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Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990-2020

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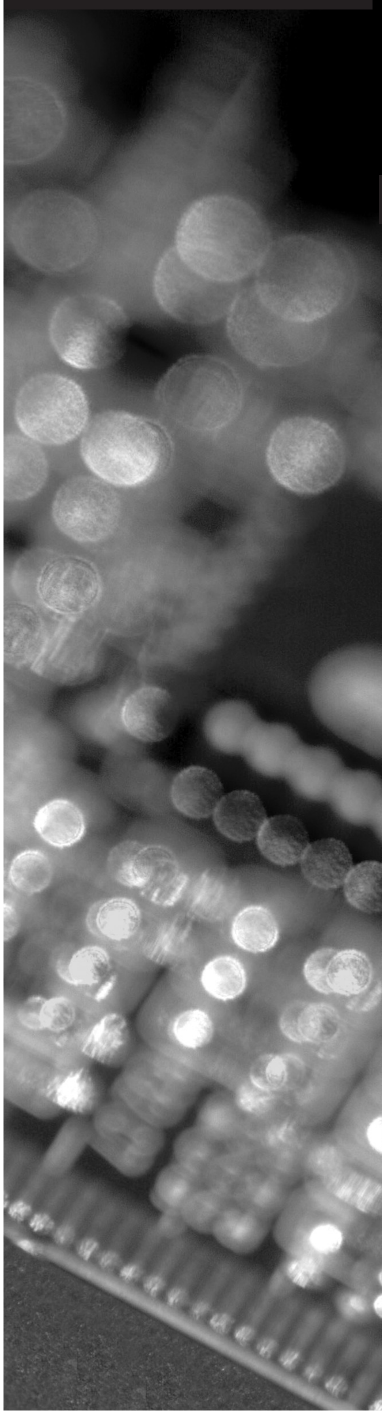

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Peer Reviewed Document

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June 2006 Revised

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Acronyms

AAMA – American Automobile Manufacturer's Association
AE – anode effects
AFEAS –Alternative Fluorocarbons Environmental Acceptability Study
ALGAS – Asia Least-Cost Greenhouse Gas Abatement Strategy
BAU – business as usual
BOD – biological oxygen demand
CDM – Clean Development Mechanism
CEIT – countries with economies in transition
CFC – chlorofluorocarbon
CF_4 – perfluoromethane
C_2F_6 – hexafluoroethane
C_3F_8 – perfluoropropane
c-C_4F_8 – perfluorocyclobutane
CH_4 – methane
CO_2 – carbon dioxide
CPA – Centrally Planned Asia
CRF – Common Reporting Format
CRW – combustible renewables and waste
CWPB – Center-Worked Prebake
DOC – degradable organic carbon
EDGAR – Emission Database for Global Atmospheric Research
EF – emission factor
EIA – Energy Information Administration
EPA – U.S. Environmental Protection Agency
EU – European Union
FAO – Food and Agriculture Organization
FSU – Former Soviet Union
FIAM – Foundry Impact Analysis Model
FWHA – U.S. Federal Highway Administration
GHG – greenhouse gas
Gg – gigagram
GTAP – Global Trade Analysis Project
GWP – global warming potential
HCFC – hydrochlorofluorocarbon
HCFC-22 – chlorodifluoromethane
HFC-23 – triflouromethane
HFCs – hydrofluorocarbons
HSS – Horizontal Stud Soderberg
IAI – International Aluminum Institute
IEA – International Energy Agency
IFPRI – International Food Policy Research Institute
IRRI – International Rice Research Institute
IMA – International Magnesium Association
IPCC – Intergovernmental Panel on Climate Change
Kg – kilogram
MCF – methane correction factor
MDI – metered dose inhalers
MtCO_2Eq – million metric tons of carbon dioxide equivalent
MSW – municipal solid waste
mt – metric ton
MVAC – motor vehicle air conditioner
N – nitrogen
NIR – National Inventory Report
N_2O – nitrous oxide
NF_3 – nitrogen trifluoride
ODP – ozone-depleting potential
ODS – ozone-depleting substance

OECD – The Organization for Economic Cooperation and Development
PFBB – Point Feed Prebake
PFC – perfluorocarbons
PEVM – PFC Emissions Vintage Model
SAR – Second Assessment Report
SF_6 – sulfur hexafluoride
SO_2 – sulfur dioxide
SRES – Special Report on Emissions Scenarios
SWPB – Side-Worked Prebake
SWDS – solid waste disposal site
TAR – Third Assessment Report
Tg – teragram
Tj – terajoule
UNFCCC – United Nations Framework Convention on Climate Change
UNDP – United Nations Development Programme
VSS – Vertical Stud Soderberg
WEC – World Energy Council
WEO – World Energy Outlook
WFW – World Fab Watch
WSC – World Semiconductor Council
VAIP – Voluntary Aluminum Industrial Partnership

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1. Introduction and Overview

1.1 Introduction

The aim of this report is to provide historical and projected estimates of emissions of non-carbon dioxide (non-CO_2) greenhouse gases (GHGs) from anthropogenic sources. The report provides a consistent and comprehensive estimate of non-CO_2 greenhouse gases for over ninety individual countries and eight regions. The analysis provides information that can be used to understand national contributions of GHG emissions, historical progress on reductions, and mitigation opportunities. Readers can find the dataset compiled for this report in spreadsheet (.xls) format on the U.S. EPA's webpage at: http://www.epa.gov/nonco2/econ-inv/international.html.

The gases included in this report are the direct GHGs—other than CO_2—covered by the United Nations Framework Convention on Climate Change (UNFCCC): methane (CH_4), nitrous oxide (N_2O), and the high global warming potential (high GWP) gases. The high GWP gases include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Compounds covered by the Montreal Protocol are not included in this report. Historical estimates are reported for 1990, 1995, and 2000 and projections of emissions are provided for 2005, 2010, 2015, and 2020. Projections reflect the currently achieved impact of sector specific climate policy programs, agreements, and measures that are already in place, but exclude GHG reductions due to additional planned activities whose impacts are less certain.

The U.S. Environmental Protection Agency (EPA) collects emission estimates from publicly available nationally-prepared GHG reports that are prepared in a manner consistent with the *Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* (IPCC Guidelines) (IPCC, 1997) and the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC Good Practice Guidance) (IPCC, 2000). If national estimates are not available, EPA estimates emissions in order to produce a complete inventory for the world. EPA's calculated emissions estimates are prepared in a consistent manner across all countries using IPCC default methodologies, international statistics for activity data, and the IPCC Tier 1 default emission factors.

1.2 Overview of Non-CO_2 Greenhouse Gas Emissions

As shown in Exhibit 1-1, global emissions of methane, nitrous oxide, and high GWP gases account for approximately 30 percent of the enhanced greenhouse effect since pre-industrial times (IPCC, 2001). Emissions of non-CO_2 GHGs contribute significantly to radiative forcing[1] since they are more effective at trapping heat than CO_2. The IPCC uses the concept of the global warming potential (GWP) to compare the ability of different gases to trap heat in the atmosphere relative to carbon dioxide. Emissions of non-CO_2 gases are converted to a CO_2-equivalent basis using the 100-year GWPs published in the IPCC's Second Assessment Report (SAR) (see Table 1-1).[2]

EPA estimates that global non-CO_2 GHG emissions in 2000 were 9,514 million metric tons of carbon dioxide equivalents ($MtCO_2eq$). When compared to the IPCC estimate for 2000 global carbon dioxide emissions of approximately 31,868 $MtCO_2$ (de la Chesnaye, F.C. et al., 2006), anthropogenic non-CO_2 emissions sources are responsible for over 23 percent of the global GHG emissions emitted annually. Table 1-2 presents additional information on the breakdown of 2000 CO_2 and non-CO_2 emissions by sector.

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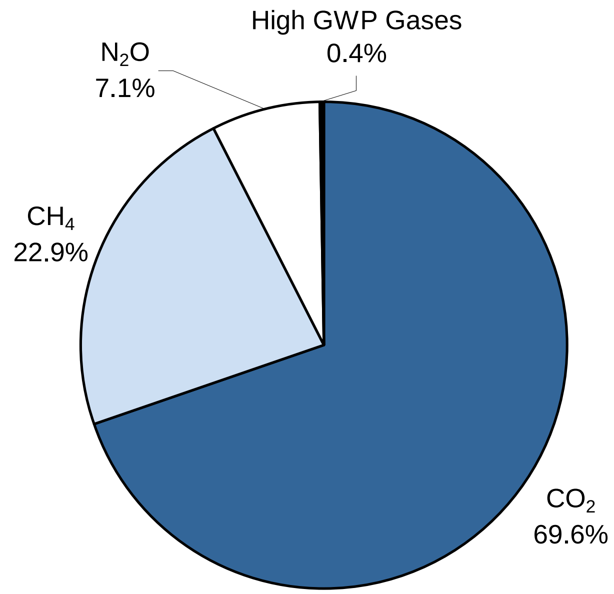
[1] Radiative forcing is the change in the balance between radiation coming into the atmosphere and radiation going out. A positive radiative forcing tends on average to warm the surface of the Earth, and negative forcing tends on average to cool the surface. (IPCC, 1996).

[2] Although the GWPs have been updated by the IPCC in the Third Assessment Report (TAR), estimates of emissions in this report continue to use the GWPs from the SAR, in order to be consistent with international reporting standards under the UNFCCC. However, some of the high GWP gases estimated in this report only have GWPs in the TAR. In these cases, this report uses the TAR GWPs (see Table 4-1 for additional gases).



Source: IPCC, 2001; Table 6-1.

Exhibit 1-1. Contribution of Anthropogenic Emissions of Greenhouse Gases to the Enhanced Greenhouse Effect from Pre-Industrial to Present (measured in Watts/meter^2)

1.3 Emission Sources

This report focuses exclusively on anthropogenic sources of the non-CO_2 GHGs. Table 1-3 lists the source categories discussed in this report. All anthropogenic sources of methane and nitrous oxide are included (with a few exceptions that are noted in Section 1.5). The major sources are considered individually and are listed in Table 1-3. Emissions from minor sources are combined under "Other" categories; these minor sources are also listed in Table 1-3. The high GWP sources include substitutes for ozone-depleting substances (ODS) and industrial sources of HFCs, PFCs, and SF_6.

1.4 Approach

In this analysis, EPA presents emissions for individual countries for 1990 – 2020 in five-year increments. In addition to the individual country data, EPA presents overall trends by region, gas, and source category and explanations for why these trends are expected.

Table 1-1. Global Warming Potentials

Gas	GWP[a]
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

Source: IPCC, 1996

[a] 100 year time horizon.

Table 1-2. Global Greenhouse Gas (GHG) Emissions for 2000 ($MtCO_2eq$)

Sectors	CO_2[a]	CH_4	N_2O	High GWP	Global Total	Percentage of Global Total
Energy	23,408	1,646	237		25,291	61%
Agriculture	7,631	3,113	2,616		13,360	32%
Industry	829	6	155	380	1,370	3%
Waste		1,255	106		1,361	3%
Global Total	31,868	6,020	3,114	380	41,382	100%
Percentage of Global Total	77%	15%	8%	1%		

[a] Source: de la Chesnaye, F.C., et al., 2006

Table 1-3. Sources Included

Methane	Nitrous Oxide	High GWP Gases
ENERGY Coal Mining Activities Natural Gas and Oil Systems Stationary and Mobile Combustion Biomass Combustion **INDUSTRIAL** Other Industrial Non-Agricultural: • Chemical Production • Iron and Steel Production • Metal Production • Mineral Products • Petrochemical Production • Silicon Carbide Production **AGRICULTURE** Manure Management Enteric Fermentation Rice Cultivation Other Agricultural: • Agricultural Soils • Field Burning of Agricultural Residues • Prescribed Burning of Savannas **WASTE** Landfilling of Solid Waste Wastewater Other Non-Agricultural (included with waste totals) [a]: • Solvent and Other Product Use • Waste Combustion	**ENERGY** Biomass Combustion Stationary and Mobile Combustion **INDUSTRIAL** Adipic Acid and Nitric Acid Production Other Industrial Non-Agricultural: • Metal Production • Miscellaneous Industrial Processes **AGRICULTURE** Manure Management Agricultural Soils Other Agricultural: • Field Burning of Agricultural Residues • Prescribed Burning of Savannas **WASTE** Human Sewage Other Non-Agricultural (included with waste totals) [a]: • Fugitives from Solid Fuels • Fugitives from Natural Gas and Oil Systems • Solvent and Other Product Use • Waste Combustion	**INDUSTRIAL (category and gas)** Substitutes for Ozone-Depleting Substances: • HFCs, PFCs HCFC-22 Production: • HFC-23 Primary Aluminum Production: • PFCs Magnesium Manufacturing: • SF_6 Electrical Power Systems: • SF_6 Semiconductor Manufacturing: • HFC, PFCs, SF_6

[a] Other Non-Agricultural is included in the waste sector because waste combustion is the dominant sub-source of emissions.

The regional groupings include countries in the following geographic or geopolitical classifications:

- OECD 1990 & EU[3] - all of the countries in the Organization for Economic Cooperation and Development (OECD) as of 1990, the 25 current members of the European Union (EU), and countries whose accession to the EU is scheduled for 2007,[4]
- Africa,
- China and Centrally Planned Asia (China/CPA),
- Latin America,
- Middle East,
- Non-European Union nations that are newly independent states from the former Soviet Union (non-EU FSU),
- Other non-EU nations in Eastern Europe (non-EU Eastern Europe), and
- South and Southeast Asia (S&E Asia).

These regional country groupings are further defined in Table 1-4 and Appendix H.

The general approach for developing the emissions estimates is to use data from a hierarchy of country-prepared, publicly-available reports. These include Annex I inventory submissions to the UNFCCC Secretariat which consist of a National Inventory Report (NIR) and Common Reporting Format (CRF), National Communications to the UNFCCC, the Asia Least-Cost Greenhouse Gas Abatement Strategy (ALGAS) Reports, and/or other country prepared reports. The preferred source for historical data is the 2005 CRFs since these provide the latest GHG emissions estimates for most Annex I Parties.[5]

National Communications are the preferred source for projections and non-Annex I historical data, with the Third National Communication available for most Annex I Parties and First and Second National Communications available for many non-Annex I countries. The estimates in the UNFCCC inventory submissions and National Communications for each reporting Party are comparable because they rely on the IPCC methodologies and are reported for the standard list of IPCC source categories which generally follow the categories shown in Table 1-3.

The projections represent a business as usual (BAU) scenario where currently achieved reductions are incorporated and future mitigation actions are included only if either a well established program or an international sector agreement is in place.[6] As discussed below, a secondary set of projections that do not include reductions from international agreements (the “No-Action” Baselines) are included for the high GWP sources in Section 4. This second set of projections demonstrates the impact of the international agreements.

[3] The OECD90 & EU is referred to simply as OECD in the text, but as OECD90 & EU in graphs and tables.

[4] The Holy See, Liechtenstein, Monaco, Andorra, and San Marino are also included in OECD90 & EU grouping.

[5] Annex I Parties include the industrialized countries that were members of the OECD in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States. Annex I countries are noted in Table 1-4.

[6] Estimates in this report are presented at the source category level, therefore, only policies and programs that affect source level emissions directly are reflected in the BAU projections. For example, the reductions attributable to the EU landfill directive regulations, U.S. sector level voluntary programs, and international sector agreements such as the World Semiconductor Council agreement are reflected in BAU projections presented here. The reductions associated with Kyoto commitments are not reflected in projections by GHG or source category because these are country level goals that are difficult to disaggregate to the required degree.

Table 1-4. Definition of Regional Groupings

Africa

-Algeria
-Democratic Republic of Congo (Kinshasa)
-Egypt
-Ethiopia
-Nigeria
-Senegal
-South Africa
-Uganda
-"Rest of Africa" [1, 2]

China/CPA

-Cambodia
-China
-Laos
-Mongolia
-North Korea
-Viet Nam
-"Rest of China/CPA" [1, 2]

Latin America

-Argentina
-Bolivia
-Brazil
-Chile
-Colombia
-Ecuador
-Mexico
-Peru
-Uruguay
-Venezuela
-"Rest of Latin America" [1, 2]

Middle East

-Iran
-Iraq
-Israel
-Jordan
-Kuwait
-Saudi Arabia
-United Arab Emirates
-"Rest of Middle East" [1, 2]

Non-EU Eastern Europe

-Albania
-Croatia [A]
-Macedonia
-"Rest of Non-EU Eastern Europe" [1, 2]

Non-EU Former Soviet Union

-Armenia
-Azerbaijan
-Belarus [A]
-Georgia
-Kazakhstan
-Kyrgyzstan
-Moldova
-Russian Federation (Russia) [A]
-Tajikistan
-Turkmenistan
-Ukraine [A]
-Uzbekistan

South & Southeast Asia

-Bangladesh
-India
-Indonesia
-Myanmar
-Nepal
-Pakistan
-Philippines
-Singapore
-South Korea
-Thailand
-"Rest of South & Southeast Asia" [1, 2]

OECD1990 & EU

-Australia [A, O]
-Austria [A, E, O]
-Belgium [A, E, O]
-Bulgaria [A, C]
-Canada [A, O]
-Czech Republic [A, E,]
-Denmark [A, E, O]
-Estonia [A, E,]
-Finland [A, E, O]
-France [A, E, O]
-Germany [A, E, O]
-Greece [A, E, O]
-Hungary [A, E,]
-Iceland [A, O]
-Ireland [A, E, O]
-Italy [A, E, O]
-Japan [A, O]
-Latvia [A, E]
-Liechtenstein [A]
-Lithuania [A, E]
-Luxembourg [A, E, O]
-Monaco [A]
-Netherlands [A, E, O]
-New Zealand [A, O]
-Norway [A, O]
-Poland [A, E,]
-Portugal [A, E, O]
-Romania [A,C]
-Slovak Republic [A, E,]
-Slovenia [A, E]
-Spain [A, E, O]
-Sweden [A, E, O]
-Switzerland [A, O]
-Turkey [A, O]
-United Kingdom (UK) [A, E, O]
-United States (U.S.) [A, O]
"Rest of OECD" [1, 2]

Codes:

A – Annex I countries.
C – Countries whose accession to the European Union (EU) is scheduled for 2007.
E – European Union (EU) countries.
O – OECD countries as of 1990.

Notes:

1. The complete list of countries included in the "Rest Of" groupings can be found in Appendix H.
2. In this report, when emissions totals are presented for a region, the regional sum includes the estimates for all of the individually reported countries AND the aggregated value for the "Rest Of" countries. Thus, the emissions total for the "Middle East" found in the graphs and Appendices A-D, includes the sum of Iran, Iraq, Israel, Jordan, Kuwait, Saudi Arabia, the United Arab Emirates AND the smaller emitters already aggregated under "Rest of Middle East"

If no nationally developed emissions data are available or if the data are insufficient, EPA estimates emissions or projections using the default methodologies presented in the IPCC Guidelines and the IPCC Good Practice Guidance. EPA uses the IPCC Tier 1 methodologies and available country or region-specific activity data to estimate emissions.

Most countries do not include detailed estimates for high GWP emissions and projections in their National Communications. To compile the high GWP inventory, this analysis applies consistent methodologies and modeling techniques to estimate emissions for all countries for the high GWP source categories. For high GWP sources, the projections include an analysis with and without planned climate measures since the major emitting industries have agreed to clearly defined international reduction goals that will have a substantial impact on emissions. Both of these scenarios are presented in the industry section (Section 4) and Appendices D-7 to D-11b. However, the summary section (Section 2) and the summary tables for total emissions by gas and country (Appendices A-1 to A-4), present emission projections that include the anticipated results of established programs and international sectoral agreements.

A detailed description of the methodology used for each country and category can be found in Section 7 and Appendices E-1 to E-12.

1.5 Limitations

Although the latest available information is reflected in these estimates, the projections are sensitive to changes in key assumptions regarding technological changes and production/consumption patterns. For example, the emission rates of new equipment using ODS substitutes are likely to be much lower than the emission rates of the older equipment. This newer equipment is only now being phased in, and the long-term emission characteristics are not yet well known. In the agriculture sector the effect of changing consumer preferences on product demand, such as increased beef consumption, is extremely difficult to predict and creates large uncertainties in the projected emissions from many of the agricultural sources.

While efforts have been made to provide projected emissions on a consistent basis, the distinction between currently achieved GHG reductions from climate mitigation measures in place and those from additionally planned activities is not always clearly defined in the reported data. The inclusion of incidental GHG reductions in projected emissions as a result of climate related actions or government polices still in development is a possibility in some isolated cases. However, due to the consistent approaches established for reporting projected data and policies and measures in the National Communications, the information developed from these sources are generally considered comparable.

Another limitation of this report is that since data are only presented in five-year increments and reported data for Annex I countries are available on a yearly basis through 2003, there may, in some cases, be a disconnect between reported 2003 data and projected 2005 data. This is due to the fact that projected rates of growth were derived from the older National Communications and applied to the 2000 base year from the more recently reported data from the CRFs. Projections from the earlier report may have under- or over-estimated the actual 2003 trend line.

Finally, data gaps exist in both historical and projected emissions data for several countries. To fill gaps, EPA uses methods ranging from interpolation to growth patterns based on analogous countries. Also, estimates for many smaller, non-Annex I countries are not available in any form, and are prepared using IPCC default methodologies. There are substantial uncertainties in applying the default factors on a country-by-country basis due to the variety of national conditions encountered. The Appendices E-1 to E-12 describe specific adjustments for each country and source.

Sources of Non-CO_2 Greenhouse Gas Emissions Not Included in This Estimate

Due to methodological limitations, a few sources have not been fully included in this analysis. These include methane from hydroelectric reservoirs and abandoned coal mines, nitrous oxide from wastewater, and high GWP emissions from flat panel displays and the manufacture of electrical equipment. If a country report included an estimate, this estimate is included in the country total in the “other” category.

1.6 Organization of this Report

The remainder of this report expands upon these results in six main sections. Section 2 presents a summary of global emissions and briefly discusses global trends. Sections 3 to 6 present information and emission estimates for methane, nitrous oxide, and high GWP gases for the following sectors: energy, industry, agriculture, and waste. Within each of these chapters, the discussion is divided into key sources that contribute to emissions. These source category discussions present an overview of global emissions for that category and regional trends for 1990 to 2020. Section 7 presents the methodology used to gather the most recent emissions inventory and projection data, and the data sources and methods used to adjust the available data for each country in order to make the overall estimates internally consistent and comparable. Documentation of individual data points, references, and data tables presenting detailed estimates by country and source category as well as global summary emissions for each gas and country are provided in the Appendices A-E.

2. Summary Results

2.1 Summary Estimates

Global anthropogenic non-CO_2 emissions are estimated at nearly 9,000 $MtCO_2eq$ for 1990 and are expected to grow approximately 44 percent by 2020. This scenario represents a business as usual (BAU) scenario in which currently achieved reductions are incorporated but future mitigation actions are included only if either a regulation, well established program, or an international sector agreement is in place.[1] As illustrated in Exhibit 2-1, non-CO_2 GHG emissions grow slowly early in the study period, but are expected to increase more rapidly between 2005 and 2020. Methane emissions increase from 5,816 $MtCO_2eq$ to 7,904 $MtCO_2eq$ between 1990 and 2020, while nitrous oxide emissions increase from 2,871 $MtCO_2eq$ to 4,057 $MtCO_2eq$ during the same period. High GWP emissions increase from 239 $MtCO_2eq$ in 1990 to 935 $MtCO_2eq$ in 2020.

The historical trends observed for methane and nitrous oxide are the cumulative effect of several drivers. Although the basic activities have increased (waste generation and landfilling, energy production and consumption, etc.), several factors have mitigated emission growth. First, recovery and use of methane has reduced emissions in many countries. Second, sectoral level restructuring has decreased emissions. For example, European agricultural policies led to more efficient farming practices and decreased use of fertilizer. Finally, economic restructuring in several countries such as Russia and Germany caused a decrease in emissions in the 1990s. After 2000, emissions begin to increase again due to a number of factors including 1) economic and sectoral growth in recently restructured countries and sectors, and 2) only partial mitigation coverage in the BAU projections (as described above). High GWP emissions, although relatively small in 1990, are projected to nearly quadruple over the study period as new chemicals are deployed as substitutes for the ozone-depleting substances (ODS) that are being phased out under the Montreal Protocol.

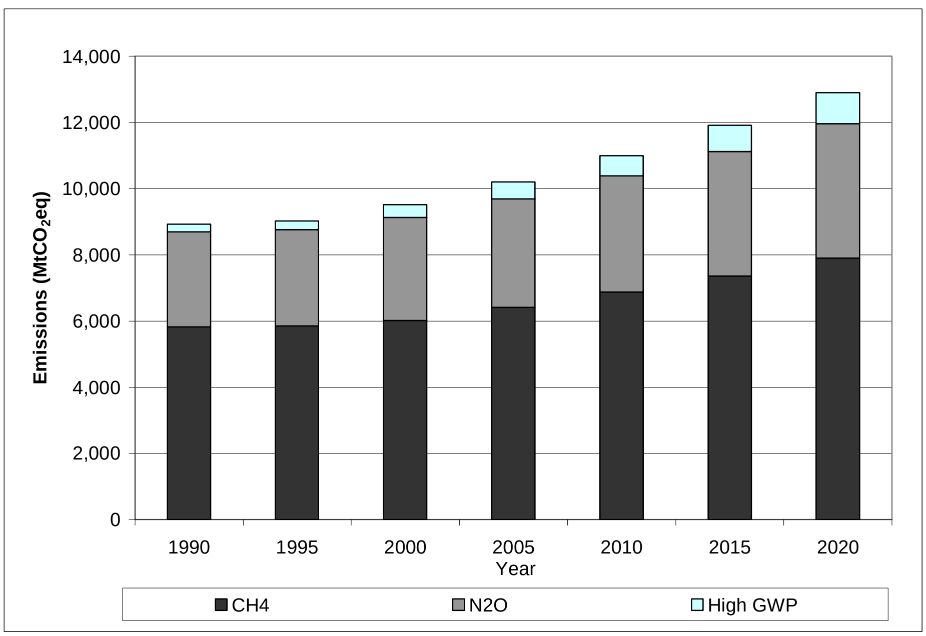


Exhibit 2-1. Total Global Non-CO_2 Emissions by Gas ($MtCO_2eq$)

[1] Estimates in this report are presented at the source category level, therefore, only policies and programs that affect source level emissions directly are reflected in the BAU projections. For example, the reductions attributable to the EU landfill directive regulations, U.S. sector level voluntary programs, and international sector agreements such as the World Semiconductor Council agreement are reflected in BAU projections presented here. The reductions associated with Kyoto commitments are not taken into account because these are country level goals that are difficult to disaggregate to the source category level.

2.2 Trends by Region

Exhibit 2-2 shows the regional contribution of emissions from 1990 to 2020. Over the entire period, BAU emissions of non-CO_2 GHGs are projected to increase in every region except the non-EU FSU. The non-EU FSU shows a 38 percent decrease from 1990 to 2000 that is followed by a gradual increase, however, even 2020 emission levels are not expected to reach the1990 level. On an individual country basis, China, Brazil, India, and the U.S. show the largest absolute increases in projected emissions between 1990 and 2020, growing by 741, 357, 306, and 212 $MtCO_2eq$, respectively.

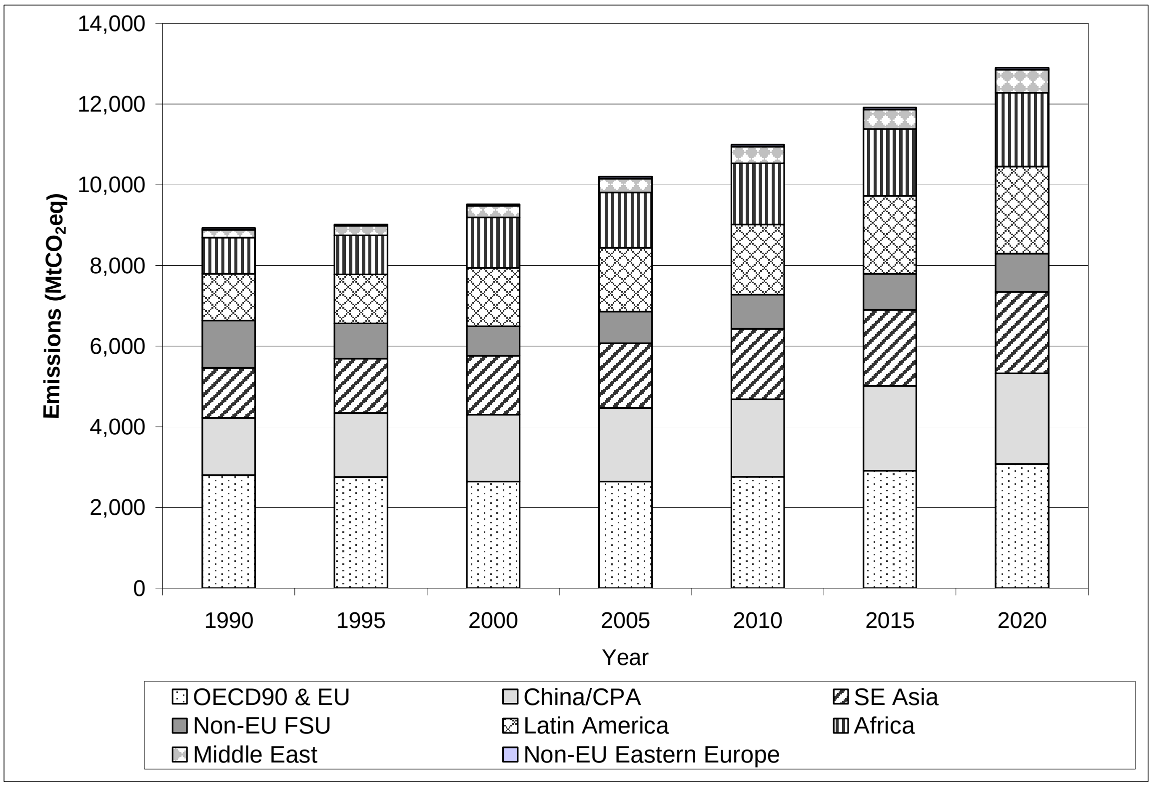


Exhibit 2-2. Total Global Non-CO_2 Emissions by Region ($MtCO_2eq$)

Table 2-1 shows regional growth rates. The cumulative growth rate in emissions is largest in the developing regions of the Middle East, Africa, Latin America, S&E Asia, and China/CPA with growth rates of 197 percent, 104 percent, 86 percent, 64 percent, and 58 percent respectively. Developed regions tend to increase at much slower rates with the OECD emissions predicted to grow at 10 percent from 1990-2020.

Table 2-1. Percent Change by Decade and by Region

Region	% Change			
	1990-2000	2000-2010	2010-2020	1990-2020
Middle East	50%	47%	35%	197%
Africa	40%	20%	21%	104%
Latin America	24%	21%	24%	86%
S&E Asia	19%	19%	16%	64%
China/CPA	16%	17%	16%	58%
Non-EU Eastern Europe	-9%	12%	15%	18%
OECD90 & EU	-6%	4%	12%	10%
Non-EU FSU	-38%	16%	13%	-19%

A review of the decadal growth rates reveals different patterns for each region. The non-EU Eastern Europe, OECD, and non-EU FSU have declining emissions through 2000, followed by a period of increasing emissions. Economic and sectoral restructuring, and methane recovery and use are factors in these regions. The projected emissions reflect economic and population growth and represent BAU conditions, as described earlier in the chapter. Additionally, although these countries are expected to see future growth, the rates are not as large as for the other regions. In contrast, developing regions show a steady increase in the level of emissions throughout the study period, although the accelerated growth rates of the late 1990s and early 2000s begin to slow somewhat in later periods in areas such as the Middle East, and Africa. The S&E Asia, China/CPA, and Latin America regions show sustained growth rates throughout the period.

Exhibit 2-3 shows the total emissions from 1990 to 2020 for countries in the following groupings:

1) Group 1 - Africa, China/CPA, Latin America, Middle East, and S&E Asia; and

2) Group 2 - The OECD, non-EU FSU and non-EU Eastern Europe.

The consistent increases in global emissions in Group 1 are due to several factors in the developing world, including rapid industrialization, expanding economies, and a large and growing population. As mentioned earlier, the trends in Group 2 are due, in part, to the restructuring of several industries in key countries or regions and the historical decrease in emissions from 1990 to 2000 as a result of methane emission reductions in sources including coal mining and landfills. In the 1990s, coal production declined rapidly in England and Germany, which substantially reduced methane emissions from this category in the EU. In the EU, a waste directive that limits the disposal of organic waste significantly decreased current and projected emissions from landfills in that region. A decline in the U.S. methane emissions from landfills and coal mining also significantly impacted the OECD trend during the period 1990 to 2000.

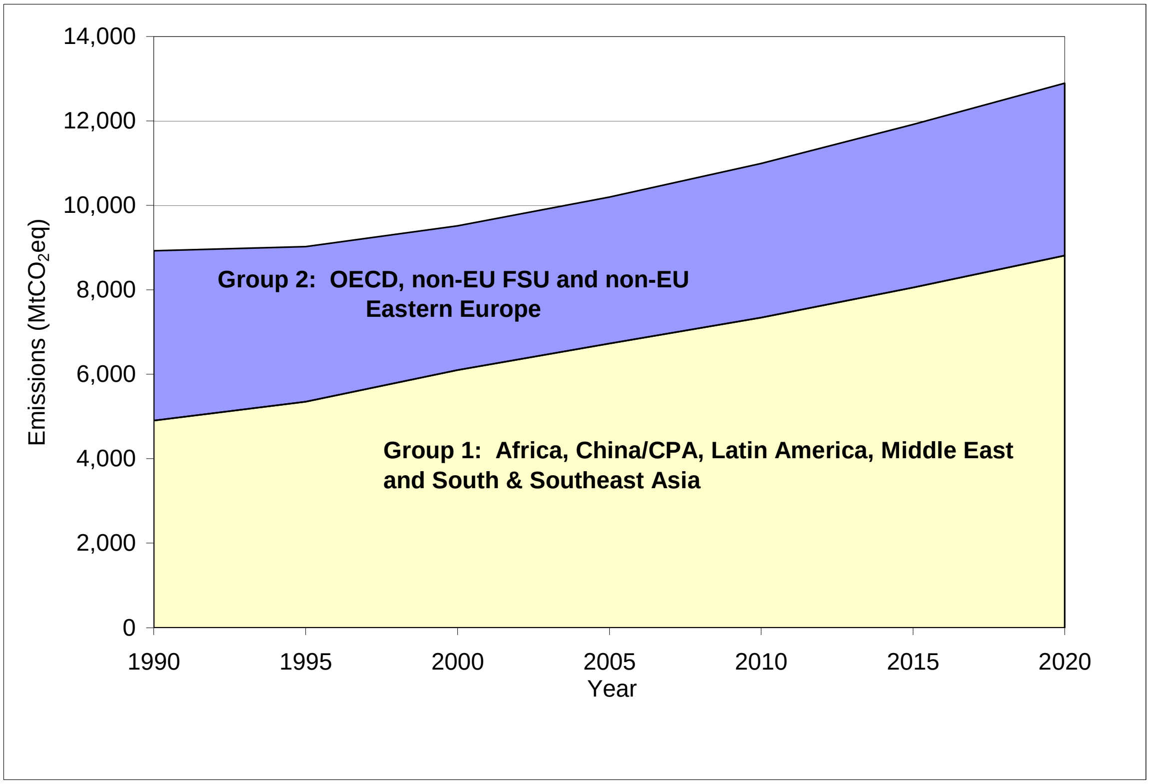


Exhibit 2-3. Total Global Non-CO_2 Emissions by Region and Group ($MtCO_2eq$)

For non-EU Eastern Europe and non-EU FSU, two main forces account for declines in methane and nitrous oxide emissions. First, the economic transitions to market economies during the early 1990s resulted in historical GHG emissions decline due to restructuring within many industries. Second, in Russia and other Eastern European coal producing countries, many of the gassiest underground mines were closed during this period resulting in a sustained decrease in methane emissions in the projection years. However, overall GHG emissions are expected to start gradually increasing around 2005-2010 in many of these countries, as economic recovery widens and domestic production increases in many sectors.

2.3 Trends By Gas and Source Category

Agricultural sources are the largest global source of non-CO_2 emissions, as illustrated in Exhibit 2-4. In absolute terms, emissions from agricultural sources are projected to increase more than 2,000 $MtCO_2eq$ between 1990 and 2020. Countries with large, sustained agricultural production sectors such as the U.S. and Australia and countries with fast-growing populations and economies such as China/CPA, S&E Asia, Latin America, and Africa offset the emission reductions experienced by other countries in this sector. Nitrous oxide emissions from agricultural soils and methane from enteric fermentation compose the largest agricultural sources. These two sources account for nearly 70 percent of emissions from the category throughout the study period.

Non-CO_2 emissions from the energy sector also increase significantly (927 $MtCO_2eq$) during the study period. Significant increases are predicted for natural gas and oil systems (84 percent) and stationary and mobile combustion (42 percent). However, emissions from coal mines are projected to fall by 13 percent through 2020. The largest non-agricultural source of nitrous oxide emissions shifts from adipic and nitric acid production to stationary and mobile sources. Adipic acid and nitric acid production emissions dropped dramatically between 1990 and 2000 and are expected to stay near 2000 levels to 2020. However, total nitrous oxide emissions increase overall due to an increase in mobile source emissions and steadily increasing emissions from agricultural soils after 2000.

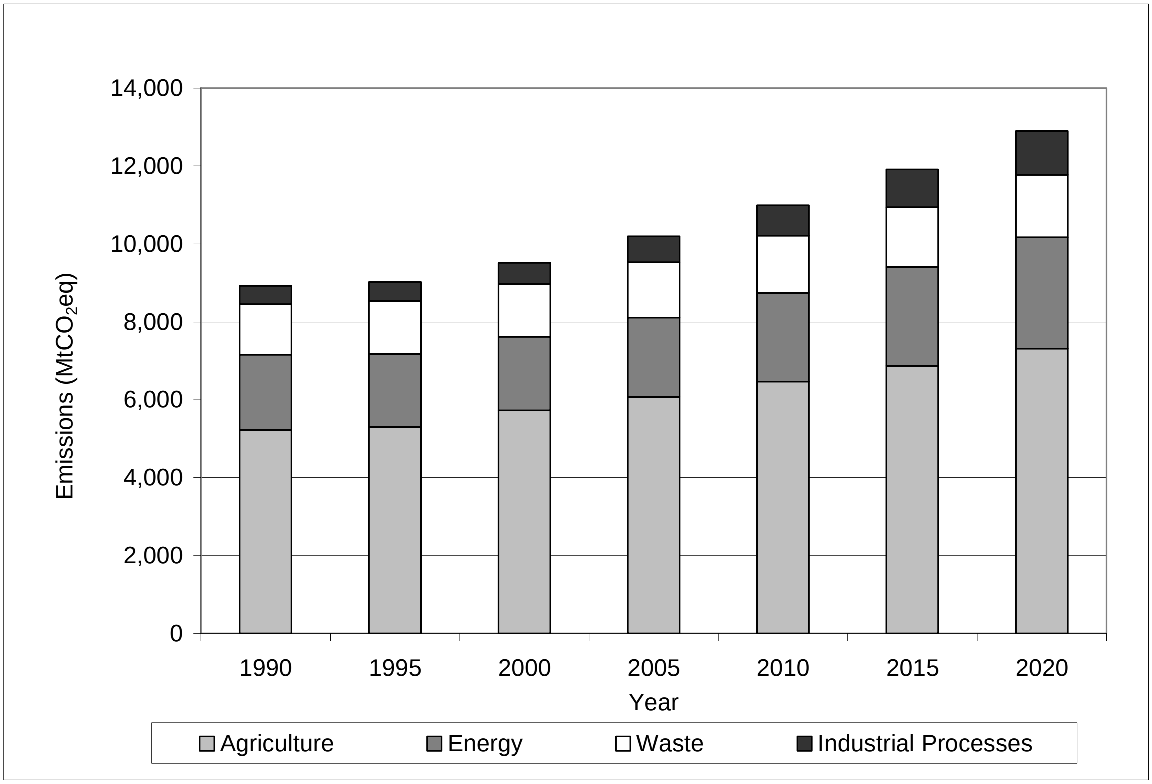


Exhibit 2-4. Global Non-CO_2 Emissions by Sector and Year ($MtCO_2eq$)

Emissions from high GWP gases occur exclusively in the industrial sector and dominate emissions and trends in that sector. High GWP and thus industrial emissions increase significantly from 1990 to 2020 for all regions. Unlike methane and nitrous oxide, emissions of high GWP gases are expected to grow significantly over this period due to the phase out of ODS under the Montreal Protocol, and strong predicted growth in other applications such as semiconductor manufacturing. As ODS are phased out in developed countries, other gases, including HFCs and PFCs, are substituted. The rate of growth is uncertain, however, because the choice of chemicals and potential new technologies or operating procedures could eliminate or diminish the need for these gases.

In the waste sector, methane from landfills accounts for more than half of non-CO_2 emissions in 1990. After increasing slightly between 1990 and 1995, landfill emissions drop to a low point in 2000 before beginning a gradual increase through 2020. Increases in waste generation and population drive emissions upward but increases in waste-related regulations and gas recovery and use will temper that increase. Wastewater emissions exhibit a much higher growth rate than landfills and by 2020 account for nearly an equal share of global non-CO_2 waste emissions. Projected wastewater emissions are driven by population growth and the underlying assumption that growing populations in the developing world are served by latrines and open sewers and not advanced wastewater treatment systems.

2.4 Other Global Datasets

Although non-CO_2 global emissions data are not as prevalent as CO_2 data, other datasets exist and EPA has included information on those datasets for comparison. It should be noted that in some cases, those datasets rely partly on either segments or earlier versions of the dataset presented in this report. Additionally, the dataset presented in this report includes data on biomass burning taken from the Emission Database for Global Atmospheric Research (EDGAR).

Table 2-2 presents global historical and projected emissions of methane, nitrous oxide, and high GWP gases for 2000, 2010, and 2020 from the following sources:

- Energy Management Forum 21 (EMF-21) Analysis (U.S. EPA, 2003).
- IPCC Special Report on Emissions Scenarios (SRES) (IPCC, 2001).
- Emission Database for Global Atmospheric Research (EDGAR) 3.2 Fast Track 2000 dataset (Olivier et al., 2005).

For the SRES, the IPCC created 40 future emissions scenarios which make different assumptions about (among other things) economic and population growth rates, energy sources, environmental policies, and future technologies. This report uses the A2 and B2 marker scenarios in its comparison table. The data compiled for EMF-21 share many of the data sources and methods EPA employed in this report for methane and nitrous oxide. The EDGAR 3.2 Fast Track 2000 dataset assumes that control technologies have not changed since 1995, but does apply emissions reductions when country-specific reduction information is available. EDGAR inventories are compiled using international statistics as activity data and emission factors from the scientific literature.

Although there are differences among individual numbers, the trends are similar. Furthermore, the difference between EPA's methane and nitrous oxide data and the other datasets does not exceed 22 percent for any single year. A slightly larger gap appears among the high GWP data; EPA's 2010 projection for high GWP emissions differs by 44 percent from the SRES projection.

Table 2-2. Comparison of EPA Global Database to Other Global Inventories ($MtCO_2eq$)

	Methane			Nitrous Oxide			High GWP		
Inventory	2000	2010	2020	2000	2010	2020	2000	2010	2020
EPA Global Database (2006)	6,020	6,875	7,904	3,114	3,514	4,057	380	602	935
EMF-21 Analysis (2003)[a]	5,922	6,573	7,866	3,483	3,968	4,613	443	780	1102
IPCC SRES Version (2001)[b]	6,783-7,287	7,329-7,770	8,064-8,904	3,410	3,020-3,945	2,972-4,676	498	867-869	1,032-1,041
EDGAR 3.2 Fast Track 2000[c]	6,741	NE	NE	3,784	NE	NE	465[d]	NE	NE

Codes:
NE indicates "not estimated."

Notes:
[a] Energy Management Forum 21 (EMF-21) Analysis (U.S. EPA, 2003).
[b] IPCC Special Report on Emissions Scenarios (SRES) (IPCC, 2001).
[c] Emission Database for Global Atmospheric Research (EDGAR) 3.2 Fast Track 2000 (Olivier, et al., 2005).
[d] 295 metric tons of C_7F_{16} not included in total; unknown GWP.

3. Energy

3.1 Introduction

This chapter presents global methane and nitrous oxide emissions for 1990 to 2020 for the following anthropogenic sources:

- Natural gas and oil systems (methane)
- Coal mining activities (methane)
- Stationary and mobile combustion (methane and nitrous oxide)
- Biomass combustion (nitrous oxide and methane).

The energy sector is the second largest contributor (22 percent) to global emissions of non-CO_2 emissions. In 1990, the energy sector accounts for 1,931 $MtCO_2eq$ of non-CO_2 GHG emissions. As shown in Exhibit 3-1, fugitive emissions from natural gas and oil systems are the largest source of non-CO_2 GHG emissions from this sector, accounting for 51 and 63 percent of energy related emissions in 1990 and 2020, respectively. The next largest source in this sector is fugitive emissions from coal mining, but this source has a declining share over time, constituting roughly 27 percent of the energy sector in 1990, 20 percent in 2000, and 16 percent by 2020.

Several key factors play a role in the emissions from the energy sector as a whole: economic restructuring in Eastern Europe and the Former Soviet Union (FSU); a shift from coal to natural gas as an energy source in several regions; restructuring in several key coal mining countries and expansive growth in energy consumption in less developed regions. These effects are further discussed within each source discussion.

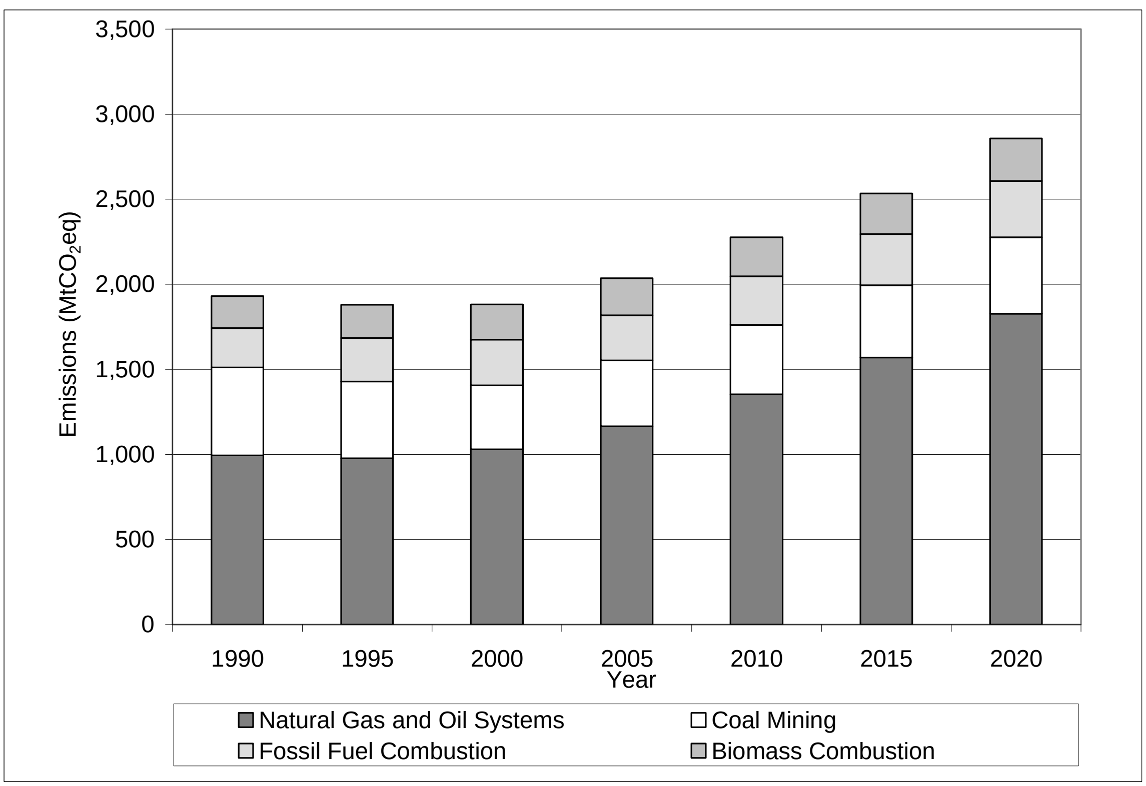


Exhibit 3-1. Total Emissions from the Energy Sector by Source ($MtCO_2eq$)

3.2 Natural Gas and Oil Systems (Methane)

3.2.1 Source Description

Methane is the principal component (95 percent) of natural gas and is emitted from natural gas production, processing, transmission and distribution. Oil production and processing can also emit methane in significant quantities since natural gas is often found in conjunction with petroleum deposits. In both oil and natural gas systems, methane is a fugitive emission from leaking equipment, system upsets, and deliberate flaring and venting at production fields, processing facilities, transmission lines, storage facilities, and gas distribution lines.

