miles, loaded and unloaded barge-miles are consistent with the data entered at the row level for the different barge type/size combinations. These three values must be within 5% of the totals calculated as follows:

Equation 6

$$\text{Total Ton-miles} = [\textstyle\sum_b (\text{number of barges x Annual Loaded Miles per Barge x Average Loaded Payload per Barge})]$$

Equation 7

$$\text{Loaded Barge-Miles} = [\textstyle\sum_b (\text{number of barges x Annual Loaded Miles per Barge})]$$

Equation 8

$$\text{Unloaded Barge-Miles} = [\textstyle\sum_b (\text{number of barges x Annual Empty Miles per Barge})]$$

The Barge Tool also conducts a validation check to confirm product densities are within a reasonable range, with payloads flagged if the calculated cargo density is greater than 0.6 tons per cubic foot or less than 0.003 tons per cubic foot.[17]

Barge volumes were estimated for each barge type/size combination using standardized assumptions regarding depth and width. Volumes are summarized below in Table 5 and Table 6.

Table 5. Barge Capacity by Type/Length Combination (1,000 cubic feet)

	Barge Volume (1,000 cubic feet)			
Barge Type*	*250-300'*	*195-200'*	*175'*	*150'*
Hopper Barge	182	90	81	69
Covered cargo barge[18]	165	82	74	63
Tank Barges	160	56	48	41
Deck Barges	182	90	81	69
Container Barges	218	82	65	49

* "Other" barge types require volumes input by the user

[17] High end approximately equal to that of gold, low end to density of potato chips. See http://www.aqua-calc.com/page/density-table/substance/Snacks-coma-and-blank-potato-blank-chips-coma-and-blank-white-coma-and-blank-restructured-coma-and-blank-baked. Accessed 2-11-19.

[18] Assumed maximum volume for covered cargo barge for 250-300 was 265 ft long 52 ft wide and 12 feet deep = 165,360; 195-200 was 195 long 35 ft wide and 12 ft deep; 175 and 150 had the same width and depth of the 195 ft barge.

Volumes for articulated/integrated barges were derived from a listing of 134 bluewater units protected by US cabotage law, 114 of which included volume estimates.[19] Four barge size groupings were defined as shown in Table 5.

Table 6. Articulated/Integrate Barge Capacity by Volume Category (barrels)

Size Category	Average Volume
< 100,000	373,591
100,000 < 150,000	683,827
150,000 < 200,000	944,121
200,000 +	1,583,898

The Barge Tool performs one other validation check, ensuring that the fleet's total payload, as determined from the Barge Operations screen, does not exceed the maximum possible payload based on the reported towing capacities reported on the Vessel Operations screen.

[19] US Maritime Administration data compiled by Tradeswindsnews.com; provided by Terrence Houston, American Waterway Operators, December 15, 2016.

5.0 Future Enhancements

The following enhancements are being considered for future versions of the Barge Tool:

- Develop validation ranges for barge-mile, ton-mile, payload, towing capacity, rated power, and other inputs based on Partner data submissions and/or other sources.
- Compile list of common data sources for vessel and barge data, based on Partner data submissions.
- Expanding the list of pollutants to include black carbon.
- Add option for dual-fuel propulsion engines.
- Allow user-specified propulsion engine load factors.
- Develop default average volume utilization and payloads based on commodity type and other Partner data.

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Appendix A: Marine Propulsion and Auxiliary Engine Emission Factors[20]

Table A-1. Category 1 Distillate (15 ppm) Emission Factors

Category	Engine Size	Model Year	NO_X Weighted EF g/kW-hr	PM_{10} Weighted EF g/kW-hr
1	<600kW	2018+	4.66	0.06
1	<600kW	2017	4.66	0.07
1	<600kW	2016	4.66	0.07
1	<600kW	2015	4.66	0.07
1	<600kW	2014	4.66	0.07
1	<600kW	2013	5.64	0.10
1	<600kW	2012	5.95	0.12
1	<600kW	2011	6.00	0.12
1	<600kW	2010	6.00	0.12
1	<600kW	2009	6.00	0.12
1	<600kW	2008	6.00	0.12
1	<600kW	2007	6.00	0.12
1	<600kW	2006	6.34	0.14
1	<600kW	2005	6.34	0.14
1	<600kW	2004	6.49	0.15
1	<600kW	2003	9.72	0.35
1	<600kW	2002	9.72	0.35
1	<600kW	2001	9.72	0.35
1	<600kW	2000	9.72	0.35
1	<600kW	pre-2000	10.00	0.235
1	600<kW<=1000	2018+	1.30	0.03
1	600<kW<=1000	2017	4.71	0.07
1	600<kW<=1000	2016	4.71	0.07
1	600<kW<=1000	2015	4.71	0.07
1	600<kW<=1000	2014	4.71	0.07
1	600<kW<=1000	2013	5.32	0.09

[20] Emission factors are mostly consistent with EPA's 2008 locomotive and marine Federal Rulemaking - https://www.gpo.gov/fdsys/pkg/FR-2008-06-30/pdf/R8-7999.pdf – Accessed 2-11-19. One inconsistency was identified where PM emissions for pre-2000 engines where lower than for newer engines. These values have been set equal to model year 2000 engine emissions for use in the Barge Tool.