3.2.2 Source Results

Total Methane Emissions from Natural Gas and Oil Systems

Year	$MtCO_2eq$	Gg CH_4
1990	994	47,313
1995	977	46,536
2000	1,030	49,041
2005	1,165	55,478
2010	1,354	64,496
2015	1,570	74,749
2020	1,828	87,028

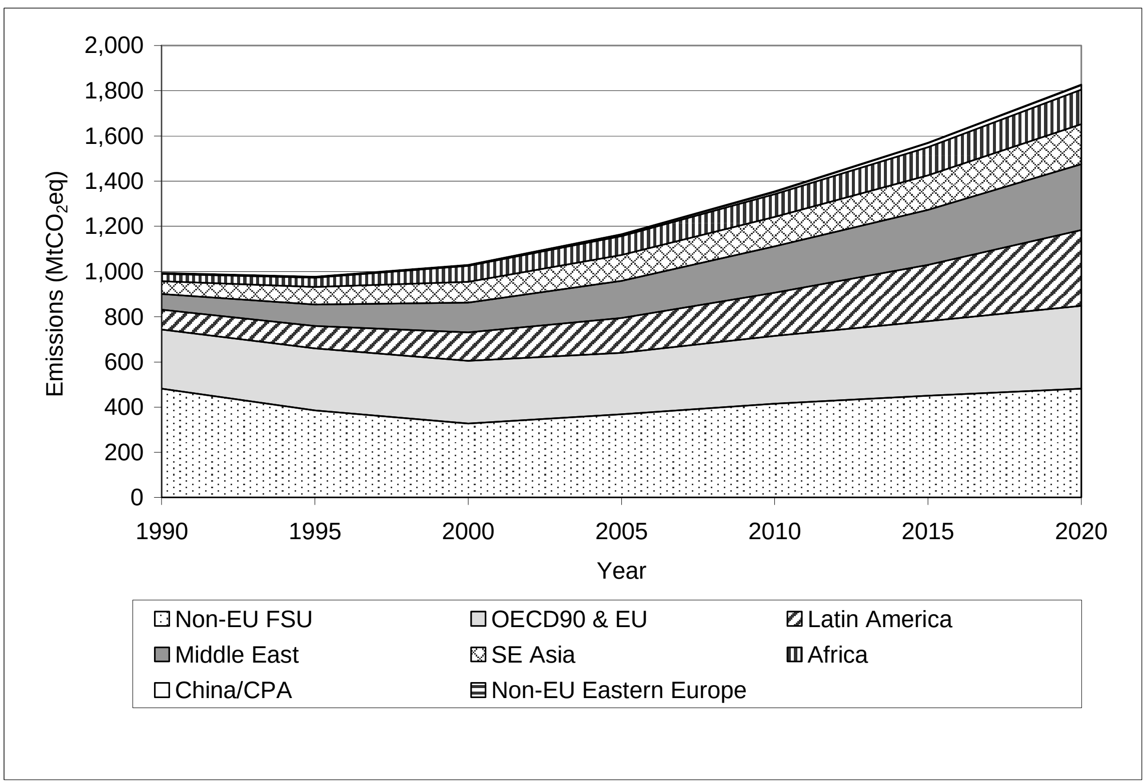


Exhibit 3-2: Methane Emissions from Natural Gas and Oil Systems 1990 – 2020 ($MtCO_2eq$)

Global oil and gas methane emissions are projected to increase by 84 percent between 1990 and 2020, with a slight decrease from 1990 to 1995 and an increasingly positive growth rate after 1995, as shown in Exhibit 3-2. Three key factors influence the overall trend in global emissions from 1990 to 2020: the non-EU FSU economic transition; the mild growth in production in parts of the OECD; and the accelerated growth in energy production and demand in all other regions, especially Asia. Increasing emissions over the period 1990 to 2020 are expected in all regions except the non-EU FSU, as shown in Table 3-1. Although the rank order of the regions does not change during the study period, each region's contribution to global emissions changes dramatically. For example, in 1990, the non-EU FSU and OECD countries account for 75 percent of the global methane emissions. By 2020, their collective share falls to 47 percent.

The non-EU FSU is the only region where the 2020 emissions level is expected to remain level over the 30 year study period, as illustrated in Exhibit 3-2 and Table 3-1. Russian natural gas emissions dominate this region's emissions and trends. Russia's economic transition causes a short term decline in the production and use of natural gas and oil, which leads to a sharp decrease in emissions from 1990 to 2000. The emissions are expected to increase after 2000, but the percentage of Russia's contribution to the global emissions still falls to 11 percent by 2020, from 33 percent in 1990. Without Russia in the total, this region still shows a decline from 1990 to 2000 since most FSU countries experienced a similar, though sometimes smaller, economic decline during the period. However, the growth in the rest of the non-EU FSU region is large enough to overcome the temporary decline in emissions, leading to an overall growth rate of over 98 percent from 1990 to 2020 for these countries.

After the non-EU FSU region, OECD countries have the next lowest growth rate, as illustrated in Exhibit 3-2 and Table 3-1. The OECD countries experience only mild growth (40 percent) compared to the developing regions. Several reasons may underlie this trend. Many of these countries have mature natural gas and oil industries with stabilized or limited growth in production sectors. Additionally, many OECD countries have instituted air quality and safety rules that have the ancillary benefit of reducing methane emissions. However, it is likely there will be a continued and growing demand for natural gas in the OECD, which may result in increased emissions in the distribution and transmission sectors.

By contrast, the Middle East, Latin American, and S&E Asian regions are expected to account for a much greater share of global emissions by 2020, increasing from 22 percent in 1990 to 44 percent in 2020. In the less developed countries of these regions, electricity production and demand are expected to increase rapidly as populations become more urbanized and concentrated, and industries expand. In turn, these energy demands are expected to drive the rapid growth in fuel production and consumption. Also, the Middle East includes some of the largest oil production and exporting countries, and emissions are expected to increase there as a result of increasing world demand for oil. China/CPA shows the largest rate of growth in emissions at 812 percent; however, it still accounts for only about 1 percent of the global total in 2020 since it relies more heavily on coal than oil and gas production for its energy needs.

Table 3-1. Percentage Change in Methane Emissions from Natural Gas and Oil Systems Between 1990 and 2020

Region	% change
China/CPA	812%
Africa	370%
Middle East	321%
Latin America	285%
S&E Asia	211%
Non-EU Eastern Europe	55%
OECD90 & EU	40%
Non-EU FSU	0%
Global	84%

Actual future emissions may differ from these projections for several reasons. Efforts are underway to modernize gas and oil facilities in Russia and many Eastern European countries, which could help reduce fugitive emissions. In areas where gas production is projected to increase, such as Western Europe, emissions will not necessarily increase at the same rate. Leakage and venting do not necessarily increase linearly with throughput, and newer equipment tends to leak less than older equipment. Projections of oil and natural gas production and consumption are, by nature, highly uncertain. The uncertain future of gas prices adds an additional level of uncertainty.

3.3 Coal Mining Activities (Methane)

3.3.1 Source Description

Methane is produced during the process of coalification, where vegetation is converted by geological and biological forces into coal. Methane is stored within the coal seams and the surrounding rock strata and is liberated when the pressure above or surrounding the coal bed is reduced as a result of natural erosions, faulting, or mining (U.S. EPA, 1993; U.S. EPA, 1999).

The quantity of gas emitted from mining operations is a function of two primary factors: coal rank and coal depth. Coal rank is a measure of the carbon content of the coal, with higher coal ranks corresponding to higher carbon content and generally higher methane content. Coals such as anthracite and semianthracite have the highest coal ranks, while peat and lignite have the lowest. Pressure increases with depth and prevents methane from migrating to the surface. Thus, underground mining operations typically emit more methane than surface mining (EPA, 1993).

Methane emissions from the coal mining sector come from four main sources:

- **Underground Mines.** Underground mines account for the majority of global methane emissions from coal mining. Geologic pressure traps larger volumes of methane in deeper coal seams and the surrounding rock strata. Because methane is explosive at concentrations of between five and fifteen percent, methane is removed from underground mines by ventilation or degasification as a safety precaution (U.S. EPA 1993; U.S. EPA, 1999).

- **Surface Mines.** As the coal seam is exposed during surface mining, methane is liberated directly to the atmosphere. Surface mines generally emit considerably less methane than underground mines because coal ranks are typically lower and there is less pressure to trap methane in the coal.

- **Post-Mining Operations.** Post-mining operations refer to the processing, storage, and transportation of the mined coal. Coal can continue to emit methane for months after mining, depending on the characteristics of the coal and the handling procedures. The highest releases occur when coal is crushed, sized, and dried for industrial and utility uses (EPA, 1999).

- **Abandoned Mines.** Methane emissions from coal mines can continue after operations have ceased. The key factors are surrounding strata permeability and emissions while active.

Abandoned mines are not considered in this analysis due to a lack of data. Methane recovery and use is not explicitly estimated in this analysis, however, if a country includes such estimates in its historical emissions, it is included here.

3.3.2 Source Results

As shown in Exhibit 3-3, global coal mine methane emissions decline substantially from 1990 to 2000, but are expected to increase steadily after 2000 and return to nearly 1990 levels by 2020. Key factors influencing both the historical and projected trends are the changes in coal production in China, restructuring of the energy industries in Europe and the non-EU FSU, and industry changes in the U.S.

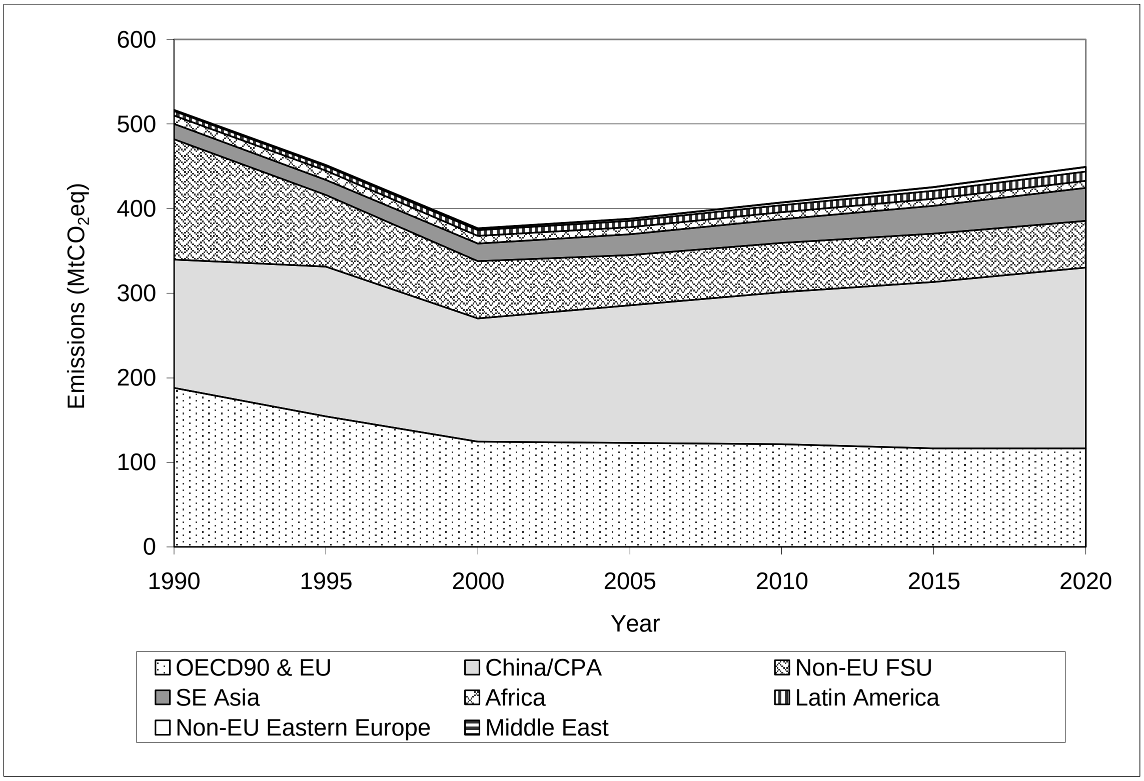


Exhibit 3-3. Methane Emission from Coal Mining Activities 1990 – 2020 ($MtCO_2eq$)

The China/CPA region shows an increase and then subsequent decline between 1990 and 2000. The upward trend from 1990 to 1995 in the China/CPA region is largely due to an increase in coal mining in China and North Korea, which account for most of the emissions in the region and are among the top six emitters for the source. The declining trend from 1995 to 2000 is caused primarily by changes in the Chinese coal industry. Many mines closed during this period and coal production slowed significantly. This trend is not predicted to continue past 2000, with China's emissions expected to increase 50 percent by 2020 in response to increased coal production to meet expanding energy needs.

The non-EU FSU and OECD regions experienced a significant decline in emissions from 1990 to 2000. In the 1990s, coal production declined rapidly in England and Germany, contributing substantially to the reduction in OECD emissions from 1990 to 2000. In Russia and Eastern European coal producing countries, restructuring of the energy industries caused many of the gassiest underground mines to close during the 1990s resulting in a decrease in emissions that has been sustained in the projection years. Emissions in non-EU FSU region are expected to decline throughout the analysis period, though more gradually after 2000 as economic recovery widens and domestic production increases in many sectors of these countries.

Emissions from coal mining activities are expected to decrease in the U.S. through 2020, which also affects the downward trend in OECD emissions. Production is shifting from underground coal mines to surface mines, as well as shifting to the less gassy western basins for a portion of the remaining underground mining. Additionally, reductions due to methane recovery and use of coal bed methane will impact emissions. These reductions in emissions are expected despite anticipated growth in overall coal production over the analysis period.

	Total Methane Emissions from Coal Mining Activities	
Year	$MtCO_2eq$	Gg CH_4
1990	517	24,607
1995	452	21,502
2000	377	17,946
2005	388	18,483
2010	408	19,408
2015	426	20,265
2020	449	21,404

3.4 Stationary and Mobile Combustion (Nitrous Oxide and Methane)

3.4.1 Source Description

Nitrous oxide is a product of the reaction between nitrogen and oxygen during combustion of fossil fuels and biomass. Both mobile and stationary sources emit nitrous oxide, and the volume emitted varies according to the type of fuel, combustion technology, and pollution control device used, as well as maintenance and operating practices. Stationary and mobile combustion also result in methane emissions due to incomplete combustion. However, combustion is a relatively minor contributor to overall methane emissions.

Stationary combustion encompasses all fossil fuel combustion activities except transportation (i.e., mobile combustion). These activities primarily include combustion of fossil fuels and commercially-traded biomass fuels[1] used in large power plants and boilers. Total emissions from stationary and mobile combustion are small in comparison to other sources, amounting to only 6 percent of global nitrous oxide emissions.

Mobile combustion sources such as automobiles and airplanes emit nitrous oxide as an exhaust emission from a variety of engine and fuel configurations. As with stationary sources, nitrous oxide emissions are closely related to air-fuel mixtures and combustion temperature, as well as pollution control equipment on transportation vehicles. Key factors affecting fuel consumption and, ultimately emissions, for mobile sources include the distance traveled for vehicles, hours of operation for off-road equipment, age of vehicles, and mode of operation. Road transport accounts for the majority of mobile source fuel consumption, and as a result, the majority of mobile nitrous oxide emissions.

3.4.2 Source Results

In 1990, the OECD nations contribute 76 and 67 percent to global nitrous oxide and methane emissions from combustion sources, respectively. However, as shown in Table 3-2, the expected growth in emissions between 1990 and 2020 for the OECD is among the lowest of all regions (32 percent for nitrous oxide and -15 percent for methane). Although the percent contribution of the OECD nations is expected to decline, the OECD nations are expected to remain the largest emitters throughout the period, accounting for 66 percent and 48 percent for methane and nitrous oxide emissions in 2020, respectively, as illustrated in Exhibits 3-4.1 and 3-4.2. The third largest emitter of nitrous oxide in 1990, the non-EU FSU, is predicted to have a negative growth rate (-39 percent) between 1990 and 2020 and is projected to drop to the seventh largest emitter in 2020. This region is surpassed by the increasing emissions of the developing nations of S&E Asia, Latin America, China/CPA, and Africa. China/CPA, the second largest source of nitrous oxide in 1990 (6 percent), is expected to increase its emissions nearly 2.5 times by 2020 and S&E Asia is predicted to have a growth rate well over 200%. The increases in these

[1] This report includes emissions for biomass fuels along with stationary and mobile combustion only for the Annex I countries. For these countries, biomass combustion emissions are reported together with fossil fuels in the Common Report Format. For non-Annex I countries, emissions for biomass were calculated separately and are reported in Appendices B-4 and C-2. See Section 3.5 for more information.

developing regions are driven by higher demand for and production of energy and the increased use of automobiles.

Total Methane and Nitrous Oxide Emissions from Stationary and Mobile Combustion

Year	$MtCO_2eq$	Gg CH_4	Gg N_2O
1990	233	3,171	537
1995	256	3,004	622
2000	268	2,933	667
2005	265	3,040	648
2010	286	3,242	703
2015	300	3,478	731
2020	331	3,771	813

From 1990 to 1995, the two driving forces behind the decrease in stationary combustion emissions are the decline in energy consumption in Russia and Eastern Europe and a shift in Western Europe from coal to natural gas. However, as the economies of Eastern Europe and Russia recover after 2000, energy demand is expected to rise and emissions are expected to grow. High-emitting coal boilers and furnaces will continue to be the primary source of emissions in these regions as long as coal remains a major source of energy. Emissions from the EU are also expected to increase with energy consumption; however, emissions per unit of energy will decrease because of a shift from coal to natural gas, and the increased use of fluidized bed systems in coal-fired plants, which reduce nitrous oxide emissions. The remaining regions all show increases over the time period, though none approach the level of emissions from the OECD.

The increase in nitrous oxide emissions from mobile sources in the OECD region is due to two factors. First, an increasing share of the automotive fleet is equipped with emission reduction catalysts. Certain types of catalyst technologies, while achieving substantial reductions in volatile organic compounds (VOCs), carbon monoxide (CO), and nitrogen oxides (NO_x), may actually result in higher nitrous oxide emissions. In the U.S. and Canada, the automobile industry is currently phasing-in new emission control technologies that produce lower nitrous oxide emissions. The penetration of these new control technologies is expected to occur somewhat later and at a slower rate in the EU. Second, a substantial increase in distance traveled and fuel consumption has occurred since 1990 due to strong economic growth and low fuel prices during the 1990s. The trend in increased distance traveled is likely to continue in the future as the driving population increases. However, some of this increased activity may also be dampened by increasing fuel costs and offset by increasing energy efficiency of passenger cars.

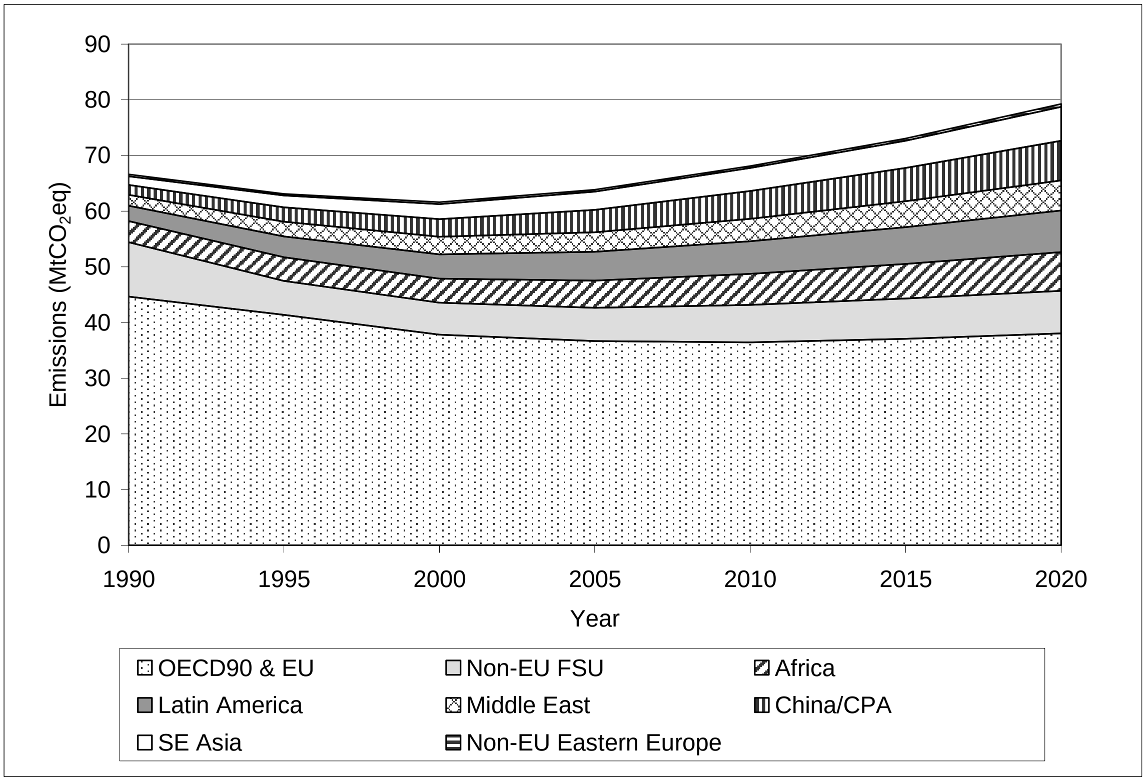


Exhibit 3-4.1. Methane Emissions from Stationary and Mobile Combustion 1990 – 2020 ($MtCO_2eq$)

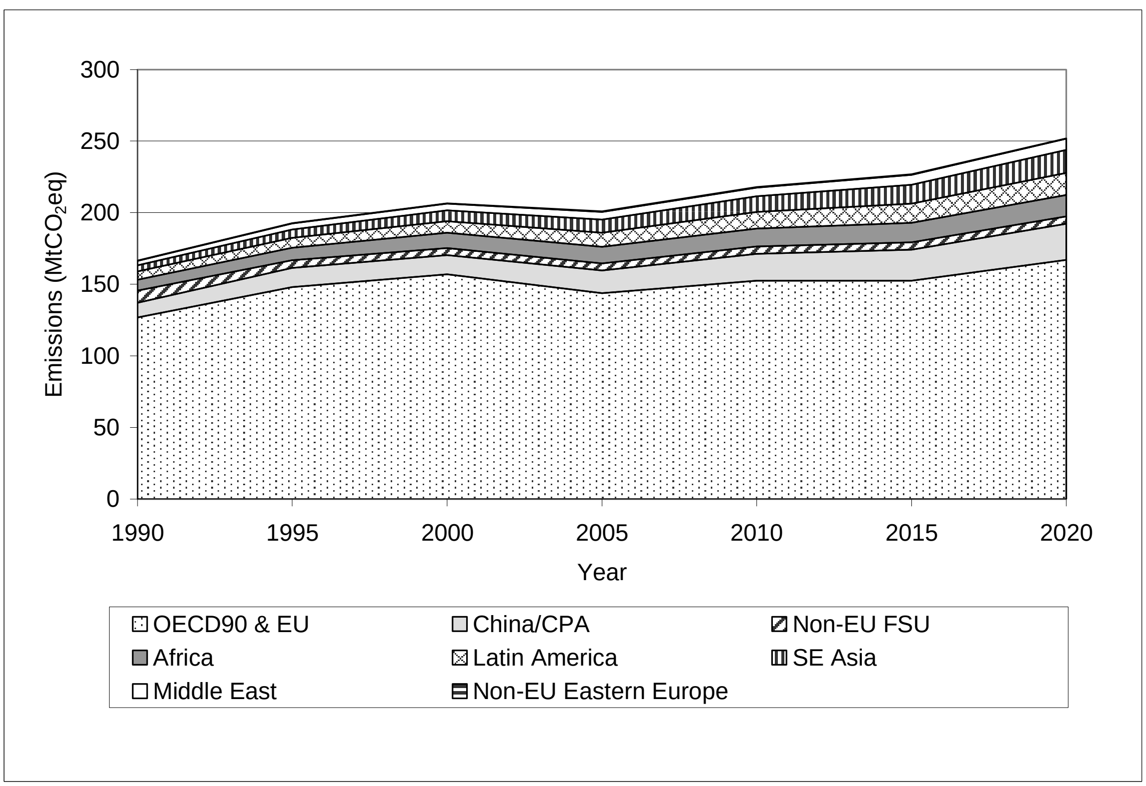


Exhibit 3-4.2. Nitrous Oxide Emissions from Stationary and Mobile Combustion 1990 – 2020 ($MtCO_2eq$)

Table 3-2. Percentage Change in N_2O and CH_4 Emissions Between 1990 and 2020

Region	**N_2O**	**CH_4**
Non-EU Eastern Europe	391%	54%
S&E Asia	268%	280%
Latin America	173%	165%
China/CPA	146%	310%
Middle East	144%	179%
Africa	92%	86%
OECD90 & EU	32%	-15%
Non-EU FSU	-39%	-22%

3.5 Biomass Combustion (Methane and Nitrous Oxide)

3.5.1 Source Description

Methane and nitrous oxide are produced as a result of incomplete biomass combustion. Fuel wood, charcoal, agricultural residues, agricultural waste, and municipal waste combustion are the major contributors to methane and nitrous oxide emissions within this category. Biomass combustion in the developing world often refers to the combustion of biofuels in small-scale combustion devices for heating, cooking, and lighting purposes. Because of the wide variety in the types and conditions under which these fuels are burned, estimates for this category are highly uncertain and difficult to predict.

The data presented here are for non-Annex I countries only. Emissions from biomass combustion for Annex I countries are included in the stationary and mobile combustion section due to UNFCCC reporting (see Section 3.4).

3.5.2 Source Results

Total Methane and Nitrous Oxide Emissions from Biomass Combustion			
Year	**$MtCO_2eq$**	**Gg CH_4**	**Gg N_2O**
1990	187	7,666	84
1995	196	7,985	92
2000	208	8,458	98
2005	218	8,869	102
2010	229	9,323	108
2015	239	9,721	112
2020	249	10,137	118

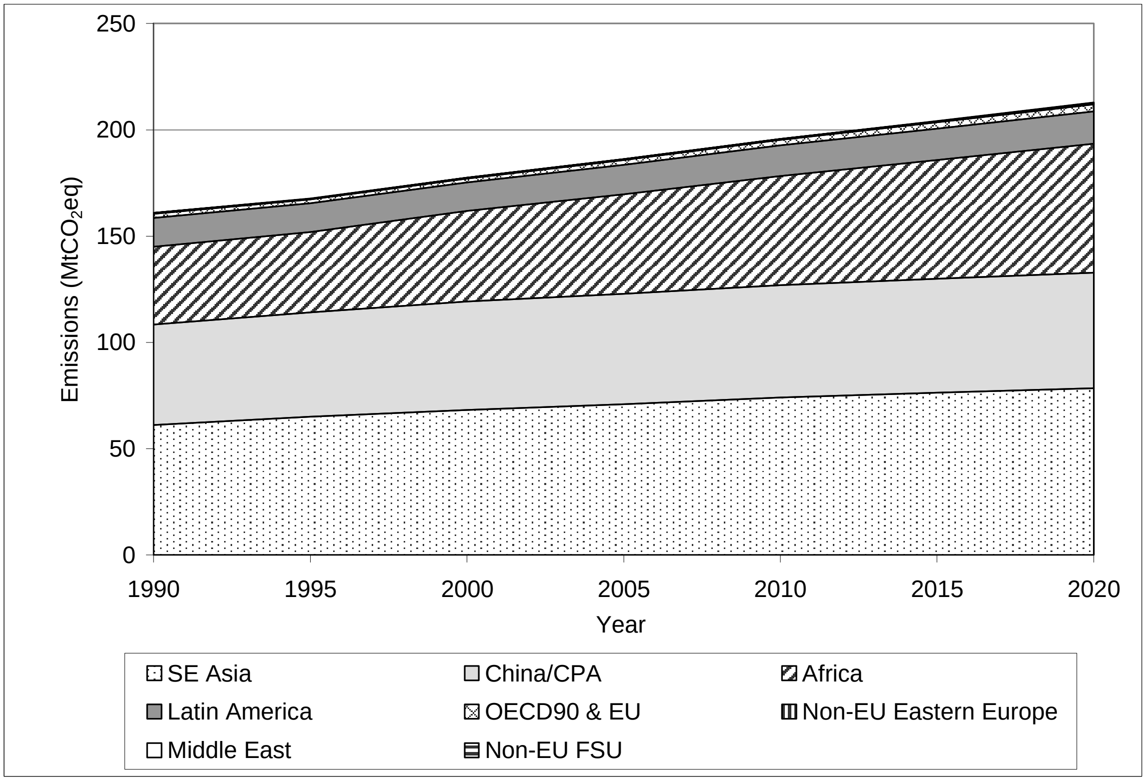


Exhibit 3-5.1. Methane Emissions from Biomass Combustion 1990 – 2020 ($MtCO_2eq$)

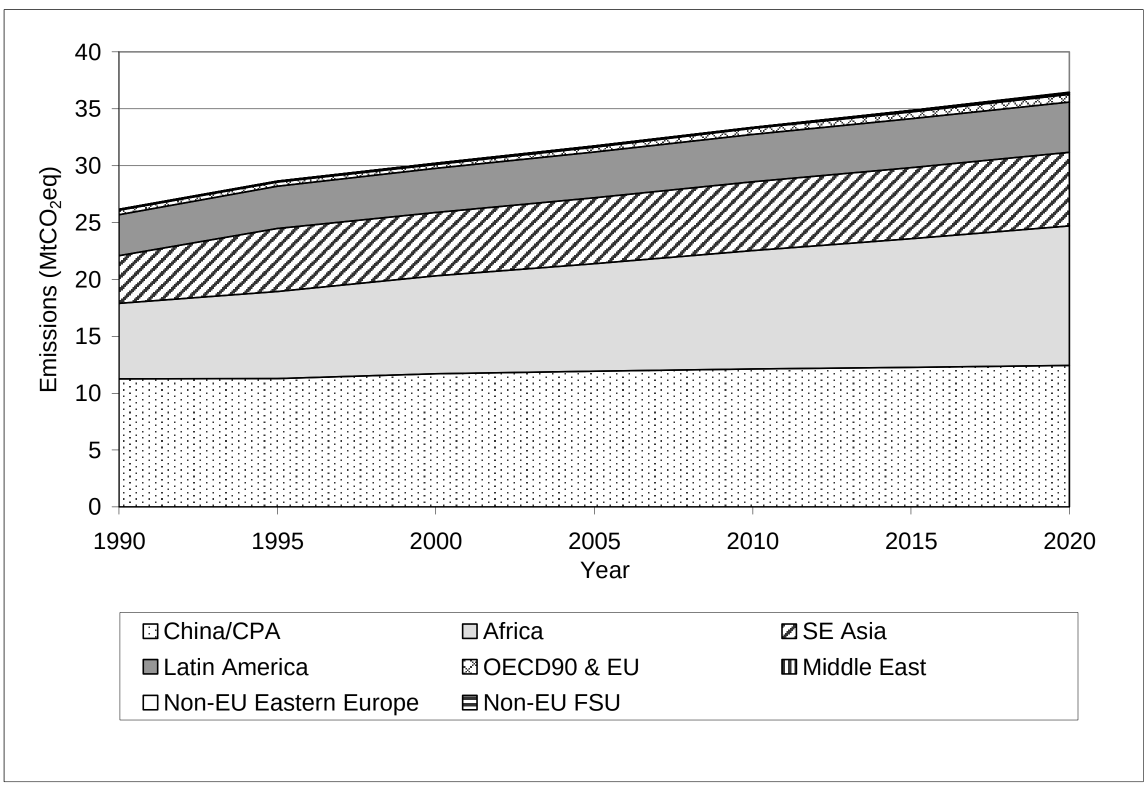


Exhibit 3-5.2. Nitrous Oxide Emissions from Biomass Combustion 1990 – 2020 ($MtCO_2eq$)

Both methane and nitrous oxide emissions from biomass combustion show an upward trend from 1990 to 2020. The combined regions of S&E Asia, China/CPA, and Africa contribute over 90 and 84 percent of the methane and nitrous oxide emissions, respectively. The largest sub-source for this sector is residential solid biomass combustion fuels. The activity data for solid fuel in the energy and manufacturing sector are also high but the emission factors are an order of magnitude lower for methane since the processes tend to be more efficient. Nitrous oxide emissions are minimal, with an emission factor from 10 to 100 times smaller than the methane emission factor for the main categories of emissions. In the future, this section may be integrated fully into the stationary and mobile emissions sector.

4. Industry

4.1 Introduction

This section presents non-CO_2 emissions from the industrial sector for 1990-2020. The industrial sector includes industrial sources of nitrous oxide (N_2O) and methane (CH_4), along with several sources of the high global warming potential (high GWP) gases. The high GWP sources include the use of substitutes for ozone-depleting substances (ODS) and industrial sources of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The categories and their GHG emissions presented in this section are as follows:

- Adipic acid and nitric acid production (N_2O)
- Substitutes for ozone-depleting substances (HFCs, PFCs)
- HCFC-22 production (HFCs)
- Electric power systems (SF_6)
- Primary aluminum production (PFCs)
- Semiconductor manufacturing (HFCs, PFCs, SF_6)
- Magnesium manufacturing (SF_6)
- Other miscellaneous industrial sources (CH_4, N_2O).

4.1.1 Trends in Emissions from Industrial Sources

As shown in Exhibit 4-1[1], emissions from this sector increase by 138 percent between 1990 and 2020. Through 2000, the largest emissions source is adipic acid and nitric acid production. In 1990, this source contributed nearly 48 percent of the emissions for this sector. However, by 2020, this source will contribute only 16 percent of the sector's emissions. During the 30-year period from 1990 to 2020, the replacement of ODS with HFCs and PFCs will lead to a large increase in high GWP emissions from ODS substitutes. ODS substitutes have a wide variety of applications including use as refrigerants, aerosol propellants, solvents, foam blowing agents, medical sterilization carrier gases, and fire extinguishing agents.

It should be noted that the ODSs themselves are greenhouse gases; however, following international conventions, the emissions of these substances are not included in the baseline emissions presented here. Only emissions of non-ozone-depleting fluorinated gases used as substitutes for ODSs are included in the baseline emissions.

ODS substitutes will grow at a rate of more than 1200% between 1995 and 2020 and are expected to account for 66 percent of the sector's emissions in 2020. Emissions from electric power systems and semiconductor manufacturing will also increase during the study period at rates of 36 and 193 percent, respectively. Three categories will show significant declines in emissions during the study period as new technologies are implemented: emissions from primary aluminum production (-54 percent), HCFC-22 production (-14 percent), and magnesium production (-60 percent).

[1] Projected estimates incorporate the planned reductions from the "Technology-Adoption" Baselines.

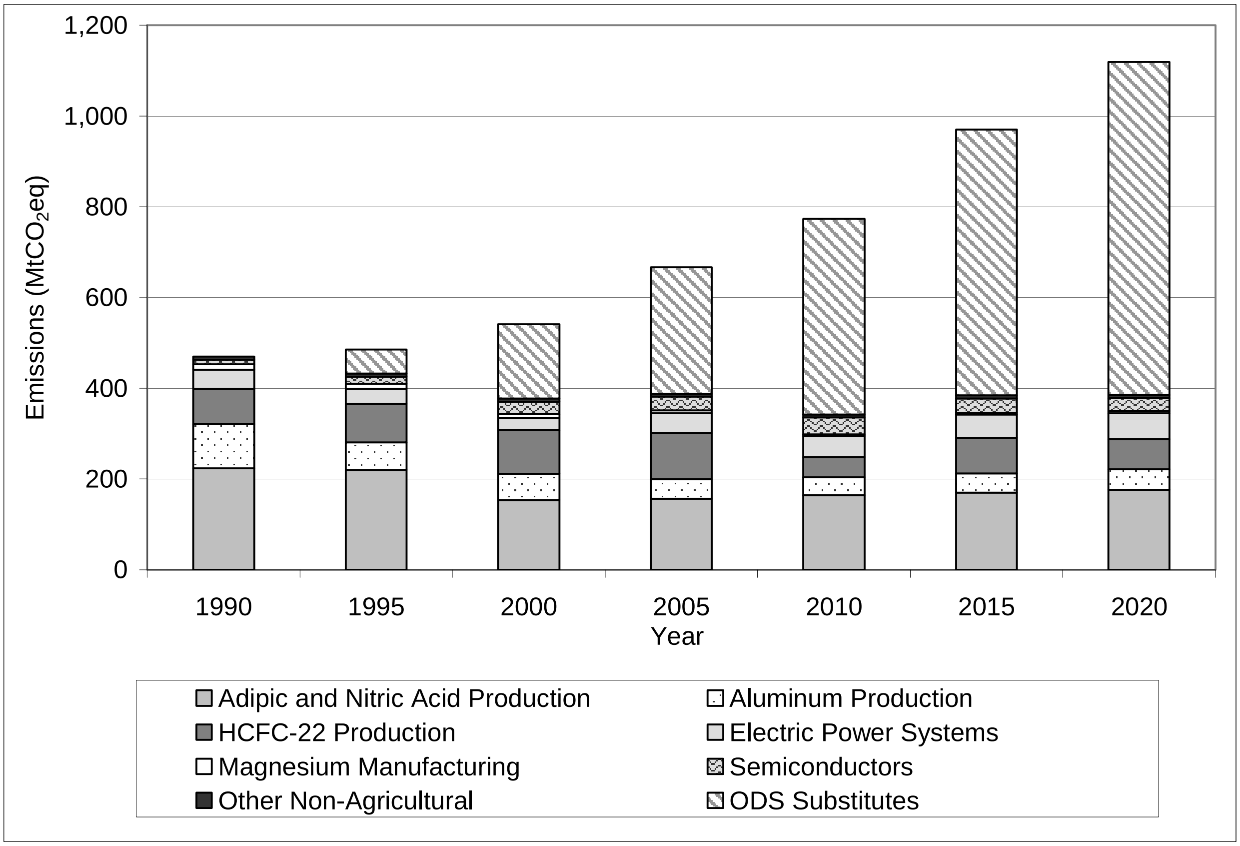


Exhibit 4-1. Emissions from Industrial Processes by Source ($MtCO_2eq$)

4.1.2 The Technology-Adoption and No-Action Baselines

This section presents two future scenarios for the industrial sources[2] that emit high GWP gases, as shown in Exhibit 4-2.

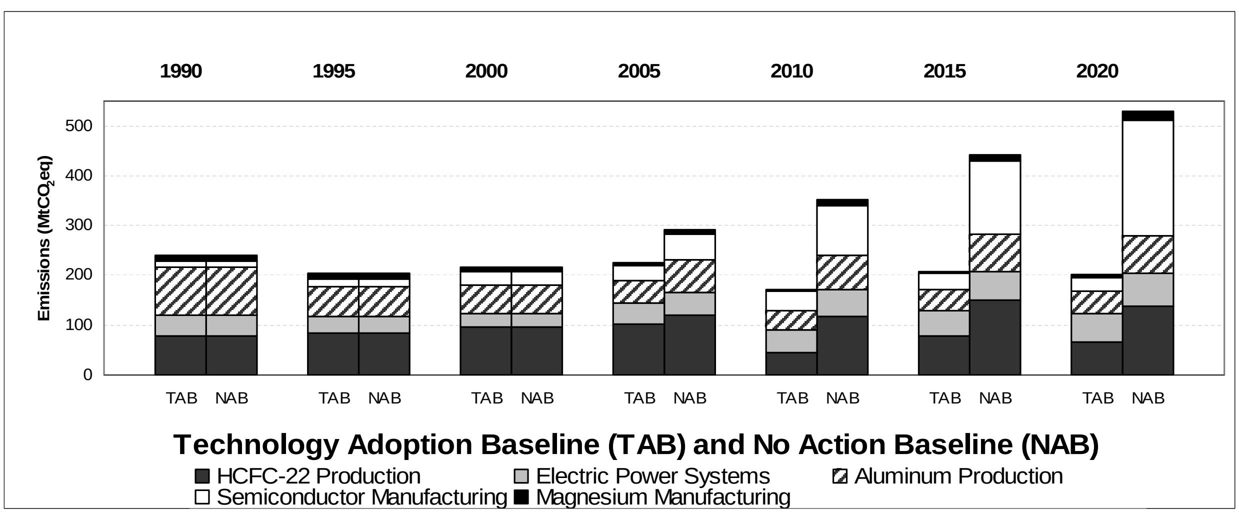


Exhibit 4-2. Technology-Adoption and No-Action Baseline Emissions by Year ($MtCO_2eq$)

[2] This discussion does not include high GWP emissions from ODS Substitutes.

The first scenario, the "Technology-Adoption Baseline," is based on the assumption that those industries that have announced clearly defined, industry-specific global or regional reduction goals will achieve their goals for the year 2010 and beyond. These industries include the production of aluminum, semiconductors, magnesium, and HCFC-22, and the use of electrical equipment. The goals are discussed in more detail in Section 7.3 of the methodology discussion. The second scenario, the "No-Action Baseline," is based on the assumption that emission rates will remain constant from the present onward in these industries.

EPA believes that actual future emissions are likely to be far closer to those envisioned in the Technology-Adoption Baseline than those envisioned in the No-Action Baseline. Since 1990, all five industries have already made great progress in reducing their emission rates, and research is continuing into methods to further reduce those rates. Nevertheless, additional actions will be required to actually realize additional reductions. These actions range from process optimization and chemical recycling to chemical replacement. Thus, depending on the context, either baseline may be of interest. For example, analysts interested in the incremental costs of reducing emissions below the levels anticipated in current global industry commitments can use the Technology-Adoption Baseline. On the other hand, analysts interested in the future costs of achieving the currently planned industry reductions can use the No-Action Baseline. The difference between the two baselines is itself of interest, demonstrating that the industry commitments are likely to avert very large emissions.

Past emissions (1990-2000) for all sources are identical under either scenario, but they are provided with both scenarios to provide context for the divergent future trends.

As shown in Exhibit 4-2, GWP-weighted emissions from this sector are predicted to decrease by 16 percent from 1990-2020 under the Technology-Adoption Baseline; under the No-Action Baseline, emissions would increase by 122 percent over that same period. Historically, the largest sources of high-GWP emissions have been HCFC-22 production and aluminum production. Under the Technology-Adoption Baseline, HCFC-22 production is expected to remain the largest contributor to total GWP-weighted emissions through 2020, accounting for 33 percent of emissions in 2020. However, emissions from aluminum production are expected to decline in both absolute and relative terms as that industry continues to implement emission reduction measures to meet the International Aluminum Institute's (IAI) global emission reduction goal. Given similar efforts to control emissions in the semiconductor and magnesium industries, emissions from electric power systems are predicted to increase in relative importance to become the second largest source of industrial high-GWP emissions (29 percent) in 2020 in the Technology-Adoption Baseline. As discussed further in the section on electric power systems, the primary driver for emissions growth in this sector is the growth of electrical grids in developing countries; this growth counteracts expected declines in emissions from developed countries.

HCFC-22 production emissions would remain one of the largest contributors under the No-Action Baseline as well. However, in this scenario, which does not account for efforts by the semiconductor industry to reduce emission rates, the high activity growth rate for semiconductor manufacturing translates directly into a rapid growth in emissions. Consequently, under the No-Action Baseline, emissions from semiconductor manufacturing account for almost half (44 percent) of total high-GWP industrial emissions in 2020.

4.1.3 Global Warming Potentials for High GWP Gases

Table 4-1 lists the high GWP gases included in this analysis of the industrial sector with their atmospheric lifetime, global warming potentials (GWP), and associated uses or emission sources. Although the GWPs have been updated by the IPCC in the Third Assessment Report (TAR), estimates of emissions in this report continue to use the GWPs from the Second Assessment Report (SAR) in order to be consistent with international reporting standards under the United Nations Framework Convention on Climate Change (UNFCCC). However, some of the high GWP gases estimated in this report only have GWPs in the TAR. In these cases, this report uses the TAR GWPs.

Table 4-1. High GWP Chemicals – Partial List

Chemical	Life-time (yrs)	GWP (100-yr)	Use
Hydrofluorocarbons (HFCs)			
HFC-23	264	11,700	Byproduct of HCFC-22 production, used in very-low temperature refrigeration, blend component in fire suppression, and plasma etching and cleaning in semiconductor production.
HFC-32	5.6	650	Blend component of numerous refrigerants.
HFC-41	3.7	150	Not in commercial use today.
HFC-125	32.6	2,800	Blend component of numerous refrigerants and a fire suppressant.
HFC-134	10.6	1,000	Not in commercial use today.
HFC-134a	14.6	1,300	Most widely used HFC refrigerant, blend component of other refrigerants, propellant in metered-dose inhalers and aerosols, and foam blowing agent.
HFC-152a	1.5	140	Blend component of refrigerant blends, propellant in aerosols, foam blowing agent, and under consideration as a stand-alone refrigerant for use in motor vehicle air conditioners.
HFC-143	3.8	300	Not in commercial use today.
HFC-143a	48.3	3,800	Refrigerant blend component.
HFC-227ea	36.5	2,900	Fire suppressant and propellant for metered-dose inhalers.
HFC-236ea	10.0[a]	1200[a]	Not in commercial use today.
HFC-236fa	209	6,300	Refrigerant and fire suppressant.
HFC-245ca	6.6	560	Not in commercial use today.
HFC-245fa	7.2[a]	950[a]	Foam blowing agent and under consideration as a refrigerant.
HFC-365mfc	9.9[a]	890[a]	Foam blowing agent.
HFC-43-10mee	17.1	1,300	Cleaning solvent.
Perfluorocarbons (PFCs)			
CF_4	50,000	6,500	Byproduct of aluminum production. Plasma etching and cleaning in semiconductor production and component of low temperature refrigerant blends.
C_2F_6	10,000	9,200	Byproduct of aluminum production. Plasma etching and cleaning in semiconductor production.
C_3F_8	2,600	7,000	Component of low-temperature refrigerant blends and fire suppressant. Used in plasma cleaning in semiconductor production.
C_4F_{10}	2,600	7,000	Fire suppressant.
c-C_4F_8	3,200	8,700	Not in much use, if at all, today. Emerging for plasma etching in semiconductor production.
C_5F_{12}	4,100	7,500	Not in much use, if at all, today.
C_6F_{14}	3,200	7,400	Precision cleaning solvent.
Nitrogen Trifluoride (NF_3)			
NF_3	740[b]	8,000[b]	Plasma cleaning in semiconductor production.
Sulfur Hexafluoride (SF_6)			
SF_6	3,200	23,900	Cover gas in magnesium production and casting, dielectric gas and insulator in electric power equipment, used to test fire suppression discharge in military systems and civilian aircraft, atmospheric and subterranean tracer gas, sound insulation, process flow-rate measurement, medical applications, and formerly an aerosol propellant. Used for plasma etching in semiconductor production.
Hydrofluoroethers (HFEs)			
$C_4F_9OCH_3$	5.0[a]	390[a]	Cleaning solvent and heat transfer fluid.
$C_4F_9OC_2H_5$	0.77[a]	55[a]	Cleaning solvent.

Table excludes ozone-depleting substances controlled by the Montreal Protocol.
GWPs and atmospheric lives are reprinted from the Intergovernmental Panel on Climate Change, Second Assessment Report (IPCC, 1996), except as noted below:

[a]IPCC, 2001. Third Assessment Report.

[b] Molina, L.T., P.J. Woodbridge, and M. Molina, 1995.

4.2 Production of Adipic Acid and Nitric Acid (Nitrous Oxide)

4.2.1 Source Description

Nitrous oxide (N_2O) is emitted during the production of adipic and nitric acids, both of which are feedstocks or components to the manufacture of a variety of commercial products.

Adipic acid (hexane-1, 6-dioxic acid) is a white crystalline solid used as a feedstock in the manufacture of synthetic fibers, coatings, plastics, urethane foams, elastomers, and synthetic lubricants. Commercially, it is the most important of the aliphatic dicarboxylic acids, which are used to manufacture polyesters. In the U.S., for example, 90 percent of all adipic acid is used in the production of nylon 6,6 (SRI, 1999). Adipic acid is produced through a two-stage process with nitrous oxide generated in the second stage. By treating nitrogen oxides (NO_x) and other regulated pollutants in the waste gas stream, nitrous oxide emissions can be reduced. Studies confirm that these abatement technologies can reduce nitrous oxide emissions by up to 99 percent, depending on plant specifications (Riemer et al., 2000).

Nitric acid (HNO_3) is an inorganic compound used primarily to make synthetic commercial fertilizer. It is also a major component in the production of adipic acid and explosives. During the catalytic oxidation of ammonia, nitrous oxide is formed as a byproduct and released from reactor vents into the atmosphere. While the waste gas stream may be cleaned of other pollutants such as nitrogen dioxide (NO_2), there are currently no control measures aimed at eliminating nitrous oxide.

4.2.2 Source Results

Total Nitrous Oxide Emissions from Adipic Acid and Nitric Acid Production

Year	$MtCO_2eq$	Gg N_2O
1990	223	721
1995	220	710
2000	154	497
2005	156	505
2010	165	531
2015	170	550
2020	177	570

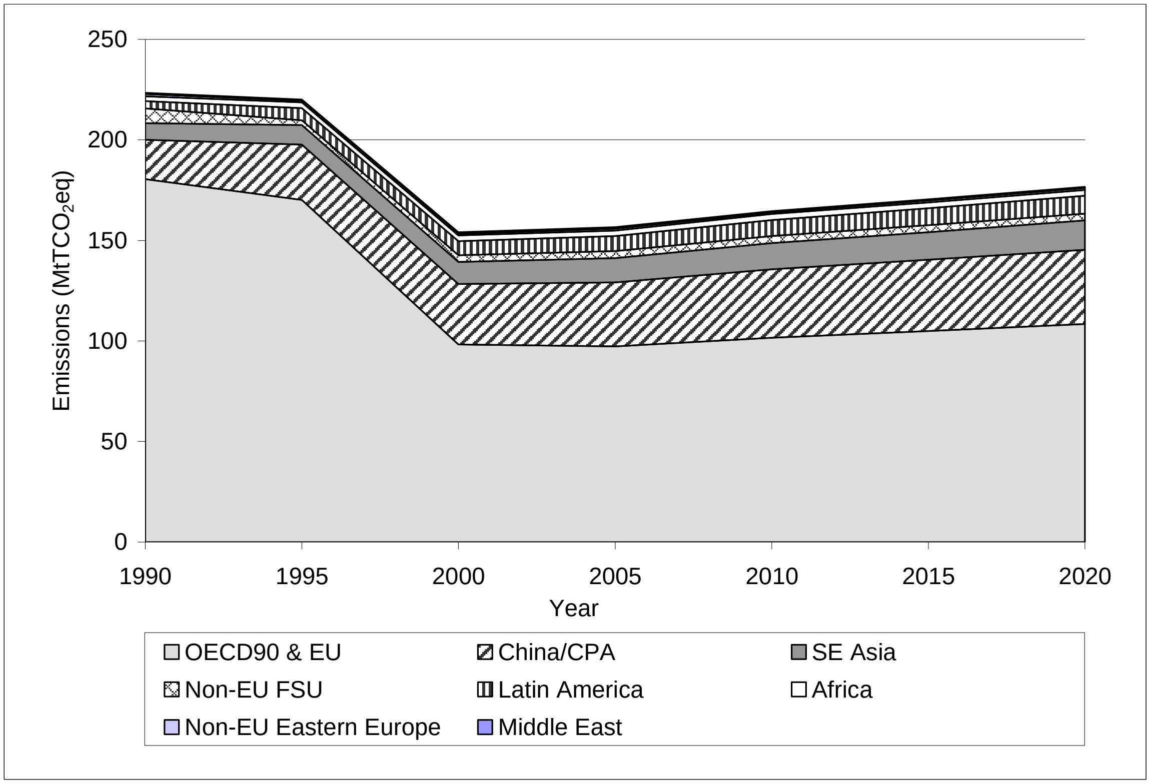


Exhibit 4-3. Nitrous Oxide Emissions from Adipic Acid and Nitric Acid Production 1990 – 2020 ($MtCO_2eq$)

As shown in Exhibit 4-3, global nitrous oxide emissions from adipic and nitric acid production peaked in 1990 at 223 $MtCO_2eq$. Efforts to control nitrous oxide emissions from adipic acid production resulted in a steep decline in emissions through 2000. However, the post-2000 period is characterized by a steady but gradual increase in emissions. By 2020, emissions from this source reach 79 percent of the 1990 levels. Exhibit 4-3 illustrates the changing regional distribution of adipic and nitric acid emissions. In 1990, the OECD was responsible for nearly 80 percent of the emissions from this source. China/CPA, the second largest regional source, accounted for only 9 percent of emissions. Between 1990 and 2020, OECD emissions decrease by 40 percent, leaving this region with only a 61 percent share of the global emissions. Projections indicate that by 2020, the China/CPA, S&E Asia, and Latin America regions will contribute approximately 34 percent of the world's emissions.

Efforts in the U.S., EU, and Canada to reduce nitrous oxide emissions from the adipic acid production process came into effect in the late 1990s. Their effects can be seen in Exhibit 4-3 in the substantial reduction in emissions from 1995 to 2000. These changes in the adipic acid production process have the capability of reducing nitrous oxide emissions by more than 95 percent, and their long-term affects may have an even greater effect than illustrated in Exhibit 4-3 for countries that have a high penetration rate for these process changes. Capacity expansions to meet increased global demand for adipic acid demand are expected in the Far East, while market restructuring is expected in Western Europe and North America.

Fertilizer demand, and thus nitric acid use, is expected to decline in Western Europe but increase elsewhere. The decline in Western Europe is due to concerns about nitrates in the water supply. Since nitric acid involves little global trade (SRI, 1999; U.S. EPA, 2001), it is expected that nitric acid production in this region will decline as well, leading to a decline in nitrous oxide emissions from this source in the EU. As demand for fertilizer increases in other regions after 2000, so will nitrous oxide emissions, counteracting the trend in Western Europe.

4.3 Use of Substitutes for Ozone-Depleting Substances (Hydrofluorocarbons and Perfluorocarbons)

4.3.1 Source Description

Hydrofluorocarbons (HFCs) and, to a lesser extent, perfluorocarbons (PFCs) and hydrofluoroethers (HFEs), are used as alternatives to several classes of ODS that are being phased out under the terms of the Montreal Protocol. Ozone-depleting substances, which include chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, and hydrochlorofluorocarbons (HCFCs), have been used in a variety of industrial applications including refrigeration and air conditioning equipment, aerosols, solvent cleaning, fire extinguishing, foam production, and sterilization. Although the HFCs and PFCs that would replace the ODSs are not harmful to the stratospheric ozone layer, they are powerful greenhouse gases.

4.3.2 Source Results

Total HFC and PFC Emissions from Substitutes for Ozone-Depleting Substances

Year	$MtCO_2eq$	Gg HFC-134a Eq
1990	0	0
1995	53	41
2000	164	126
2005	279	214
2010	431	331
2015	585	450
2020	734	564

Exhibit 4-4 illustrates the rapid growth expected in the emissions for this source. In 1995, ODS substitute emissions were only 53 $MtCO_2eq$,[3] but by 2020, global emissions are expected to exceed 734 $MtCO_2eq$. In 1995, nearly all ODS substitute emissions originated in the OECD countries, but by 2020, all regions will make some contribution to global emissions. In 2020, the OECD, China/CPA, S&E Asia, and Latin America are projected to account for 66 percent, 10 percent, 9 percent, and 6 percent of emissions, respectively.

[3] 1990 emissions for ODS substitutes were not estimated for all countries and so are not presented here. In 1990, emissions for this category were negligible with U.S. emissions accounting for less than 0.5 $MtCO_2eq$.

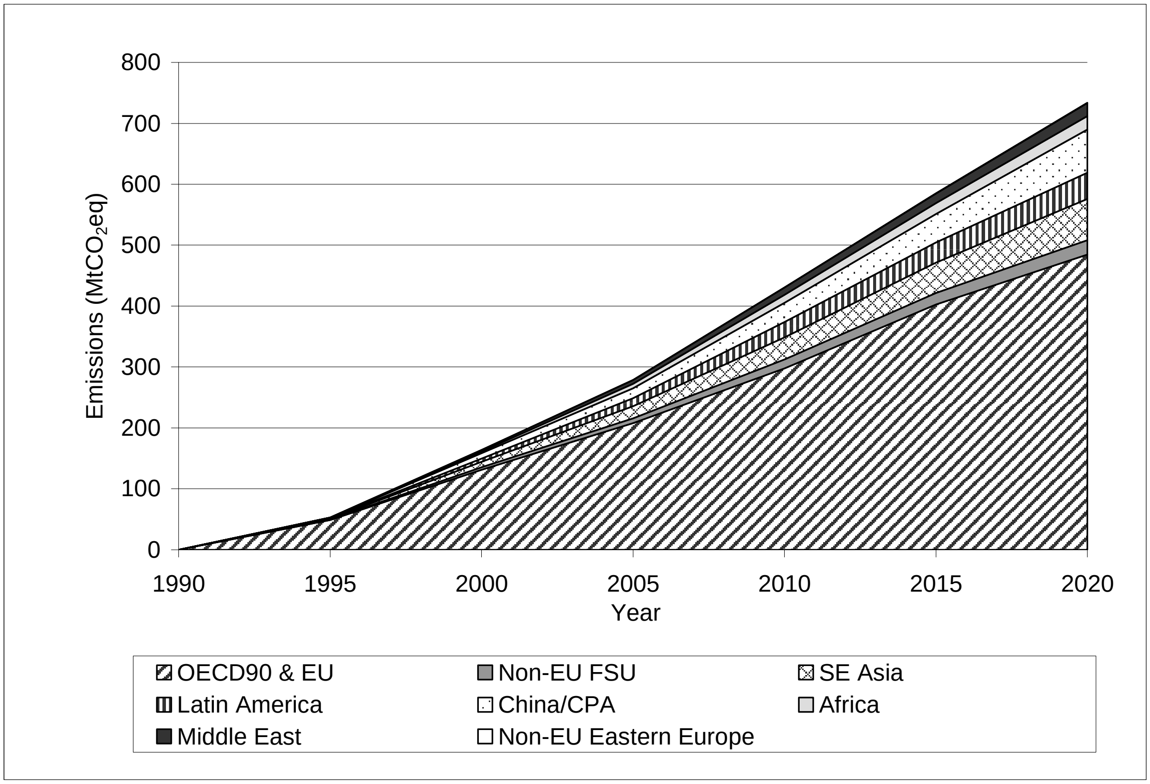


Exhibit 4-4. HFC and PFC Emissions from Substitutes for Ozone-Depleting Substances 1990 – 2020 by Region ($MtCO_2eq$)

The dramatic increase in HFC and PFC emissions shown in Exhibits 4-4 and 4-5 is the result of efforts to phaseout CFCs and other ODSs. This trend is expected to continue for many years, and will accelerate in the early part of this century as HCFCs, which are interim substitutes in many applications, are themselves phased out under the provisions of the Copenhagen Amendments to the Montreal Protocol. In addition, in some ODS replacement applications, such as solvent cleaning or aerosol applications, the substitutes are emitted immediately, but in others, such as refrigeration and air conditioning applications, the substitutes are replacing ODSs in equipment that slowly releases the gas. Therefore, the rate of increase in ODS substitute emissions is driven by the pace of the phaseout in each country and by the emissions profile for the source in which the gas is used. Global emissions by end-use sector are provided in Exhibit 4-5.

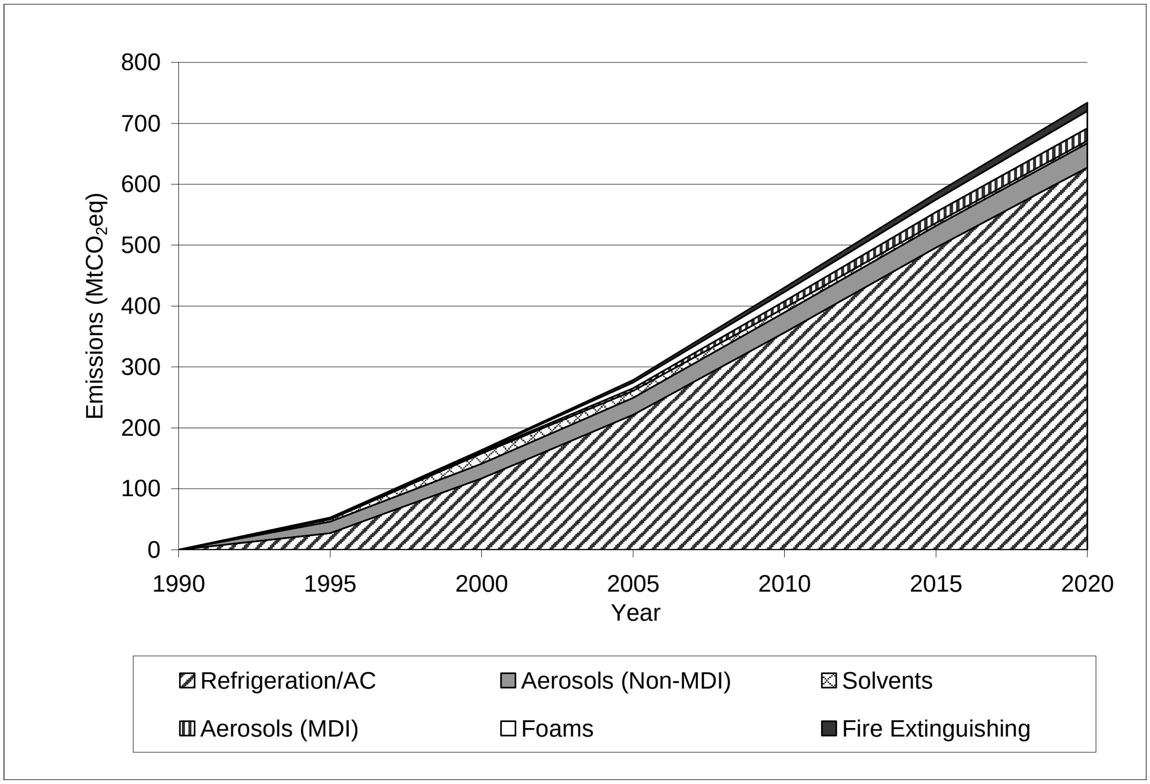


Exhibit 4-5. HFC and PFC Emissions from Substitutes for Ozone-Depleting Substances 1990 – 2020 by Sector (MtCO$_2$eq)

4.4 Production of HCFC-22 (Hydrofluorocarbons)

4.4.1 Source Description

Trifluoromethane (HFC-23) is generated and emitted as a byproduct during the production of chlorodifluoromethane (HCFC-22). HCFC-22 is used both in emissive applications (primarily air conditioning and refrigeration) and as a feedstock for production of synthetic polymers. Because HCFC-22 depletes stratospheric ozone, its production for non-feedstock uses is scheduled to be phased out under the Montreal Protocol. However, feedstock production is permitted to continue indefinitely.

Nearly all producers in developed countries have implemented process optimization or thermal destruction to reduce HFC-23 emissions. In a few cases, HFC-23 is collected and used as a substitute for ozone-depleting substances, mainly in very-low temperature refrigeration and air conditioning systems. Emissions from this use are quantified under air conditioning and refrigeration and are therefore not included here. HFC-23 exhibits the highest global warming potential of the HFCs, 11,700 under a 100-year time horizon, with an atmospheric lifetime of 264 years.

4.4.2 Source Results

No-Action Baseline

The table below presents No-Action Baseline emissions of HFC-23 from HCFC-22 production.

No-Action Baseline HFC-23 Emissions from HCFC-22 Production		
Year	**$MtCO_2eq$**	**Gg HFC-23**
1990	77	7
1995	84	7
2000	96	8
2005	120	10
2010	118	10
2015	149	13
2020	138	12

As shown above, global HFC-23 emissions from HCFC-22 production grew by 24 percent between 1990 and 2000, driven by an over 60 percent growth in global HCFC-22 production during that period. (Emissions grew more slowly than production due to the implementation of thermal destruction and process optimization in Europe and the U.S.)

Under the No-Action Baseline, between 2000 and 2015, world HFC-23 emissions from HCFC-22 production are expected to grow by an additional 56 percent, but between 2015 and 2020 emissions are expected to decline as a result of the phaseout of non-feedstock HCFC-22 production in developing countries.

Exhibit 4-6 reveals a striking shift of the majority of emissions from OECD countries to China and other developing countries. This is due to (1) a combination of increased use of emission controls and the phaseout of HCFC-22 under the Montreal Protocol in OECD countries and (2) increased HCFC-22 production in China. (These drivers are discussed further below.) Thus, while HFC-23 emissions from developed countries are expected to decline by over 60 percent from 1990 to 2020 in the No-Action Baseline, HFC-23 emissions in the China/CPA region are expected to increase dramatically. S&E Asia and Latin America are also projected to show increasing emissions through this period. In 1990, the three largest emitters for this source were the U.S., Japan, and France, which together accounted for over two-thirds of all emissions. In 2020, the three largest emitters are projected to be China, India, and the U.S. These nations are anticipated to account for 90 percent of all HFC-23 emissions, while China alone is expected to be the world's major HFC-23 emitter, accounting for over 65 percent of total emissions.

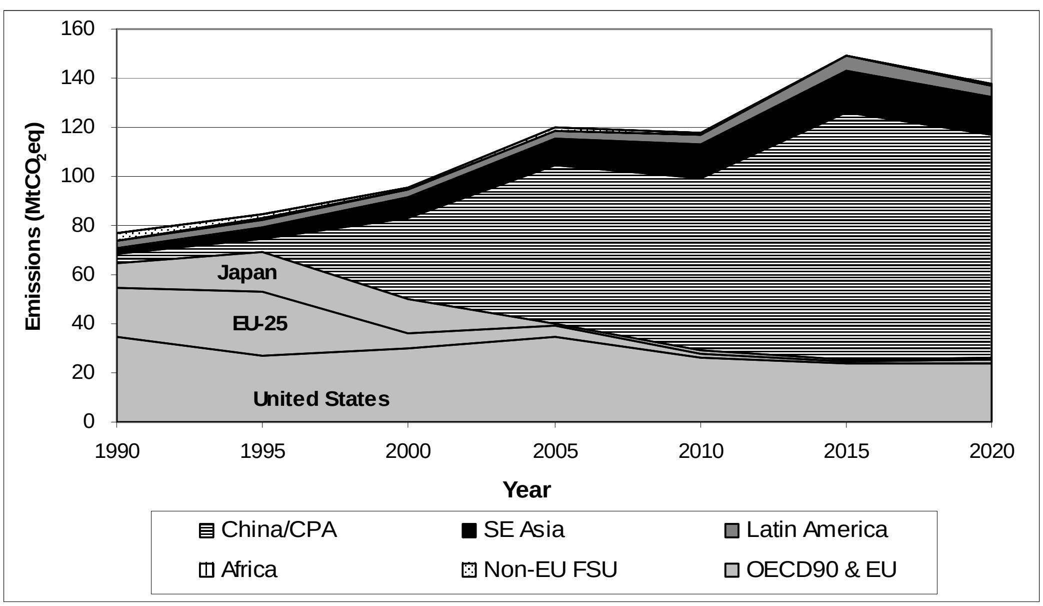


Exhibit 4-6. HFC-23 Emissions as a Byproduct of HCFC-22 Production Based on a No-Action Baseline 1990 – 2020 ($MtCO_2eq$)

In the developed world, HFC-23 emissions decreased between 1990 and 2000 due to process optimization and thermal destruction, although there were increased emissions in the intervening years. The U.S. and the European Union (EU) drove these trends in the developed world. Although emissions increased in the EU between 1990 and 1995 due to increased production of HCFC-22, a combination of process optimization and thermal oxidation led to a sharp decline in EU emissions after 1995, resulting in a net decrease in emissions of 67 percent for this region between 1990 and 2000. U.S. emissions also declined by 15 percent during the same period, despite a 35 percent increase in HCFC-22 production; however, during that time period U.S. emissions demonstrate two distinct trends. Between 1990 and 1995, U.S. emissions declined by 23 percent due to a steady decline in the emission rate of HFC-23 (i.e., the amount of HFC-23 emitted per kilogram of HCFC-22 manufactured). Between 1995 and 2000, U.S. emissions increased due to increases in HCFC-22 production.[4]

As illustrated in Exhibit 4-6 under the No-Action Baseline, HFC-23 emissions in developed countries are predicted to continue to decrease through 2020 as a result of (1) Japan's implementation of either thermal abatement or HFC-23 capture (for use) for 100% of its production beginning in 2005 (JICOP, 2006), (2) 100% implementation of thermal abatement in all EU countries except Spain by 2010, (3) closure of the HCFC-22 production plant in Greece in 2006 and (4) the HCFC-22 production phaseout scheduled under the Montreal Protocol.

In the developing world, particularly China, emissions are increasing quickly due to a rapid increase in the production of HCFC-22. This production is meeting growing demand for unitary air conditioning, for commercial refrigeration, and for substitutes for chlorofluorocarbons, which are currently being phased out in developing countries under the Montreal Protocol (UNEP, 2003). Under the No-Action Baseline, the increase in HFC-23 emissions is expected to continue through 2015, when HCFC-22 itself will begin to be phased out by developing countries for most end uses under the Montreal Protocol.

Technology-Adoption Baseline

The table below presents Technology-Adoption Baseline emissions of HFC-23 from HCFC-22 production.

Technology-Adoption Baseline HFC-23 Emissions from HCFC-22 Production

Year	$MtCO_2eq$	Gg HFC-23
1990	77	7
1995	84	7
2000	96	8
2005	102	9
2010	45	4
2015	78	7
2020	66	6

As shown in the table above, global HFC-23 emissions from HCFC-22 production are expected to decline by 31 percent between 2000 and 2020. These trends are mainly a result of the expected implementation of Clean Development Mechanism (CDM) projects in China, India, Korea, and Mexico, as well as implementation of thermal oxidation in Spain and the HCFC-22 production phaseout scheduled under the Montreal Protocol.

However, as seen in Exhibit 4-7, the most striking trend apparent in the Technology-Adoption Baseline is the dramatic decline in emissions from China (and thus for the world, since by 2005 China accounts for the majority of emissions) between 2005 and 2010, followed by an increase in emissions from 2010 to 2015, at which point emissions again decline. The primary driver of this zig zag pattern is the implementation of CDM projects in China. However, despite the constant abatement of HFC-23 emissions as a result of the implementation of the CDM projects, HFC-23 emissions continue to increase beyond 2010 as a result of the increase in production of HCFC-22 in China (as discussed under the No-

[4]The apparent increase in U.S. emissions between 2000 and 2005 is an artifact of the method used to estimate U.S. emissions in the No-Action baseline. Under this approach, the U.S. emission factor was assumed to revert to its relatively high 1990 level in 2005, despite reductions in earlier years.

Action Baseline). The increase in HFC-23 emissions is expected to continue through 2015, when HCFC-22 itself will begin to be phased out by developing countries for most end uses under the Montreal Protocol.

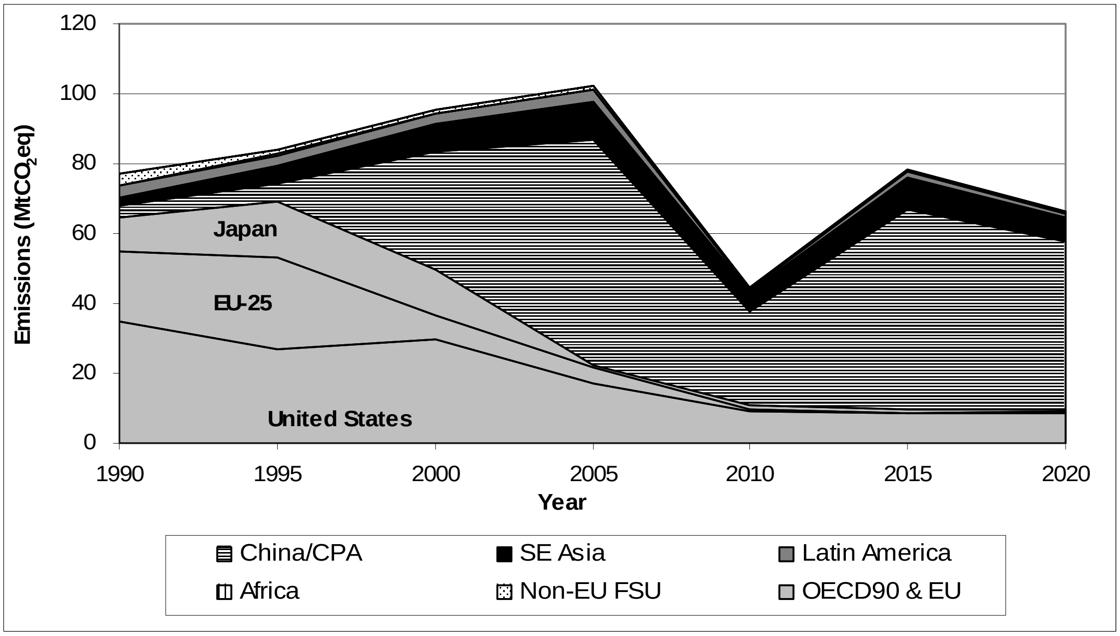


Exhibit 4-7. HFC-23 Emissions as a Byproduct of HCFC-22 Production Based on a Technology-Adoption Baseline 1990 – 2020 ($MtCO_2eq$)

Emissions in OECD countries are expected to decline by 86 percent between 1995 and 2015. As Exhibit 4-7 reveals, the majority of these emissions shift to China and other developing countries. This is due to (1) a combination of increased use of emission controls and the phase-out of HCFC-22 under the Montreal Protocol in OECD countries and (2) increased HCFC-22 production in China. Thus, while HFC-23 emissions from developed countries are expected to decline by 85 percent from 1990 to 2020, HFC-23 emissions in the China/CPA region are expected to increase dramatically, despite the adoption of abatement measures under the CDM. S&E Asia and Latin America are also projected to show increasing emissions through this period.

Global emissions in years 1990 to 2000 follow the same trends as in the No-Action Baseline. As illustrated in Exhibit 4-7, HFC-23 emissions in developed countries are predicted to decrease to lower levels than the No-Action Baseline during the period from 2010 to 2020 mainly as a result of the U.S.'s implementation of thermal abatement.

4.5 Operation of Electric Power Systems (Sulfur Hexafluoride)

4.5.1 Source Description

Sulfur hexafluoride (SF_6) is a colorless, odorless, non-toxic, and non-flammable gas with a GWP that is 23,900 times that of carbon dioxide over a 100-year time horizon, and an atmospheric lifetime of 3,200 years (U.S. EPA, 2005). SF_6 is used as both an arc quenching and insulating medium in electrical transmission and distribution equipment. Several factors affect SF_6 emissions from electrical equipment, including the type and age of SF_6-containing equipment, and the handling and maintenance protocols used by electric utilities. Historically, approximately 20 percent of total global SF_6 sales have gone to electric power systems, where the SF_6 is believed to have been used primarily to replace emitted SF_6. Approximately 60 percent of global sales have gone to manufacturers of electrical equipment, where the SF_6 is believed to have been mostly banked in new equipment (Smythe, 2004).

SF_6 emissions from electrical equipment used in transmission and distribution systems occur through leakage and handling losses. Leakage losses can occur at gasket seals, flanges, and threaded fittings, and are generally larger in older equipment. Handling emissions occur when equipment is opened for servicing, SF_6 gas analysis, or disposal. Baseline emission estimates under both a Technology-Adoption and a No-Action Baseline are presented below.

4.5.2 Source Results

Total SF_6 Emissions from Electric Power Systems

Technology-Adoption			No-Action		
Year	**$MtCO_2eq$**	**Gg SF_6**	**Year**	**$MtCO_2eq$**	**Gg SF_6**
1990	42	1.8	1990	42	1.8
1995	34	1.4	1995	34	1.4
2000	27	1.1	2000	27	1.1
2005	43	1.8	2005	47	1.9
2010	47	2.0	2010	52	2.2
2015	52	2.2	2015	59	2.5
2020	57	2.4	2020	66	2.8

Technology-Adoption Baseline

As shown above, global emissions from electric power systems are believed to have fallen significantly between 1990 and 1995, based on SF_6 sales to utilities and estimated equipment retirements.[5] This decline was due to a significant increase in the cost of SF_6 gas in the mid-1990s, which motivated electric utilities to implement better management practices to reduce their use of SF_6. However, sales of SF_6 increased by over 37 percent between 2000 and 2003, reversing the trend (Smythe, 2004). In addition, equipment retirements (based on a 40-year equipment lifetime) are estimated to have more than doubled between 2000 and 2003. Together, these two trends result in an estimated 55 percent increase in global emissions between 2000 and 2003, resulting in emissions levels similar to those observed in 1990.

These global trends are reflected in the trends of the individual regions except for the U.S., the EU-25+3,[6] and Japan. For the U.S., emission estimates for 1990-2003 are taken from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003* (U.S. EPA, 2005). For the EU-25+3, *Reductions of SF_6 Emissions from High and Medium Voltage Electrical Equipment in Europe* (Ecofys, 2005) is the source of emission estimates for 1990 through 2020. For Japan, *Recent Practice for Huge Reduction of SF_6 Gas Emission from GIS&GCB in Japan* (Yokota et al., 2005), as well as personal communications

[5] The relationship between emissions, SF_6 sales to utilities, and equipment retirements is discussed in detail in Section 7, Methodology.

[6] The EU-25+3 includes the 25 member countries of the European Union (EU) and Norway, Switzerland, and Iceland. Appendix I contains a complete list of EU countries.

with T. Yokota (2006) provided emission estimates for 1990 through 2010. These studies show declining emissions in these regions through 2003.

As illustrated in Exhibit 4-8, beyond 2005, emissions in developed countries are expected either to remain steady or to decline. Emissions in Non-EU Eastern Europe and Non-EU FSU are expected to remain relatively constant through 2020. Since the electric grids in these countries are mature and well developed, it is assumed that there will be no additional growth of emissions from their electric transmission and distribution systems. Any system growth is expected to be offset by decreases in the equipment's average SF_6 capacity and emission rate as new, small, leak-tight equipment gradually replaces old, large, leaky equipment. In the U.S., the EU-25+3, and Japan, emissions are expected to continue to decline as utilities, through government-sponsored voluntary and mandatory programs, implement reduction measures such as leak detection and repair and gas recycling practices.

In contrast, emissions from developing countries (i.e., Latin America, S&E Asia, Middle East, Africa and China/CPA) are expected to continue growing over the next 15 years. In these countries, it is assumed that SF_6-containing equipment has been installed relatively recently, and that all equipment is new. Consequently, as infrastructure expands to meet the demands of growing populations and economies, emissions are estimated to grow at a rate proportional to country- or region-specific net electricity consumption (EIA, 2002). This growth drives global emissions growth, resulting in world-wide emissions of 57 $MtCO_2eq$ in 2020. By 2020, Latin America, S&E Asia, Middle East, Africa and China/CPA are expected to account for 63 percent of total emissions, versus approximately 10 percent in 1990. The OECD is projected to account for only 29 percent of global emissions in 2020, versus approximately 82 percent in 1990.

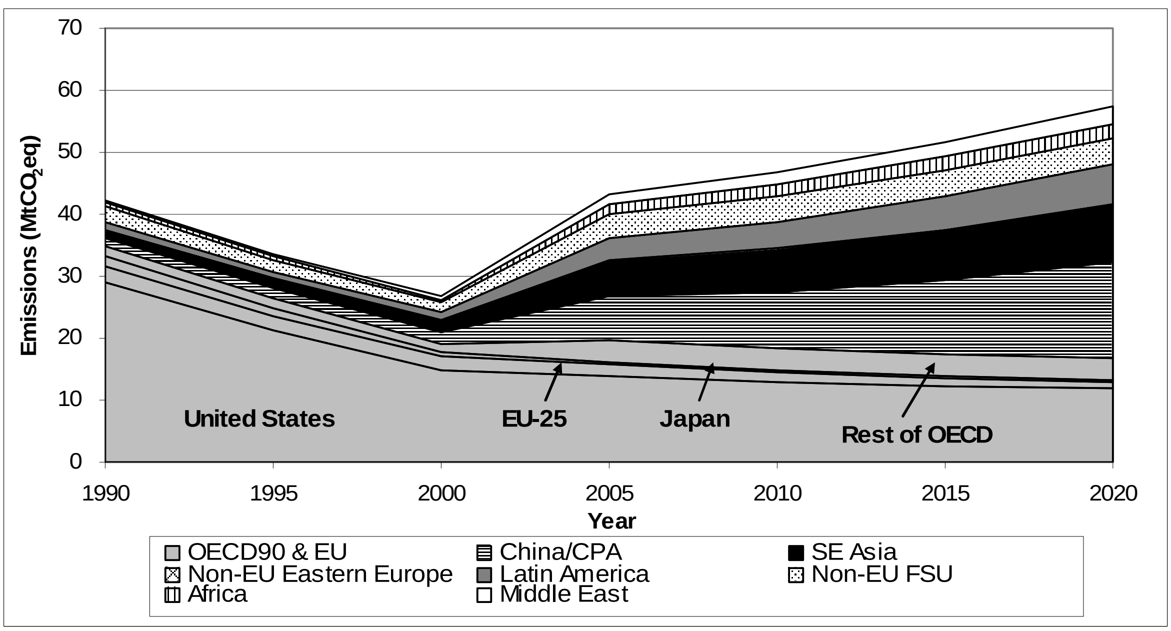


Exhibit 4-8. SF_6 Emissions from Electric Power Systems Based on a Technology-Adoption Baseline 1990 – 2020 ($MtCO_2eq$)

No-Action Baseline

As illustrated in Exhibit 4-9, No-Action Baseline emissions for the period 1990 through 2000 follow the same trajectory as those under the Technology-Adoption Baseline, with both baselines diverging after 2003. Assumptions and emissions estimates for developing regions (i.e., Latin America, S&E Asia, Middle East, Africa, and China/CPA) are the same as discussed under the Technology-Adoption Baseline. For the U.S., Japan, and the EU-25+3, it is assumed that no additional voluntary measures are adopted after 2003. For the U.S., the EU-25+3, and Japan, emissions are expected to increase from 2003 levels, with system growth being the driver in the EU and Japan. The marked increase in U.S. emissions after 2000 is an artifact of the method used to estimate U.S. emissions in the No-Action

Baseline. Under this approach, the U.S. emission factor was assumed to revert to its relatively high 1999 level in 2005, despite reductions in earlier years.

The assumption that the U.S., the EU-25+3, and Japan will pursue no additional voluntary measures after 2003 increases their contribution to world emissions in 2020. Unlike the Technology-Adoption Baseline, in which the OECD accounts for only 29 percent of emissions in 2020, in the No-Action Baseline, OECD accounts for 38 percent. In contrast, the contribution of developing regions, of Latin America, S&E Asia, Middle East, Africa, and China/CPA decrease to 55 percent of total 2020 emissions in the No-Action Baseline, versus 63 percent under the Technology-Adoption Baseline.

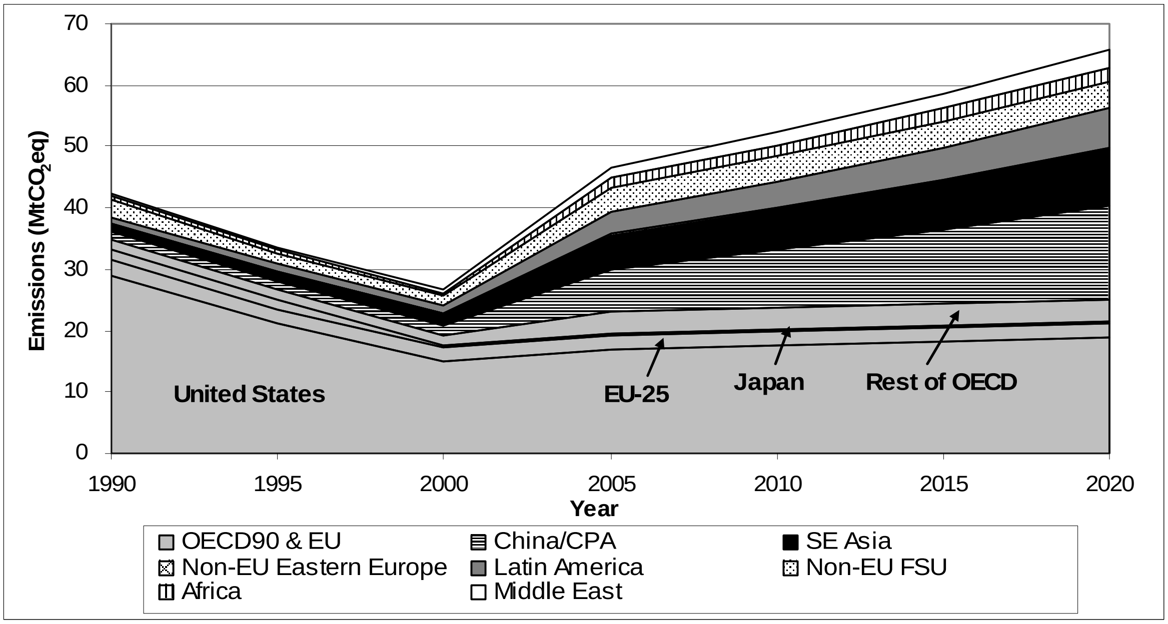


Exhibit 4-9. SF_6 Emissions from Electric Power Systems Based on a No-Action Baseline 1990 – 2020 ($MtCO_2eq$)

4.6 Primary Aluminum Production (Perfluorocarbons)

4.6.1 Source Description

The primary aluminum production industry is currently the largest source of PFC emissions globally. During the aluminum smelting process, when the alumina ore content of the electrolytic bath falls below critical levels required for electrolysis, rapid voltage increases occur. These are termed "anode effects" (AEs). Anode effects produce CF_4 and C_2F_6 emissions when carbon from the anode and fluorine from the dissociated molten cryolite bath combine. In general, the magnitude of emissions for a given level of production depends on the frequency and duration of these anode effects; the more frequent and long-lasting the anode effects, the greater the emissions.

4.6.2 Source Results

Total PFC Emissions from Aluminum Production ($MtCO_2eq$)		
Year	**Technology-Adoption**	**No-Action**
1990	98	98
1995	61	61
2000	58	58
2005	43	66
2010	39	70
2015	42	73
2020	45	77

Technology-Adoption Baseline

Under the Technology-Adoption Baseline, it is assumed that aluminum producers will continue to introduce technologies and practices aimed at reducing PFC emissions. It is assumed that under the Technology-Adoption Baseline, global aluminum producers, in accordance with International Aluminum Institute (IAI) PFC emission reduction commitments will reduce their PFC emission intensity (i.e., PFC emissions per ton of produced aluminum) by 80 percent from 1990 levels by 2010. This reduction can be achieved by retrofitting smelters with emission-reducing technologies such as computer control systems and point feeding systems, by shifting production to Point-Feed Prebake (PFPB) technology, and by adopting management and work practices aimed at reducing PFC emissions.

Five different electrolytic cell types are used to produce aluminum: Vertical Stud Soderberg (VSS), Horizontal Stud Soderberg (HSS), Side-Worked Prebake (SWPB), Center-Worked Prebake (CWPB), and Point Feed Prebake (PFPB), which is considered the most technologically-advanced process to produce aluminum. Although PFPB systems can be improved through the implementation of management and work practices, as well as improved control software, the analysis assumes that retrofit abatement options will only occur on existing VSS, HSS, SWPB, and CWPB cells.

Exhibit 4-10 presents total PFC emissions from aluminum production under the Technology-Adoption Baseline from 1990 to 2020. Between 1990 and 1995, global emissions declined from 98 to 61 $MtCO_2eq$. This significant decline was the result of voluntary measures undertaken by global smelters to reduce their AE minutes per cell day. These measures included incremental improvements in smelter technologies and practices, and a shift in the share of SWPB-related production to more state-of-the-art PFPB facilities. Although a continuation of this AE minute reduction trend occurred through 2000, emission reductions were offset by a 24 percent increase in global aluminum production between 1995 and 2000.

The declining global emission levels through 2010 reflect the successful adoption of IAI emission reduction goals through both retrofits and a continued shift of production from VSS, HSS, and SWPB to PFPB. From 2010 to 2020, the emissions intensity is assumed to remain constant; consequently, emissions will be driven by increasing aluminum production. PFC emissions in OECD, as well as Non-EU Eastern Europe, Non-EU FSU, China/CPA, and S&E Asia are projected to remain relatively constant from 2010 to 2020, due to slowing aluminum production growth. Trends in the U.S. and the EU reflect overall trends in the developed (OECD) countries. Africa, Latin America, and the Middle East are projected to increase their share of global emissions from 2010 to 2020, due to strong growth in aluminum production. In 2020, China/CPA, Latin America, Africa, and the Middle East are collectively expected to account for 50 percent of global emissions. In comparison, OECD is projected to account for 36 percent of global emissions, down from 51 percent in 2000.

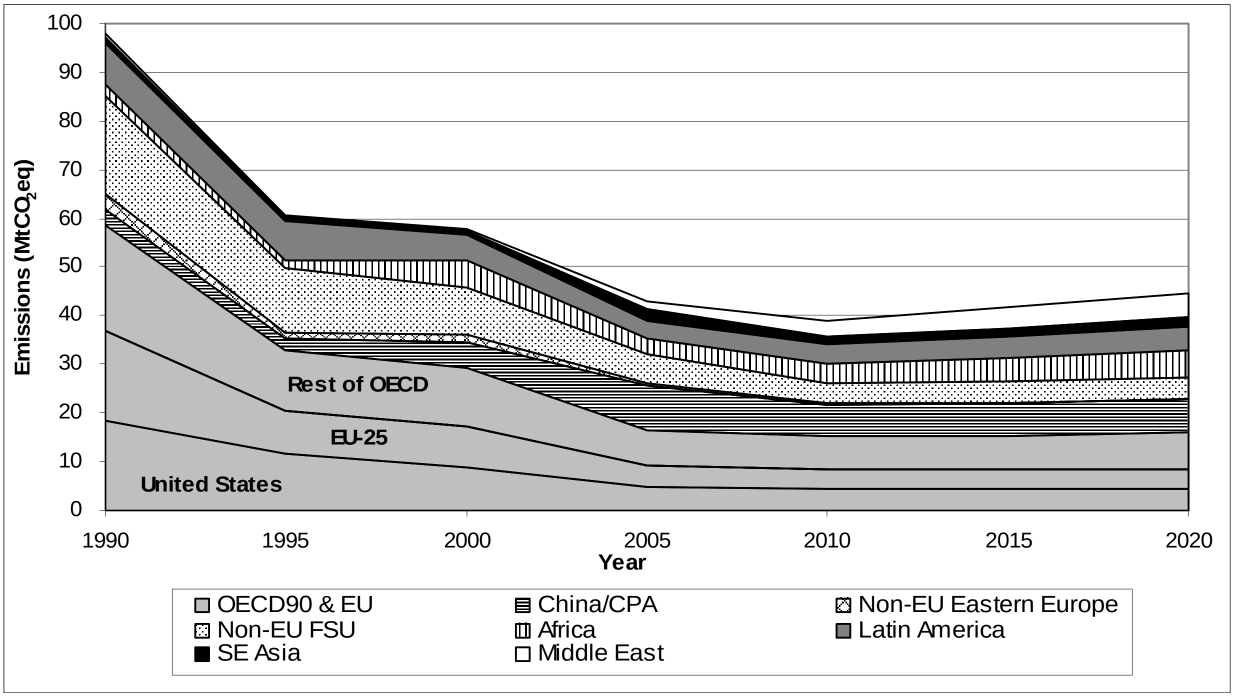


Exhibit 4-10. PFC Emissions from Aluminum Production Based on a Technology-Adoption Baseline 1990 – 2020 ($MtCO_2eq$)

No-Action Baseline

Under the No-Action Baseline, it is assumed that aluminum producers will take no retrofit actions to reduce their emissions below the levels of the late 1990s; as a result, emission projections do not reflect anticipated technology adoptions and/or the implementation of improved work and management practices to reduce emissions. Exhibit 4-11 presents total PFC emissions from aluminum production under the No-Action Baseline from 1990 to 2020. The trends from 1990 through 2000 are the same as those in the Technology-Adoption Baseline. From 2000 through 2020, no additional abatement retrofits are assumed to occur; however, as in the Technology-Adoption Baseline, it is assumed that the global historical trend in the shift of production from SWPB to PFPB continues (IAI, 2000; IAI, 2005). Based on these assumptions, global emissions under this scenario rise to 77 $MtCO_2eq$ in 2020, a 33 percent increase over 2000 levels. This is primarily driven by increasing global aluminum production.

In 1990, OECD emissions accounted for approximately 60 percent of global emissions; however, by 2020, this share is reduced to 40 percent in this scenario. This reduction is the result of relatively flat aluminum production levels between 2000 and 2020, as cheaper aluminum from developing countries enters the global marketplace. The primary sources of this cheaper aluminum are China/CPA, the Middle East, Latin America and Africa, which in 2020 are projected to have production levels approximately 200 percent greater than their 2000 levels. In 2020, China/CPA is projected to account for 17.5 percent of global emissions, compared to 3 percent in 1990 and 9 percent in 2000.

The EU and the U.S. reflect the general OECD trend, except that between 2000 and 2005 there is an increase in U.S. emissions and a decrease in EU emissions. The decrease in EU emissions is primarily the result of their transition from SWPB to PFPB technology. The increase in U.S. emissions is an artifact of the baseline calculation methodology. Past U.S. emissions reflect reductions already implemented by members of EPA's Voluntary Aluminum Industrial Partnership (VAIP), but under this scenario, future U.S. emissions (from 2005 forward) are projected to occur at a higher rate.