Table A-1. Category 1 Distillate (15 ppm) Emission Factors

Category	Engine Size	Model Year	NO_X Weighted EF g/kW-hr	PM_{10} Weighted EF g/kW-hr
1	600<kW<=1000	2012	5.82	0.11
1	600<kW<=1000	2011	6.00	0.12
1	600<kW<=1000	2010	6.00	0.12
1	600<kW<=1000	2009	6.00	0.12
1	600<kW<=1000	2008	6.00	0.12
1	600<kW<=1000	2007	6.00	0.12
1	600<kW<=1000	2006	7.67	0.21
1	600<kW<=1000	2005	7.67	0.21
1	600<kW<=1000	2004	7.67	0.21
1	600<kW<=1000	2003	9.44	0.31
1	600<kW<=1000	2002	9.44	0.31
1	600<kW<=1000	2001	9.44	0.31
1	600<kW<=1000	2000	9.44	0.31
1	600<kW<=1000	pre-2000	10.16	0.31
1	1000<kW<=1400	2017+	1.30	0.03
1	1000<kW<=1400	2016	4.72	0.07
1	1000<kW<=1400	2015	4.72	0.07
1	1000<kW<=1400	2014	4.72	0.07
1	1000<kW<=1400	2013	0.68	0.10
1	1000<kW<=1400	2012	0.68	0.11
1	1000<kW<=1400	2011	6.00	0.12
1	1000<kW<=1400	2010	6.00	0.12
1	1000<kW<=1400	2009	6.00	0.12
1	1000<kW<=1400	2008	6.00	0.12
1	1000<kW<=1400	2007	6.00	0.12
1	1000<kW<=1400	2006	7.26	0.19
1	1000<kW<=1400	2005	7.26	0.19
1	1000<kW<=1400	2004	7.26	0.19
1	1000<kW<=1400	2003	9.55	0.31
1	1000<kW<=1400	2002	9.55	0.31
1	1000<kW<=1400	2001	9.55	0.31
1	1000<kW<=1400	2000	9.55	0.31

Table A-1. Category 1 Distillate (15 ppm) Emission Factors

Category	Engine Size	Model Year	NO_X Weighted EF g/kW-hr	PM_{10} Weighted EF g/kW-hr
1	1000<kW<=1400	pre-2000	10.27	0.31
1	kW>1400	2016+	1.30	0.03
1	kW>1400	2015	4.81	0.07
1	kW>1400	2014	4.81	0.07
1	kW>1400	2013	4.81	0.07
1	kW>1400	2012	4.81	0.07
1	kW>1400	2011	6.00	0.12
1	kW>1400	2010	6.00	0.12
1	kW>1400	2009	6.00	0.12
1	kW>1400	2008	6.00	0.12
1	kW>1400	2007	6.00	0.12
1	kW>1400	2006	9.20	0.29
1	kW>1400	2005	9.20	0.29
1	kW>1400	2004	9.20	0.29
1	kW>1400	2003	9.20	0.29
1	kW>1400	2002	9.20	0.29
1	kW>1400	2001	9.20	0.29
1	kW>1400	2000	9.20	0.29
1	kW>1400	pre-2000	11.00	0.29
2	<600kW	2013+	5.97	0.11
2	<600kW	2012	8.33	0.31
2	<600kW	2011	8.33	0.31
2	<600kW	2010	8.33	0.31
2	<600kW	2009	8.33	0.31
2	<600kW	2008	8.33	0.31
2	<600kW	2007	8.33	0.31
2	<600kW	2006	10.55	0.31
2	<600kW	2005	10.55	0.31
2	<600kW	2004	10.55	0.31
2	<600kW	2003	10.55	0.31
2	<600kW	2002	10.55	0.31
2	<600kW	2001	10.55	0.31