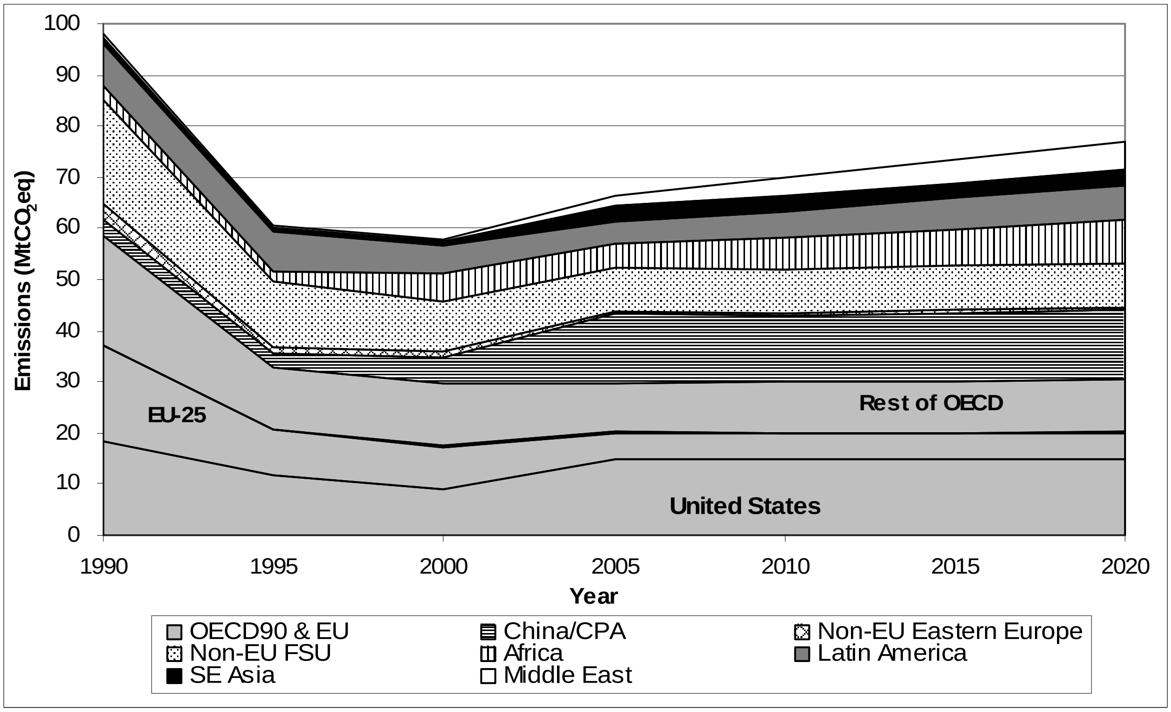


Exhibit 4-11. PFC Emissions from Aluminum Production Based on a No-Action Baseline 1990 – 2020 ($MtCO_2eq$)

4.7 Manufacture of Semiconductors (Hydrofluorocarbons, Perfluorocarbons, Sulfur Hexafluoride)

4.7.1 Source Description

The semiconductor industry currently uses several fluorinated compounds (CF_4, C_2F_6, C_3F_8, C_4F_8, HFC-23, NF_3, and SF_6) during the fabrication process.[7] A fraction of each of these gases is emitted during two manufacturing steps: (1) the plasma etching of thin films, and (2) the cleaning of chemical-vapor-deposition chambers. In addition, byproduct emissions of CF_4 also result when a fraction of the heavier gases consumed is converted during the manufacturing process. Total PFC emissions from this source vary by process and device type.[8] Estimates of historical and forecasted semiconductor manufacturing PFC emissions 1990 through 2020 under two different scenarios are presented below.

[7] The chemical compound CHF_3 is more commonly referred to as HFC-23; thus, the latter term is used here.

[8] Note that while the term PFC (strictly referring to only perfluorocarbon compounds) does not include all of the fluorinated compounds emitted from this source, the semiconductor industry commonly refers to the mix of fluorinated compounds as PFCs; this report adopts the same convention.

4.7.2 Source Results

Total HFC, PFC, SF_6 Emissions from Manufacture of Semiconductors ($MtCO_2eq$)		
Year	**Technology-Adoption**	**No-Action**
1990	10	10
1995	15	15
2000	27	27
2005	30	48
2010	37	99
2015	32	147
2020	28	232

Technology-Adoption Baseline

The Technology-Adoption Baseline incorporates those reductions that have resulted or are anticipated to result from international voluntary climate commitments. In April 1999, the semiconductor manufacturing industry set an aggressive target to reduce PFC emissions. The World Semiconductor Council (WSC) then agreed to reduce PFC emissions to 10 percent below 1995 levels by the year 2010. Since WSC members then accounted for production of over 90 percent of the world's semiconductors, the goal is expected to have dramatic effects in decreasing emissions over time, widening the gap between emission forecasts shown under the two scenarios presented in Exhibit 4-12 and Exhibit 4-14 (note that the scales are different in the two graphs).

The OECD and Asia (including China/CPA and S&E Asia) regions are expected to account for the vast majority of production, and therefore emissions, throughout the study period. The highest-emitting countries worldwide in 2000 were Japan, the U.S., Taiwan, South Korea, and Russia. By 2010, and through 2020, the highest emitting country worldwide is expected to be China, followed by the U.S., Japan, South Korea, Singapore,[9] and Malaysia. The appearance of China, Singapore, and Malaysia among the top emitting countries reflects a geographic shift in production such that the majority of future growth takes place in these countries. This reflects an industry trend toward outsourcing production to dedicated manufacturing firms, called foundries, concentrated in these countries.

Global emissions are estimated to have grown at a compound annual growth rate of 11 percent per year through the year 2000. Following the introduction of voluntary commitments and resulting mitigation efforts, however, a noticeable shift in direction is expected to occur under the Technology-Adoption Baseline. As shown in Exhibit 4-12, the overall trend in OECD emissions is reflected in the emissions from the U.S., the EU, and Japan. WSC members, representing most manufacturing in these regions, are expected to achieve their stated emission reduction goal by 2010. In the long run, even countries whose manufacturers have not adopted the WSC goal, such as China and other Asian countries not part of the WSC, are expected to reduce their emission rates as new, lower-emitting manufacturing equipment saturates the global market in response to demand from WSC members. This expectation accounts for the reduction in emissions from China and S&E Asia between 2010 and 2020.

[9] This reflects the top emitting countries in 2020, in descending order of emissions; in 2010, Singapore has greater emissions than South Korea.

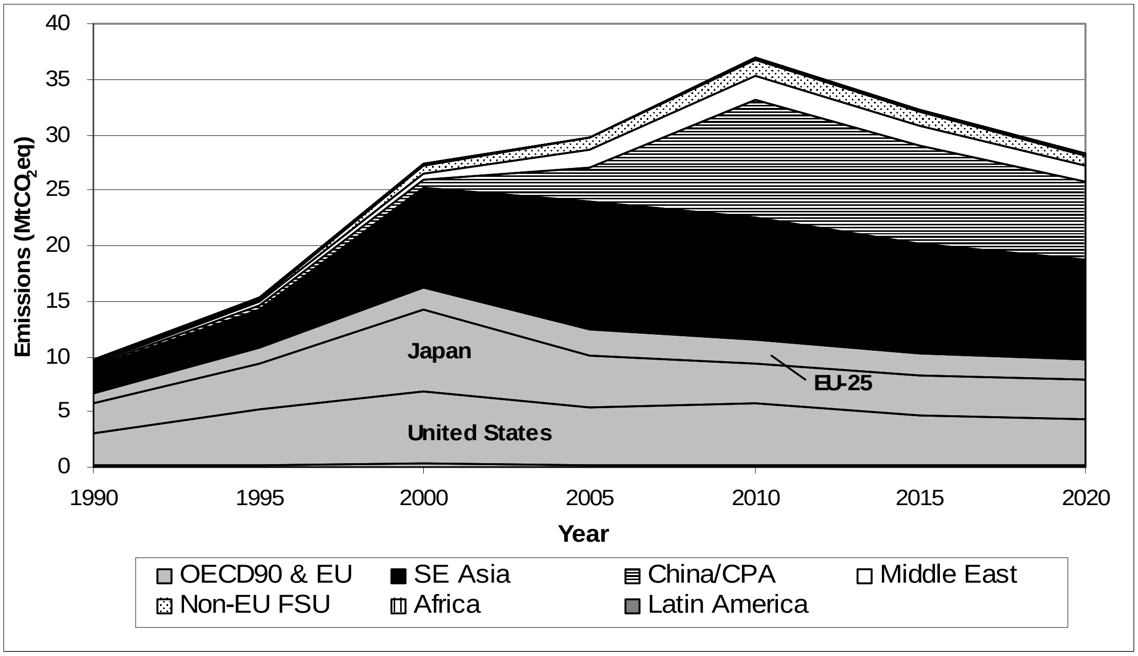


Exhibit 4-12. PFC Emissions from Semiconductor Manufacturing Based on a Technology-Adoption Baseline 1990 – 2020 (MtCO$_2$eq)

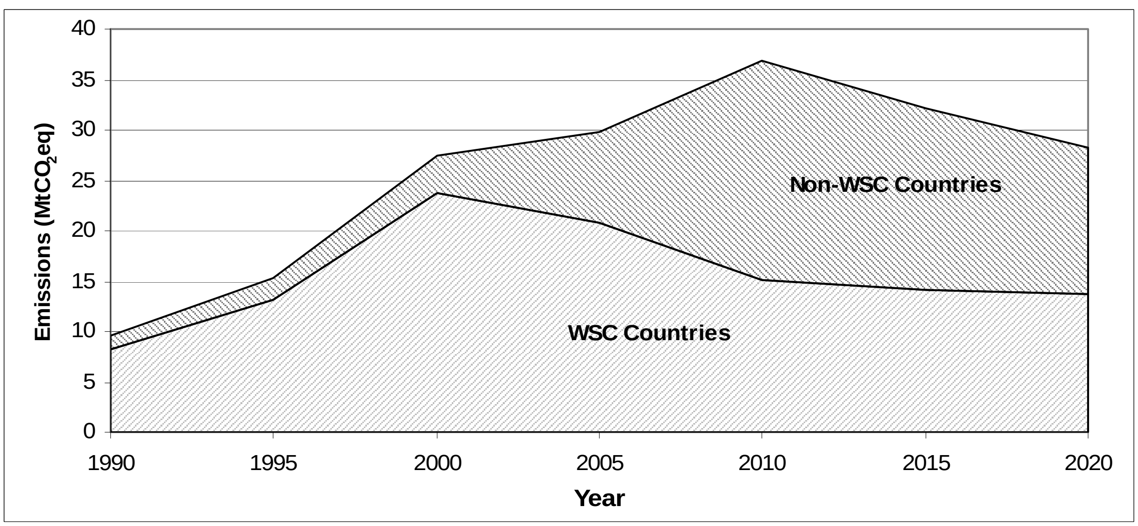


Exhibit 4-13. WSC and non-WSC Countries' Contribution to Global PFC Emissions (MtCO$_2$eq)

Exhibit 4-13, which shows the relative distribution of global emissions under the Technology-Adoption Baseline between WSC and non-WSC members, illustrates these trends even more clearly. Note that emissions from WSC countries peak in 2000.

No-Action Baseline

The No-Action Baseline estimates emissions that would result from normal industry activity with no emission control measures, voluntary or regulation-driven. This trajectory can be considered an upper bound, and can serve as a reference level to which the alternative Technology-Adoption Baseline emissions can be compared. The difference between these two emission sets represents the emission reductions achieved by semiconductor manufacturers as they implement emission control technologies or other mitigation measures.

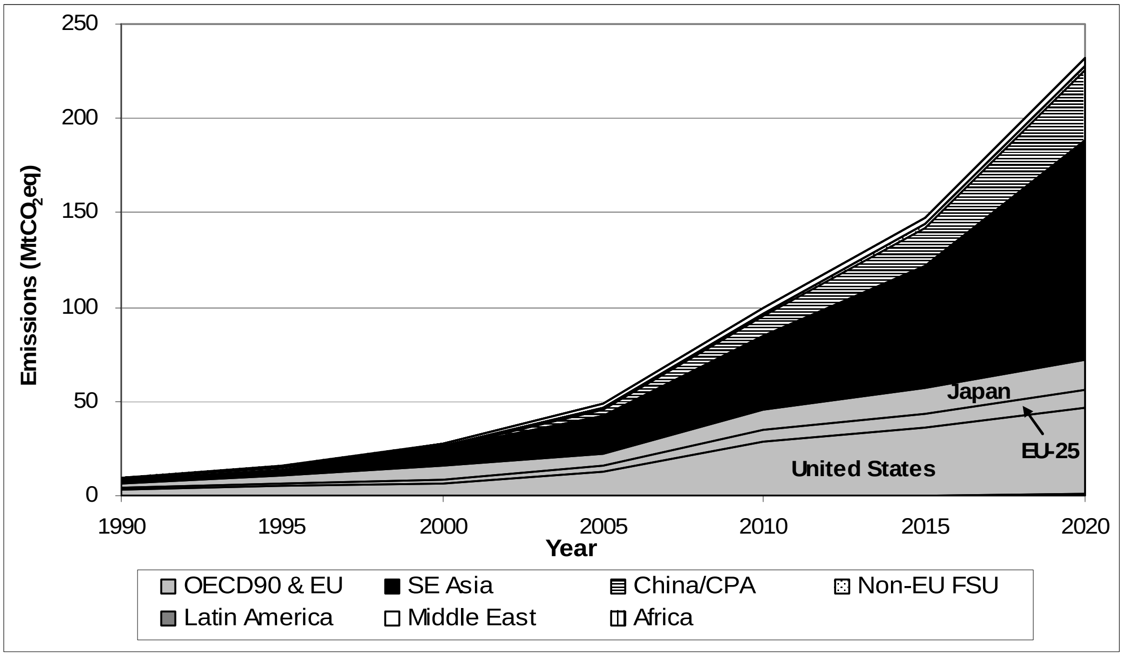


Exhibit 4-14. PFC Emissions from Semiconductor Manufacturing Based on a No-Action Baseline 1990 – 2020 ($MtCO_2eq$)

Exhibit 4-14 shows the relative distribution of global emissions under the No-Action Baseline. As in the Technology-Adoption Baseline, the OECD and Asia regions are expected to remain the largest emitters throughout the time horizon studied; emissions from these regions (including OECD, China/CPA, and S&E Asia) combined are expected to comprise 98 percent of global emissions in 2020.

Historical trends are the same as those presented for the Technology-Adoption Baseline, including the 11 percent per year annual growth through 2000. However, in the No-Action Baseline, this high annual growth continues virtually unabated through 2010 and is particularly pronounced in Asia beyond 2010. In these countries, most notably China, Singapore, and Malaysia, semiconductor manufacturing is expected to increase significantly, as discussed above in the Technology-Adoption Baseline, contributing to higher emissions over the study period. Beyond 2010, the growth rate is assumed to decline by one half, reflecting slower growth in demand for semiconductors. Nevertheless, global emissions continue to climb substantially, reaching 232 $MtCO_2eq$ by 2020.

4.8 Magnesium Manufacturing (Sulfur Hexafluoride)

4.8.1 Source Description

The magnesium metal production and casting industry uses sulfur hexafluoride (SF_6) as a cover gas to prevent the violent oxidation of molten magnesium in the presence of air. The industry originally adopted SF_6 to replace sulfur dioxide (SO_2) as the primary cover gas. Although recent studies indicate some destruction of SF_6 in its use as a cover gas (Bartos et al., 2003), this analysis follows current IPCC guidelines (IPCC, 2000), which assume that all SF_6 used is emitted to the atmosphere. Fugitive SF_6 emissions occur primarily during three magnesium manufacturing processes: primary production, die-casting, and recycling-based production. Additional processes that may use SF_6 include sand and gravity casting; however, these are believed to be minor sources and are not included in the analysis. Baseline emission estimates under both a Technology-Adoption and a No-Action Baseline are presented below.

4.8.2 Source Results

Total SF_6 Emissions from Magnesium Manufacturing					
Technology-Adoption			No-Action		
Year	$MtCO_2eq$	Gg SF_6	Year	$MtCO_2eq$	Gg SF_6
1990	12	0.5	1990	12	0.5
1995	12	0.5	1995	12	0.5
2000	9	0.4	2000	9	0.4
2005	7	0.3	2005	9	0.4
2010	4	0.1	2010	12	0.5
2015	3	0.1	2015	15	0.6
2020	5	0.2	2020	18	0.8

Technology-Adoption Baseline

Under the Technology-Adoption Baseline, it is assumed that magnesium producers and processors outside of China will introduce technologies and practices aimed at reducing SF_6 emissions. Specific technologies include alternative cover gases, such as Novec™ 612 (a proprietary fluoroketone produced by 3M) and HFC-134a, and better containment and pollution control systems, which enable the use of SO_2 without the toxicity and odor problems of the past. Under this scenario, International Magnesium Association (IMA) members, who account for 80 percent of the global magnesium industry outside of China (DOE, 2003) meet a target of eliminating the use of SF_6 by 2011.

Exhibit 4-15 presents total SF_6 emissions from the magnesium industry under the Technology-Adoption Baseline from 1990 to 2020. As shown in the graph, total emissions from the magnesium industry remained fairly constant through the mid 1990s, but fall sharply to 9 $MtCO_2eq$ in 2000. The drop in global emissions between 1995 and 2000 is the result of both facility closures in the U.S. and global reductions in SF_6 usage through more efficient operational practices. The latter is a response to increasing SF_6 gas prices during the middle 1990s. Additional plant closings have been reported in Norway, Canada, and Japan, adding to the decline in the OECD's share of global emissions through 2020. This lost production has been primarily absorbed by China, which has dominated the foreign market with low-cost exports.

From 2000 through 2010, the steep decline in global SF_6 emissions is attributable to the adoption of alternative cover gases; either SO_2 or Novec™ 612 and HFC-134a. By 2011, in accordance with the IMA goal, all countries except China and the U.S. are assumed to have eliminated the use of SF_6 from magnesium production and casting operations.

For China, it is assumed that some primary production and all casting facilities will use SF_6 to produce high quality magnesium and products for the world market. Because Chinese producers and processors are not IMA members and have not committed to the IMA emission reduction goal, their SF_6 use is assumed to continue through 2020. Consequently, from 2010 through 2020, the increase in global emissions from 4 to 5 $MtCO_2eq$ will be driven entirely by China, whose emissions are expected to increase from 2 to 4 $MtCO_2eq$. In 2020, the China/CPA share of global emissions is expected to be 77 percent, compared to 0.3 percent in 1990. OECD's share of global emissions is projected to decrease from 77 percent in 1990 to 21 percent in 2020, due to adoption of the IMA goal and reduction in production capacity. In 2020, U.S. emissions account for a majority of OECD emissions. These emissions are due to U.S. casting and recycling firms that have not committed to phase out use of SF_6 (U.S., EPA, 2005).

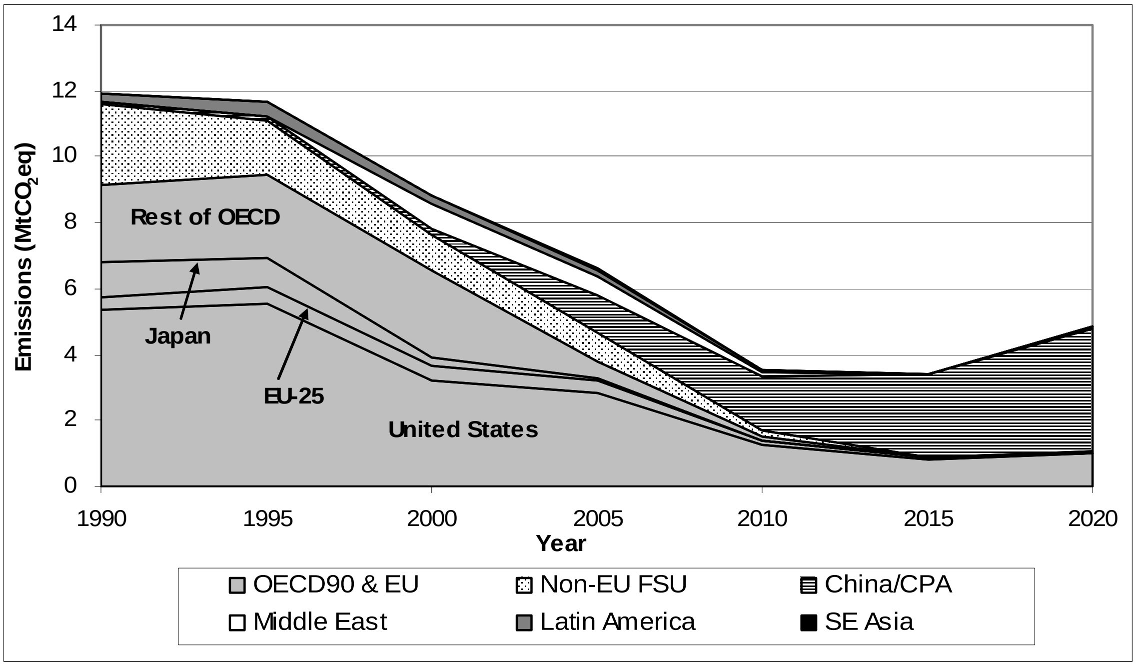


Exhibit 4-15. SF_6 Emissions from Magnesium Manufacturing Based on a Technology-Adoption Baseline – 1990 through 2020 ($MtCO_2eq$)

No-Action Baseline

Under the No-Action Baseline, magnesium producers and processors take no action to reduce their emissions; as a result, emission projections do not reflect anticipated technology adoptions and/or preventive maintenance steps taken to reduce emissions.

Exhibit 4-16 presents total SF_6 emissions from magnesium production under the No-Action Baseline from 1990 to 2020. The trends from 1990 to 2000 are the same as those discussed in the Technology-Adoption Baseline. From 2000 through 2020, global emissions in this scenario double to 18 $MtCO_2eq$ as the industry experiences strong growth, particularly in the die casting and recycling segments. China/CPA registers particularly significant emissions growth between 1990 and 2020, increasing its global share of emissions from 0.3 percent in 1990 to approximately 21 percent in 2020. OECD, emissions continue to drop between 2000 and 2005 because of facility closures in Canada stemming from pricing pressure from Chinese imports. However, by 2020, OECD emissions are expected to return to 1990 levels as production levels increase. Since global emissions increase by over 50 percent during this period, this results in the OECD share of global emissions falling from 77 percent in 1990 to 53 percent in 2020.

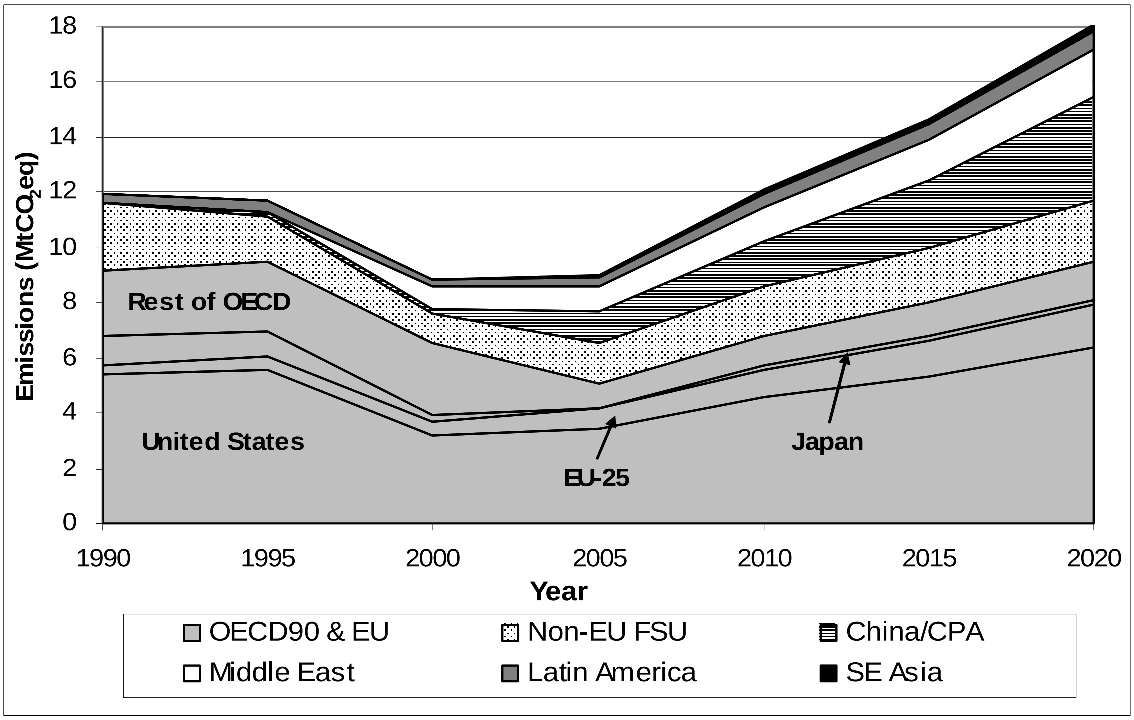


Exhibit 4-16. SF_6 Emissions from Magnesium Manufacturing Based on a No-Action Baseline 1990 – 2020 ($MtCO_2eq$)

Increasing Chinese primary production and die casting is being fueled by local and foreign investment, which has driven the overall increase in China/CPA's share of global emissions. China's emissions growth is driven by their die-casting and by the 10 percent of their primary production that is assumed to use SF_6 as the cover gas mechanism.

4.9 Other Non-Agricultural Sources (Methane and Nitrous Oxide)

4.9.1 Source Description

This category includes miscellaneous industrial emission sources which are generally small. The data presented here include:

- Methane from chemical production
- Methane from iron and steel production
- Methane from metal production
- Methane from mineral products
- Methane from petrochemical production
- Methane from silicon carbide production
- Nitrous oxide from metals production.

4.9.2 Source Results

Data presented below are for mainly from Annex I countries. These data are not fully comparable as emissions were not calculated for all countries in these regions.

Total Methane and Nitrous Oxide Emissions from Other Industrial Non-Agricultural Activities

Year	$MtCO_2eq$	Gg CH_4	Gg N_2O
1990	7	301	3
1995	7	306	3
2000	7	308	3
2005	7	293	3
2010	7	294	3
2015	7	294	3
2020	7	295	3

5. Agriculture

5.1 Introduction

This section presents global methane and nitrous oxide emissions for 1990 to 2020 for the following agricultural sources:

- Agricultural soils (nitrous oxide)
- Enteric fermentation (methane)
- Rice cultivation (methane)
- Manure management (methane and nitrous oxide)
- Other agricultural sources, including:
  - Savanna burning (methane and nitrous oxide)
  - Field burning of agricultural residues (methane and nitrous oxide)
  - Open burning from forest clearing (methane and nitrous oxide)
  - Agricultural soils (methane)

The agricultural sector is the largest contributor (59 percent in 1990; 57 percent in 2020) to global emissions of non-CO_2 emissions. In 1990, the agricultural sector accounted for 5,223 $MTCO_2eq$ of GHG emissions. The sector is dominated by nitrous oxide emissions from agricultural soils and methane from enteric fermentation, which constitute 38 percent and 34 percent, respectively, of all agricultural emissions in 1990, as illustrated in Exhibit 5-1. Emissions from agricultural soils are projected to increase by more than 46 percent by 2020, with its share of the sector's total emissions growing to 40 percent. Enteric fermentation emissions are expected to grow by 32 percent from 1990 to 2020, but its relative share of agricultural emissions will remain approximately the same.

Methane emissions from rice cultivation, methane and nitrous oxide emissions from manure management, and other smaller agricultural sources constitute the remaining non-CO_2 emissions from this sector. Although emissions from rice cultivation and manure management both are projected to grow from 1990 to 2020, the expected growth is moderate compared to the larger sources. The emissions from these and all other agricultural sources combined represent only 28 percent of total agricultural emissions in both 1990 and 2020. Meanwhile, combined emissions from agricultural soils and enteric fermentation are expected to contribute more than 72 percent of total agricultural emissions in 2020.

The key driver for this sector is agricultural production, which is expected to increase to meet the demand of fast-growing population centers in China/CPA, S&E Asia, Latin America, and Africa. Increases in both population and income in many areas of these regions will cause consumption of agricultural products to rise quickly. Also, changes in diet preferences, such as an increase in per-capita meat consumption, are expected to increase consumer demand for a variety of agricultural products. Increases in consumption will be met by domestic production gains from increased yields, livestock herds, and agricultural acreage, as well as imports from traditionally high-producing countries. Increased commercialization of production in less developed regions is also expected to increase fertilizer usage and livestock production capacity.

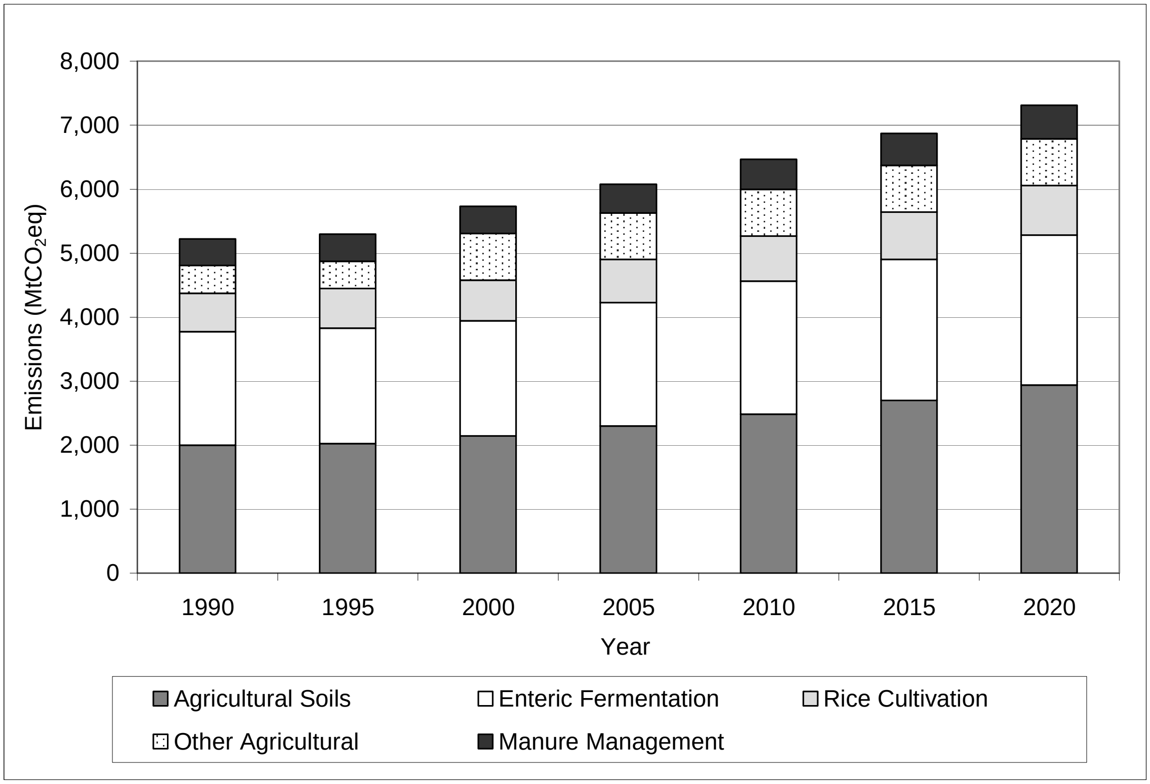


Exhibit 5-1. Total Emissions from the Agricultural Sector by Source ($MtCO_2eq$)

5.2 Agricultural Soils (Nitrous Oxide)

5.2.1 Source Description

Nitrous oxide is produced naturally in soils through the microbial process of denitrification and nitrification. A number of anthropogenic activities add nitrogen to the soils, thereby increasing the amount of nitrogen available for nitrification and denitrification, and ultimately the amount of nitrous oxide emitted. Anthropogenic activities may add nitrogen to the soils either directly or indirectly.

Direct additions of nitrogen occur from the following activities:

- Various cropping practices, including: (1) application of fertilizers, (2) production of nitrogen-fixing crops (e.g., beans, pulses, and alfalfa), (3) incorporation of crop residues into the soil, and (4) cultivation of high organic content soils (histosols); and

- Livestock waste management, including: (1) spreading of livestock wastes on cropland and pasture, and (2) direct deposition of wastes by grazing livestock.

Indirect additions occur through volatilization and subsequent atmospheric deposition of ammonia and oxides of nitrogen that originate from (a) the application of fertilizers and livestock wastes onto cropland and pastureland, and (b) subsequent surface runoff and leaching of nitrogen from these same sources.

5.2.2 Source Results

Total Nitrous Oxide Emissions from Agricultural Soils		
Year	**$MtCO_2eq$**	**Gg N2O**
1990	2,001	6,455
1995	2,023	6,525
2000	2,146	6,922
2005	2,299	7,418
2010	2,482	8,005
2015	2,696	8,696
2020	2,937	9,474

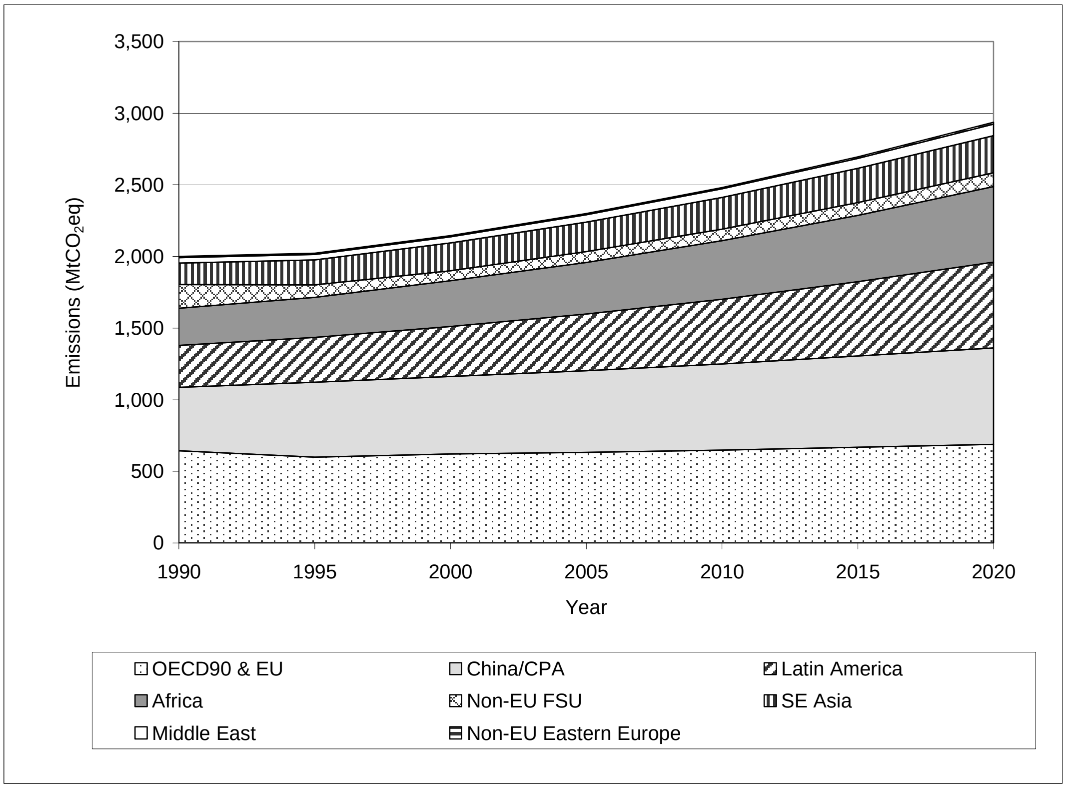


Exhibit 5-2. Nitrous Oxide Emissions from Agricultural Soils 1990 – 2020 ($MtCO_2eq$)

Emissions of nitrous oxide from agricultural soils are projected to increase by 47 percent from 1990 to 2020 (Exhibit 5-2). In 1990, four regions accounted for more than 80 percent of nitrous oxide from agricultural soils: OECD, China/CPA, Latin America, and Africa. By 2020, OECD is expected to contribute only 23 percent of emissions, compared to 32 percent in 1990. Over the same period, China/CPA and S&E Asia are expected to experience growth rates of more than 50 percent, while Africa, Latin America, and the Middle East are expected to experience growth rates of over 100 percent. These regional increases are driven largely by projected emissions increases in China, Brazil, Argentina, Nigeria, Bangladesh, India, and Iran. Only a handful of OECD countries are expected to show increased emissions through 2020; prominent among these are the U.S., Canada, Turkey, New Zealand, Australia, and Spain. The non-EU FSU is the only region expected to show a decrease in emissions between 1990 and 2020.

The primary factor for the increase in emissions illustrated in Exhibit 5-2 is the expected increase in crop and livestock production, with expanded use of synthetic fertilizers, to meet the growing consumption requirements of S&E Asia, China/CPA, Latin America, and Africa. Emission increases in these areas are somewhat offset by declining or slower growth in developed countries (such as the EU and U.S.) due to decreases in agricultural acreage, economic and environmental agricultural policies, and the changing world market for goods. Due to the complexities of agricultural product markets and the influences of disruptions in the industry (such as food safety issues), many of these factors are hard to predict. The following paragraphs explain some of the relevant current developments that influence emissions.

Overall, the expected decrease in emissions for most of the OECD region, economic transitioning in Eastern European countries of the OECD, and an expected modest increase in the emissions for the U.S., result in a projected moderate rate of growth over the study period for the OECD. Many OECD countries have little opportunity for expanding crop acreage for key crops (e.g., wheat, corn) and therefore growth in production is in the form of yield growth, which tends to have less of an impact on emissions growth than acreage increases. The market restructuring during the 1990s in Eastern Europe, as well as in the non-EU FSU countries, resulted in an economic downturn in those countries. Because of lower farm income, farmers purchased and used less fertilizer, a main driver for emissions from this category. During the same period, EU farmers reduced their use of fertilizer in response to the Common Agricultural Policy (CAP), which reduced market support prices to world prices while offsetting the negative financial impact on farmers with direct payments. In the U.S., the 1990s were characterized by increases in synthetic fertilizer usage, crop and forage production, and manure production. However, the use of synthetic fertilizers is estimated to have peaked in the late 1990s and is expected to decrease in the future. Offsetting this decreasing trend in emissions to some extent will be the expectation that OECD countries will continue to be important agricultural exporters to the fast-growing regions of the developing world.

In China/CPA, S&E Asia, Africa, and Latin America, the anticipated growth in agricultural soils emissions has several causes. Increases in population as well as per-capita income, particularly in China, India, and parts of Latin America, will increase the demand for agricultural products such as cereal grains, milk, oilseed products, and meat. In addition, livestock operations are expected to become more advanced in these areas, thereby increasing demand for high-quality feed crops (e.g., corn-based). While some of this demand will be addressed in the short term through increases in imports, long term expansion of domestic production capabilities is expected. The increased commercialization of the livestock industries in these growing countries is also expected to increase livestock productive capacity and the production of livestock manure, an important component of nitrous oxide emissions for this source category.

5.3 Enteric Fermentation (Methane)

5.3.1 Source Description

Normal digestive processes in animals result in methane emissions. Enteric fermentation refers to a fermentation process whereby microbes in an animal's digestive system ferment food. Methane is produced as a byproduct and can be exhaled by the animal.

Domesticated ruminants such as cattle, buffalo, sheep, goats, and camels account for the majority of methane emissions in this sector. Other domesticated non-ruminants such as swine and horses also produce methane as a byproduct of enteric fermentation, but emissions per animal species vary significantly. Total emissions are driven by the size of livestock populations and the management practices in use, particularly the feed regime used. The quantity, quality, and type of feed are significant determinants of methane emissions. Feed intake varies by animal type, as well as by weight, age, and growth patterns for individual animals.

5.3.2 Source Results

Total Methane Emissions from Enteric Fermentation		
Year	**$MtCO_2eq$**	**Gg CH_4**
1990	1,772	84,388
1995	1,804	85,909
2000	1,799	85,648
2005	1,929	91,851
2010	2,079	99,002
2015	2,204	104,963
2020	2,344	111,633

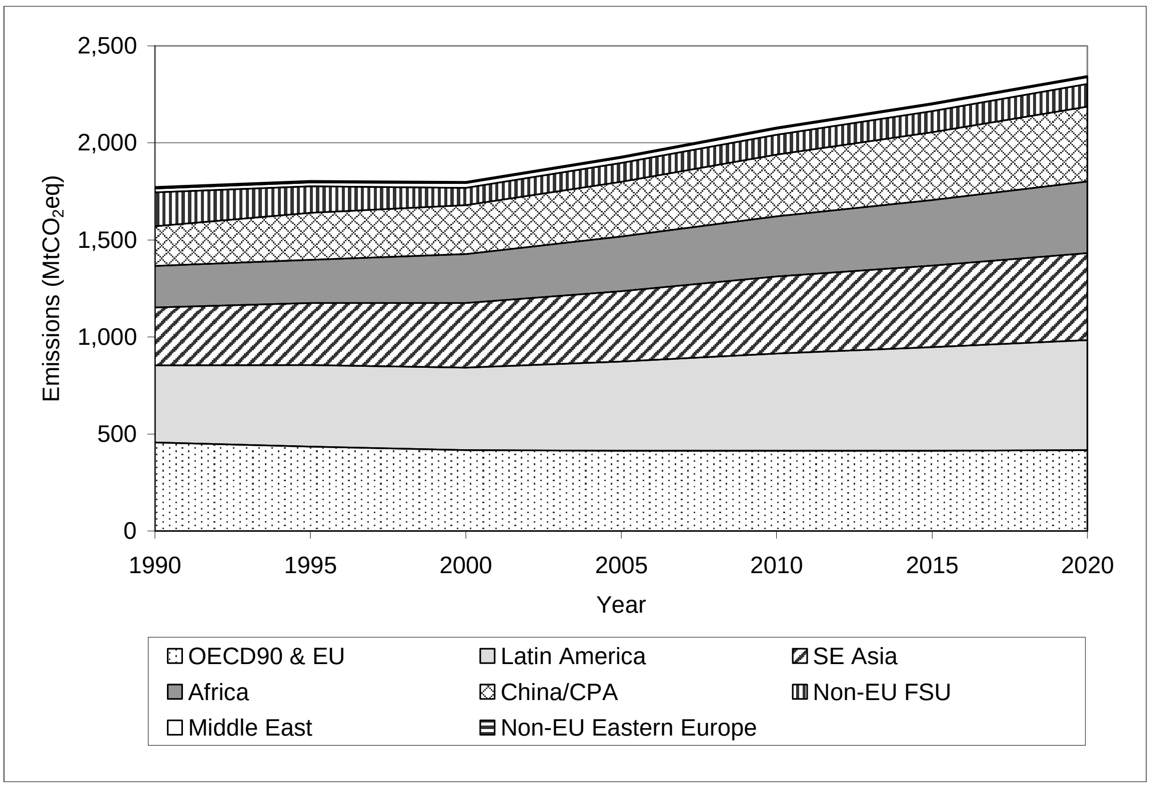


Exhibit 5-3. Methane Emissions from Enteric Fermentation 1990 – 2020 ($MtCO_2eq$)

Global emissions from this source are projected to increase 32 percent by 2020. However, three regions are projected to show declining emissions through 2020: OECD (-9 percent), non-EU FSU (-34 percent), and non-EU Eastern Europe (-20 percent), as illustrated in Exhibit 5-3. The remaining regions are expected to show significant increases in methane emissions over the same period: China (90 percent), Latin America (43 percent), Africa (73 percent), S&E Asia (50 percent), and the Middle East (81 percent). By 2020, Latin America is projected to be the largest contributor of methane emissions for this category, followed closely by S&E Asia and the OECD. In 1990, the top five countries were China, Brazil, India, the U.S., and Russia. These five nations accounted for 43 percent or 761 $MtCO_2eq$ of global methane emissions from enteric fermentation in 1990. In 2020, the top five are expected to be China, Brazil, India, the U.S., and Pakistan.

Historical trends in enteric emissions follow beef, dairy, or buffalo production cycles, since these animals are responsible for the majority of the world enteric emissions. Despite recent setbacks in the beef industry due to concerns about food safety, world projections for the period 2003 to 2013 show increases in meat and dairy product consumption, production, and trade (FAPRI, 2004). A combination of advancing domestic beef and dairy production capabilities in some key developing countries, combined with the maintenance of relatively high levels of production (but not necessarily high productivity growth) for large exporting countries, are expected to shape the emissions projections for this source.

In Latin America, Africa, India, and China, urban population growth and an increase in per capita income are expected to lead to an increase in livestock product demand, domestic livestock populations, and thus methane emissions. For example, it is estimated that over 44 percent of the increase in global milk production in the next decade will occur in China and India (FAPRI, 2004). Also, the anticipated transformation of management systems from dispersed, pasture operations to larger-sized, commercialized production is expected to increase breeding herd productivity, animal size, and overall meat production. Such transformations are occurring now throughout the developing world and will likely increase emissions, particularly in Africa and Latin America.

In many developed countries, methane emissions from enteric fermentation are expected to decline by 2020. In the EU, where approximately two-thirds of all cows are dairy cows, the cattle population is decreasing by approximately 2 percent per year due to milk quotas and increasing yields per animal. The number of beef cows (as well as sheep and goats) is expected to remain stable and emissions are not expected to increase in the EU after 2000. During the 1990s, the farm industries in Eastern European countries and the non-EU FSU reduced their livestock production as part of their transition to market economies; however this trend is expected to gradually reverse after 2000 as production increases to meet growing demand. A slight decline in emissions is projected for the U.S. from 2000 to 2020, resulting from increased production efficiencies, such as those occurring in the dairy industry, and the dampening effect on export production between 2003 and 2005 due to bovine spongiform encephalopathy (BSE) cases in the industry. Also, in many of the mature beef production industries, such as the U.S. and Australia, there are normal cyclical population fluctuations from year to year that follow animal growing cycles, and emissions will track these cycles.

5.4 Rice Cultivation (Methane)

5.4.1 Source Description

The anaerobic decomposition of organic matter in flooded rice fields produces methane. When fields are flooded, aerobic decomposition of organic material gradually depletes the oxygen present in the soil and flood water, causing anaerobic conditions in the soil to develop. Once the environment becomes anaerobic, methane is produced through anaerobic decomposition of soil organic matter by methanogenic bacteria. Several factors influence the amount of methane produced, including water management practices and the quantity of organic material available to decompose.

5.4.2 Source Results

	Total Methane Emissions from Rice Cultivation	
Year	**$MtCO_2eq$**	**Gg CH_4**
1990	601	28,628
1995	621	29,564
2000	634	30,169
2005	672	31,995
2010	708	33,726
2015	744	35,416
2020	776	36,958

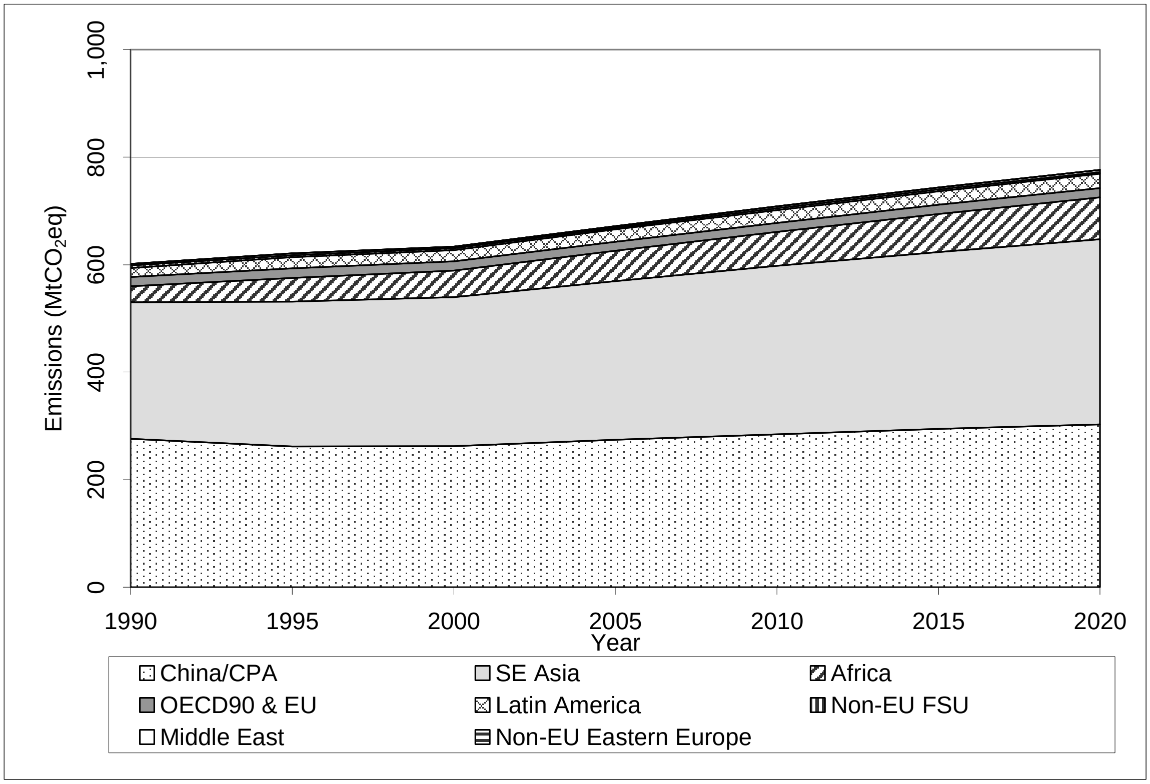


Exhibit 5-4. Methane Emission from Rice Cultivation 1990 – 2020 (MtCO$_2$eq)

The China/CPA and S&E Asian regions are the largest sources of methane emissions from rice cultivation, accounting for nearly 90 percent of the emissions for this source in 1990, as illustrated in Exhibit 5-4. The single largest contributors in these regions are China, India, Thailand, Indonesia, Vietnam, and Myanmar, which together emit 78 percent of all emissions from rice cultivation. Emissions from China/CPA are projected to increase 10 percent between 1990 and 2020, while S&E Asia's emissions are expected to increase by 36 percent during the same period.

The projected increase in emissions from 1990 to 2020 is primarily attributed to increased demand for rice due to expected population growth in rice consuming countries. Total global rice consumption is expected to rise in the projection years; however, this increase is partially offset by projected decreases in per-capita consumption over the next 10 years (FAPRI, 2004). Emissions growth has also been tempered by innovations that increased rice production without increasing rice acreage–the most important determinant of rice methane emissions. It is anticipated that yield growth, as opposed to acreage growth, will continue to be the main source of the production growth, with the continued development and adoption of higher-yielding rice varieties in many producing countries (FAPRI, 2004).

Thailand, Vietnam, and India are projected to dominate global rice exports through the 2005 to 2015 projection period, with an estimated 60 percent or greater share of the global export market. Continued yield growth in Vietnam, and both yield and area growth in Myanmar, is expected to increase production in those key rice-producing countries. China is expected to continue to be a significant contributor, but at a lower rate of growth due to decreases in production area. (FAPRI, 2004)

5.5 Manure Management (Methane and Nitrous Oxide)

5.5.1 Source Description

Manure management produces methane and nitrous oxide. Methane is produced during the anaerobic decomposition of manure, while nitrous oxide is produced by the nitrification and denitrification of the organic nitrogen content in livestock manure and urine. Emissions from only the managed collection, handling, storage, and treatment of manure are included here; emissions from the distribution of manure on pastures, ranges, and paddocks are included with agricultural soils emissions and are discussed in Section 5.2.

The quantity of methane emitted from manure management operations is a function of three primary factors: the type of treatment or storage facility, the ambient climate, and the composition of the manure. When manure is stored or treated in liquid systems such as lagoons, ponds or pits, anaerobic conditions can often develop and the decomposition process results in methane emissions. Ambient temperature and moisture content also affect methane formation, with higher ambient temperature and moisture conditions favoring methane production. The composition of manure is directly related to animal types and diets. For example, milk production in dairy cattle is associated with higher feed intake, and therefore higher manure excretion rates than non-dairy cattle. Also, supplemental feeds with higher energy content generally result in a higher potential for methane generation per unit of waste excreted than lower quality pasture diets. However, some higher energy feeds are more digestible than lower quality forages, which can result in less overall waste excreted. Ultimately, a combination of all these factors affects the actual emissions from manure management systems.

Nitrous oxide generation is a function of the composition of the manure, the type of bacteria involved in the decomposition process, and the oxygen and liquid content of manure. Nitrous oxide emissions occur through the processes of nitrification and denitrification, where the manure is first treated aerobically (nitrification) and then handled anaerobically (denitrification). Nitrous oxide generation is most likely to occur in dry manure handling systems that can also create pockets of anaerobic conditions.

5.5.2 Source Results

Total Methane and Nitrous Oxide Emissions from Manure Management

Year	$MtCO_2eq$	Gg CH_4	Gg N_2O
1990	418	10,596	631
1995	424	10,727	642
2000	421	10,732	632
2005	445	11,170	679
2010	470	11,617	728
2015	496	12,221	771
2020	523	12,832	818

Global methane emissions from manure management are projected to increase by 21 percent between 1990 and 2020, with increasing emissions in all regions except the non-EU FSU countries, as illustrated in Exhibit 5-5. Historically, methane emissions from manure management are largely from the OECD, which account for nearly 55 percent of all emissions in 1990. The top emitting countries in 1990 are: the U.S., Germany, India, China, France, Russia, Turkey, and Brazil. Emissions from the OECD, however, are projected to increase by only 3 percent between 1990 and 2020. In contrast, the expected growth rate is large and positive in several of the other regions during the same period: S&E Asia (53 percent), China/CPA (89 percent), Latin America (51 percent), and Africa (66 percent).

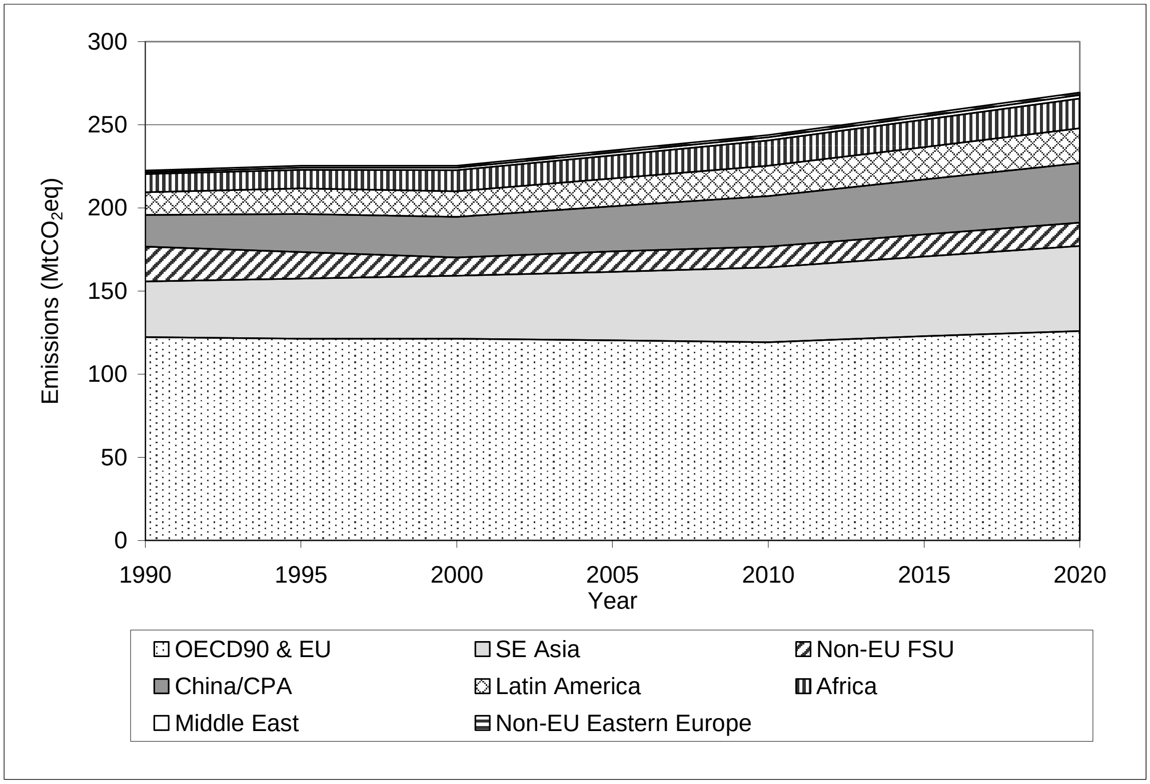


Exhibit 5-5. Methane Emissions from Manure Management 1990 – 2020 ($MtCO_2eq$)

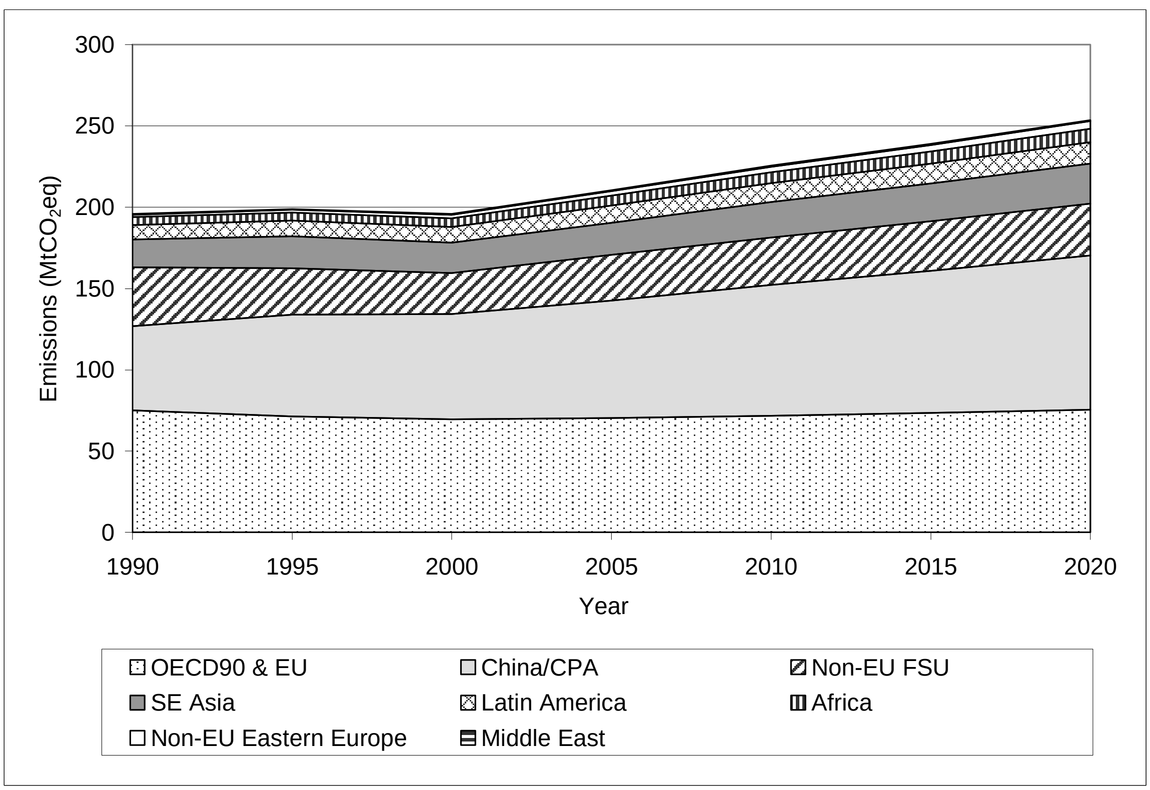


Exhibit 5-6. Nitrous Oxide Emissions from Manure Management 1990 – 2020 ($MtCO_2eq$)

Nitrous oxide emissions from manure management, illustrated in Exhibit 5-6, also are expected to increase globally, with a growth rate estimated at 30 percent between 1990 and 2020. Emissions are dominated by three regions: OECD, China/CPA, and the non-EU FSU. The top 10 emitters by country in 1990 are China, Russia, the U.S., Japan, Ukraine, Poland, France, Brazil, Thailand, and Germany. These 10 countries account for over 71 percent of the nitrous oxide emissions from manure management in 1990. This ranking is projected to change little by 2020. It is also important to note that while the 1990-2020 emissions growth in most regions is either positive or stable, there was a substantial historical decline in emissions for the non-EU FSU during the early 1990s due to the general decline in production as a result of market restructuring.

The key factors influencing both methane and nitrous oxide emissions in this category are expected to be the growth in livestock populations necessary to meet the expected worldwide demand for dairy and meat products, and the trend toward larger, more commercialized livestock management operations. These larger operations typically result in more liquid-based manure management systems that produce higher methane emissions. All of the factors related to the increase in cattle and buffalo production described in the enteric fermentation section are pertinent to manure management as well, since livestock population increases will lead to increased manure production. However, poultry and swine are other livestock categories that are particularly important for manure management emissions. Trends for these livestock are described in the following paragraphs.

Poultry and swine can contribute significantly to manure management emissions. Expected increases in worldwide poultry production, estimated to have the fastest rate of growth of all livestock types (over 26 percent) over the next decade (FAPRI, 2004), will in particular drive increases in nitrous oxide emissions because of the relatively high nitrogen content of poultry waste and the management systems used. China/CPA, S&E Asia, and Latin America (particularly Brazil and Argentina) all are expected to strongly increase poultry production (generally over 2.6 percent for key producing countries) as industry investments in these areas improve productivity and producers expand exporting capabilities. Continued steady growth in traditionally large poultry producing and exporting countries, such as the U.S., also contributes significantly to the projected increases in nitrous oxide emissions for this category.

Swine production can have a large influence on methane emissions. Continued transformation of the pork industry from locally dispersed individual producers to larger commercialized operations in countries such as China and Brazil is expected to increase both production and livestock population. In addition, larger commercialized operations tend to utilize more liquid-based manure management systems, which generate more methane emissions than smaller, individual feedlot operations. In the U.S., one of the largest and most commercialized pork producing countries in the world, swine are responsible for almost half of the methane emissions from manure management primarily because a large portion of the manure is handled with liquid-based systems. As other key pork producing countries transform to larger management systems, the trend will likely be toward increasing methane emissions.

5.6 Other Agricultural Sources (Methane and Nitrous Oxide)

5.6.1 Source Description

Methane and nitrous oxide are produced from the open burning of biomass during agricultural activities and from land use change. The sources included in this section are savanna burning, agricultural residue burning, and open burning from forest clearing[1]. This category also includes minor amounts of country-reported emissions data on methane from agricultural soils. However, biomass burning constitutes the majority of emissions for this source.

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[1] 1990 and 1995 estimates for biomass burning were obtained from the Emission Database for Global Atmospheric Research (EDGAR), Version 3.2 (Olivier and Berdowski, 2001; Olivier, 2002). Estimates for 2000 were obtained from the EDGAR 3.2 Fast Track 2000 dataset (32FT2000) (Olivier, 2005).

5.6.2 Source Results

Total Methane and Nitrous Oxide Emissions from Other Agricultural Activities			
Year	$MtCO_2eq$	Gg CH_4	Gg N_2O
1990	431	12,745	526
1995	425	13,068	487
2000	730	21,689	886
2005	730	21,691	885
2010	730	21,693	885
2015	730	21,696	885
2020	730	21,698	885

Exhibits 5-7.1 and 5-7.2 graphically depict trends in methane and nitrous oxide emissions for this category. Latin America, Africa, and S&E Asia are the largest emitters in this source category. These three regions account for 91 percent of the nitrous oxide emissions and 85 percent of the methane emissions in 1990. Projections for future years have been held constant at 2000 levels due to a lack of information for projecting the variety of emissions within this category.

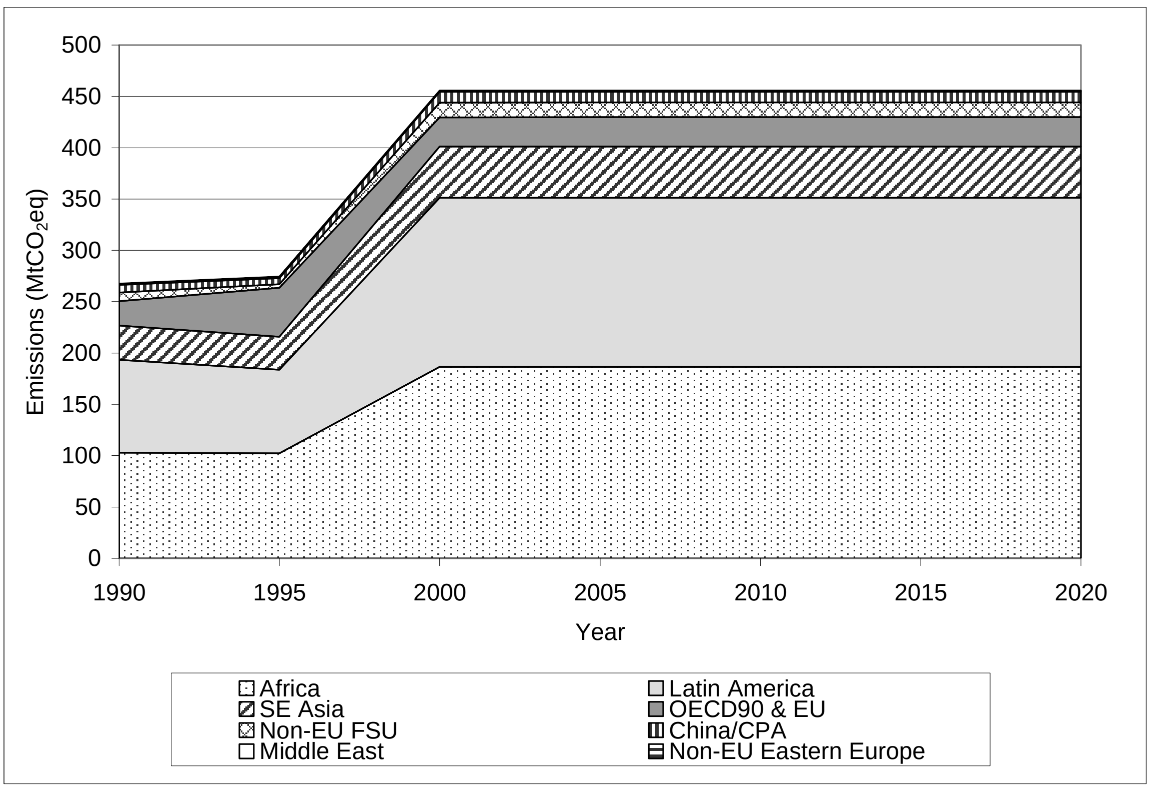

Exhibit 5-7.1. Methane Emissions from Other Agricultural Sources 1990 – 2020 ($MtCO_2eq$)

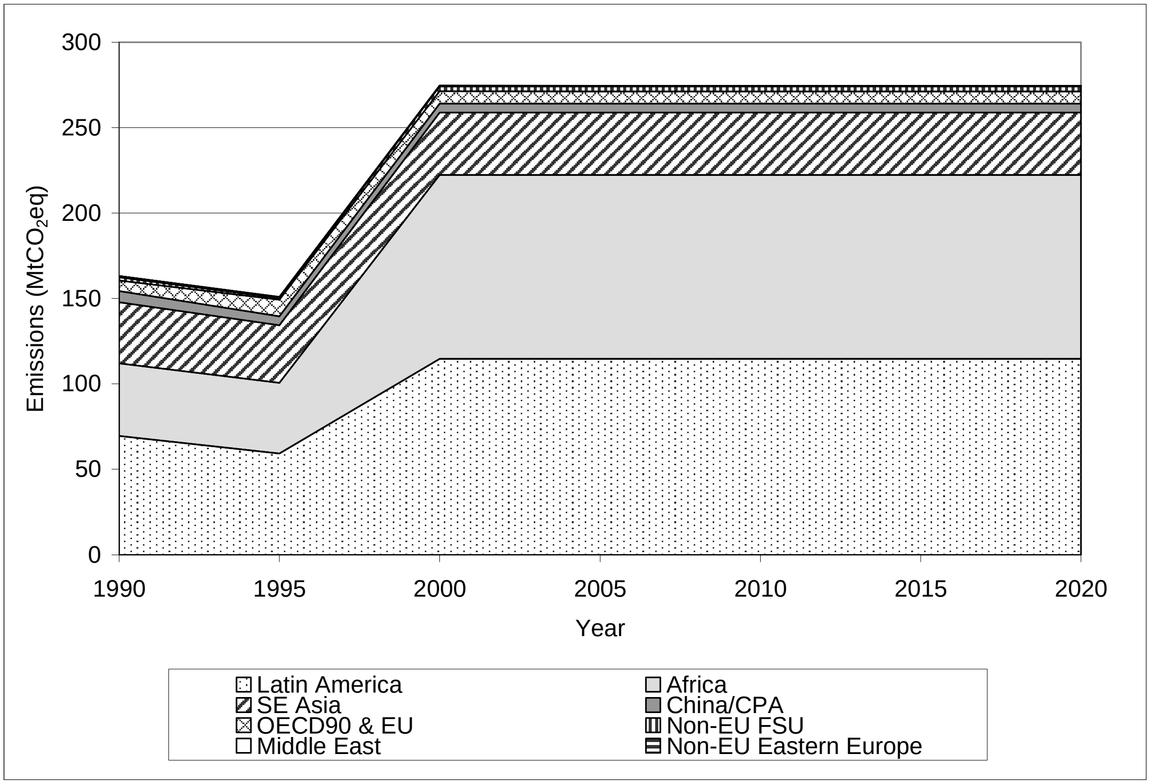

Exhibit 5-7.2. Nitrous Oxide Emissions from Other Agricultural Sources 1990 – 2020 ($MtCO_2eq$)

6. Waste

6.1 Introduction

This section presents global methane and nitrous oxide emissions for 1990 to 2020 for the following sources in the waste sector:

- Landfilling of solid waste (methane)
- Wastewater (methane)
- Human sewage (nitrous oxide)
- Other non-agricultural sources (methane and nitrous oxide).

The “other non-agricultural” category contains minor emissions from miscellaneous waste generating activities, waste combustion, and minor emissions from other sources not accounted for elsewhere in this document.

The waste sector is the third largest contributor to global emissions of non-CO_2 GHGs. The two largest sources of non-CO_2 GHG emissions within the waste sector are landfilling of solid waste and wastewater. Although the sector as a whole accounts for only 15 percent of all non-CO_2 GHG emissions, landfilling is the fourth largest individual source of non-CO_2 GHG emissions (761 $MtCO_2eq$), following agricultural soils (2,001 $MtCO_2eq$), enteric fermentation (1,772 $MtCO_2eq$), and natural gas and oil systems (993 $MtCO_2eq$).

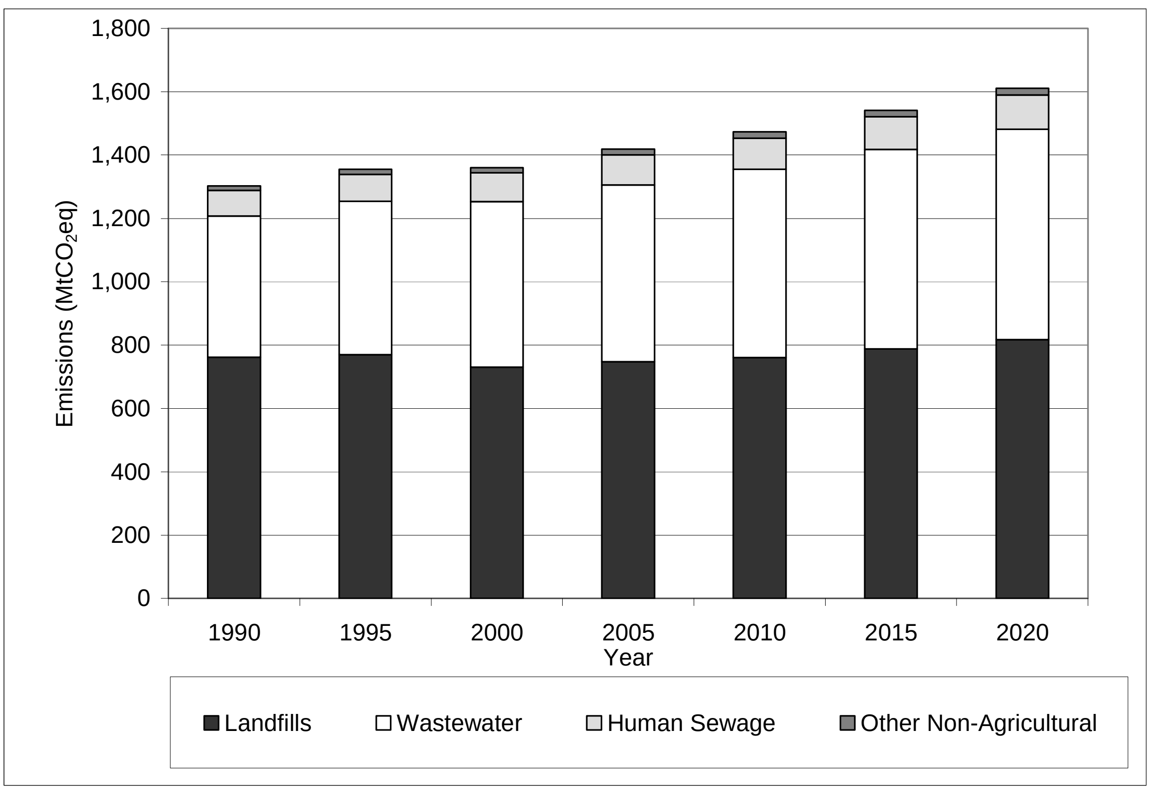

Exhibit 6-1. Total Emissions from the Waste Sector by Source ($MtCO_2eq$)

6.2 Landfilling of Solid Waste (Methane)

6.2.1 Source Description

Methane is produced and emitted from the anaerobic decomposition of organic material in landfills. The major drivers of emissions are the amount of organic material deposited in landfills, the extent of anaerobic decomposition, and the level of landfill methane collection and combustion (e.g., energy use or flaring). The amount of waste deposited in landfills can be affected by waste-reduction and recycling efforts. Because organic material deep within landfills takes many years to decompose completely, past landfill disposal practices greatly influence present day emissions.

6.2.2 Source Results

The OECD countries emit nearly 49 percent of the global methane produced from the landfilling of solid wastes in 1990, as shown in Exhibit 6-2. In the same year, the remaining regions each contribute less than 15 percent of the methane emissions for this source category. Within the OECD, the U.S. is the largest source of emissions from the landfilling of solid waste. In 1990, the U.S. emitted over 170 $MtCO_2eq$ of methane, which is almost 46 percent of the OECD total and 23 percent of the global total.

Total Methane Emissions from Landfilling of Solid Waste		
Year	**$MtCO_2eq$**	**Gg CH_4**
1990	761	36,257
1995	770	36,653
2000	730	34,777
2005	747	35,589
2010	761	36,220
2015	788	37,527
2020	817	38,898

Long-term projections show significant shifts in contributions to landfill emissions. The OECD is projected to have an almost 31 percent decrease in emissions between 1990 and 2020, decreasing from 49 percent to 32 percent of the global emissions for this source. By 2020, three regions are projected to hold more than a 10 percent share of the global emissions pool: Africa (16 percent), Latin America (13 percent), and S&E Asia (14 percent). The factors behind these trends are described in the following paragraphs.

Driving factors for landfill emission trends are growing populations, increases in personal incomes, and expanding industrialization, all of which can lead to increases in the amount of solid waste generated for a country. Countries with fast-growing economies and populations are expected to contribute more to the global methane total from landfills as their economies grow and waste generation rates increase. Countries with more steady-state economic growth, and small or even declining population growth rates, are likely to experience minimal growth in landfill emissions. Waste reduction programs, as well as methane recovery and use, will also impact the amount of methane that is actually released to the atmosphere.

The decline in emissions from 1990 to 1995 in the OECD is largely due to non-climate regulatory programs and the collection and flaring or use of landfill methane. In many OECD countries, landfill methane emissions are not expected to grow, despite continued or even increased waste generation, because of non-climate change related regulations that result in mitigation of air emissions, collection of gas, or closure of facilities. A major driver in the OECD is the European Union Landfill Directive, which limits the amount of organic matter that can enter solid waste facilities. Although organic matter is expected to decrease rapidly in the EU, emissions occur as a result of total waste in place. Emissions will have a gradual decline over time.

In regions other than the OECD, an increase in methane emissions is projected. In these regions, solid waste is expected to be increasingly diverted to managed landfills as a means of improving overall waste management. The combined effects of rapid economic change, expansive growth policies, and population increase, particularly in the urban centers of developing countries, will result in changing consumption patterns and increases in waste generation. Per-capita waste generation rates can increase by three or four times in the transition from a rural, low-income scenario to higher income urban-based populations. Areas showing high growth in emissions between 1990 and 2020 (e.g., Africa at 77 percent growth, S&E Asia at 34 percent, Latin America at 52 percent) are all undergoing such transformations.

A major limitation to this sector is the use of default emission factors. Many large developing countries did not report emissions or used default parameters. This leads to some unusual trends such as the low level of emissions in many Asian countries. The improvements in both method and default values in the 2006 IPCC Guidelines will help improve these estimates in the future.

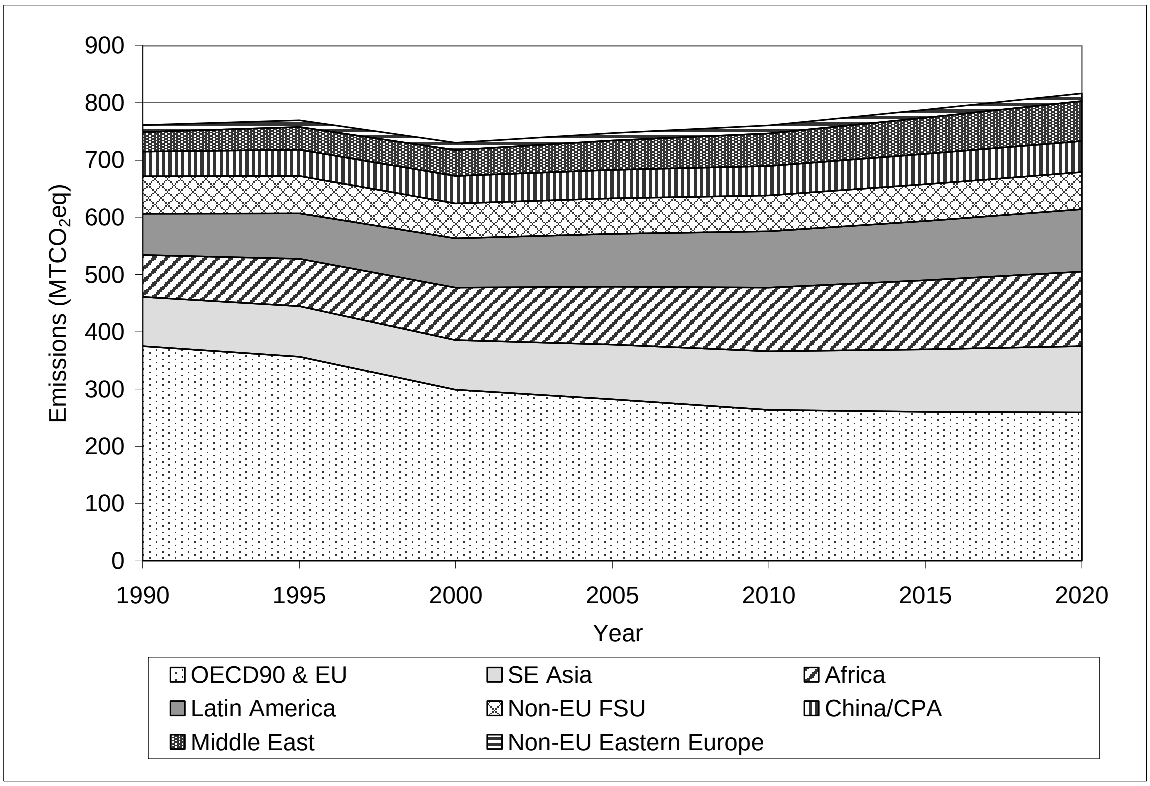

Exhibit 6-2. Methane Emission from Landfilling of Solid Waste 1990 – 2020 (MtCO$_2$eq)

6.3 Wastewater (Methane)

6.3.1 Source Description

Methane is emitted both incidentally and deliberately during the handling and treatment of municipal and industrial wastewater. The organic material in the wastewater produces methane when it decomposes anaerobically. Most developed countries rely on centralized aerobic wastewater treatment to handle their municipal wastewater, so that methane emissions are small and incidental. However, in developing country areas with little or no collection and treatment of wastewater, anaerobic systems such as latrines, open sewers, or lagoons are more prevalent. Industrial wastewater can also be treated anaerobically, with significant methane being emitted from those industries with high organic loadings in their wastewater stream, such as food processing and pulp and paper facilities.

	Total Methane Emissions from Wastewater	
Year	**$MtCO_2eq$**	**Gg CH_4**
1990	446	21,232
1995	484	23,039
2000	523	24,883
2005	558	26,577
2010	594	28,287
2015	630	29,997
2020	665	31,665

6.3.2 Source Results

In 1990, S&E Asia and China/CPA account for 57 percent (33 percent and 24 percent, respectively) of global methane emissions due to wastewater handling. Three regions account for between 10-12 percent each in 1990: Africa, OECD, and Latin America. The largest emitters by country in 1990 are China (21 percent), India (18 percent), the U.S. (6 percent), and Indonesia (4 percent). In 2020, S&E Asia and China/CPA are expected to obtain a 56 percent share of global emissions for this source in 2020. Wastewater emissions are growing most rapidly in Africa and the Middle East. Wastewater methane in Africa and the Middle East is expected to approximately double between 1995 and 2020.

The main driver for increasing municipal wastewater emissions is population growth, particularly growth associated with countries that rely on less advanced, anaerobic treatment and collection systems such as latrines, septic tanks, open sewers, and lagoons. Most developed countries have an extensive infrastructure to collect and treat urban wastewater, in which the majority of systems rely on aerobic treatment with minimal methane production and thus less effect on the emissions trend. In contrast, there is widespread use of less advanced, anaerobic systems in some of the fastest growing parts of the world.

It is estimated that over 80 percent of domestic wastewater goes uncollected and untreated in large portions of the China/CPA, S&E Asia, and Africa. For rural areas, the amount is likely to be even higher. Much of this untreated wastewater is found in open sewers, pits, latrines, or lagoons where there is potential for methane production. For example, nearly 75 percent of China's wastewater emissions come from latrines, with the majority of wastewater generated in rural China being untreated. The largest share of India's emissions also comes from latrines (62 percent), but open sewers contribute a sizable amount as well (34 percent). Like India, most of Indonesia's emissions come from latrines and open sewers. As long as populations grow significantly without large scale advances in wastewater treatment, these areas will continue to have a major influence on the upward trend in wastewater methane emissions. The impact of urban center growth in these regions, however, may offset this trend if migrating rural populations are served by more advanced urban treatment systems.

Less advanced treatment systems are still widely used in some developed countries. In the U.S., for example, septic tanks are responsible for 75 percent of the emissions, though only 25 percent of treatment. Septic tanks are utilized in many parts of the developed world where centralized sewer infrastructure is not available; however, their usage is not expected to increase significantly in the future since there are economic and site considerations that limit their widespread applicability.

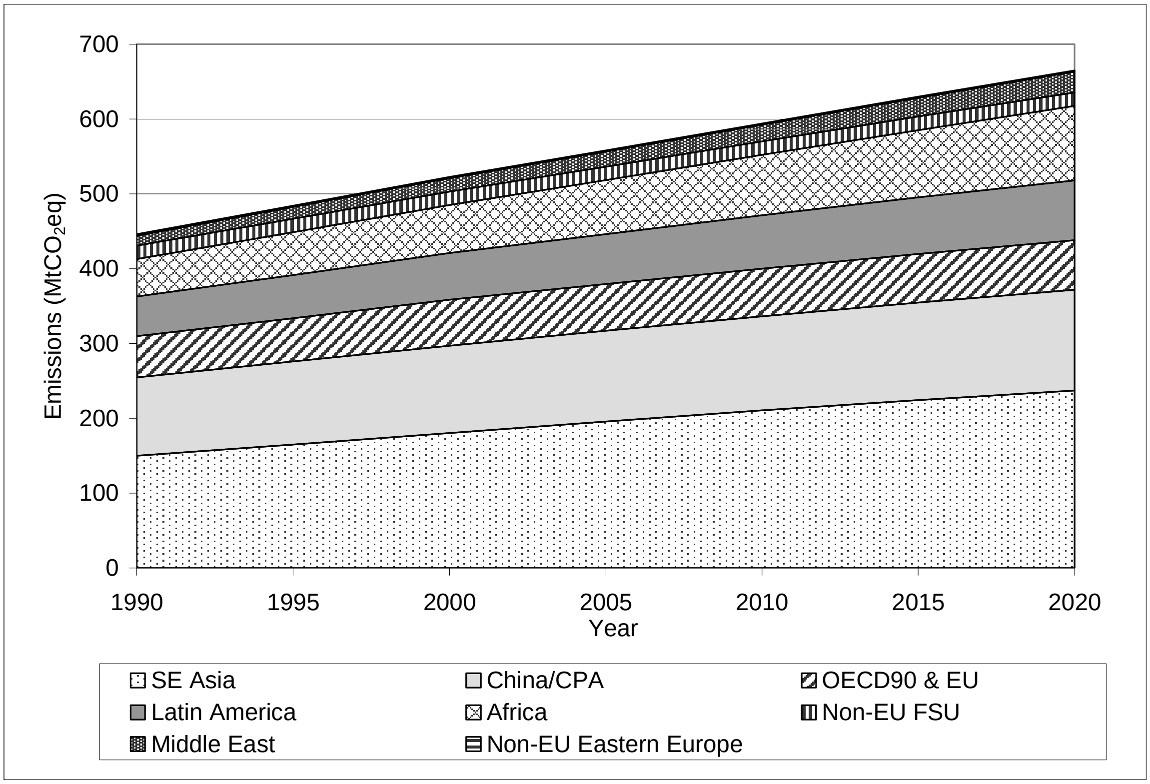

Exhibit 6-3. Methane Emission from Wastewater 1990 – 2020 (MtCO$_2$eq).

6.4 Human Sewage – Domestic Wastewater (Nitrous Oxide)

6.4.1 Source Description

Domestic and industrial wastewater are also a source of nitrous oxide emissions. Domestic wastewater includes human waste as well as flows from shower drains, sink drains, washing machines and other domestic effluent. Some industries produce wastewater with significant nitrogen loadings that is discharged to the city sewer, where it mixes with domestic, commercial, and institutional wastewater. The wastewater is transported by a collection system to an on-site, decentralized wastewater treatment (WWT) system, or a centralized WWT system. Decentralized WWT systems are septic systems and package plants. Centralized WWT systems may include a variety of processes, ranging from treatment in a lagoon to advanced tertiary treatment technology for removing nutrients. After processing, treated effluent may be discharged to a receiving water environment (e.g., river, lake, estuary) applied to soils, or disposed of below the surface.

Nitrous oxide may be generated during both nitrification and denitrification of the nitrogen present in the wastewater stream, usually in the form of urea, ammonia, and proteins. These are converted to nitrate via nitrification, an aerobic process converting ammonia-nitrogen into nitrate (NO_3-). Denitrification occurs under anoxic conditions (without free oxygen), and involves the biological conversion of nitrate into dinitrogen (N_2). Nitrous oxide can be an intermediate product of both processes, but is more often associated with denitrification.

Although several waste streams potentially lead to nitrous oxide emission, this section only covers human sewage emissions unless reported emissions include additional sources.

Total Nitrous Oxide Emissions from Human Sewage		
Year	**$MtCO_2eq$**	**Gg CH_4**
1990	81	260
1995	85	275
2000	91	293
2005	95	306
2010	99	320
2015	103	333
2020	107	346

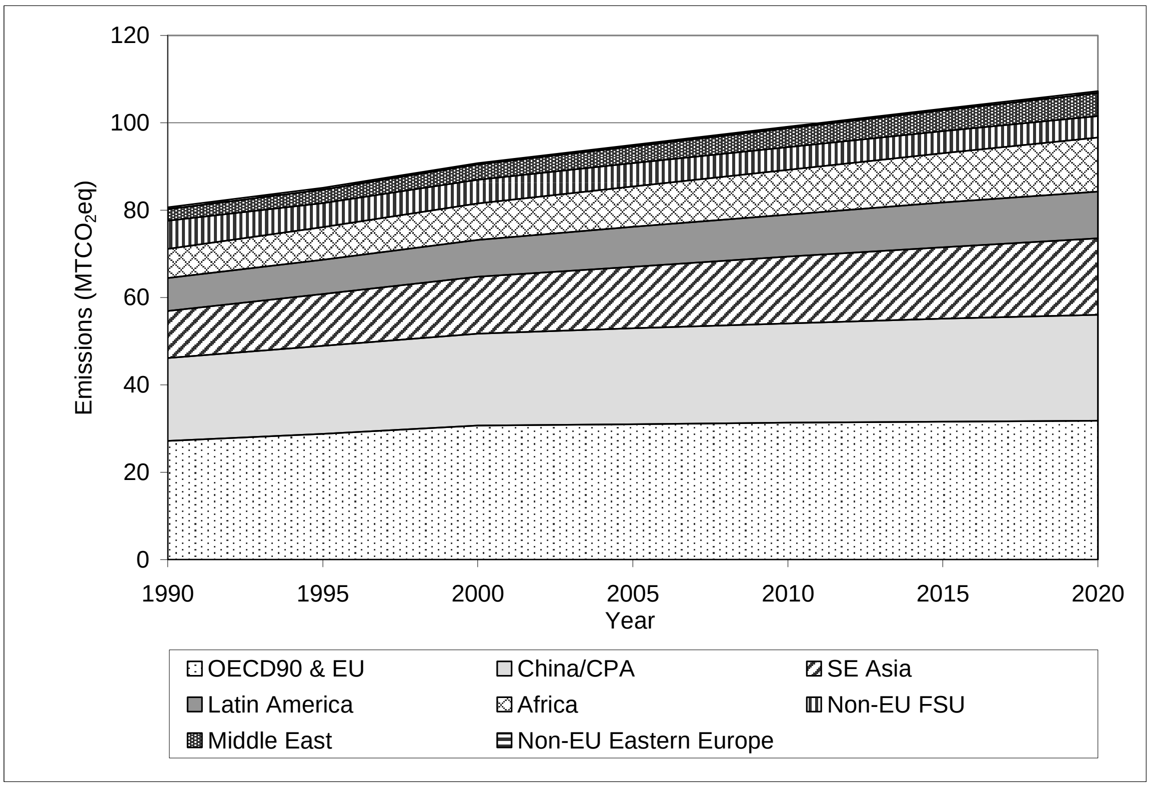

Exhibit 6-4. Nitrous Oxide from Human Sewage 1990 – 2020 ($MtCO_2eq$)

6.4.2 Source Results

In 1990, the OECD, China/CPA, and S&E Asian regions account for over 70 percent of the nitrous oxide emissions from human sewage, as illustrated in Exhibit 6-4. Within these regions, the top countries are: China, the U.S., Germany, and Indonesia. The U.S. accounts for nearly 50 percent of the OECD's emissions. Overall, nitrous oxide emissions from human sewage are projected to increase by almost 33 percent by 2020. Although the same three regions are expected to continue to constitute approximately 70 percent of the emissions, Africa is projected to grow by 86 percent and contribute over 11 percent of the emissions for this source in 2020. Emissions in several of the EU countries are expected to decrease by 2020.

The main driver for human sewage emissions is population increase. Emissions may be linked to treatment type (lagoons versus advanced treatment such as nitrification/denitrification plant), not enough information is available to account for advanced treatment methods. The IPCC default methodology uses the same emission factor for all wastewater generated). Therefore, the total quantity of wastewater generated, regardless of treatment type, is the principle factor.

In addition to population, rise in per-capita income tends to increase the amount of nitrogen available in the wastewater generated due to increases in per-capita protein consumption. Milk and meat consumption in developed countries can be more than five times higher than in developing countries. However, per capita consumption of meat and dairy products rises fastest in countries where current consumption levels are low, rapid urbanization is occurring, and incomes are growing rapidly from a low base. Therefore, the long term trend of nitrous oxide emissions from human sewage will be largely impacted by fast-growing economies such as China and India.

6.5 Other Non-Agricultural Sources (Methane and Nitrous Oxide)

6.5.1 Source Description

This category includes emission sources that are relatively small and provided by specific countries. These countries have chosen to estimate emissions for these sources with their own methods as these are generally sources without IPCC methodologies. The data presented here include the following sources of methane and nitrous oxide:

- Fugitives from natural gas and oil systems (nitrous oxide)
- Fugitives from solid fuels (nitrous oxide)
- Miscellaneous waste handling practices ("other waste") (methane and nitrous oxide)
- Solvent and other product use (nitrous oxide)
- Waste combustion (methane and nitrous oxide).

The sources listed above encompass several different sectors, but are placed in the waste sector because waste combustion emissions dominate these miscellaneous sources. These emissions are NOT included elsewhere in this report.

6.5.2 Source Results

The OECD and non-EU FSU regions constitute the majority of the emissions. The data in the table below are not fully comparable to data in the remainder of this report since emissions are not calculated for all countries in these regions. If a projection of future emissions was not available, EPA assumed future emissions remain constant.

Total Methane and Nitrous Oxide Emissions from Other Non-Agricultural Sources

Year	$MtCO_2eq$	Gg CH_4	Gg N_2O
1990	15	53	44
1995	16	68	47
2000	17	88	48
2005	18	83	53
2010	19	78	57
2015	20	74	60
2020	21	72	64

7. Methodologies Used to Compile and Estimate Historical and Projected Emissions

Overview

This chapter outlines the methodologies used to compile and estimate category and country-specific historical and projected emissions of methane (CH_4), nitrous oxide (N_2O), and high global warming potential (GWP) gases. The preferred approach for estimating historical and projected emissions is to use a hierarchy of country-prepared, publicly-available reports. If country-supplied data are not available, EPA estimates emissions consistent with the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC Guidelines) (IPCC, 1997) and the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC Good Practice Guidance) (IPCC, 2000). A preferred data source for historical emissions is the 2005 Inventory and accompanying Common Reporting Format (CRF) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat by Annex I countries. As identified by the UNFCCC, Annex I countries, include all OECD countries in 1992, plus countries with economies in transition and most of Central and Eastern Europe. Annex I countries are noted in Table 1-4 and Appendix H. The 2005 CRFs contain inventory data from 1990 through 2003. Data for non-Annex I countries are obtained from a mixture of country-reported data (e.g., First National Communications), country reports, and EPA developed estimates. The hierarchy of data sources and an overview of the methods used to augment missing historical and projected estimates are discussed below in Section 7.1. A detailed discussion of the methodology associated with each source category and gas begins in Section 7.2.

This report does not describe in detail the methodology used to generate the publicly-available CRF data. However, the CRF inventory data are generally comparable across countries because they are based on IPCC methodologies and are reported for a standard list of IPCC source categories. Although the CRFs provide the latest historical GHG emissions data for Annex I countries, they do not contain projected emissions. A preferred source for projected emissions is the National Communications, the Third National Communication for Annex I countries and the First or Second National Communications for non-Annex I countries. The Third National Communications were submitted primarily in 2001 and 2002. The National Communications are documents that were submitted by each Party to the UNFCCC Secretariat to report on steps taken to implement the Convention; they contain emissions and projections to 2020. The non-Annex I countries have a more flexible schedule, with submissions of First and/or Second National Communications from 1997 to 2005. The projected information from the National Communication is adjusted to be compatible with the most recent inventory data, if necessary.

7.1 Data Sources for Historical and Projected Emissions

7.1.1 Methane and Nitrous Oxide

The preferred approach for estimating historical and projected emissions is to use country-prepared, publicly-available reports. If reported estimates do not exist, EPA estimates methane and nitrous oxide emissions in order to produce a complete inventory for the world. When developing emissions estimates or projections, EPA uses the default methodologies presented in the IPCC Guidelines and IPCC Good Practice Guidance. In other cases, it is necessary to modify data from publicly-available reports in order to ensure consistency in the presentation of the data. For example, some countries report projections that account for additional GHG mitigation strategies over and above current effects of measures in place. Since the purpose of this report is to provide projected emissions that reflect the currently achieved effects of climate policy programs and measures that are already in place, but to exclude reductions due to future impacts of current programs or additional planned activities that are much less certain, the anticipated emissions reductions due to these "additional" measures have been added back into the estimates, if necessary.

The following country-specific or country-provided data sources are used to compile the methane and nitrous oxide emissions in this report:

Annex I Countries:

- *2005 National Inventory Report (NIR) and Accompanying Common Reporting Format (CRF) submissions to the UNFCCC.* The 2005 CRF is the preferred data source for historical estimates. The 2005 CRFs contain inventory data from 1990-2003 and are prepared in accordance with IPCC Guidelines and the IPCC Good Practice Guidance.