Table A-1. Category 1 Distillate (15 ppm) Emission Factors

Category	Engine Size	Model Year	NO_X Weighted EF g/kW-hr	PM_{10} Weighted EF g/kW-hr
2	<600kW	2000	10.55	0.31
2	<600kW	pre-2000	13.36	0.31
2	600<=kW<1000	2018+	1.30	0.03
2	600<=kW<1000	2017	1.30	0.11
2	600<=kW<1000	2016	1.30	0.11
2	600<=kW<1000	2015	1.30	0.11
2	600<=kW<1000	2014	1.30	0.11
2	600<=kW<1000	2013	5.97	0.11
2	600<=kW<1000	2012	5.97	0.31
2	600<=kW<1000	2011	5.97	0.31
2	600<=kW<1000	2010	5.97	0.31
2	600<=kW<1000	2009	5.97	0.31
2	600<=kW<1000	2008	5.97	0.31
2	600<=kW<1000	2007	8.33	0.31
2	600<=kW<1000	2006	10.55	0.31
2	600<=kW<1000	2005	10.55	0.31
2	600<=kW<1000	2004	10.55	0.31
2	600<=kW<1000	2003	10.55	0.31
2	600<=kW<1000	2002	10.55	0.31
2	600<=kW<1000	2001	10.55	0.31
2	600<=kW<1000	2000	10.55	0.31
2	600<=kW<1000	pre-2000	13.36	0.31
2	1000<=kW<1400	2017+	1.30	0.03
2	1000<=kW<1400	2016	1.30	0.11
2	1000<=kW<1400	2015	1.30	0.11
2	1000<=kW<1400	2014	1.30	0.11
2	1000<=kW<1400	2013	5.97	0.11
2	1000<=kW<1400	2012	5.97	0.31
2	1000<=kW<1400	2011	5.97	0.31
2	1000<=kW<1400	2010	5.97	0.31
2	1000<=kW<1400	2009	5.97	0.31
2	1000<=kW<1400	2008	5.97	0.31

Table A-1. Category 1 Distillate (15 ppm) Emission Factors

Category	Engine Size	Model Year	NO_X Weighted EF g/kW-hr	PM_{10} Weighted EF g/kW-hr
2	1000<=kW<1400	2007	8.33	0.31
2	1000<=kW<1400	2006	10.55	0.31
2	1000<=kW<1400	2005	10.55	0.31
2	1000<=kW<1400	2004	10.55	0.31
2	1000<=kW<1400	2003	10.55	0.31
2	1000<=kW<1400	2002	10.55	0.31
2	1000<=kW<1400	2001	10.55	0.31
2	1000<=kW<1400	2000	10.55	0.31
2	1000<=kW<1400	pre-2000	13.36	0.31
2	1400<=kW<2000	2016+	1.30	0.03
2	1400<=kW<2000	2015	6.17	0.16
2	1400<=kW<2000	2014	6.17	0.16
2	1400<=kW<2000	2013	6.55	0.16
2	1400<=kW<2000	2012	8.33	0.31
2	1400<=kW<2000	2011	8.33	0.31
2	1400<=kW<2000	2010	8.33	0.31
2	1400<=kW<2000	2009	8.33	0.31
2	1400<=kW<2000	2008	8.33	0.31
2	1400<=kW<2000	2007	8.33	0.31
2	1400<=kW<2000	2006	10.55	0.31
2	1400<=kW<2000	2005	10.55	0.31
2	1400<=kW<2000	2004	10.55	0.31
2	1400<=kW<2000	2003	10.55	0.31
2	1400<=kW<2000	2002	10.55	0.31
2	1400<=kW<2000	2001	10.55	0.31
2	1400<=kW<2000	2000	10.55	0.31
2	1400<=kW<2000	pre-2000	13.36	0.31
2	2000<=kW<3700	2016+	1.30	0.03
2	2000<=kW<3700	2015	1.30	0.18
2	2000<=kW<3700	2014	1.30	0.18
2	2000<=kW<3700	2013	8.33	0.19
2	2000<=kW<3700	2012	8.33	0.31

Table A-1. Category 1 Distillate (15 ppm) Emission Factors

Category	Engine Size	Model Year	NO_X Weighted EF g/kW-hr	PM_{10} Weighted EF g/kW-hr
2	2000<=kW<3700	2011	8.33	0.31
2	2000<=kW<3700	2010	8.33	0.31
2	2000<=kW<3700	2009	8.33	0.31
2	2000<=kW<3700	2008	8.33	0.31
2	2000<=kW<3700	2007	8.33	0.31
2	2000<=kW<3700	2006	10.55	0.31
2	2000<=kW<3700	2005	10.55	0.31
2	2000<=kW<3700	2004	10.55	0.31
2	2000<=kW<3700	2003	10.55	0.31
2	2000<=kW<3700	2002	10.55	0.00
2	2000<=kW<3700	2001	10.55	0.31
2	2000<=kW<3700	2000	10.55	0.31
2	2000<=kW<3700	pre-2000	13.36	0.31
2	kW>=3700	2017+	1.30	0.05
2	kW>=3700	2016	1.30	0.05
2	kW>=3700	2015	1.30	0.05
2	kW>=3700	2014	1.30	0.18
2	kW>=3700	2013	8.33	0.31
2	kW>=3700	2012	8.33	0.31
2	kW>=3700	2011	8.33	0.31
2	kW>=3700	2010	8.33	0.31
2	kW>=3700	2009	8.33	0.31
2	kW>=3700	2008	8.33	0.31
2	kW>=3700	2007	8.33	0.31
2	kW>=3700	2006	10.55	0.31
2	kW>=3700	2005	10.55	0.31
2	kW>=3700	2004	10.55	0.31
2	kW>=3700	2003	10.55	0.31
2	kW>=3700	2002	10.55	0.31
2	kW>=3700	2001	10.55	0.31
2	kW>=3700	2000	10.55	0.31
2	kW>=3700	pre-2000	13.36	0.31

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