- *Third National Communication.* If CRF data are not available, Third National Communications are the preferred source for historical data. The Third National Communications are also the preferred source for developing projected emissions estimates. If CRF historical estimates are available, EPA extracts emissions projections through 2020 from the Third National Communication and scales these projected data to CRF historical emissions. EPA uses projected data that reflect the current impact of existing mitigation programs, but in a small number of cases, the only available projections include planned mitigation measures. In these cases, EPA makes adjustments to the projected data.

- *Other Country-Prepared Publications.* If the CRF or Third National Communication is not submitted or is incomplete, EPA uses the next most recent country-prepared publication. For some countries, EPA uses country-specific reports that have more recent projection information than the information provided in the most recently submitted National Communication. The projections obtained from the country-prepared publication are scaled to historical estimates from either the CRF or most recent National Communication.

- *IPCC Tier 1 Estimates.* If data are not available from any of these sources, EPA estimates emissions in accordance with IPCC Guidelines and IPCC Good Practice Guidance using IPCC Tier 1 methodologies.

Non-Annex I Countries:

For non-Annex I countries, EPA first seeks country-specific data using the following preference hierarchy: 1) Second National Communication, 2) First National Communication, 3) Country Case Study report, or 4) Asia Least-Cost Greenhouse Gas Abatement Strategy (ALGAS) report. If data are not available from any of these sources, EPA prepares estimates in accordance with IPCC Guidelines and Good Practice Guidance using the IPCC Tier 1 methodology.

Augmenting Missing Historical Estimates

Many of the historical emissions time series have gaps. In addition, some countries aggregate projections (e.g., livestock), which have to be disaggregated into their constituents (e.g., enteric fermentation and manure management). The following steps are taken if the emissions data are available, but are either incomplete or aggregated:

- When two years are reported such that a year requiring an estimate (e.g., 1995) occurred between the reported years (e.g., 1993 and 1997), EPA interpolates the missing estimate (1995) using the reported estimates. EPA then "backcasts" or forecasts as described below to complete the series for 1990, 1995 and 2000.

- For countries that report emissions for any year (or years) between 1990-1995, the 1990-1995 Tier 1 growth rate[1] is applied to backcast emissions to 1990 and forecast emissions to 1995. Then, the 1995-2000 Tier 1 growth rate is applied to the 1995 estimate to obtain the 2000 estimate.

- For countries that report emissions for any year (or years) between 1995-2000, the 1995-2000 Tier 1 growth rate is applied to backcast emissions to 1995 and forecast emissions to 2000. Then, the 1990-1995 Tier 1 growth rate is applied to the 1995 estimate to obtain the 1990 estimate.

- If a country reports an estimate for an individual source for one year, but reports aggregate estimates for other years, EPA disaggregates the estimates using the percent contribution of the individual source in the latest reported year.

Projecting Estimates to 2020

- For countries with CRF data, EPA forecasts emissions for 2005, 2010, 2015, and 2020 using growth rates calculated either from Third National Communications or other reported data. In some cases, the 2000-2010 growth rate is applied to 2010-2020 if projections past 2010 are not available in the country-reported data. If projections are not available for any years in a National Communication or other country-specific data source, EPA applies Tier 1 derived growth rates to historical data.

- For non-Annex I countries, projections for 2005, 2010, 2015, and 2020 are usually created by applying Tier I derived growth rates to reported historical data. However, for a few countries, the National Communications provide BAU projected estimates and these are given priority over EPA estimates.

For specific details on how estimates are developed for each country, category and year, see Appendices E-1 to E-12.

7.1.2 High Global Warming Potential Gas Emissions

For most countries, emissions and projections are not available for the sources of high GWP gases. Therefore, EPA estimates high GWP emissions and projections using detailed source methodologies described later in this chapter (see Section 7.3).

7.2 Specific Methodologies for Methane and Nitrous Oxide Sources

The following sections describe the detailed methodologies used to develop historical and projected emissions for countries for which reported data are not available or data are available for only part of the time series. In these cases, EPA uses the IPCC Tier 1 methodology from the IPCC Guidelines as the basis for calculating emissions. For each category, the source of historical and projected data to calculate emissions is presented.

7.2.1 Methane Emissions from Natural Gas and Oil Systems

If no estimates are available or the data are insufficient, EPA uses the IPCC Tier 1 methodology to estimate emissions. The Tier 1 basic equation to estimate fugitive methane emissions from oil and natural gas production, transmission, and distribution systems is as follows:

[1] A Tier 1 growth rate is a rate of growth (or decline) derived from historical and future emissions estimated using IPCC Tier 1 methodology. Growth/decline ratios are calculated at five-year intervals for: 1990-1995, 1995-2000, 2000-2005, 2005-2010, and 2015-2020.

Fugitive CH_4 Emissions =
*(Annual Oil Production x Emission Factor + Annual Oil Consumption x Emission Factor) + (Annual Natural Gas Production x Emission Factor + Annual Natural Gas Consumption x Emission Factor) + (Venting & Flaring Activity Data * Venting and Flaring Emission Factor)*

Assuming that the emission factors do not change, the driver for determining fugitive methane emissions from oil and natural gas is the respective production and consumption of these fuels.

Historical Emissions

Activity Data

- Obtain historic natural gas and oil production and consumption data from U.S. Energy Information Agency (EIA) for 1980 through 2000 (EIA, 2002).

Emission Factors and Emissions

- Use IPCC (IPCC, 1997) default factors for natural gas production, natural gas consumption, oil production, oil consumption, and venting and flaring for 1990, 1995, and 2000 emissions.

- Multiply appropriate oil and natural gas production and consumptions statistics for 1990, 1995, and 2000 by IPCC (IPCC, 1997) default factors.

- If country-provided historical data combines oil and natural gas emissions into one estimate, EPA determines the percentage of emissions generated from each industry sector using the IPCC Tier 1 methodology. EPA applies this percentage to country-provided historical data to determine the approximate emissions associated with each industry.

- For missing historical years, EPA extrapolates emissions based on changes in oil and natural gas production and consumption from EIA (EIA, 2002).

If emissions are not reported and EIA production data are not available, EPA assumes zero emissions for this source.

Projected Emissions

Activity Data

Projections of natural gas and oil production and consumption are available from the EIA (EIA, 2002). EPA uses growth rates as provided by EIA "reference case" projections for 2000-2005, 2005-2010, 2010-2015, and 2015-2020. These are available by country or region.

Emissions

EPA applies the average annual consumption growth rate for the corresponding periods, to the emissions attributed to consumption of oil and the average annual production growth rate, for the corresponding periods, to the emissions attributed to production of oil. For natural gas, only a consumption rate is provided; consequently, EPA applies this rate to all reported natural gas emissions to project emissions to 2020.

Adjustments to General Approach

Azerbaijan, Kazakhstan, Turkmenistan and Uzbekistan: The countries of the Former Soviet Union (FSU) are expected to be key producers in the future. Since EIA (EIA, 2002) provides only natural gas consumption projections, EPA used country-specific production projections to 2020 from *Oil and Gas Journal* (OGJ, 2001).

Uncertainties

The greatest uncertainties are due to the use of default emission factors, and difficulties in projecting oil and natural gas consumption and production through 2020 for rapidly changing global economies such as those in the FSU and developing Asia. In addition, methane emissions from oil and natural gas systems are not linearly related to throughput, so the IPCC Tier 1 methodology and emission factors can lead to overestimates.

Appendix B-1 presents historical and projected emissions for all countries for this source. Appendix E-1 contains data sources and methodology summaries for each country.

7.2.2 Methane from Coal Mining Activities

If no estimates are available or the data are insufficient, EPA uses the IPCC Tier 1 methodology to estimate emissions. The Tier 1 basic equation to estimate fugitive methane emissions from underground, surface, and post-mining operations is as follows:

$$\textit{Fugitive } CH_4 \textit{ Emissions} = \textit{Annual Coal Production} \times \textit{Emission Factor}$$

Assuming that the emission factors do not change, the driver for determining fugitive methane emissions from coal mining is coal production. Because a default methodology for fugitive emissions from abandoned mines is not currently available, this source is not considered in this report.

If a country does not report emissions and does not produce coal domestically according to both the *International Energy Outlook* (EIA, 2002) and the International Energy Agency (IEA), methane emissions are assumed to be zero.

Unless otherwise noted, EPA assumes that hard coal is produced in underground coal mines and soft coal is produced in surface mines. However, this assumption does not have a major impact on the overall emission estimates for this category because most countries that do not report fugitive methane emissions from coal mining have relatively insignificant levels of coal production.

Historical Emissions

<u>Activity Data</u>

- EPA obtains historic coal production data from 1980 to 2000 (EIA, 2002).

<u>Emission Factors and Emissions</u>

- EPA multiplies hard coal production for 1990, 1995, and 2000 by IPCC (IPCC, 1997) default factors for underground and associated post-mining activities.

- EPA multiplies soft coal production for 1990, 1995, and 2000 by IPCC (IPCC, 1997) default factors for surface and associated post-mining activities.

Projected Emissions

Activity Data

- EPA extrapolates production data from 2000 to 2020, with each five-year interval based on changes in coal production from 1995 to 2000.

- EPA assumes a zero production level for regions if production is projected to fall below zero.

Emission Factors and Emissions

- EPA projects emissions to 2020 based on estimates of future coal production, using average emission factors based on the IPCC high and low default values (IPCC, 1997).

Adjustments to General Approach

For a few countries, EPA adjusts the above methodology, as outlined below:

China: China is one of the countries for which methane emission estimates through 2020 are available (UNDP, 1998). However, energy policy in China has changed significantly since the report was published. By 1999, coal production fell below 1990 levels. To account for the unexpected reduction in coal production, EPA adjusts the estimates from 2000 to 2020 as follows:

- The emission factor is assumed to remain the same as in the United Nations Development Programme (UNDP) analysis. UNDP provides projections of coal production for each 10-year increment, including the year 2000. The implied emission factor is determined by dividing the emissions by the production.

- The updated production estimate for 2000 (EIA, 2002) is multiplied by the implied emission factor to produce an adjusted emission estimate for 2000.

- For 2005 to 2020, emissions are estimated by applying the growth rates from UNDP to the adjusted 2000 emission estimate.

- Estimates derived using the method outlined above are scaled to the1994 estimate provided in China's First National Communications.

India: The First National Communications provides methane emission estimates for 1994. World Energy Council (WEC, 2000) reports production estimates for 2000 to 2020. The projected production is in line with reports that India's coal production will potentially double by 2010 (Mining India, 2000).

The 1994 estimate is extrapolated through 2020 based on changes in coal production, assuming the average emission factor will remain constant.

Kazakhstan and Uzbekistan: In the early 1990s, the countries of the Former Soviet Union (FSU) began a transition to market economies. This transformation led to an economic downturn in many sectors, including coal mining. As these countries recover, coal production is expected to stop decreasing as quickly. Therefore, projecting emissions based on recent coal production trends would likely lead to underestimated emissions. To account for the unique situation of these countries, emission estimates after 2000 were assumed to follow the trend predicted for Russia.

North Korea: Using the general methodology, coal production and thus emissions, are projected to decline drastically from 2000 to 2020. This trend seems unlikely as coal is expected to remain the key energy source in North Korea. North Korea does not export coal and imports only a small amount of coal. Assuming this trade situation remains the same, coal consumption was used to determine production.

- For 2000 through 2020, EPA assumes coal production grows at the same rate as coal consumption in developing Asia (EIA, 2002).

- EPA multiplies the projected coal production by the default emission factors to determine projected methane emissions through 2020.

South Korea: In the 1990s, South Korea began supporting programs to decrease coal production and consumption for local environmental reasons. The recent coal production decline is not likely to continue, however, and appears to have been leveling off in the last few years. There may be some additional decline similar to the most recent years. As a result, coal production decline rates are kept constant at the 2000-2005 level.

Russia: Estimates from 1990 to 2010 are from Russia's Third National Communications. Projected emissions from 2010-2020 are based on a draft EPA report that focused exclusively on historical and projected coal mining methane emissions in Russia. For the majority of underground mines, the methodology is consistent with the IPCC Tier 3 methodology, using measurement data collected by the individual mines. For the remaining underground mines and for surface and post-mining, EPA estimates emissions using the IPCC Tier 2 methodology. To determine the projected emissions, the total projected coal production for that year is multiplied by the share of coal production in the region for the year, and then multiplied by the average 1990-1998 emission factor for the specific region. Projected estimates derived using the method described above are scaled to the estimates reported in Russia's Third National Communications.

Poland: The National Communication reports that emissions are expected to decline sharply by 2010, largely due to anticipated closings of a large number of privatized mines. The pace of mine closures might be slower than anticipated, however, because of social and economic considerations. Unlike Germany and the United Kingdom (U.K.), which are expecting drastic reductions in coal production, the Polish economy is largely coal-based (97 percent of energy consumption (IEA, 2002)), with negligible natural gas and oil reserves. Also, Poland will continue to sell some coal to foreign markets to earn foreign currency. Many of Poland's highest methane producing mines are located near major industries, and there is the possibility of increased methane recovery and use, especially as mines try to remain profitable. With the expected closing of high-methane producing longwall mines and modest increases in methane recovery and use, it is expected that coal emissions will decline 5 percent over each five-year period to 2010.

Uncertainties

The greatest uncertainties are due to the use of default emission factors, and difficulties in projecting coal production through the year 2020 for rapidly changing global economies, such as those in developing Asia. The assumption that all production comes from underground mines if emissions are not reported could result in estimates that are significantly higher than actual emissions because default underground mining emission factors are 10 times greater than surface mining emission factors. However, this uncertainty does not have a major impact on the estimates because the countries that report emissions account for over 95 percent of annual global coal production and over 90 percent of estimated global emissions.

Appendix B-2 presents historical and projected emissions for all countries for this source. Appendix E-2 contains data sources and methodology summaries for each country.

7.2.3 Nitrous Oxide and Methane Emissions from Stationary and Mobile Combustion

If no historical nitrous oxide and methane emissions data are available or the data are insufficient, EPA developed emissions using fuel consumption data from the International Energy Agency's (IEA) Energy Balances (IEA, 2001a; IEA, 2001b) and the IPCC Tier 1 methodology. If no projections are available, EPA develops projections by applying projected growth rates of energy consumption from IEA's World Energy Outlook (WEO) (IEA, 2001c) to historical emission estimates.

The basic equations to estimate emissions from mobile and stationary sources are as follows:

$$CH_4 \text{ Emissions} = \text{Annual Fuel Consumption (by sector and fuel type)} \times \text{Emission Factor (by sector and fuel type)}$$

$$N_2O \text{ Emissions} = \text{Annual Fuel Consumption (by sector and fuel type)} \times \text{Emission Factor (by sector and fuel type)}$$

For mobile sources, some emission factors also vary by mode (aviation, road, railway, and navigation). Assuming that the emission factors do not change over time, the driver for determining nitrous oxide and methane emissions from stationary and mobile sources is fuel consumption.

Table 7-1 presents the IEA- and IPCC-defined sectors and modes that constitute stationary and mobile combustion. Table 7-1 shows how the IEA categories fit into the IPCC-defined sectors.

Table 7-1. Sectors and Modes

IEA-Defined Sectors	IPCC-Defined Sectors
1. Energy Industries[a]	1. Energy Industries
2. Total Industry Sector	2. Manufacturing Industries and Construction
3. Total Transport Sector	3. Transport
- International Civil Aviation	*(not used, bunker fuels)*
- Domestic Air Transport	- Aviation
- Road	- Road
- Rail	- Railways
- Pipeline Transport	*(used EF for Manufacturing Industries and Construction)*
- Internal Navigation	- Navigation
- Non-specified Transport	*(assumptions depends on fuel type)*
4. Total Other Sectors	4. Total Other Sectors
- Agriculture	- Agriculture/Forestry/Fishing
- Commercial and Public Services	- Commercial/Institutional
- Residential	- Residential
- Non-specified Other	*(used EF for residential or agriculture)*

[a] This sector comprises an aggregate of categories assumed to consume fuel primarily for the generation of heat and power. This determination was made after consultation with both IEA and ICF energy experts. The following categories are included: public electricity plants, autoproducer electricity plants, public combined heat and power (CHP) plants, autoproducer CHP plants, public heat plants, autoproducer heat plants, and own use.

Historical Emissions

If the historical time series of emissions is incomplete, EPA uses annual growth rates for energy consumption from IEA's Energy Balances (IEA, 2001a; IEA, 2001b) to backcast and forecast emissions to the missing years. For a few countries, no fuel consumption data are available from IEA's Energy Balances. In these cases, EPA applies annual growth rates for energy consumption by region from IEA's WEO to backcast and forecast emissions from available historical data. The WEO provides rates for 1971-1997 and 1997-2010.

If no historical emissions estimates are available, EPA estimates emissions for a country and/or region using the IPCC Tier 1 methodology. This methodology allows for an estimate of emissions by sector and primary fuel type. The following inputs are used to estimate emissions:

Activity Data

- Fossil fuel consumption data by country, fuel product, and sector use are collected from IEA's Energy Balances for all major fuel types (IEA, 2001a; IEA, 2001b). The sectors included in the analysis are listed in Table 7-1. The main fuel categories includes coal, oil, and natural gas (see Table 7-2 for a listing of product categories). Biomass combustion emissions are not calculated, but are included (for non-Annex I countries) in the category *Biomass Combustion*, and discussed in Section 7.2.4.

Table 7-2. Fuel Types Included Under Main Fossil Fuel Categories

Coal	Natural Gas	Oil
Hard Coal	Natural Gas	Crude
Brown Coal	Refinery Gas (in metric tons)	Motor Gasoline
Coke Oven Coke	Ethane	Aviation Gasoline
Gas Coke	Liquefied Petroleum Gases	Gasoline – Type Jet Fuel
Peat	Gas Works Gas	Kerosene – Type Jet Fuel
Brown Coal/Peat Briquettes (BKB)	Coke Oven Gas	Kerosene
	Blast Furnace Gas	Gas/Diesel Oil
	Oxygen Steel Furnace Gas	Residual Fuel Oil
		Petroleum Coke
		Non-specified Petroleum Products
		Naphtha
		Patent Fuel

Source: IEA, 2001a; IEA, 2001b

Emission Factors and Emissions

- EPA multiplies the IEA fuel consumption data by the IPCC Tier 1 nitrous oxide and methane uncontrolled emission factors for each fuel type and sector to obtain emissions.

Projected Emissions

- EPA projects emissions based on forecasts of coal, oil, and natural gas consumption for each region/country, by sector, provided by IEA WEO (IEA, 2001c).[2] Use of IEA WEO data assumes that countries within the same region have the same growth rate. EPA applies the forecasted annual growth rate of fuel consumption to emissions, based on the following scenarios:

    - Ø For 2000, 2005, and 2010: EPA forecasts 2000, 2005, and 2010 emissions using the 1997-2010 annual growth rate for energy consumption for the appropriate region, by sector and fuel type.

    - Ø For 2015 and 2020: EPA forecasts 2015 and 2020 emissions using the 2010-2020 annual growth rate for energy consumption for the appropriate region, by sector, and fuel type.

Appendices B-3 and C-1 present historical and projected emissions for all countries for this source. Appendix E-3 contains data sources and methodology summaries for each country.

Uncertainties

Large uncertainties are associated with the IPCC Tier 1 default emission factors used to calculate emissions. The IPCC Good Practice Guidance estimates uncertainty for the methane combustion emission factors at ±50 to 150 percent. Uncertainty for nitrous oxide combustion emission factors are estimated to be "an order of magnitude," and are highly uncertain due to limited testing data on which the factors are based. Also, the use of uncontrolled IPCC default emission factors may overestimate emissions in those developing countries that have adopted some level of emission control strategies for combustion sources.

Higher certainty is associated with the aggregate fuel consumption data on which estimates are based, due to well-developed statistical approaches and surveys used to collect IEA data.

[2] The regions and countries are: Transition Countries, Russia, China, South Asia, India, East Asia, Latin America, Brazil, Africa, and the Middle East.

Estimates of uncertainty for fossil fuel consumption data range from ±3 to 20 percent (IPCC, 2001).

7.2.4 Methane and Nitrous Oxide Emissions from Biomass Combustion

The basic equation to estimate emissions from biomass combustion is as follows:

*Emissions = Emission Factor * Activity*

Where:

- The emission factor is specific to each fuel type (solid biomass, charcoal, liquid biomass, other) and sector (such as energy industries and manufacturing).

- The activity is the energy input in terajoules (TJ) or metric tons of fuel.

Historical Emissions

If only 1990 reported emissions estimates are available from the National Communication, Asia Least-Cost Greenhouse Gas Abatement Strategy (ALGAS), or Country Study report, the remainder of the historical time series is based on applying growth rates to this base year estimate as follows:

- EPA applies regional (or country-specific when available) annual growth rates to the emissions estimates to fill out the rest of the historical series emissions. Compound growth rates are directly from Part D of International Energy Agency's (IEA) World Energy Outlook (WEO) 2000, Combustible Renewables and Waste (CRW) category (IEA, 2001a), for the years through 2010.

If historical emissions are not reported for any part of the time series, EPA applies the following steps:

<u>Activity Data</u>

- EPA establishes historical energy demand for each country, using 1990, 1995, and 1999 consumption data from the IEA Energy Statistics of non-OECD countries (IEA 2001b).[3] Consumption data are presented for the following sectors and subsectors: total solid biomass composed of industry (energy and manufacturing), transportation, and non-energy use; other (which is composed of residential, commercial, agricultural, and unspecified other); liquid biomass; charcoal; and industrial waste.

- EPA forecasts 2000 emissions by applying annual growth rates from Part D of IEA's WEO 2000, CRW category, EPA applies country-specific growth rates when they are available; otherwise it applies regional growth rates to the year 2000. In projecting consumption, the distribution of energy supplied by biomass into the relevant subsector is assumed to stay constant.

<u>Emission Factors and Emissions</u>

- EPA determines methane and nitrous oxide emissions from biomass combustion by multiplying activity data (i.e., biomass fuel consumption by sector for each country) by uncontrolled, default Tier 1 IPCC emission factors.

[3] For Mexico and Turkey, consumption data are from IEA Energy Statistics of OECD Countries (IEA, 2001c).

Projected Emissions

Activity Data

- EPA uses 2000 as base year to project biomass fuel consumption in 2005 and 2010. Compound growth rates are directly from Part D of IEA's WEO 2000, CRW category, for the years through 2010. For the 2015 and 2020 estimates, the growth rate is calculated from projected regional consumption reported in WEO 2000.

Emission Factors and Emissions

- The emission factors used to calculate projected emissions are the same IPCC default factors used in the historical time series calculations.

Adjustments to General Approach

EPA does not develop estimates for biomass combustion for Annex I countries. Emissions for these countries are extracted from the 2005 CRFs and are included under stationary and mobile combustion.

Uncertainties

Emission factors for biomass fuel are not as well developed as those for fossil fuels due to limited test data for the variety of types and conditions under which these fuels are burned. Uncertainties are at least as great as those for fossil fuel nitrous oxide and methane factors (± 50 to 150 percent).

Activity data for biomass fuel combustion also tends to be much more uncertain than fossil fuels due to the smaller, dispersed and localized collection and use of these fuels, which makes tracking consumption more difficult. Estimates in IPCC Good Practice Guidance suggest uncertainties in the range of ±10 to 100 percent.

Appendices B-4 and C-2 present historical and projected emissions for all countries for this source. Appendix E-4 contains data sources and methodology summaries for each country.

7.2.5 Nitrous Oxide Emissions from Adipic Acid and Nitric Acid Production

If no country-reported estimates are available, EPA uses the IPCC Tier 1 methodology to estimate emissions. The basic Tier 1 equation to estimate emissions from adipic acid production is as follows:

$$N_2O \text{ emissions} = \text{Adipic Acid Production} * \text{Emission Factor}$$
$$[1 – (\text{Destruction Factor} * \text{Abatement Utility Factor})]$$

The basic Tier 1 equation to estimate emissions from nitric acid production is as follows:

$$N_2O \text{ emissions} = \text{Nitric Acid Production} * \text{Emission Factor}$$

Historical Emissions - Adipic Acid Production

Activity Data

- Production data are estimated based on adipic acid plant capacity figures and estimated capacity utilization (*Chemical Week,* 1999a). Capacity utilization is assumed to be 75 percent for 1990, 80 percent for 1995, and 90 percent for 2000.

Emission Factors and Emissions

- The IPCC uncontrolled default emission factor for nitrous oxide generation (IPCC, 2000) is applied to all plants with the exception of one plant in Singapore, which has abatement technology. The destruction factor for this plant is assumed at 98 percent and abatement utility factor at 95 percent (Reimer, 2000).

Projected Emissions – Adipic Acid Production

Activity Data

- Production is forecast to increase by 2 percent annually until 2010 and 1 percent per year from 2011 to 2020 based on various expert projections and a historical growth of 2 percent per year (CMR, 1998; SRI Consulting, 1999; Reimer, 2000).

Emission Factors

- Emission factors used for projections are the same as those used in historical time series calculations.

Historical Emissions - Nitric Acid Production

Activity Data

- Nitric acid production for China, Brazil, and Mexico is estimated based on production figures from various sources (*C&EN, 1997; Chemical Week, 1999a, BICCA, 2000*). For other countries, production figures are estimated based on regional fertilizer plant capacities and estimated capacity utilization (*Chemical Week*, 1999b).

Emission Factors and Emissions

- The emission factor for developing countries is assumed to be 10 kilograms N_2O per metric ton nitric acid (IPCC, 2000).

- Non-selective catalytic reduction is assumed to reduce emissions by 80 percent. It is estimated to be used in 1 percent of plants in Asia.

Projected Emissions - Nitric Acid Production

Activity Data

Emissions from nitric acid production are projected based on increases in fertilizer production as discussed in the agricultural soils section (see Section 7.2.6).

Emission Factors

- Emission factors used for projections are the same as those used in the historical time series calculations.

Uncertainties

In general, IPCC default adipic acid emission factors are more certain than nitric acid emission factors because they are derived from stoichiometry of the process chemical reaction. IPCC Good Practice Guidance estimates uncertainty for adipic acid emission factor at ±10 percent, and for nitric acid emission factor at -20 to +90 percent based on the range provided for “other countries” (IPCC, 2000).

Regarding activity data, estimates of nitric acid production derived from national fertilizer usage are much more uncertain than those from published nitric acid production statistics. Fertilizer production capacities are used as a surrogate for actual production and may not reflect true annual production of nitric acid, which has other uses besides fertilizer production.

Appendix C-3 presents historical and projected emissions for all countries for this source. Appendix E-5 contains data sources and methodology summaries for each country.

7.2.6 Nitrous Oxide Emissions from Agricultural Soils

If no country-reported estimates are available, EPA uses the IPCC Tier 1 methodology to estimate emissions. EPA estimates nitrous oxide for five components of nitrous oxide emissions from agricultural soils:

- Direct emissions from commercial synthetic fertilizer application
- Direct emissions from cultivation of nitrogen-fixing crops
- Direct emissions from the incorporation of crop residues
- Direct emissions from manure (pasture, range and paddock and all applied manure)
- Indirect emissions from agricultural soils.

Appendix F presents the detailed methodology and country-specific approaches the EPA used to estimate nitrous oxide emissions from agricultural soils

Historical Emissions

Activity Data

EPA obtained activity data on fertilizer consumption, corn, wheat, soybean, and pulse production and animal populations from the Food and Agriculture Organization (FAO, 2002).

Projected Emissions

Activity Data

For estimating emissions for 2005 to 2020, EPA projects country-specific activity data based on (1) FAO regional fertilizer consumption growth rate for 1995 and 1997 to 2015 for direct emissions from fertilizer usage, (2) the historical 1990 to 2000 crop growth rate for direct emissions from nitrogen-fixing crops and crop residues, and (3) International Food Policy Research Institute (IFPRI) livestock population growth rates for direct emissions from manure applied to soils. Using the projected activity data and IPCC Tier 1 methodology, EPA calculates 2005 to 2020 emissions.

Adjustments to General Approach

- To develop "Rest-of-World"[4] emissions from agricultural soils, EPA obtains activity data from FAO for production of soybeans, pulses, corn, and wheat (FAO, 2001), nitrogenous fertilizer use, and animal populations (FAO, 2002) for each country in the "Rest of…" regions for 1990 to 2000. EPA combines these data into one value (e.g., all the fertilizer consumption in Kyrgystan and Tajikistan were combined into one "Rest of Former Soviet Union" fertilizer consumption value). The same methodology as described above was used to estimate emissions for the regions.

- For growth rates in crop production (all years) and manure applied to soils (all years), EPA uses a rate that was determined by summing the activity data from all "Rest-of-World" countries in a given region for 1990 and the latest year available, and then determining the growth rate from those two numbers. For example, to obtain the Rest of China/CPA

[4] The countries combined under "Rest of World" groupings for this source category differ slightly from the other categories. For all other categories, Kyrgystan, Tajikistan, Cambodia, and Laos were reported as individual countries.

region crop production growth rate, EPA sums the crop production of Cambodia and Laos in 2000 and in 1990. Then, from those summed numbers, EPA determines the growth rate over the time period just as was done for individual countries. To project activity data, these growth rates for crop production and manure applied to soils are applied to the latest corresponding activity data available. For fertilizer consumption beyond 2000, EPA uses the regional growth rates provided by FAO (2000) to project activity data.

Uncertainties

The greatest uncertainties are in the completeness of the activity data used to derive the emissions estimates. Emissions from fertilizers are estimated from only synthetic fertilizer use. In reality, organic fertilizers (other than the estimated manure and crop residues) also contribute to nitrous oxide emissions from soils, but this activity is not captured in these estimates. Only two nitrogen-fixing crops are used in these estimates; other crops besides soybeans and pulses fix nitrogen and therefore contribute to nitrous oxide emissions. Similarly, other crop residues besides soybeans, pulses, corn, and wheat may be left on the field, thus resulting in nitrous oxide emissions. The identity and quantity of these crops would vary among the different countries. The livestock nitrogen excretion values, while based on detailed population statistics, do not accurately reflect country-to-country variations in animal weight or feeding regimes. Finally, emissions from histosols and from sewage sludge are not calculated or included in these estimates. Though small components of the total nitrous oxide emissions from this source category, both of these sources do contribute to emissions.

Uncertainty also exists in the projected emissions. For many subcategories, growth is based on historical trends. Additionally, when EPA uses previously published projections, they are on a regional level, not a country-specific level.

Appendix C-5 presents historical and projected emissions for all countries for this source. Appendix E-6 contains data sources and methodology summaries for each country.

7.2.7 Methane Emissions from Enteric Fermentation

The basic equation to estimate emissions from enteric fermentation is as follows:

Emission Factor (kg/head/yr) x Animal Population (head) /(10^6 kg/Gg) = Emissions (Gg/yr)

The default emission factors are taken from the IPCC Guidelines (IPCC, 1997) and the population data are obtained from the Food and Agriculture Organization (FAO, 2003). Assuming that the animal characteristics upon which the default emission factors are based do not change significantly over time, the primary driver for determining methane emissions from enteric fermentation is animal population.

Historical Emissions

If reported estimates are not available, EPA uses the IPCC Tier 1 methodology for each country for which FAO animal population data are available.

<u>Activity Data</u>

- EPA obtains 1990, 1995, and 2000 animal population data from FAO. Populations of non-dairy cattle are obtained by subtracting FAO dairy cattle populations from FAO total cattle populations. These data are modified for several countries. In 1990, animal population data were not available for certain countries that were formed after the breakup of the Former Soviet Union (FSU) (Latvia, Moldova, Ukraine, Uzbekistan, and others), Yugoslavia (Bosnia, Croatia, Macedonia, Slovenia, and Serbia and Montenegro), Czechoslovakia (Czech Republic and Slovakia), and Ethiopia (Ethiopia and Eritrea). Therefore, for each region, EPA determines the percent contribution of each country to its regional total using 1995 animal population data. EPA then applied these percentages to estimate 1990 animal population for these countries.

Emission Factors

- Tier 1 default emission factors from the IPCC Guidelines are used in the calculated emissions. For buffalo, sheep, goats, camels, horses, mules and asses, and swine, enteric fermentation emission factors for “developing countries” were used. For dairy and non-dairy cattle, enteric fermentation emission factors for world regions are used, with factors assigned to countries based on the region in which they are located.

Projected Emissions

Activity Data

- EPA uses reported estimates for 2005, 2010, 2015, and 2020 if possible. If projections are not available, EPA projects emissions from 2005-2020 based on livestock population growth rates developed by International Food Policy Research Institute (IFPRI, 2004).[5] The IFPRI dataset contains population estimates for the years 2000, 2010, and 2020 for each of the main livestock species reported by country and world regions. Average annual growth rates for the periods 2000-2010 and 2010-2020 are developed from these estimates. Starting with the historical year 2000 FAO animal population statistics, these growth rates are then applied to obtain 2005, 2010, 2015, and 2020 populations for each livestock species.

Emission Factors

- Emission factors used for calculating projections are the same as those described above for the historical time series calculations.

- Projected populations for each livestock species are multiplied by the animal-specific emission factors to obtain projected methane emissions.

Uncertainties

The greatest uncertainties are associated with the use of default emission factors due to the lack of information on country-specific animal diets. Emission estimates for countries with a variety of animal diets could be inaccurate, particularly when projecting emissions since there is a lack of information on potential changes in the quality, quantity, and type of feed that could affect emissions in future years. Also, the impacts of world markets and consumption patterns on national livestock production patterns are often difficult to predict, further increasing the uncertainty of projected emissions from this source.

Appendix B-6 presents historical and projected emissions for all countries for this source. Appendix E-7 contains data sources and methodology summaries for each country.

7.2.8 Methane Emissions from Rice Cultivation

The IPCC Good Practice Guidance (IPCC, 2000) provides the following overall equation for the calculation of methane emissions from rice production:

$$\textit{Emissions from Rice Production (Tg/yr)} = S\ S\ S\ (EF_{ijk} * A_{ijk} * 10^{-12})$$

Where:

EF_{ijk} = A seasonally integrated emission factor for i, j, and k conditions in g CH_4/m^2;

A_{ijk} = Annual harvested area for i, j, k conditions in m^2/yr; and

[5] The IFPRI growth rates are generated by a model that incorporates supply and demand parameters. These parameters include the feed mix applied according to relative price movements, international trade, national income, population, and urban growth rates as well as anticipated changes in these rates over time.

i,j,k = Represent different ecosystems, water management regimes, and other conditions under which methane emissions from rice may vary.

Rice emissions vary according to the conditions under which rice is grown. Using the approach outlined above, the harvested area can be subdivided by different growing conditions (e.g., water management regime) and multiplied by an emission factor appropriate to the conditions. The sum of these individual products represents the total national estimate.

In practice, it is difficult to obtain specific emission factors for each commonly occurring set of rice production conditions in a country, so the IPCC Guidelines instruct countries to first obtain a baseline emission factor (EF_c) for continuously flooded fields without organic amendments. Different scaling factors are then applied to this seasonally integrated emission factor to obtain an adjusted seasonally integrated emission factor for the harvested area as follows:

$$EF_i = EF_c * SF_w * SF_o * SF_s$$

Where:

EF_i = Adjusted seasonally integrated emission factor for a particular harvested area

EF_c = Seasonally integrated emission factor for continuously flooded fields without organic amendments

SF_w = Scaling factor to account for the differences in ecosystem and water management regime

SF_o = Scaling factors for organic amendments (should vary for both type and amount of amendment applied)

SF_s = Scaling factor for soil type, if available.

Historical Emissions

If no estimates are available, EPA uses the IPCC Tier 1 methodology for each country/region, as detailed below:

<u>Activity Data</u>

- EPA obtains data on area harvested for rice cultivation from 1990 through 2000 (FAO, 2001).
- EPA obtains information on type of water management regime (upland, irrigated, rain-fed, or other) from International Rice Research Institute (IRRI, 2001). If information is not available from IRRI, data are obtained from the IPCC Guidelines (IPCC, 1997).

<u>Emission Factors</u>

- Country-applicable emission factors are developed for each of the five main water management types: irrigated (constantly flooded), irrigated (intermittently flooded), rain-fed lowland (flood-prone), rain-fed lowland (drought-prone), and upland. Starting point emission factors obtained from IPCC (IPCC, 1997) are based on the continuously irrigated water regime. Scaling factors from IPCC (IPCC, 2000) are then applied to adjust the starting point emission factor for each of the other water regimes. The scaling factors

0.35, 0.8, 0.4, and 0, are used for intermittently flooded, rain-fed lowland (flood-prone), rain-fed lowland (drought-prone), and upland, respectively.[6]

- In addition to the scaling factors discussed above, emission factors are further adjusted to account for the use of organic amendments (fertilizers) and the increased emissions from soils to which organic amendments are applied. A factor of two is applied to 40 percent of rice production to account for organic amendments. The factor of two is based on the IPCC-recommended default correction factor of two, while the 40 percent figure is an assumption based on expert opinion, and is applied equally to all country-specific emission factors.

- The combination of all the above adjustment factors provides the adjusted country-specific emission factors used in the emission equation above.

- If a country is similar to a country with a IPCC published emission factor, that emission factor was used:

  - Ø Thailand's emission factors are applied to Laos, Malaysia and Cambodia.

  - Ø India's emission factors are applied to Bhutan and Nepal.

- Irrigated Land: Due to limited information, EPA assumes that all irrigated land is continuously flooded with no aeration. This assumption is conservative and could lead to overestimates in emissions.

- Rainfed Land: Proportions of flood-prone and drought-prone rain-fed paddy types are based on country-specific allocations published in IPCC (IPCC, 1997) for 19 of 26 countries. For remaining countries, equal allocations of rain-fed total allocation are made to drought-prone and flood-prone types.

<u>Emissions</u>

- EPA multiplies area harvested for 1990, 1995, and 2000 by percentage in each water management type.

- EPA multiplies area harvested for each year and in each water management type by appropriate emission factor (IPCC, 1997; IPCC, 2000).

- EPA sums methane emissions from each water management type.

If no reported emissions or FAO/IRRI production data are not available, EPA assumes zero emissions from this source.

Projected Emissions

If projections are not available, EPA uses the following methodology to project emission estimates:

<u>Activity Data</u>

- Due to the lack of projections on future rice area harvested, EPA uses population as the driver for methane emissions from rice cultivation. Since this does not account for increases in yield or lack of available area, this methodology is likely to overestimate emissions in 2020.

[6] The adjustment factor 0.35 is used for intermittently flooded irrigated lowlands (relative to IPCC emission factors specific to continuously flooded fields). This value is calculated as the average of 0.5 (range of 0.2 – 0.7) and 0.2 (range of 0.1 – 0.3), respectively the IPCC-recommended scaling factors for single aeration and multiple aeration, which are the two subsets of the intermittently flooded category.

- EPA obtains population projections from *World Population Prospects: the 2002 Revision,* published by the United Nations Population Division (UN, 2003). EPA uses these population projections to create growth rates for each country and region for each five-year increment from 2000 to 2020.

<u>Emissions</u>

- EPA applies the population growth rates to the historical emissions attributed to rice cultivation to develop projections at five-year intervals.

Uncertainties

Significant uncertainties are in the estimation of methane emissions from rice cultivation. The default emission factors are one of the greatest uncertainties. The IPCC emission factor is country-specific for only a few countries. It is adjusted for water management, but, it is not adjusted for other parameters such as ratooning. Also, country-specific information is not readily available on the amount of organic amendment, flooding, and aeration in irrigated areas. A significant area of uncertainty is the use of population as a driver for projecting harvested area. Future work will examine the historic relationship between demand, yield, and area harvested to improve projections of rice production areas.

Appendix B-7 presents historical emissions and projected emissions for all countries for this source. Appendix E-8 contains data sources and methodology summaries for each country.

7.2.9 Methane and Nitrous Oxide Emissions from Manure Management

Many developing countries report estimates of methane emissions and some countries also report nitrous oxide emissions for manure management; however, there is generally less coverage of nitrous oxide emissions in the published inventory data.

The basic equation to estimate emissions from manure management is as follows:

$$\text{Emission Factor (kg/head/yr)} \times \text{Animal Population (head)} / (10^6 \text{ kg/Gg}) = \text{Emissions (Gg/yr)}$$

The default emission factors are taken from the IPCC Guidelines and IPCC Good Practice Guidance and the population data are obtained from the Food and Agriculture Organization (FAO, 2003). Assuming that the waste management and animal characteristics upon which the default emission factors are based do not change significantly over time, the key driver for determining emissions from manure management is animal population.

Historical Emissions

If reported estimates are not available, EPA uses the IPCC Tier 1 methodology for each country for which FAO animal population data are available.

<u>Activity Data</u>

- EPA obtains 1990, 1995, and 2000 animal population data from FAO (FAO, 2003).[7] Estimates for non-dairy cattle are obtained by subtracting FAO dairy cattle estimates from FAO total cattle estimates. The population data is modified in several instances. In 1990, animal population data are not available for certain countries that have since been established after the breakup of the Former Soviet Union (FSU) (Latvia, Moldova, Ukraine, Uzbekistan and others), Yugoslavia (Bosnia, Croatia, Macedonia, Slovenia, and Serbia and Montenegro), Czechoslovakia (Czech Republic and Slovakia), and Ethiopia (Ethiopia and Eritrea). Therefore, for each region, EPA determines the percent contribution of each

[7] 1990 and 2000 data for Pakistan for all livestock categories except poultry are obtained from Pakistan's ALGAS report. 1995 livestock population data are interpolated. 1990, 1995, and 2000 poultry data are obtained from FAO.

country to their regional total using 1995 animal population data. EPA then applies these percentages to estimate 1990 animal population for these countries.

<u>Emission Factors</u>

- For sheep, goats, camels and other camelids, horses, asses and mules, and poultry, emission factors for "developing countries" are obtained from the IPCC Guidelines.

- For cattle, swine and buffalo, emission factors from the IPCC Guidelines and IPCC Good Practice Guidance are used, and the selection depend on region and climate type (i.e., cool, temperate, and warm) for the country.

- EPA estimates climate type for most countries using data from the Global Historical Climatology Network, which is published by the National Climatic Data Center and contains annual average temperatures for most country's capital/major cities. These annual averages are for a range of years, which vary by country. Given the lack of animal population data by areas within a country, EPA assumes that 100 percent of the animal populations are located in a climate defined by the average temperature of the country capital.

- For Bolivia, Chile, Colombia, Ecuador, and Peru: Geographic Information System (GIS) information on temperature ranges is used to determine the climate type applicable to livestock areas in these countries (ESRI, 1999).

Projected Emissions

<u>Activity Data</u>

- If projections are not available, EPA projects emissions estimates from 2005-2020 based on livestock population growth rates developed by IFPRI (IFPRI, 2004).[8] The IFPRI dataset contains population estimates for the years 2000, 2010, and 2020 for each of the main livestock species reported by country and world regions. Average annual growth rates for the periods 2000-2010 and 2010-2020 are developed from these estimates. Starting with the historical year 2000 FAO animal population statistics, these growth rates are then applied to obtain 2005, 2010, 2015, and 2020 populations for each livestock species.

<u>Emission Factors</u>

- Emission factors for calculating projections are the same as those described above for the historical time series calculations.

- Projected populations for each livestock species are multiplied by the animal-specific emission factors to obtain projected methane emissions.

Uncertainties

The greatest uncertainties are due to the use of default emission factors due to the lack of information on country-specific manure management systems and the geographic concentration of animal populations, which affects the climate zone assignment. Considerable uncertainty in projected emissions is due to the lack of information on potential changes to management system types and animal feeding characteristics that could affect emissions in the future years. Also, the impacts of world markets and livestock product consumption patterns on national livestock production patterns are often difficult to predict, further increasing the uncertainty of projected emissions from this source.

[8] The IFPRI growth rates are generated by a model that incorporates supply and demand parameters. These parameters include the feed mix applied according to relative price movements, international trade, national income, population, and urban growth rates as well as anticipated changes in these rates over time.

Appendices B-8 and C-6 present historical and projected emissions for all countries for this source. Appendices E-9 (CH_4) and E-9b (N_2O) contain data sources and methodology summaries for each country.

7.2.10 Methane and Nitrous Oxide Emissions from Other Agricultural Sources

The sources included in this category are savanna burning, agricultural residue burning, and open burning from forest clearing. This category also includes minor amounts of country-reported emissions data on methane from agricultural soils. However, biomass burning constitutes the majority of emissions for this source.

1990 and 1995 estimates for biomass burning were obtained from the Emission Database for Global Atmospheric Research (EDGAR), Version 3.2 (Olivier and Berdowski, 2001), (Olivier, 2002). Estimates for 2000 were obtained from the EDGAR 3.2 Fast Track 2000 dataset (32FT2000) (Olivier, 2005). EDGAR sub-divides biomass burning into the following subcategories:

- Tropical forest fires; deforestation
- Savannah and shrubs fires
- Agricultural waste burning
- Middle and high latitude forest fires; temperate vegetation fires
- Indirect N_2O from tropical forest fires
- Middle and high latitude grassland fires (reported for 2000 only).

Data from all of these subcategories are included here.

Austria, Belgium, and Japan provided estimates for methane for agricultural soils.

Some of the inventory estimates may be incomplete, indicating that the values are not fully comparable. If a projection of future emissions is not available, future emissions are assumed to remain constant at the value for the latest reported year.

Appendices B-9 and C-7 present historical emissions estimates and projections for all countries

7.2.11 Methane Emissions from Landfilling of Solid Waste

If no estimates are available or the data are insufficient, EPA uses the IPCC Tier 1 methodology to estimate emissions. The Tier 1 basic equation to estimate fugitive methane emissions from landfills is as follows:

$$CH_4\ Emissions = (MSW_T * MSW_F * MCF * DOC * DOC_F * F * 16/12-R)*(1-OX)$$

Where:

MSW_T	=	Total municipal solid waste (MSW) generated = Population * waste generation per person
MSW_F	=	Fraction of MSW disposed to solid waste disposal sites
MCF	=	Methane correction factor (fraction)
DOC	=	Degradable organic carbon (fraction)
DOC_F	=	Fraction DOC dissimilated
F	=	Fraction of methane in landfill gas (default is 0.5)
R	=	Recovered methane
OX	=	Oxidation factor (fraction - default is 0)

Activity Data

- Urban population data are from the *World Population Prospects: the 2002 Revision,* published by the United Nations Population Division (UN, 2003).

Emission Factors

- The first two terms in the equation, MSW_T and MSW_F, are not readily available, thus these terms are estimated in aggregate using the following formula:
MSW disposal rate (kg/cap/day) x population (cap) x 365 (days/yr) / 10^6 (Gg/kg) = MSW disposed (Gg) = MSW_T x MSW_F

- The MSW disposal rate is from the IPCC Guidelines (IPCC, 1997) or the International Energy Agency (IEA, 1999).

- The MCF is from IPCC 1997 or IEA, 1999. Most countries use the IPCC default value for an uncategorized solid waste disposal site (SWDS) of 0.6. For the remaining countries, the MCF is calculated by multiplying the percent of MSW attributed to each SWDS type by its IPCC default correction factor and then summing these SWDS-specific products.

- DOC_F, R, and OX are IPCC default values (IPCC, 1997). The values for DOC are primarily from the IPCC Guidelines (IPCC, 1997), supplemented with values from IEA, 1999 if IPCC default values are not available.

- Oxidation (OX) and recovery (R) are assumed to equal zero.

Projected Emissions

If projections are not available, EPA uses the following methodology to project emission estimates:

Activity Data

- EPA obtains population projections from *World Population Prospects: the 2002 Revision* (UN, 2003), published by the United Nations Population Division. EPA uses these projections to determine growth rates for each country and region for each five-year increment from 2000 to 2020.

- EPA obtains Gross Domestic Product (GDP) projections by country from the World Bank.

Emission Factors

- The MSW per capita generation rate is assumed to increase at the rate of projected GDP.

- The proportion of wastes placed in landfills versus open dumps increases at the rate of per capita GDP growth.

Uncertainties

Uncertainties in the estimation of methane emissions from landfills are due in large part to the lack of one or more country-specific values for the following parameters: MSW generation per person, percent to MSW, percent to managed landfills, DOC fractions, oxidation factors, and recovery. Also, while the drivers for projections were selected to capture future trends in the movement of waste to MSW landfills, there is considerable uncertainty, particularly in the developing regions of the world, in predicting landfill utilization.

Appendix B-10 presents historical and projected emissions for all countries for this source. Appendix E-10 contains data sources and methodology summaries for each country.

7.2.12 Methane Emissions from Wastewater

The basic equation to estimate emissions from wastewater is as follows:

$$CH_4 \text{ Emissions} = \text{Emission Factor} * \text{Total Organic Waste}$$

Where:

Emission Factor	=	Maximum CH_4 producing capacity * the CH_4 conversion factor (MCF)
Maximum CH_4 Producing Capacity	=	Maximum amount of CH_4 that can be produced from a given quantity of wastewater
Methane Conversion Factor (MCF)	=	A weighted average of the amount of Wastewater handled by different systems times the appropriate MCF.
Total Organic Waste	=	Human population * the degradable organic component

Country-provided data are used for Annex I countries if they are available. For all other countries (non-Annex I and Annex I without available data), EPA calculates estimates for this category using the IPCC Tier 1 methodology for each country and/or region. The methodology is described in detail in Doorn (1999), with the exception of the emission factor. The maximum methane producing capacity, part of the emission factor, used in this analysis is 0.6 kg CH_4/kg biological oxygen demand (BOD), the recommended factor in the IPCC Good Practice Guidance.

Assuming that the emission factors do not change, the driver for determining methane emissions from wastewater is population. The emission factor may change with time, however, if countries modernize or change their handling and treatment systems as their GDP increases.

Appendix B-11 presents historical emissions estimates and projections for all countries. Appendix E-11 contains data sources and methodology summaries for each country.

7.2.13 Nitrous Oxide from Human Sewage

If no estimates are available or the data were insufficient, EPA uses the IPCC Tier 1 methodology to estimate emissions. The Tier 1 basic equation to estimate nitrous oxide from human sewage as follows:

$$N_2O_{(s)} = Protein \times Frac_{NPR} \times NR_{PEOPLE} \times EF_6$$

Where:

$N_2O_{(s)}$	=	N_2O emissions from human sewage (kg N_2O-N/yr)
Protein	=	Annual per capita protein intake (kg/person/yr)
NR_{PEOPLE}	=	Number of people in country.
EF_6	=	Emission factor (default 0.01 (0.002-0.12) kg N_2O-N/kg sewage N produced)
$Frac_{NPR}$	=	Fraction of nitrogen in protein (default = 0.16 kg N/kg protein)

Appendix C-8 presents historical and projected emissions for all countries for this source. Appendix E-12 contains data sources and methodology summaries for each country.

7.2.14 Other Non-Agricultural Sources

This category includes methane emissions sources such as waste combustion, metals production, and petrochemical production. It also includes nitrous oxide sources such as solvent use, waste combustion and miscellaneous industrial processes. These sources are typically small contributors compared to the primary sources discussed above. Some of the inventory estimates for these sources may be incomplete, indicating that the values are not fully comparable. If projected emissions are not available, future emissions are assumed to remain constant at the value for the last reported year. These "other non-agricultural" data are mainly from Annex I countries and are presented as either (other non-agricultural) industrial or waste-related emissions in Sections 4.9.1 and 6.5.1, respectively.

Appendices B-5, B-12, C-4, and C-9 present historical and projected emissions for all countries for this source.

7.3 Estimation and Projection Approaches Used for High Global Warming Potential Gases

High global warming potential (high GWP) gas emissions result from the use of substitutes for ozone-depleting substances (ODSs), from the production of aluminum, magnesium, semiconductors, flat panel display, HCFC-22, and electrical equipment, and from the use of electrical equipment[9]. Until recently, few nations have made significant efforts to track and project use and emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). If countries did present information on these gases, it was often incomplete or aggregated. Partial or aggregated estimates do not contain the level of detail required for this analysis; thus, EPA used the methods described below to estimate emissions from individual source categories.

7.3.1 The Technology-Adoption and No-Action Baselines

This report presents two future scenarios for five industries emitting high GWP gases for which clearly defined, industry-specific global or regional emission reduction goals have been announced. These industries include the primary production of aluminum, semiconductors, magnesium, and HCFC-22, and the use of electrical equipment. In response to concerns regarding the high GWPs and long lifetimes of their emissions, the global aluminum, semiconductor, and magnesium industries have committed to reduce future emissions by substantial percentages. Similarly, users (and, in some cases, manufacturers) of electrical equipment in Japan, Europe, and the U.S. have committed to reduce emissions in those countries and regions. Finally, HCFC-22 producers in several developing countries have agreed to host mitigation projects funded by developed countries under the Clean Development Mechanism (CDM) of the Kyoto Protocol. The HFC-23 abatement projects considered in this analysis are either registered or are in the process of being registered in the CDM pipeline. (HCFC-22 producers in developed countries are also continuing to reduce emissions.) These global and regional emission reduction goals are summarized in the table below.

[9] The production of electrical equipment is not included in this analysis.

Table 7-3. Global and Regional Emission Reduction Commitments

Industry	Global Industry Association, Region, or Country	Percent of World Production/ Emissions in 2003	Goal
Semiconductor Manufacturing	World Semiconductor Council (WSC)	85%	Reduce fluorinated emissions to 90% of 1995 level by 2010
Magnesium Manufacturing	International Magnesium Association (IMA)	70% (about 90% of sector's SF_6 emissions)	Phase out SF_6 use by 2011
Primary Production of Aluminum	International Aluminum Institute (IAI)	70% (but goal applies to entire industry)	Reduce PFCs/ton Aluminum by 80% relative to 1990 levels by 2010
Electrical Equipment (use)	EU-25+3[10], Japan, U.S.	40% of use emissions	Country-specific reductions from 2003 totaling 2.5 $MtCO_2eq$, or 15% of these countries' 2003 emissions from use.
HCFC-22 Production	China, India, South Korea, Mexico	65% of emissions	CDM projects totaling 55 $MtCO_2eq$, or 63% of these countries' 2010 emissions.

The first scenario presented in this report, called the "Technology-Adoption Baseline," is based on the assumption that these industries will achieve their announced global or regional emission reduction goals for the year 2010. The second scenario, called the "No-Action Baseline," is based on the assumption that emission rates will remain constant from the present onward in these industries.

EPA believes that actual future emissions are likely to be far closer to those envisioned in the Technology-Adoption Baseline than those envisioned in the No-Action Baseline. Since 1990, all five industries have already made great progress in reducing their emission rates, and research is continuing into methods to further reduce those rates. Nevertheless, additional actions will be required to actually realize additional reductions. These actions range from process optimization and chemical recycling to chemical replacement. Thus, depending on the context, either baseline may be of interest. For example, analysts interested in the incremental costs of reducing emissions below the levels anticipated in current global industry commitments can use the Technology-Adoption Baseline. On the other hand, analysts interested in the future costs of achieving the currently planned industry reductions can use the No-Action Baseline. The difference between the two baselines is itself of interest, demonstrating that the industry commitments are likely to avert very large emissions.

It should be noted that EPA modeled only those reduction efforts that had been clearly announced and quantified on an industry-specific basis at the time this report was being prepared. This means that even in the Technology-Adoption Baseline, significant reduction opportunities remain in 2010 and 2020, primarily in developing countries. This is particularly true for the HCFC-22 and electric power system industries. In fact, there is a significant probability that many of these emissions will be averted, e.g., by fuller implementation of CDM or other reduction efforts. However, the precise extent of additional reduction actions is uncertain. Thus, the Technology-Adoption baseline reflects only current, quantitative, industry-specific goals.

[10] The EU-25+3 includes the 25 member countries of the European Union (EU) and Norway, Switzerland, and Iceland. Appendix I contains a complete list of EU countries.

7.3.2 HFC and PFC Emissions from the Use of Substitutes for ODS

This section provides further detail on how EPA developed the baseline estimates for the various ODS substitute end-use sectors, which include refrigeration/air-conditioning, foams, aerosols, fire extinguishing, and solvents. In general, EPA used a modeling approach to determine emissions, because, until recently, few nations have made significant efforts to track and project use and emissions of HFCs and PFCs from ODS substitutes. However, where ODS substitute emission information was available, such as countries' submissions for the first National Communication process under the United Nations Framework Convention on Climate Change (UNFCCC), EPA used each country's data as the basis for projecting future emissions (the second National Communications were not yet available when this analysis was performed).

In the absence of reported data, EPA used the following approach. First, EPA used a "Vintaging Model" of ODS-containing equipment and products to estimate the use and emissions of ODS substitutes in the U.S. In the second step, emissions from non-U.S. countries were estimated. This was accomplished for each ODS-consuming end-use in each country. In developing these estimates, EPA initially assumed that the transition from ODSs to HFCs and other substitutes follows the same substitution patterns as the U.S. The U.S.-based substitution scenarios were then customized to each region or country using adjustment factors that take into consideration differences in historical and projected economic growth, the timing of the phaseout, and the distribution of ODS use across end-uses in each region or country. The methodology EPA used to estimate and adjust emissions is described in the following sections.

Estimating ODS Substitute Emissions in the U.S.

EPA uses the Vintaging Model of ODS- and ODS substitute-containing equipment and products to estimate the use and emissions of ODS substitutes in the U.S. The model tracks the use and emissions of each of the substances separately for each of the ages or "vintages" of equipment. The model and the equations used to estimate emissions are discussed in more detail in Appendix G.

The consumption of ODS and ODS substitutes was modeled by estimating the amount of equipment or products sold, serviced, and retired each year, and the amount of the chemical required to manufacture and/or maintain the equipment and products over time. The model estimates emissions by applying annual leak rates and/or other emission profiles to each population of equipment or product. By aggregating the data for more than 40 different end-uses, the model estimates and projects annual use and emissions of each compound over time. For this analysis, the model calculated a "business as usual" (BAU) case that does not incorporate measures to reduce or eliminate the emissions of these gases other than those regulated by U.S. law or otherwise largely practiced in the industry.

The major end-use categories defined in the Vintaging Model for characterizing ODS use in the U.S. are refrigeration and air-conditioning, aerosols (including metered-dose inhalers (MDI)), solvent cleaning, fire extinguishing equipment, foam production, and sterilization. The Vintaging Model estimates the use and emissions of ODS substitutes by taking the following steps:

1. *Gather historical emissions data*. The Vintaging Model is populated with information on each end-use, taken from published sources and industry experts.

2. *Simulate the implementation of new, non-ODS technologies*. The Vintaging Model uses detailed characterizations of the past and existing uses of the ODSs, as well as data on how the substitutes are replacing the ODSs, to simulate the implementation of new technologies that ensure compliance with ODS phaseout policies. As part of this simulation, the ODS substitutes (and/or products containing or made with these substitutes) are introduced in each of the end uses over time as needed to comply with the ODS phaseout regulations.

3. *Estimate emissions of the ODS substitutes*. The chemical use is estimated from the amount of substitutes that are required each year for the manufacture, installation, use or

servicing of products. The emissions are estimated from the emission profile for each vintage of equipment or product in each end-use. By aggregating the emissions from each vintage, a time profile of emissions from each end-use is developed.

Estimating ODS Substitute Emissions in Other Countries

After U.S. emissions are calculated using the Vintaging Model, EPA uses the following methodology to develop emission estimates for non-U.S. countries by building on the detailed assessment conducted for the U.S. Details on the assumptions used at each step are included. The general steps that EPA completed are included below in the general methodology, although the methodology was modified for several sectors where necessary. Specific deviations from this basic methodology are discussed following the general methodology description.

<u>General Methodology</u>

The following general steps are applied to estimate country-specific emissions. Steps 1 through 6 result in preliminary emission estimates calculated by Equation 1, below. The preliminary estimates were adjusted based on a series of factors discussed in Steps 7 through 10.

1. *Estimate the base level consumption of ODSs for each country or region, by chemical group, in unweighted metric tons.* UNEP (UNEP, 1999a) provided estimates of 1986 and 1989-1998 ODS consumption in terms of ozone depletion potential (ODP)-weighted totals for the major types of ODSs: CFCs, HCFCs, halons, carbon tetrachloride, and methyl chloroform. The data for 1989 were used because, in general, no substitution of ODS had taken place yet.

2. *Calculate the percent of unweighted base level ODS consumption of each chemical group used in each end-use sector.* The amount of ODS use in various industrial applications differs by country. For developed countries, data on the end-use distributions of ODS in 1990 were available for the following countries:

   - U.S. from the Vintaging Model,

   - United Kingdom (U.K.) from *U.K. Use and Emissions of Selected Halocarbons*, prepared for the Department of the Environment (March, 1996), and

   - Russia from *Phaseout of Ozone Depleting Substances in Russia*, prepared for the Ministry for Protection of the Environment and Natural Resources of The Russian Federation and the Danish Environmental Protection Agency (Russian Federation, 1994).

   The 1990 end-use sector distribution for the U.S. was assumed to apply to Canada. The U.K.'s distribution was applied to the EU-15[11], Australia and New Zealand. Russia's distribution was applied to the Former Soviet Union (FSU) countries and the non-EU-15 European countries. For developing countries, data on the 1990 consumption of ODS are available for many nations by sector and substance from the Multilateral Secretariat. For developing countries that do not have data available, EPA used a representative average. In all cases, the 1990 distributions of ODS consumption across sectors were assumed to be the same as 1989.

3. *Calculate the unweighted base level consumption of ODS for each end-use sector (metric tons).* This step involves multiplying the amount of consumption of each chemical group from Step 1 by the end-use sector distribution percentages from Step 2.

[11] The EU-15 is defined as these European Union (EU) members: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

4. *Calculate the ratio of U.S. unweighted ODS substitute consumption (metric tons) to U.S. base level unweighted ODS consumption (metric tons) for each end-use sector.* The ratio was taken from the Vintaging Model output.

5. *Calculate the ratio of U.S. GWP-weighted substitute emissions ($MtCO_2eq$) to U.S. unweighted substitute consumption (metric tons) for each end-use sector.* Similar to Step 4, this ratio was taken from the Vintaging Model output.

6. *Estimate GWP-weighted substitute emissions in a given year in $MtCO_2eq$.* This step involves multiplying the country-specific unweighted base level consumption of ODS (Step 3) by the ratio of unweighted ODS substitute consumption to base level unweighted ODS consumption (Step 4), and then multiplying that amount by the ratio of GWP-weighted substitute emissions to unweighted substitute consumption (Step 5), as shown in the following equation. EPA completed this calculation for each of the end-use sectors to estimate the GWP-weighted substitute emissions in each year for each country.

   Thus, this step produces preliminary estimates based on the general assumption that all countries will transition away from ODS in a similar manner as the U.S. (e.g., CFC-12 mobile air conditioners transitioned to HFC-134a beginning in 1994 in the U.S. Thus, as a first estimation, it is assumed that CFC-12 mobile air conditioners transition to HFC-134a in other countries). In many cases, options for ODS substitutes in each end-use are technically limited to the same set of alternatives, regardless of geographic region. Furthermore, alternative technologies used in the U.S. are available and in many cases are used worldwide. These assumptions may be adjusted in later steps to account for differences between the U.S. and other countries, as explained below.

Equation 1:

$$\text{County Specific Substitute Emissions } (MtCO_2eq) = \underset{\substack{\text{(Country-Specific)} \\ \text{(Step 3)}}}{\text{Unweighted ODS Consumption}} \times \underset{\substack{\text{(US – based)} \\ \text{(Step 4)}}}{\frac{\text{Unweighted Substitute Consumption}}{\text{Unweighted ODS Consumption}}} \times \underset{\substack{\text{(US – based)} \\ \text{(Step 5)}}}{\frac{\text{GWP-Weighted Substitute Emissions}}{\text{Unweighted Substitutes Consumption}}}$$

7. *Develop and apply adjustment factors.* In this analysis EPA applied adjustment factors to modify the emission estimates for countries based on what is known qualitatively about how their transition to alternatives, including HFCs, and technology preferences will likely differ from that of the U.S. For example, EPA applied adjustment factors less than one to refrigeration and air-conditioning end-uses, because some nations have been more likely to use hydrocarbon refrigerants than HFCs and/or because some nations may choose less emissive designs or practices. Also, HFC use in foams may be adjusted in some cases because of the use of cyclopentane in lieu of HFCs. Adjustment factors greater than one were applied to the EU-15 countries for fire-extinguishing in some years to account for rapid halon decommissioning (and hence HFC uptake) in those countries. Table 7-4 shows the adjustment factors used for each sector and country grouping.

Table 7-4. Adjustment Factors Applied in Each Sector/Country

	Ref/AC	Aerosols	Foams	Solvents	Fire-Ext.
Australia/New Zealand	0.90	1.00	1.00	1.00	1.00
European Union	0.70[a]	1.00	0.40	0.80	1.00[a]
Non-EU Europe	0.75	1.00	1.00	0.50	1.00
Canada	1.00	1.00	1.00	1.00	1.00
Japan	0.70	1.00	1.00	1.00	1.00
CEITs/Non-Annex I	0.80	1.00	1.00	0.50	1.00

[a]Some of the adjustment factors for the EU-15 vary by year and by region to account for European Regulation 2037/2000 on Substances that Deplete the Ozone Layer. These adjustments are discussed in the sector-specific methodologies section.

8. *Develop timing factors.* Since most developing countries and countries with economies in transition (CEIT) will transition to substitutes more slowly, EPA reduced the adjusted emission estimates by multiplying the results in each year by a timing factor to reflect the assumed delay in their transition. Timing factors for CEIT and non-EU Europe countries start at 25 percent in 1995 and increase by 25 percent at each 5-year interval, until they reach 100 percent in 2010, when they are assumed to have caught up to the other Annex I countries. Non-Annex I countries follow the same timing adjustments as CEIT and non-EU Europe for the CFC phaseout, but have an even further delayed phaseout of the HCFCs, to account for the fact that these countries can continue consuming new HCFCs through 2040. These factors are outlined in Table 7-5.

Table 7-5. Timing Factors Applied to ODS Substitute Emissions

Region	1995	2000	2005	2010	2015	2020
CEITs/Non EU-Europe						
CFC	0.25	0.50	0.75	1.00	1.00	1.00
HCFC	0.25	0.50	0.75	1.00	1.00	1.00
Non-Annex I						
CFC	0.25	0.50	0.75	1.00	1.00	1.00
HCFC	0.00	0.00	0.125	0.25	0.375	0.50
All Other Countries						
HCFC	1.00	1.00	1.00	1.00	1.00	1.00
CFC	1.00	1.00	1.00	1.00	1.00	1.00

9. *Develop economic growth factors.* Since other countries' economies are growing at different rates than the U.S., EPA altered emissions based on comparisons between U.S. and regional historical and projected GDP growth rates. The historical regional percent changes in GDP are shown in Table 7-6 (USDA, 2002), and the projected regional growth rates are shown in Table 7-7 (EIA, 2001).

Table 7-6. Annual Change in GDP Relative to Previous Year (Percent)

Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
United States	1.15	-1.04	2.75	2.46	3.74	2.37	3.40	4.40	4.40	4.10	4.10
Japan	5.08	3.80	1.02	0.31	0.64	1.47	3.92	0.85	-2.50	0.80	1.50
Western Europe	2.94	3.29	0.97	-0.40	2.83	2.49	1.60	2.45	2.70	2.47	3.38
Eastern Europe	-2.20	-10.01	-1.34	1.83	3.00	4.18	1.75	3.73	3.17	2.72	3.83
Former Soviet Union	-3.94	-6.03	-13.32	-10.19	-15.28	-6.05	-4.87	0.03	-4.25	2.45	7.75
China	3.80	9.20	14.20	13.50	12.60	10.50	9.60	8.80	7.80	7.10	8.00
Other Asia	7.93	5.73	5.60	5.82	7.14	7.16	6.46	4.77	-1.89	5.92	6.29
Latin America	-0.40	4.00	2.93	4.05	5.40	0.76	3.50	4.85	2.17	0.99	3.87
Middle East	6.84	4.30	6.61	3.79	0.91	4.54	6.56	3.97	2.41	2.32	6.01
Africa	0.69	1.22	0.91	0.88	2.48	3.49	5.14	2.53	2.63	2.83	3.35

Source: USDA, 2002

Table 7-7. Projected Regional Annual Growth Rates from 2001-2020 (Percent)

	U.S.	Western Europe	Japan	China	Other Asia	Middle East	Africa	Latin America	Eastern Europe	Former Soviet Union
Rate	3.1	2.3	1.5	7.0	4.9	4.3	3.9	4.2	4.2	3.8

Source: EIA, 2001

10. *Estimate adjusted GWP-weighted ODS Substitute emissions in a given year by region and country.* EPA estimated emissions and projections for each year by multiplying the estimates in Step 6 by the adjustment factors (Step 7), the timing factors (Step 8), and the growth factor (Step 9).

Sector-Specific Adjustments to General Methodology for ODS Substitutes

In addition to the adjustments discussed above, EPA adjusted the methodology for some sectors to account for information that was available on a country or regional scale. These adjustments are discussed by sector in more detail below.

<u>Fire-Extinguishing</u>

EPA adjusted global emissions in the fire extinguishing sector by region by developing Vintaging Model scenarios that were representative of country-specific substitution data. In addition, EPA adjusted emissions in the EU to account for the rapid halon phaseout due to regulation. Details of these adjustments include the following:

1. To estimate baseline emissions, information collected on current and projected market characterizations of international total flooding sectors was used to create country-specific versions of the Vintaging Model (i.e., country-specific ODS substitution patterns). For this report, current and projected market information on new total flooding systems in which halons have been previously used was obtained. Information for Australia, Brazil, China, India, Japan, Russia, and the U.K. was obtained from Halon Technical Options Committee (HTOC) members from those countries.[12] General information was also collected on Northern, Southern, and Eastern Europe. Baseline emission information from some of these countries was used to adjust the substitution patterns for all other non-U.S. countries, as described below:

    - Eastern Europe: used as a proxy for the countries in the FSU and CEITs (except Russia).
    - Australia: used as proxy for New Zealand.
    - Brazil: used as a proxy for countries in Latin America and the Caribbean.
    - China: used as a proxy for Taiwan.
    - India: used as a proxy for all other developing countries.
    - For all Annex I countries (other than the U.S.), the U.S. ODS substitution pattern was used as a proxy.[13]

[12] Fire protection experts in these countries provided confidential information on the status of national halon transition markets and average costs to install the substitute extinguishing systems in use (on a per volume of protected space basis) for 2001 through 2020.

[13] This analysis assumes that, of the new total flooding protection systems in which halons have been previously used in the U.S., the market is currently made up of approximately 33 percent HFC-227ea, 1 percent HFC-23, 14 percent inert gas, and 52 percent other not-in-kind.

2. An adjustment factor was applied to EU countries to account for European Regulation 2037/2000 on Substances that Deplete the Ozone Layer, which mandates the decommissioning of all halon systems and extinguishers in the EU-15 by the end of 2003 (with the exception of those applications that are defined as critical uses). To reflect this, the methodology assumes that all halon systems in the EU-15 will be decommissioned by 2004. No adjustments were made to the 10 countries that joined the EU in May 2004, because expansion of the EU membership had not occurred at the time this analysis was performed.

Refrigeration and Air-Conditioning

EPA applied three sector-specific adjustments to the refrigeration and air-conditioning sector, described below. The first adjusts the emissions in the EU to account for the accelerated phaseout of HCFCs, the second accounts for less refrigerant recovery (i.e., more venting) in developing countries, and the third gives a greater degree of detail to the motor vehicle air-conditioning end-use.

1. EPA assumed that countries in the EU-15 are in full compliance with EC-Regulation No. 2037/2000, stipulating that no new refrigeration and air-conditioning equipment be manufactured with HCFCs as of January 1, 2002 (with the exception of two temporary exemptions).[14] The regulation also bans the use of HCFCs in the service of equipment after January 1, 2015. Compliance with these regulations will likely lead to increased use of HFCs to replace HCFCs, and is assumed to correspond to an increase in emissions of 20 percent in 2005, 15 percent in 2010, and 15 percent in 2020 relative to a BAU baseline. These relative emission increases were determined by running a Vintaging Model scenario wherein the uses of HCFCs were assumed to comply with the regulation. No baseline adjustments were made to the 10 countries that joined the EU in May 2004, because expansion of the EU membership had not occurred at the time this analysis was performed.

2. An additional adjustment factor was applied to the estimates in CEITs, non-Annex I countries and Turkey to account for increased emissions, compared to the U.S., which results from a lack of recovery, recycling, and reclamation of refrigerants in these countries.

These estimates assume that recovery does not occur in these countries in any small refrigeration and air-conditioning units, but does occur in larger units, such as chillers. To calculate emissions that would result if refrigerant from small stationary end-uses were not recovered, EPA used a model developed to estimate the costs and benefits of recycling in the U.S. (the U.S. Clean Air Act Section 608 Regulatory Impact Analysis model). Residential air-conditioners were omitted from the calculations because they will transition away from HCFC-22 at a slower rate than in the U.S. (timing factors to account for this slower HCFC phaseout are applied in Step 8, above). Information on fleet size and emissions avoided per vehicle in the U.S. (Baker, 2002) was used to determine the emissions avoided by recycling from motor vehicle air-conditioners (MVACs).

This scenario assumes that recycling efforts in developing countries and CEIT is currently 30 percent, and that these efforts will improve over time, while recycling in the U.S. is assumed to be 80 percent. The resulting adjustment factors are shown in Table 7-8.

Table 7-8. Recycling Adjustment Applied to Refrigeration Emissions Estimates

Country Group/Year	**2000**	**2005**	**2010**	**2015**	**2020**
All Other Annex I	1.00	1.00	1.00	1.00	1.00
CEITs/Non-Annex I	1.22	1.22	1.20	1.18	1.20

[14] The ban was delayed until July 1, 2002 for fixed air-conditioning equipment with a cooling capacity of less than 100 kW, and until January 1, 2004 for reversible air-conditioning/heat pump systems.

3. Because the market penetration of air-conditioning into new vehicles is assumed to vary among countries and regions,[15] and because MVACs are assumed to account for a different proportion of total refrigeration and air-conditioning emissions in the U.S. compared to most other developed and developing countries, this end-use has been modeled separately to achieve a higher degree of accuracy in MVAC emission estimates. For selected countries, vehicle fleets were modeled based on a variety of available data on international motor vehicle sales, air-conditioning usage, and refrigerant emissions. These MVAC emission estimates by region were then used to determine the relative share of refrigeration and air-conditioning emissions attributable to MVACs and to reapportion emissions from all other end-uses accordingly, relative to the end-use breakout calculated for the U.S. The methodology used to perform this analysis is explained in detail below.

For all countries except India and China, the number of operational MVACs was estimated based on (1) annual historical sales of passenger cars and light trucks, as provided in Ward's (2001); and (2) estimates of the percentage of the vehicle fleet equipped with air-conditioning, based on quantitative and qualitative data provided in EC (2003); Hill and Atkinson (2003); OPROZ (2001); and Barbusse, Clodic, and Roumegoux (1998). MVACs were assumed to increasingly penetrate vehicle fleets over time, as shown in Table 7-9 below.

Table 7-9. Percentage of Newly Manufactured Vehicles Assumed to Have Operational Air Conditioning Units

Country/Region	**2005**	**2010**	**2015**	**2020**
Annex I countries (other than U.S.)	65.5	70.0	80.5	95.0
Latin America and Caribbean	50.0	55.0	60.0	65.0
All other non-Annex I countries, Russia, and Ukraine (except China and India)	23.0	28.0	33.0	38.0

Once the MVAC fleet was estimated by country/region, annual MVAC emissions were calculated assuming the same annual average leak and service emissions as assumed for the U.S. (i.e., 10.9 percent).[16] MVAC emissions at disposal are assumed to be 42.5 percent of the original MVAC charge in developed countries and 69 percent in developing countries (as a result of zero recovery assumed).[17] All systems are assumed to use HFC-134a refrigerant in the baseline.

India and China were modeled slightly differently to account for the rapid economic growth experienced in those countries in the past and expected for the future. Specifically, the following methodology was used:

- For India, MVAC fleet estimates were developed based on (1) data on MVAC sales prior to 2004 from the Society of Indian Automobile Manufacturers (SIAM, 2005), (2) projected annual growth rates of new vehicle sales, and (3) projected annual growth rates of air-conditioning penetration. Based on these data, India's future vehicle fleet growth was assumed to be 8 percent per year,[18] while air-conditioning penetration was assumed to increase linearly reaching 95 percent in 2010[19] and remaining at that level through 2020.

- For China, MVAC estimates were based on data on Chinese production of vehicles with MVACs from 1994 to 2004, provided by the China Association of Automobile Manufacturers (2005). Because no future projections of vehicle fleet growth were readily

[15] Except for Japan, which is assumed to have the same market penetration of MVACs into new vehicles as the U.S.

[16] This emission rate includes emissions released during routine equipment operation from leaks, as well as those released during the servicing of equipment by both professionals and do-it-yourselfers.

[17] This percentage (69 percent) is the implied loss at disposal given the assumption that twice the original MVAC charge is emitted over the course of a vehicle's lifetime in developing countries.

[18] This growth rate is based on the annual growth rate of passenger vehicles (assumed to be linear) between 2000 and 2004, with the fleet size in 2000 based on Ward's (2001) and the fleet size in 2004 based on SIAM (2005).

[19] Air-conditioning penetration was grown from 92 percent in 2004, based on data from SIAM (2005).

available for China, the future growth rate of vehicles with air conditioning was assumed to be the same as the fleet growth for India (8 percent per year).

Recently, an EC Directive has banned the use of HFC-134a in new models planned from 2011 onwards, and in all vehicles from 2017. Because this regulation was in draft when this analysis was performed, it was not directly considered in developing baseline emissions from the Refrigeration and Air Conditioning sector. Note, however, that other regulations and social factors that may lead Europe to low-GWP refrigerants are considered in Step 7 above.

Solvents

EPA applied three sector-specific adjustments to the solvent sector. First, PFC/PFPE solvents are assumed to be used in countries with significant annual output from the electronics industry. Global PFC usage for solvent cleaning was geographically distributed using the semiconductor industry as a proxy; specifically, data on the share of world silicon wafer starts per month (8-inch equivalent) from SEMI International (2003) were used. Based on expert opinion, PFC/PFPE solvent use is assumed to be discontinued by 2010 in the U.S. and by 2015 in other countries.

Second, emissions in the EU countries are assumed to equal only 80 percent of the preliminary estimate to reflect that not-in-kind (NIK) technology has taken a more significant market share in European countries (ECCP, 2001). Consequently, the resulting EU emission estimate was reduced by 20 percent. This reduction is accounted for in the adjustment factors listed in Table 7-3.

The third and final adjustment is a 50-percent adjustment factor that was applied to countries with economies in transition (CEIT), European countries that are not members of the EU, and developing (non-Annex I) countries. For these countries, the primary barriers to the transition from ODS solvents to fluorinated solvents has been the high cost of HFC-4310mee and the lack of domestic production (UNEP, 1999b; UNEP, 1999c). This reduction is accounted for in the adjustment factors listed in Table 7-3.

Aerosols

Since the ban on CFC use in non-metered dose inhalers (MDI) aerosols caused the U.S. to transition out of CFCs earlier than other countries, the U.S. consumption of ODS in 1990 for non-metered dose inhalers (non-MDI) aerosols is equal to zero. In order to determine a non-zero denominator for the ratio calculated in step 4, EPA used the unweighted U.S. consumption of non-MDI ODS substitutes (including a large market segment that transitioned into non-GWP, non-ODP substitutes) as a proxy for U.S. 1990 non-MDI ODS consumption. This assumption is valid if it is assumed that the market size of U.S. non-MDI aerosols was not affected by the transition from ODS to ODS substitutes. For countries other than the U.S., it was assumed that 15 percent of the non-MDI aerosols ODS consumption transitioned to HFCs, while the remainder was assumed to transition to NIK or hydrocarbon alternatives.

Foams

Most global emissions were estimated in the foam-blowing sector by developing Vintaging Model scenarios that were representative of country- or region-specific substitution and consumption patterns. To estimate baseline emissions, current and projected characterizations of international total foams markets were used to create country or region-specific versions of the Vintaging Model. The market information was obtained from Ashford (2004), based on research conducted on global foam markets. Scenarios were developed for Japan, Europe (both EU and non-EU countries combined), other developed countries (excluding Canada), CEITs, and China. It was assumed that other non-Annex I countries would not transition to HFCs during the scope of this analysis. Once the Vintaging Model scenarios had been run, the emissions were disaggregated to a country specific level based on estimated 1989 CFC consumption for foams developed for this analysis. Emission estimates were adjusted slightly to account for relative differences in countries' economic growth as compared to the U.S. (step 9 above).

Appendices D-1 to D-6 present historical and projected emissions for all countries for ODS Substitutes: aerosols (MDI), aerosols (non-MDI), fire-extinguishing, foams, refrigeration and air conditioning, and solvents.

7.3.3 HFC-23 Emissions as a Byproduct of HCFC-22 Production

Background

Trifluoromethane (HFC-23) is generated and emitted as a byproduct during the production of chlorodifluoromethane (HCFC-22). HCFC-22 is used both in emissive applications (primarily air conditioning and refrigeration) and as a feedstock for production of synthetic polymers. Because HCFC-22 depletes stratospheric ozone, its production for non-feedstock uses is scheduled to be phased out under the Montreal Protocol. However, feedstock production is permitted to continue indefinitely.

Nearly all producers in developed countries have implemented process optimization or thermal destruction to reduce HFC-23 emissions. In a few cases, HFC-23 is collected and used as a substitute for ozone-depleting substances, mainly in very-low temperature refrigeration and air conditioning systems. Emissions from this use are quantified under air conditioning and refrigeration and are therefore not included here. HFC-23 exhibits the highest global warming potential of the HFCs, 11,700 under a 100-year time horizon, with an atmospheric lifetime of 264 years.

Estimating HFC-23 Emissions in the United States

<u>Historical Activity Data</u>

For both No-Action Baseline and Technology-Adoption Baseline, information on historical (1990-2003) U.S. HCFC-22 production and historical U.S. HFC-23 emission estimates was reported to EPA by HCFC-22 manufacturers under a voluntary agreement.

Projected HFC-23 Emissions in the United States – No-Action Baseline

EPA based emission projections on projections of HCFC-22 production and HFC-23 emission rates, as described below. U.S. feedstock production was projected using a growth rate of 2 percent, which is close to the historical average growth rate for feedstock between 1996 and 2003. Non-feedstock U.S. production was phased out according to the projections of the 2005 version of the Vintaging Model of ODS and their alternatives. Emissions of HFC-23 at plants where abatement is not implemented are assumed to be 2 percent of HCFC-22 production.

Projected HFC-23 Emissions in the United States – Technology-Adoption Baseline

For projections under the Technology-Adoption Baseline, EPA estimated emissions of HFC-23 for 2004-2010 by assuming that the emission rate declined linearly from the 2000 level of 1.36 percent to 0.76 percent in 2010. The latter value is the lowest collective U.S. industry emission rate ever achieved. For 2011-2020, emissions were estimated by assuming that the emission rate remained flat at 0.76 percent in those years. This implies a market penetration of 65 percent by thermal oxidation, based on an assumed baseline emission rate of 2 percent and an abatement efficiency of 95 percent.

Estimating HFC-23 Emissions in Other Countries

This section presents assumptions used for estimating non-U.S. historical and projected activity data (i.e., country-specific levels of HCFC-22 production). Activity data are assumed to be the same for both the No-Action Baseline and the Technology-Adoption Baseline.

Historical Activity Data

EPA estimated historical emissions for 1990, 1995, and 2000 based on available 1990, 1995, and 1999[20] country-specific HCFC production data as reported to the United Nations Environmental Program (UNEP) Ozone Secretariat: global production of HCFC-22 and other HCFCs reported to the Alternative Fluorocarbons Environmental Acceptability Study (AFEAS); and 2001 country-specific production capacity information from the Chemical and Economics Handbook (2001) (Oberthür, S., 2001; AFEAS, 2001; CEH, 2001).[21] The UNEP-reported HCFC production data were used as the foundation of the 1995 and 1999 production estimates.

For India and Russia, which are not included in AFEAS surveys, and for Latin America (Mexico, Brazil, and Venezuela), all of the UNEP-reported HCFC production was assumed to consist of HCFC-22 (World Bank, 2002).[22] For other countries included in AFEAS surveys, the UNEP-reported HCFC production was pooled, and then AFEAS data were used to estimate the share of this HCFC production that is HCFC-22. The CEH country-specific production capacities were then used to allocate this production to individual countries.

Finally, 20 percent was added to the production estimates for each country to account for feedstock production, which is not included in UNEP or AFEAS reports.

Appendix I-1 presents historical HCFC-22 production activity data.

Projected Activity Data

For all countries except the U.S., China, and Japan[23], HCFC-22 production from 1999 was used as a baseline to project future emissions. Non-feedstock and feedstock production were projected separately.

The method for projecting HCFC-22 production was as follows:

Project Non-Feedstock Production. To project non-feedstock production, EPA applied the following assumptions:

- For developed countries other than the U.S., Japan, and Greece, non-feedstock production was assumed to decrease linearly after 1999 so that complete phaseout occurred by the phaseout date for that country (2015 for most European countries and 2020 for other developed countries and CEIT).

    - For Japan, 2005 production data were provided by the Japan Industrial Conference for Ozone Layer and Climate Protection (JICOP, 2006). JICOP reported that 20 percent of Japan's 2005 HCFC-22 production was for non-feedstock uses. This fraction was assumed to decrease linearly to 0 by 2020.

    - For Greece, the single HCFC-22 production facility was reported to have closed in early 2006 (Campbell, 2006). Thus, this analysis assumed that all HCFC-22 production in Greece stopped in 2006 as a result of the plant closure.

[20] 2000 activity data were based on reported information for 1999. To obtain 2000 production estimates, 1999 production was grown for one year at the growth rates discussed in the next section.

[21] Production estimates for India were based on a later version of the UNEP data (Oberthür, S., 2001), because India had not reported 1999 HCFC production in time for the 2000 version.

[22] For South Korea, which is not included in AFEAS surveys but is known to manufacture several HCFCs, estimates were based on reported HCFC-22 production (CEH, 2001).

[23] Production estimates for China were based on the 2003 actual production data reported on the IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System (SROC, 2005). Production estimates for Japan were provided by JICOP (2006).

- For developing countries other than China, non-feedstock production was assumed to increase at the expected rate of growth of the GDP (World Bank, 2001) for that country until 2015, the date when developing countries must begin phasing out HCFCs. After 2015, this production was assumed to decrease linearly so that complete phaseout occurred by 2040.

  - Ø For China, 2000 production was derived in the same way as for other developing countries. To derive 2005 and 2010 production, the 2003 production data from SROC (2005) was grown linearly to reach the 2003 SROC-reported production capacity of 200,000 tons in 2010. Production for 2015 was estimated by growing the 2010 production at the expected rate of growth of GDP for China. After 2015, non-feedstock production was assumed to decrease linearly so that complete phaseout occurred by 2040.

Project Feedstock Production: To project feedstock production, EPA applied the following assumptions:

- For developed countries other than Japan and Greece, production of HCFC-22 for feedstock materials was assumed to grow at 2.5 percent per year (the anticipated growth of "chemical products" in the U.S. in the 2001 Annual Energy Outlook) (EIA, 2001).

  - Ø For Japan, 2005 production data were provided by JICOP (2006). JICOP reported that 80 percent of Japan's 2005 HCFC-22 production was for feedstock. Feedstock production beyond 2005 was assumed to grow at 2.5 percent per year as described above.

  - Ø For Greece, the single HCFC-22 production facility was reported to have closed in early 2006 (Campbell, 2006). Thus, this analysis assumed that all HCFC-22 production in Greece stopped in 2006 as a result of the plant closure.

- Developing country production of HCFC-22 for feedstock materials was assumed to grow at the expected rate of growth of the GDP for that country.

  - Ø For China, 2000 production was derived in the same way as for other developing countries. To derive 2005 and 2010 production, the 2003 production data from SROC (2005) was grown linearly to reach the 2003 SROC-reported production capacity of 200,000 tons in 2010. Feedstock production for 2015 and 2020 was estimated by growing the 2010 production at the expected rate of growth of GDP for China.

Emission Factors and Related Assumptions

To estimate and project emissions of HFC-23, the HCFC-22 production levels estimated above were multiplied by emission factors (i.e., tons of HFC-23 emitted per ton of HCFC-22 produced). In some cases the emission estimate was reduced due to assumed market penetrations of thermal abatement technologies. These emission factors and other assumptions are discussed below.

Historical Emission Factors

The emission factor for estimating 1990 and 1995 emissions was assumed to be 2 percent for developed countries and 3 percent for developing countries, based on reports from manufacturers and other sources (U.S. EPA, 2001; Rand et al., 1999). Russia was assumed to have an emission rate of 3 percent, based on country-specific information (Ahmadzai, 2000).

Projected Emission Factors – No-Action Baseline

To reflect the adoption of thermal oxidation technology between 1995 and the present, EPA assumed that current emission rates had been reduced relative to historical emission rates in some regions. In the No-Action Baseline, current emission rates were then assumed to be maintained through 2020. The following levels of abatement were incorporated into the analysis in the No-Action Baseline:

- For developing countries and Russia, the HFC-23 emission rate was kept constant at 3 percent between 2000 and 2020.

- In 2000, the baseline market penetration of thermal oxidation was estimated to be 100 percent in France, Germany, Italy and the Netherlands; 75 percent in the U.K.; and 0 percent in Spain and Greece (Harnisch and Hendriks, 2000). Except for the U.K., these levels were assumed to be maintained through 2020. In 2005, the baseline market penetration of thermal oxidation in the U.K. was estimated to be 87.5 percent. This was intended to reflect the 2005 commissioning of a thermal oxidizer at the one U.K. plant that had not had one previously (Campbell, 2006). In 2006 and following years, the level of baseline market penetration in the U.K. was estimated to be 100 percent.

- In 2000, Japan had no thermal oxidation. However, by 2002, Japan had installed thermal oxidation for an estimated 25 percent of its HCFC-22 production (JICOP, 2004). By 2005, Japan had increased the level of thermal oxidation to 65 percent and the level of capture (for use) to about 35 percent (JICOP, 2006). This level of abatement was assumed to remain constant through 2020.

Projected Emission Factors – Technology-Adoption Baseline

Future climate policies in many countries are likely to increase levels of thermal oxidation and thereby lower HFC-23 emission rates below current levels. This analysis quantifies future HFC-23 emission reductions that have been announced, although it does not attempt to quantify future emission reductions that may occur but that have not yet been announced. Therefore, in addition to the thermal oxidation modeled for the No-Action Baseline, EPA modeled the following levels of thermal oxidation for the Technology-Adoption Baseline:

- HCFC-22 producers in several developing countries have agreed to host mitigation projects funded by developed countries under the Clean Development Mechanism (CDM) of the Kyoto Protocol. The HFC-23 abatement projects considered in this analysis are either registered or are in the process of being registered in the CDM pipeline. For all countries hosting such projects, including China, India, Mexico and Korea, it was assumed that all currently-identified CDM projects are implemented starting in 2010. The absolute level of abatement (in $MtCO_2eq$) was assumed to remain constant through 2020.

- The HCFC-22 manufacturer in Spain has announced its intent to install thermal oxidation on its Spanish plant by 2010 (Campbell, 2006). Thus, the baseline market penetration of thermal oxidation was assumed to be 100 percent in Spain in 2010 and 2020.

Uncertainties and Sensitivities

In developing these emission estimates, EPA made use of multiple international data sets, country-specific information on abatement levels (where available), the IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System, and the IPCC guidance on estimating emissions from this source. Nevertheless, uncertainties exist in both the activity data and the emission rates used to generate these emission estimates. Although EPA used four separate sources to estimate country-by-country production of HCFC-22 (UNEP-reported, country-specific HCFC production; AFEAS-reported global production of HCFC-22 and other HCFCs; country-by-country production capacities from the Chemical and Economics Handbook; and the IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System), none of these sources is comprehensive. Specifically, none provide country-by-country production of HCFC-22 for all countries.

Future production levels, emission rates and abatement levels are particularly uncertain. Future policies (e.g., under the Montreal Protocol) could affect total production of HCFC-22 and therefore emissions of HFC-23. Changing emission rates may also have a significant impact on emissions. In the Technology-Adoption Baseline, EPA assumed that currently identified CDM projects will be implemented in China, India, Korea and Mexico. However, even after implementation of these projects, significant reduction opportunities remain, both in these countries and elsewhere. There is a significant probability that many of these emissions will be averted, either through CDM or other mechanisms. In this case, HFC-23 emissions will be lower than projected in the Technology-Adoption Baseline.

Appendices D-7 and D-7b present historical and projected emissions for all countries for this source for the Technology-Adoption and No-Action Baselines.

7.3.4 Sulfur Hexafluoride (SF_6) Emissions from Electric Power Systems

Estimating Historical Global SF_6 Emissions

To estimate global emissions from use of electrical equipment,[24] EPA used the 2004 RAND survey of global SF_6 sales to electric utilities and equipment manufacturers, estimates of net electricity consumption, and the following equation, which is derived from the equation for emissions in the IPCC Good Practice Guidance (IPCC, 2000):

Emissions = SF_6 purchased to refill existing equipment + nameplate capacity of retiring equipment. [25]

Note that the above equation holds whether the gas from retiring equipment is released or recovered. If the gas is recovered, it is used to refill existing equipment, lowering the amount of SF_6 purchased by utilities for this purpose.

Gas purchases by utilities and equipment manufacturers from 1961 to 2003 are available from the 2004 RAND survey (Smythe, 2004). For the SF_6 markets represented in the RAND survey (believed to include all SF_6-using countries except Russia and China), SF_6 purchased to refill existing equipment in a given year was assumed to be approximately equal to the SF_6 purchased by utilities in that year.[26] To estimate the quantity of SF_6 released or recovered from retiring equipment, the nameplate capacity of retiring equipment in a given year was assumed to equal 77.5 percent of the amount of gas purchased by electrical equipment manufacturers 40 years previous (e.g., in 2000, the nameplate capacity of retiring equipment was assumed to equal 77.5 percent of the gas purchased by original equipment manufacturers (OEMs) in 1960).[27] The remaining 22.5 percent was assumed to have been emitted at the time of manufacture. The 22.5 percent emission rate is an average of IPCC SF_6 emission rates for Europe and Japan for years

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[24] This report does not include emissions from the manufacture of electrical equipment.

[25] According to the IPCC G*ood Practice Guidance,* emissions from electrical equipment can be summarized by the following equation:

Emissions = Annual Sales of SF_6 – Net Increase in nameplate (SF_6) capacity of equipment – SF_6 stockpiled or destroyed

where

Annual Sales = SF_6 purchased to fill new equipment + SF_6 purchased to refill existing equipment;

Net Increase in nameplate capacity = nameplate capacity of new equipment-nameplate capacity of retiring equipment; and

SF_6 stockpiled or destroyed = SF_6 stockpiled or recovered from electrical equipment and destroyed

In general, the quantity of SF_6 destroyed is believed to be small compared to the other quantities in the equation. In addition, if no gas from retiring equipment is used to fill new equipment, then the quantity of new SF6 used to fill new equipment is equal to the nameplate capacity of the new equipment. In this case, the IPCC equation simplifies to the expression above.

[26] Recent communications with electrical equipment manufacturers indicate that a small but increasing fraction of new equipment is now filled with gas purchased by utilities rather than by equipment manufacturers. In this analysis, EPA assumed that in 1999, one percent of new equipment was filled using gas purchased by utilities and that by 2003, this fraction had grown to five percent. This assumption has the effect of decreasing estimated global refills and emissions by 11 percent in 2003.

[27] The volume of SF_6 sold for use in new equipment before 1961 was assumed to have risen linearly from 0 in 1950 to 91 tons in 1961, the first year for which the RAND survey has data.

before 1996 (IPCC, 2000). The 40-year lifetime for electrical equipment is drawn from *Reductions of SF_6 Emissions from High and Medium Voltage Electrical Equipment in Europe* (Ecofys, 2005). To reduce the potential impact of inventory fluctuations on the estimates, EPA applied three-year smoothing to both the utility and the OEM sales figures. The results of the two components of the above equation were then summed to yield estimates of total SF_6 emissions for all of the countries represented in the RAND survey from 1990 to 2003.

To estimate total global emissions, EPA also estimated SF_6 emissions from Russia and China, which are not included in the RAND survey. In the absence of more specific data, EPA assumed Russian and Chinese emissions were proportional to the net electricity consumption of these countries. Estimates of net electricity consumption were available from the Energy Information Administration (EIA, 2002; EIA, 2001a). To obtain global emissions, the total emissions derived for the countries represented in the RAND survey were multiplied by the ratio of total global net electricity consumption (including Russia and China) to global net electricity consumption excluding Russia and China. This increased the estimate of annual global emissions by approximately 16 percent.

According to a recent report from China's Energy Research Institute (ERI), China's 2003 production of SF_6 was 2,150 tons (ERI, 2006). The total 2003 production reported by the RAND survey was 6,438 tons. Summing together the Chinese and RAND estimates, Chinese SF_6 production accounted for 25 percent of global SF_6 production in 2003. The ERI did not provide information on how this SF_6 was used, and China may have applied it to a number of end-uses other than use of electrical equipment. These include manufacture of electrical equipment, production and processing of magnesium, production of semiconductors, and export for these and other uses (e.g., manufacture of flat panel display in other Asian countries). However, the large production figure certainly does not contradict the 16 percent add-on for electric power systems used in this analysis, which is intended to account for Russia as well as China.

See Appendix I-2 for historical activity data for electric power systems – net electricity consumption by selected countries.

Estimating Historical Country-by-Country SF_6 Emissions

United States

EPA estimated current and historical SF_6 emissions in the U.S. electric power system based on data obtained from the EPA's SF_6 Emissions Reduction Partnership for Electric Power Systems. Participants in the Partnership, which together account for 35 percent of U.S. high-voltage transmission miles, annually report their emissions to EPA. These emissions are then extrapolated to the U.S. as a whole using a regression equation that relates emissions to miles of high-voltage transmission lines. These data are discussed in more detail in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks:1990-2003* (U.S. EPA, 2005a).

EU-25+3[28]

Emission estimates for the EU-25 and Norway, Switzerland, and Iceland (i.e., EU-25+3) were based on those provided for equipment use and decommissioning in "Reductions of SF_6 Emissions from High and Medium Voltage Electrical Equipment: Final Report to CAPIEL" (Ecofys, 2005). The Ecofys study relied on bottom-up estimates of emission rates and of the SF_6 bank in equipment, both of which varied by region and over time. The study supplemented published information and national reporting with surveys of electrical equipment manufacturers and users.

The Ecofys report provided estimates on a regional level (EU-15[29], EU+10, +3) for the years 1995, 2003, 2010, and 2020. For this analysis, estimates were extrapolated or interpolated to obtain

[28] The EU-25+3 includes the 25 member countries of the European Union (EU) and Norway, Switzerland, and Iceland. Appendix I contains a complete list of EU countries.

[29] The EU-15 includes these European Union (EU) members: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

values for 1990, 2000, 2005, and 2015, and regional totals were disaggregated to the country level using either country-specific data (for Germany) or GDP (for all other countries).[30] To estimate 1990 emissions from the EU-15 and from Norway, Switzerland, and Iceland, German trends between 1990 and 1995 were applied. 1990 emissions from the EU-10[31] were assumed to have been the same as in 1995.

Japan

Emission estimates for Japan were obtained from *Recent Practice for Huge Reduction of SF_6 Gas Emission from GIS & GCB in Japan* (Yokota et al., 2005). This paper includes information on both historical emissions and efforts to reduce those emissions over time.

All Other Countries

For all countries except the U.S., Japan, and the EU-25+3, historical emissions (1990-2000) from electrical equipment were estimated using world sales of SF_6 to electrical utilities and net electricity consumption data (Smythe, 2004; EIA, 2002; EIA, 2001b). Country-specific SF_6 emissions were estimated using the following assumptions:

- Global emissions were estimated as described above;
- Emissions from the U.S., Japan, and the EU-25+3, were subtracted from this total; and
- The remaining emissions were allocated to the remaining countries according to each country's share of world net electricity consumption (minus the net consumption of the U.S., Japan, and the EU-25+3). Country-specific electricity consumption data for the period 1990 to 2000 was obtained from the International Energy Outlook 2002 (EIA, 2002). For those countries not reported in EIA (2002), electricity consumption data were obtained from the International Energy Annual 2001 (EIA, 2001b).

Projected Emissions – Technology-Adoption Baseline

Since the mid-to-late 1990s various developed countries have implemented voluntary (and in some cases, mandatory) programs aimed at reducing SF_6 emissions from electric power systems. These countries include the U.S., Japan, and the EU-25+3. To model the successful attainment of developed country SF_6 reduction goals, a Technology-Adoption Baseline was developed.

United States

For the U.S., EPA assumed that emissions would decline over time as new, small, leak-tight equipment gradually replaced old, large, leaky equipment, and as many utilities implemented reduction measures under EPA's SF_6 Emissions Reduction Partnership for Electric Power Systems (U.S. EPA, 2005b).

EU-25+3

For the EU 25+3, emissions projections are based on those presented for equipment use and decommissioning in the "Additional Voluntary Action" scenario of the Ecofys study (Ecofys, 2005). These projections reflect the increasing implementation of reduction measures both historically (starting in 1995) and in the future. Implementation is assumed to be complete by 2010. The measures include operator training, equipment repair and replacement, improved gas recycling techniques (deep recovery), and a decommissioning infrastructure. As in the U.S., the projections also reflect the increasing leak-tightness of new equipment.

[30] Ecofys indicated that within the three European regions, GDP was a slightly better predictor of emissions than net electricity consumption.

[31] The EU-10 includes these EU members: Poland, Hungary, Czech Republic, Slovak Republic, Lithuania, Latria, Slovenia, Estonia, Cyprus, and Malta.

In early 2006, the European Parliament and Council agreed to a regulation on fluorinated greenhouse gases that requires both operator training and "proper" recovery of SF_6 during equipment servicing and decommissioning. The regulation was expected to be adopted by mid-2006. In view of this, it appears likely that operator training and gas recycling will be increasingly implemented throughout the EU-25.

Japan

For Japan, estimates were obtained from T. Yokota (2006) and reflect the increasing implementation of reduction measures both historically (starting in 1995) and in the future. Japan's 2005 emissions from use of electrical equipment were 13 tons of SF_6, considerably below its original Voluntary Action Plan target for 2005 (set in 1998) of 40 tons SF_6 from use (Maruyama, 2001). Emissions were assumed to remain constant at their 2005 level through 2020 (Yokota, 2005). Because the SF_6 bank in Japan is expected to grow substantially during the same period, EPA assumed that implementation of reduction measures would increase in order to maintain this emission level through 2020.

Other Developed Countries

For the technology adoption scenario, EPA assumed that country-specific SF_6 emissions would grow at different rates in developed and developing countries. For all developed countries except the U.S., Japan, and the EU-25+3, EPA assumed that emissions would remain constant from 2003 levels through 2020. That is, any system growth was expected to be offset by decreases in the equipment's average SF_6 capacity and emission rate as new, small, leak-tight equipment gradually replaced old, large, leaky equipment.

Developing Countries

For developing countries, which began to install SF_6 equipment relatively recently, all current equipment was assumed to be new. Consequently, as infrastructure expanded, emissions from developing countries were estimated to grow at the same rate as country- or region-specific net electricity consumption projections (EIA, 2002).

Projected Emissions – No Action Baseline

In the No-Action Baseline, estimates represent a hypothetical scenario in which voluntary actions described in the Technology-Adoption Baseline are not implemented. Consequently, emissions for the U.S., Japan, the EU-25+3, continue at levels that assume no additional reduction measures are implemented after the base year.

United States

For the No-Action baseline, U.S. emissions projections through 2020 were estimated based on the hypothetical assumption that no additional reduction measures were implemented after 1999.

EU-25+3

For the EU 25+3, emissions projections were based on those presented for equipment use and decommissioning in the "Business As Usual 2003" scenario of the Ecofys study (Ecofys, 2005). These projections reflect the historical implementation of reduction measures through 2003, but no additional implementation. Under this scenario, emissions rise slightly between 2003 and 2010 as the bank of SF_6 in equipment increases, but emissions between 2010 and 2020 are assumed to be constant.

Japan

For Japan, 2005 and 2010 No-Action emissions estimates were developed based on the Technology-Adoption estimates supplied by T. Yokota. The Japanese No-Action estimates were assumed to have the same relationship to the Japanese Technology-Adoption estimates as the

EU-25+3 No-Action (i.e., 2003 BAU) estimates had to the EU-25+3 Technology-Adoption estimates. That is, EPA assumed that in the Technology-Adoption scenario, Japan would achieve the same relative (percent) emissions reductions through implementation of additional voluntary measures as the EU-25+3 countries would achieve in their Technology-Adoption scenario relative to their No-Action scenario. This is a reasonable assumption, because by 2003, Japan and the EU countries had implemented reduction measures to approximately the same extent (Ecofys, 2005; Yokota et al., 2005). Consequently, the No-Action Baseline for Japan was calculated by multiplying the Technology-Adoption Baseline for Japan by the ratio between the EU-25+3 No-Action and Technology-Adoption Baselines. Emissions were then held constant through 2020 to reflect the stabilization of regional bank growth.

<u>All other countries</u>

Emissions projections estimates for 2005 through 2020 for all other developed and developing countries remain the same as under the Technology-Adoption scenario. Again, it is assumed that in developing countries, emissions will increase with infrastructure growth, while in developed countries, emissions will hold steady as system growth is countered by decreases in the equipment's average SF_6 capacity and emission rate.

Uncertainties and Sensitivities

In developing these emission estimates, EPA made use of multiple international data sets and IPCC guidance on estimating emissions from this source. The bottom-up estimates used for the U.S., Japan, and the EU-25+3 are believed to be reasonably robust, with uncertainties for the U.S. historical estimates in the range of -20/+40 percent for the EU-25+3 (Harnisch, 2006) and ±15 percent for the U.S. (U.S. EPA, 2005). Nevertheless, this analysis is subject to a number of uncertainties that affect both global and country-specific emission estimates, particularly estimates for countries other than the U.S., Japan, and the EU-25+3.

First, the SF_6 manufacturers represented in the RAND survey do not represent 100 percent of global SF_6 production and consumption. EPA has attempted to account for unreported Chinese and Russian SF_6 production, consumption, and emissions by assuming that they have the same relationship to these countries' net electricity consumption that emissions appear to have to net electricity consumption in the rest of the world. However, this assumption is itself subject to uncertainty. One source of this uncertainty is the fact that net exports from or imports into Russia and China affect the relationship between SF_6 consumption and net electricity consumption in the rest of the world. Net exports from Russia and China would make the "consumption factor" (SF_6 consumption/net electricity consumption) in the rest of the world appear to be smaller than it actually is, while net imports would do the reverse. Information from manufacturers of electrical equipment indicates that exports from Russia and China have fluctuated over time, peaking around 2000 and declining more recently. Thus, the apparent dip in global emissions between 1995 and 2000, and the subsequent rise between 2000 and 2005, may be partly an artifact of these export trends rather than purely a result of changes in emissions from electric power systems.[32] Another source of uncertainty is that the relationship between SF_6 emissions and net electricity consumption varies from country to country, even when imports and exports are properly accounted for.[33]

Second, the RAND survey's attribution of SF_6 sales to particular end uses is also uncertain, because SF_6 manufacturers frequently sell to distributors rather than directly to end-users. Although manufacturers would be expected to have a reasonably good understanding of their markets, this understanding is not always perfect. Thus, some of the SF_6 sales that are attributed in the survey to utilities may actually have been to other uses, or vice versa.

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[32] The bottom-up studies cited above indicate that emissions from this sector did decline between 1995 and 2000, and atmospheric studies confirm that emissions declined globally (Maiss and Brenninkmeijer, 2000). Other atmospheric studies indicate that emissions increased after 2000 (Peters et. al, 2005). However, the post-2000 increase may be from other sectors, e.g., magnesium or electronics.

[33] S. Reiman and M. Vollmer of EMPA have performed a preliminary analysis of this relationship, comparing the SF_6 emission reported through national inventories to the net electricity consumption reported by EIA. They find that the ratios between these two values vary by more than a factor of ten.

Third, the typical lifetime of electrical equipment, and therefore the amount of equipment that is now being retired, is uncertain. This analysis uses a lifetime of 40 years (Ecofys, 2005); however, other estimates place the lifetime at 30 years (IPCC, 2000). The difference is important because the amount of equipment built 40 years ago is considerably smaller than that built 30 years ago. If the average lifetime of equipment were assumed to be 30 years in this analysis, then the estimate of 2003 global emissions would increase by almost 25 percent.

Fourth, for countries other than the U.S., Japan, and EU-25+3, EPA assumes that each country's share of past and current global emissions is directly proportional to that country's share of past and current global net electricity consumption. In fact, as noted above, the relationship between emissions and electricity consumption varies between regions and over time, particularly as regions make efforts to reduce their emission rates. Thus, this analysis may err in its allocation of global emissions to individual regions.

Finally, emission projections are based on the assumptions that emissions in developing countries will grow with those countries' net electricity consumption. However, the application, design, and maintenance of equipment all affect equipment banks and emission rates. All may change over time, altering current trends.

Appendices D-8 and D-8b present historical and projected emissions for all countries for this source for the Technology-Adoption and No-Action Baselines.

7.3.5 Perfluorocarbon (PFC) Emissions from Primary Aluminum Production

EPA calculated country-specific emission estimates from primary aluminum production using historical and forecasted production data and cell type-specific emission factors. This section first discusses the historical and projected activity data utilized. Next, it discusses the methodology used to develop PFC emission factors for historical and projected emissions. In particular, this section details the Technology-Adoption and No-Action Baselines for aluminum production, which are based on different assumptions regarding the adoption of technology retrofit options in the baseline.

Historical Activity Data

EPA estimated historical U.S. primary aluminum production based on data from the EPA's Voluntary Aluminum Industrial Partnership (VAIP). For all other aluminum-producing countries, except Western Europe, Eastern Europe, and the FSU, historical aluminum production estimates for 1990, 1995 and 2000 were obtained from International Aluminum Institute (IAI) surveys (IPAI, 1998; IAI 2002; IAI 2005a). Region and country-specific aluminum production was disaggregated to cell type using information provided by the International Energy Agency (IEA, 2000). However, the shares of production represented by two cell types, Side-Worked Prebake (SWPB) and Point-Feed Prebake (PFPB), were adjusted to better reflect the global technology trends observed from 1990 to 2003 in the IAI surveys. In each region, EPA assumed the share of SWPB production declined linearly by approximately 6 percent per year (expressed as a fraction of the 1990 SWPB production share in that region) between 1990 and 2000 (IAI, 2000; IAI, 2005b). Globally, this adjustment resulted in a decline in the SWPB share from 13.9 percent to 7.2 percent between 1990 and 2000, which is comparable to the decline in the SWPB share observed between 1990 and 2000 in the IAI surveys, from 14.7 percent to 7.7 percent. In each region, the share of production lost by SWPB was assumed to be taken up by PFPB. This is consistent with the trends observed in the IAI surveys. For Western Europe, Eastern Europe, and the Former Soviet Union (FSU), production estimates by cell type were obtained from the European Aluminum Association (Nordheim, 1999).

Appendix I-3 contains historical aluminum production activity data.

Projected Activity Data

For all countries except China and the U.S., Vertical Stud Soderberg (VSS), Horizontal Stud Soderberg (HSS) and Center-Worked Prebake (CWPB)-specific production projections for 2005 to

2020 were drawn from *Greenhouse Gas Emissions from the Aluminum Industry* (IEA, 2000). These data were estimated based upon anticipated expansion of smelter capacity, smelter closings, and regional changes in aluminum demand. Primary aluminum demand by region was forecasted using regional Gross Domestic Product projections (IEA, 2000). Due to the significant growth in Chinese aluminum production between 2000 and 2005 (i.e., over 100 percent), EPA updated IEA (2000) estimates for China using recent IAI production statistics (IAI 2005a). Since this level of growth cannot be sustained indefinitely, EPA assumed that technology-specific production in China would remain constant at 2005 levels through 2020. For the U.S., EPA obtained projected activity data from EPA's VAIP (U.S. EPA, 2005).

Like the IEA historical activity estimates for SWPB and PFPB, the IEA projections for SWPB and PFPB were adjusted to account for the observed shift of SWPB production to PFPB. Between 2000 and 2005, the global share of SWPB production was assumed to decline by 6 percent per year (expressed as a fraction of the 1990 SWPB production share in that region), after which it was assumed to remain constant at 2005 market share levels through 2020.

Emission Factors and Related Assumptions

EPA estimated PFC emission factors using the Intergovernmental Panel for Climate Change (IPCC) Tier 2 methodology for calculating PFC emissions from primary aluminum production (IPCC, 2000). These emission factors were derived from smelter operating parameters that describe anode effect (AE) duration and frequency and a slope-coefficient, which relates the parameters to actual cell type-specific PFC emissions. AE duration and frequency were combined into an overall AE minutes-per-cell-day value. The slope coefficient is the parameter that, when multiplied by the AE minutes per cell day, provides the specific emissions estimates in kg CF_4 or kg C_2F_6 per metric ton of aluminum.

Historical Emission Factors and Related Assumptions

Except for the U.S., where smelter-specific operating parameter and slope coefficient data are available, cell type-specific default values for AE duration and frequency and slope coefficients were used (IAI, 1999; IPCC, 2000). For all countries except the U.S., average cell type-specific AE duration and frequency data for 1990 and 1995 were obtained from IAI surveys (IAI, 1999). Table 7-10 illustrates these production-weighted AE minutes per cell-day by cell type used for 1990 and 1995 emission estimates. The reduction in AE minutes between 1990 and 1995 was the result of several factors, including incremental improvements in smelter technologies and practices, and the construction of state-of-the-art facilities.

Table 7-10. Cell Type Specific Production Weighted AE Minutes per Cell Day

Cell Type	1990	1995
VSS	10.3	7.1
HSS	3.5	3.1
SWPB	6.5	5.3
CWPB	3.4	1.6

Source: IAI, 1999

Table 7-11 illustrates slope coefficient information for each cell type that was obtained from IPCC (2000). For the U.S., smelter-specific anode effect duration and frequency, and slope coefficient data were obtained from the EPA's VAIP (U.S. EPA, 2005).

Table 7-11. Slope Coefficients by Cell Type (kg PFC/metric ton Al/AE minutes/cell day)

Cell Type	CF4	C2F6
VSS	0.07	0.003
HSS	0.18	0.018
SWPB	0.29	0.029
CWPB	0.14	0.018

Source: IPCC, 2000

Projected Emission Factors and Related Assumptions – Technology-Adoption Baseline

Recently, the IAI, whose members account for approximately 80 percent of world primary aluminum production, committed to reducing the industry's PFC emission intensity (i.e., PFC emissions per metric ton of aluminum produced) by 80 percent from 1990 levels by 2010. To model the successful attainment of the IAI PFC reduction goal, a Technology-Adoption Baseline was developed to model the adoption of minor and major retrofit abatement options by global facilities in the near future. Minor retrofits entail the installation of computer control systems, and major retrofits entail the installation of point feeding systems. Complete retrofits entail the installation of both. A complete retrofit essentially converts a cell to the lowest-emitting technology, Point-Feed Pre-Bake (PFPB).

Projected emission factors were estimated by assuming that minor and major retrofit improvements to smelter processes continue through 2010. For all countries except the U.S., EPA modeled these process improvements in the baseline by assuming an increasing level of adoption of complete retrofits. By 2010, almost all VSS and CWPB smelters were assumed to have adopted complete retrofits, while 25 percent and 75 percent of SWPB and HSS smelters, respectively, were assumed to have adopted them.

For the U.S., emission projections were based on smelter-specific production, AE minutes per cell day, and slope coefficients obtained from the U.S. EPA's VAIP (U.S. EPA, 2005b).

Using these assumptions along with the reduction efficiencies in Table 7-12, the modeled global 2010 PFC emission intensity reduction is 78 percent compared to 1990 levels, which is consistent with the IAI PFC reduction goal. With the attainment of the IAI goal in 2010, it is assumed that through 2020, the regional and technology-specific emission factors will remain constant at 2010 levels.

Table 7-12. Reduction Efficiency of Potential Reduction Opportunities (Percent)

Abatement Option/Technology-Type	VSS	HSS	SWPB	CWPB
Computer Controls (Minor retrofit)	35.5	33.5	23	31
Point Feed (Major Retrofit)	35.5	33.5	70	10

Source: U.S. EPA, 2006.

Projected Emissions Factors and Related Assumptions – No-Action Baseline

In the No-Action Baseline, the emission factors for each cell technology were assumed to remain constant from 2000 to 2020. The No-Action Baseline is intended to model the hypothetical scenario in which no action is taken by the aluminum industry to reduce their emission rates below the levels observed during the late 1990s. This would represent a break from the historical trend; IAI member surveys (IAI 1999; IAI, 2000) have noted significant reductions in AE duration and frequency for all cell-types during this period. In addition, as noted above, IAI has established a voluntary goal of reducing global PFC emission intensity by 80 percent, compared to 1990 levels, by 2010. Thus, it is unlikely that actual emissions will be as high as those presented in the No-Action Baseline. Nevertheless, the Baseline is presented to provide an upper-bound estimate of future emissions and to provide a reference to which the Technology-Adoption Baseline can be compared.

For all countries except the U.S., EPA obtained production-weighted AE minutes per cell-day by cell type used to estimate emissions for this scenario from 2000 to 2020 from IEA (2000). These emission factors reflect the declines in AE minutes per cell-day observed during the 1990s. For the U.S., data were obtained from the EPA's VAIP (U.S. EPA, 2005).

Uncertainties and Sensitivities

In developing these emission estimates, EPA made use of multiple international data sets and the most recent IPCC guidance on estimating emissions from this source. Nevertheless, uncertainties exist in both the activity data and the emission rates used to generate these emission estimates.

First, while this study incorporated recent data on total aluminum production by region (IAI, 2005a), it relied primarily on the 2000 IEA report, *Greenhouse Gas Emissions from the Aluminum Industry,* to disaggregate aluminum production by cell type, and this information was gathered several years ago. Cell type is important because emissions per ton of aluminum can vary by a factor of five or more across different cell types (IPCC, 2000). In its 2000 report, IEA attempted to account for expected plant openings and closings, but these may not be occurring as expected, particularly given the large increase in Chinese aluminum production since 2000. When EPA compared the IEA data on regional production by cell type with more recent industry data on global production by cell type (IAI, 2005; Marks, 2006), it found that the IEA projections had not fully captured either (1) a sharp decline in production from VSS, HSS, and SWPB smelters (the most emissive type), or (2) a sharp increase in production by PFPB plants (the least emissive type). As discussed above, EPA attempted to compensate for this by modeling a shift from SWPB to PFPB between 1990 and 2005. In addition, EPA modeled increasing levels of adoption of complete retrofits, which essentially convert VSS, HSS, CWPB, and SWPB cells to PFPB cells. However, even with the adjustment, EPA appears to be underestimating global production by PFPB. This may have a significant impact on emission estimates because PFPB is the least emissive cell type.

Second, EPA also relied on the 2000 IEA report to disaggregate the regional production reported by IAI into country-by-country production. Again, due to the age of the IEA report and the recent large growth of production in China, this may no longer accurately represent country-by-country production. Published IAI (2005) results for PFC emissions in 1990 and 2000 are approximately 14 and 9 percent, respectively, below EPA estimates. While global aluminum production levels are similar, the difference in PFC emissions is likely the result of differing country-specific technology mixes, in particular in China, where historic production data are limited.

Third, the technology-adoption scenario assumes that the IAI goal (i.e., an 80 percent reduction in PFC emission intensity by 2010 from 1990 levels) will be attained, after which there will be no further improvement in PFC intensity levels. However, it is possible that additional improvement will occur due to changes in the technology mix and continued operational improvements. If this is the case, technology-adoption PFC projections may overestimate emissions.

Fourth, EPA used the 1990 and 1995 technology-specific anode effect minutes (AE minutes) reported by the IAI (IAI, 1999), but it projected AE minutes and emission rates for all other years, including 2000, based on (1) the estimated levels of adoption of PFC mitigation technology (i.e., minor and/or major retrofit), and (2) the estimated reduction efficiencies for these technologies. Given the changes in the global aluminum industry since 2000, this may under- or overestimate the actual level of technology adoption (and hence the AE minutes and emissions) for both the Technology-Adoption Baseline (between 1995 and 2020) and the No-Action Baseline (between 1995 and 2000). Similarly, based on recent technology developments, this approach may underestimate cell-specific reduction efficiencies and therefore overestimate AE minutes and emissions. (For example, recently Alcan Pechiney reported an improved software and feed system that has the potential to make substantial reductions in emissions on cells that are already considered to be high performing relative to PFC emissions (Marks, 2006)).

Fifth, to estimate emissions, EPA used slope coefficients from the IPCC Good Practice Guidance (IPCC, 2000). The CF_4 and C_2F_6 slope coefficients recommended in the draft *2006 IPCC Guidelines* are noticeably different from these values. The slope coefficients from the 2006 *Guidelines* will likely have lower uncertainty than the values from the *Good Practice Guidance* because the set of smelter-specific PFC measurements that have been used to develop these coefficients is significantly larger.

Appendices D-9 and D-9b present historical and projected emissions for all countries for this source for the Technology-Adoption and No-Action Baselines.

7.3.6 Emissions from Semiconductor Manufacturing

Six perfluorinated compounds and one partially fluorinated compound—collectively called PFCs—are used worldwide in semiconductor manufacturing: perfluoromethane (CF_4), hexafluoroethane (C_2F_6), perfluoropropane (C_3F_8), perfluorocyclobutane (c-C_4F_8), sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3), and trifluoromethane (HFC-23). Note that although NF_3 was not listed with a GWP in the IPCC's Second Assessment Report (SAR) (Molina et al., 1995), this analysis presents NF_3 emissions and emission reduction options being considered by the semiconductor industry. The semiconductor industry uses a broader definition of the term "PFC"—perfluorocompound, rather than perfluorocarbon—and therefore includes HFC-23, NF_3, and SF_6 when referring to PFC emissions.

PFC emissions are reported to come from two repeated activities in semiconductor manufacturing: (1) cleaning of chambers used to deposit thin layers of insulating materials, a process referred to as chemical vapor deposition (CVD) chamber cleaning, and (2) etching intricate patterns into successive layers of insulating films and metals, a process referred to as plasma etching. Film deposition and etching begins with the semi-conductive crystalline silicon (Si) wafer and continues as successive films (layers) are deposited and etched to form and complete a device (i.e., the connection of all the elements of the device). Industry reports indicate that approximately 70-80 percent of emissions result from chamber cleaning processes and 20-30 percent from etching processes (IPCC, 2002; Beu and Brown, 1998).

In the absence of emission control measures, the rapid growth of this industry (11-12 percent per year through the late 1990s) and the increasing complexity of microchips would be expected to result in significantly increased future emissions from the semiconductor industry. In view of this possibility, EPA and the U.S. semiconductor industry launched a voluntary partnership to reduce PFC emissions in 1996. In 1999, the U.S. partnership catalyzed a global industry commitment through the World Semiconductor Council (WSC), which represents approximately 85 percent of world-wide semiconductor manufacturing capacity, to reduce PFC emissions to 90 percent of the 1995 level by 2010.[34] As discussed below, this analysis models emissions both with and without achievement of the WSC goal. These emission scenarios are respectively referred to as the "Technology-Adoption" and "No-Action" Baselines, respectively.

The methods used in this report for estimating PFC emissions from semiconductor manufacturing follow those in the PFC Emissions Vintage Model (PEVM, Burton and Beizaie, 2001) and in the Foundry Impact Analysis Model (FIAM) (Bartos, Lieberman, and Burton, 2004).

The No-Action Baseline is intended to model the hypothetical scenario in which no action is taken by semiconductor manufacturers to reduce their emission rate (expressed per average layer per unit area of Si) below the level observed through 2000. In fact, World Semiconductor Council (WSC) members have already taken significant steps to reduce their emission rates and to achieve the WSC goal of reducing emissions to 90 percent of the 1995 level by 2010. These steps include not only research programs in several countries, but the widespread adoption of technologies (such as NF_3 Remote Clean) that are already reducing emissions below the historical rates. Such actions make it unlikely that actual future emissions will be as high as those presented in the No-Action Baseline. Nevertheless, the No-Action Baseline is presented to provide an upper-bound estimate of future emissions and to provide a reference to which the Technology-Adoption Baseline can be compared.

[34] For the U.S. Semiconductor Industry Association (SIA), Japan Electronic and Information Technology Industries Association (JEITA) and European Semiconductor Industry Association (ESIA), the baseline year is 1995; for the Korean Semiconductor Industry Association (KSIA), the baseline year is 1997; and for the Taiwan Semiconductor Industry Association (TSIA), the baseline is the average of the emission values in 1997 and 1999. According to the World Fab Watch database (2004), WSC-member companies accounted for approximately 85% of theoretical design manufacturing capacity in 2003.

No-Action Baseline Emissions

U.S. Emissions

Estimates of historical U.S. emissions were drawn from the U.S. Inventory (EPA, 2005). Estimates of future U.S. emissions were based on estimates in EPA's PFC Emissions Vintage Model (PEVM). These U.S. figures are consistent with the set estimated by EPA for the upcoming 2006 U.S. Climate Action Report.

Emissions from Other Countries

To generate the No-Action Baseline, EPA used WSC members' reported emissions and the FIAM presented in Bartos, Lieberman, and Burton (2004).

For WSC members' historical emissions through 2000, EPA adopted those emissions reported either by (1) countries or regions in their 2005 Greenhouse Gas Inventory Submissions to the UNFCCC, or by (2) country trade associations at the 11th International Semiconductor Environment, Safety, and Health Conference in Makuhari, Japan (2004). Inventory submissions were used for the EU-15 and Japan, while trade association reports were used for South Korea and Taiwan.

For all other regions and years, emissions were adapted from those obtained from FIAM. In addition to projecting likely growth in global semiconductor manufacturing and emissions, the FIAM analysis models the increasing emergence of foundry-type manufacturing facilities and a geographical shift in manufacturing to Southeast Asia. FIAM therefore captures the growing industry trend of outsourcing production to foreign (particularly Asian) manufacturing plants. FIAM provides both historical and forecast emissions for specific countries and world regions under the No-Action Baseline. This section presents a brief overview of the method through which FIAM estimated those emissions, and presents the added steps taken in order to adjust those estimates for inclusion in this report.

FIAM is based on the assumption that PFC emissions from semiconductor manufacturing vary with (1) silicon consumption (i.e., the area of semiconductors produced) and (2) the number of layers on each semiconductor device.[35] The number of layers is determined by the technology node or linewidth of the device. Linewidth refers to the smallest feature size used in manufacturing the device.[36] As feature sizes shrink, the number of active elements (e.g., transistors) on the same size device increases, requiring additional layers to connect the elements. Since logic devices (e.g., microprocessors) have more layers than memory devices (e.g., DRAM) at each technology node, the precision of emission estimates increases if Si projections take into account the respective portions of Si consumed in logic and memory devices. EPA assumed that only logic and memory devices are manufactured because Si consumed for the manufacturing of devices other than logic and memory units has constituted less than 10 percent of total Si consumption since the early 1990s (VLSI, 2003).

Global activity data comprise historical and projected global Si consumption by linewidth and device type (i.e., memory vs. logic) provided by VLSI Research, Inc. (VLSI, 2003). For 1990 through 2005, this activity was apportioned to individual countries and regions using information from the World Fab Watch (WFW) databases on manufacturing capacity by linewidth and country (WFW, July 1996, 2001, and April 2003 Editions). For 2010, this activity was apportioned to individual countries and regions using both the WFW data and forecasts of capital expenditures, which relied on financial analysts' reports that predict investment in new manufacturing capacity. The WFW data were used to apportion manufacturing of devices with linewidths ≥ 120 nm while capital expenditures were used to apportion manufacturing of devices with linewidths < 120 nm.

[35] FIAM is based on data from EPA's PFC Emissions Vintage Model (PEVM), which is described in detail in Burton & Beizaie (2001).

[36] The term "technology node" refers to the smallest feature size used in manufacturing a semiconductor device (microprocessor, DRAM, etc.), for example, 130 nm, 90 nm, 65 nm, etc. An organizing principle of the modern semiconductor sector (known as Moore's Law) is the pursuit of ever-shrinking feature sizes so that, for the same or less cost, the same size silicon substrate contains more transistors, which increases the cost performance of the device.

(That is, capital expenditures were assumed to be devoted to the smallest, most advanced linewidths.) For all historical and forecast activity, country-by-country estimates of per-node Si consumption were multiplied by per-node emission factors to obtain country- and linewidth-specific estimates of emissions.

FIAM uses emission factors from Burton and Beizaie (2001), which used U.S. industry reports of U.S. emissions to develop an annual emission factor that expresses the industry *average* PFC emissions[37] per *average* layer per unit area of Si consumed during manufacture (including wafers used to test process performance during manufacture that experience PFC treatment). This "average per-layer" emissions factor remains relatively constant from year to year in the absence of emission reduction efforts. Given the global nature of the semiconductor industry, the emission factor was assumed to be applicable to worldwide semiconductor manufacturing as well as to U.S. manufacturing.

The No-Action Baseline is an adjusted version of the historical and forecast emissions estimates obtained from FIAM. FIAM's estimates were compared to those reported by members of the WSC for 1995 and 2000.[38] Differences emerged, and these were reasonably constant over time for specific regions. Assuming WSC reports are accurate, differences can be attributed to over- or underestimated emission factors, Si consumption, or a combination of these. To calibrate FIAM's estimates with those reported by WSC members, FIAM estimates were adjusted across all years and regions by applying a factor specific to each WSC country. For countries that are not WSC members, historical and forecast estimates from FIAM were scaled by a factor of 0.8, which is the average ratio of FIAM estimates to member-reported estimates for 1995 and 2000. Table 7-13 shows the emissions reported by WSC members, the corresponding FIAM estimates, the ratios between them, and the resulting adjustment factors.

Table 7-13. Ratios Between Reported and FIAM Estimated WSC Emissions and the Resulting Adjustment Factors

WSC Member Country/Region	Reported Emissions ($MtCO_2eq$)		FIAM-Estimated Emissions ($MtCO_2eq$)		Ratio between Emissions		Adjustment factor
	a	*b*	*c*	*d*	*a/c=e*	*b/d=f*	*(e+f)/2*
	1995/97[a]	**2000**	**1995/97[a]**	**2000**	**1995**	**2000**	
Japan	4.1	7.4	13.3	15.3	0.31	0.48	0.40
Europe	1.4	1.9	2.0	4.3	0.67	0.44	0.56
Taiwan	0.7	4.8	1.1	3.9	0.68	1.2	0.96
South Korea	2.6	3.3	1.8	2.9	1.4	1.2	1.3
Total *(a,b,c,d)*[b] **or Average** *(e,f)*	**8.8**	**17.4**	**18.2**	**26.4**	**0.77**	**0.83**	**0.80**

[a] All values are for 1995, except those for South Korea which uses 1997 as its baseline year.
[b] Due to rounding, values may not sum perfectly.

Because FIAM generates country-specific emission estimates only for seven countries (U.S., Japan, Taiwan, South Korea, China, Singapore, and Malaysia), FIAM's regional estimates of emissions from Europe and from the Rest of World group were broken down using data on each country's share of capacity as projected by the World Fab Watch (WFW) database of semiconductor manufacturing facilities (WFW, 2002).

[37] The PFC emissions are expressed in units of MMTCE because the semiconductor industry reports its emissions as a total of all PFC gases.

[38] WSC members include SIA in the U.S., JEITA in Japan, ESIA in Europe, TSIA in Taiwan, and KSIA in South Korea.

Finally, because FIAM projects emissions only to 2010, the emission estimates as described above (adapted from FIAM) were extrapolated to 2020 by assuming that post-2010 emissions grow at a rate equal to one-half the compound annual growth rate observed over the years 1995 to 2010.

Technology-Adoption Baseline Emissions

Historical emissions under the Technology-Adoption Baseline are the same as under the No-Action Baseline. The Technology-Adoption Baseline forecast models the scenario in which WSC members achieve their goal of reducing emissions to 90 percent of the 1995 level by 2010. The Technology-Adoption Baseline therefore reflects current and future actions to reduce emissions, such as the adoption of alternative chemistries (e.g., NF_3, CH_2F_2), process optimization, and thermal and plasma abatement.

<u>U.S. Emissions</u>

Estimates of historical U.S. emissions were drawn from the U.S. Inventory (U.S. EPA, 2005). Estimates of future U.S. emissions were based on estimates in PEVM, which were adjusted to reflect the expected achievement of the WSC goal by manufacturers in EPA's PFC Reduction/Climate Partnership for the Semiconductor Industry. These U.S. figures are consistent with the set estimated by EPA for the upcoming 2006 U.S. Climate Action Report. Because not all U.S. semiconductor manufacturers have committed to the 2010 WSC goal, 2010 U.S. emissions are projected to be approximately 10 percent higher than 1995 U.S. emissions. However, by 2020, total U.S. emissions are expected to decline to less than 90 percent of 1995 emissions, reflecting the penetration of the entire semiconductor market by low-emitting technologies.

<u>Emissions from Other Countries</u>

For all WSC member countries other than the U.S., EPA assumed that emission levels will reach stated goals of 10 percent below 1995[39] levels by 2010. Beyond 2010, these countries' emissions were assumed to remain constant. Through 2010, non-member countries' emissions were assumed to match those presented in the No-Action Baseline. Beyond 2010 and through 2020, however, it was expected that low-emitting equipment will permeate the international market for semiconductor manufacturing equipment as a result of increased demand from WSC countries. EPA assumed that non-WSC members will lag about 10 years behind WSC members in their application of control technologies. Therefore, EPA assumed that 2020 non-members' emissions under the Technology-Adoption Baseline have the same relationship to 2020 non-WSC No-Action emissions as the 2010 Technology-Adoption emissions of the WSC members have to 2010 WSC No-Action emissions.

Uncertainties and Sensitivities

In developing these emission estimates, EPA used multiple international data sets and the most recent IPCC guidance on estimating emissions from this source. In the Technology-Adoption Baseline, EPA also attempted to reflect recent technological developments and industry emission reduction goals. However, several factors, including the high growth rate of this sector, the rapid pace of technological change in this sector, and a growing industry trend of outsourcing production to foreign manufacturing plants, make both global and country-specific emissions projections uncertain.

First, based on the history of this industry, EPA has used relatively high activity growth rates to project emissions; therefore, slight changes in these rates can lead to large changes in projected emissions.

Second, the Technology-Adoption Baseline projects emissions assuming that the current semiconductor manufacturing process continues and that currently available abatement

[39] South Korea and Taiwan were assumed to reduce their emissions to 10 percent below the levels of their baseline years, which are 1997 and 1997/1999 (average), respectively.

technologies are used to reduce the resulting PFC emissions. It does not attempt to model a possible future in which PFCs are no longer used in semiconductor manufacturing at all. Thus, even the Technology-Adoption Baseline may overestimate emissions.

Appendices D-10 and D-10b present historical and projected emissions for all countries for this source.

7.3.7 Sulfur Hexafluoride (SF_6) Emissions from Magnesium Production

For this analysis EPA developed SF_6 baseline emissions for three magnesium metal processes: primary production, die-casting, and recycling-based or secondary production. Country-specific emission estimates are expressed as the product of process-specific emission factors and historical and forecasted production. This section first discusses the historical and projected activity data utilized, specifically country-specific production and anticipated market trends (projections), such as future plans to expand, shift, or curtail production. Next, it discusses the process-specific emission factors used to estimate historical and projected emissions.

In the absence of emission control measures, the rapid growth of this industry would be expected to result in significantly increased future emissions from magnesium production and processing. In view of this possibility, EPA and the U.S. magnesium industry launched a voluntary partnership to reduce SF_6 emissions in 1999. In 2003, the U.S. partnership catalyzed a global industry commitment through the International Magnesium Association (IMA), which represents approximately 80 percent of magnesium production and processing outside of China, to eliminate SF_6 emissions from magnesium operations by the end of 2010 (U.S. EPA, 2005). As discussed below, this analysis models emissions both with and without significant reductions in the SF_6 emission rate of this industry. These emission scenarios are referred to as the “Technology-Adoption” and “No-Action” Baselines, respectively.

Historical Activity Data

This section summarizes process-specific production data used to estimate historical (1990-2000) emissions.

<u>Primary Production</u>

Countries that produced magnesium between 1990 and 2003 include: the U.S., Russia, Ukraine, Canada, Kazakhstan, Israel, China, Brazil, France and Norway. (French and Norwegian primary production ceased after 1999 and 2002, respectively). Data for primary magnesium production for all countries for 1990 to 2003 (except for the U.S. for some years) were obtained from the U.S. Geological Survey (USGS, 2002 and 2004). U.S. data were obtained from USGS and from information supplied by the U.S. EPA’s SF_6 Emissions Reduction Partnership for the Magnesium Industry (U.S. EPA, 2005).

<u>Die-Casting</u>

- *United States.* EPA obtained U.S. die-casting production data from USGS and from U.S. EPA’s SF_6 Emissions Reduction Partnership for the Magnesium Industry (USGS, 2002; USGS, 2003; USGS, 2004; U.S. EPA, 2005).

- *European Union (EU).* For EU countries that cast some or all of their magnesium using SF_6 as the cover gas, specifically, France, Germany, Italy, Portugal, Spain, Sweden and the United Kingdom (U.K.), historical emissions were derived from Harnisch and Schwarz (2003). 2001 emissions were estimated as the product of a region-specific emission factor and country-specific data on SF_6-based magnesium casting from Harnisch and Schwarz. 1995 emissions estimates were derived from the 1995 emissions presented by Harnisch and Schwarz for the EU as a whole; country-specific emissions were calculated by multiplying the aggregate EU emission estimate (20 metric tons SF_6) by each country’s share of total SF_6-based EU die-casting production in 2001. 2000 emissions were estimated by linearly interpolating between the 1995 and 2001 data. For 1990, emissions were estimated using the 1995 estimates and two trends between 1990 and 1995: (1) EU auto production, and (2) the quantity of magnesium used per car in the U.S. Between 1990 and 1995, EU auto production declined by three percent. However, the quantity of magnesium used per car in the U.S. rose by 46 percent. Thus, SF_6 emissions in the EU were assumed to have risen by 42 percent between 1990 and 1995, since emission factors were believed to have remained constant over the same period.

- *China (2000 only).* 2000 Chinese casting volume was drawn from Edgar (2004).

- *All Other Countries.* Casting estimates for other countries and other historical years (for China) were not readily available. Consequently, die-casting for the years 1990 to 1999 was estimated as a function of automobile production. That is, for Brazil, Canada, China, Japan, Russia, and Ukraine, casting was estimated using the ratio of country-specific automobile production to U.S. automobile production. This ratio was multiplied by U.S. die-casting production to obtain an estimate of die-casting production in each country. Automobile production was obtained from Ward's Motor Vehicle Data (Ward's, 2001). For countries that do not produce automobiles but have growing casting industries, such as Kazakhstan, Norway, and Israel (IMA, 2002), production was estimated from the ratio of primary production to casting production for a similar country. Russia was used as a proxy for estimating production in Kazakhstan, while the U.S. was used as a proxy for Norway and Israel.

Recycling-based Production

Recycling-based production by country from 1990 to 1999 was obtained from U.S. Geological Surveys (USGS, 2002). USGS (2002) reports that Brazil, Japan, U.K., the Czech Republic and the U.S. currently conduct magnesium recycling. The processing of magnesium scrap falls into two subgroups: magnesium- and aluminum-base alloys. For all countries except the U.S., USGS (2001) reports country-specific production that combines both magnesium- and aluminum-base alloy recycling. For the U.S., USGS (2001) reports the production of recycled magnesium from both magnesium- and aluminum-base alloys separately. Since it is assumed that SF_6 is only consumed during the processing of magnesium-base alloys, the ratio of U.S. magnesium- to aluminum-base alloy recycling was used to estimate magnesium-base production for the other countries.

Appendix I-4 contains historical magnesium activity data for primary, secondary, and die-casting production.

Projected Activity Data

This section discusses the regional growth rates and country-specific assumptions used to forecast magnesium primary production, casting, and recycling-based production from 2005 through 2020. Growth rates are summarized in Table 7-15. In general, annual growth rates used in this analysis were assumed to account for new facility construction as well as facility capacity expansion. Primary production and die-casting growth rates were based on information supplied by Edgar (2004) for China, by EPA (2005) for the U.S. and by Webb (2005) for the rest of the world. For recycling, growth rates will be driven by automotive use, and consequently, it is assumed that they will be similar to casting growth rate estimates for each region.

Primary Production

- *Growth Rates.* In all countries except the U.S. and China, EPA assumed primary production will grow 3.4 percent per year between 2001 and 2010. Between 2011 and 2020, growth was assumed to decrease to an annual rate of 1.7 percent. In the U.S., primary production was assumed to grow to approximately 45,900 tons by 2006. This is based on an October 2004 announcement by U.S. Magnesium that it will expand production capacity to 51,000 metric tons by June 2005. EPA assumed that 90 percent of this capacity will be utilized by 2006. From 2007 to 2020, annual primary production growth was assumed to be 1 percent, reflecting slower growth after the near-term expansion. From 2000 to 2005, Chinese primary production has increased at an annual rate of approximately 8.2 percent; however, this rate is expected to decrease to approximately 5.9 percent from 2006 to 2010 (Edgar, 2004). During this period, Chinese producers are expected to maintain 100 percent of their domestic market, but also increase their share of the global export market. The decrease in growth rate to 5.9 percent reflects domestic issues that Chinese producers will likely face, such as increasing costs from chronic domestic electricity shortages and pending national legislation in banking, health and safety, and environmental standards, as well as potential trade barriers in the export market (Edgar, 2004). Based on this assumption, growth projections from 2011 to 2020 were assumed to remain constant at 5.9 percent.

- *Country-Specific Assumptions.* In Norway, primary production at Norsk Hydro's Porsgrunn facility ceased after 2002 (Norsk Hydro, 2001). EPA assumed that with this closure, no future primary production will occur in Norway. In Canada, due to pricing pressure from China and technical problems, magnesium production at a 58,000 metric ton per year facility in Quebec was shut down indefinitely in April 2003 (USGS, 2004). This facility was assumed to remain off line through 2020. In Ukraine, USGS (2002) reports that the Kalush primary production plant that closed in 1999 would reopen in 2003 and produce 10,000 metric tons of magnesium (Mg) that year, after which it is assumed that production will grow at rate of 3.4 and 1.7 percent between the periods 2004-2010 and 2011-2020, respectively.

<u>Die-Casting</u>

- *Growth Rates.* In Asia (except China), Europe, and Canada, die casting is expected to grow at 9.6 percent, 8.6 percent, and 1.6 percent respectively from 2004 to 2010 (Webb, 2005). Between 2010 and 2020, growth is expected to decrease to half those rates. This decrease reflects the likelihood that the current period of high growth will not continue indefinitely. For China, casting is assumed to grow annually at approximately 10 percent through 2020 (Edgar, 2004). This growth is spurred by increasing investments by Western, Japanese and Taiwanese companies in China to meet domestic demand for camera, computers, and automobile parts. In the U.S., casting is assumed to continue growing at the recent historical growth rate of 10.4 percent through 2010, and then to decline to half that rate.

- *Country-Specific Assumptions.* Due to increasing competition from low-cost imports from China and Taiwan, it is assumed that Japanese die-casting declines and ceases by 2005 (IMA, 2002). Japanese production was assumed to have moved in equal shares to China and Taiwan. The growth in casting observed in China between 2000 and 2005 is more than adequate to have absorbed the Chinese share; thus, this additional casting is not modeled explicitly for China. However, the Japanese casting that is assumed to move to Taiwan is modeled beginning in 2005.

<u>Recycling-based Production</u>

- *Growth Rates.* For all countries but the U.S., recycling growth rates are equated to casting growth rates. In the U.S., recycling is assumed to continue growing at the recent historical growth rate of 9.1 percent through 2010, and then to decline to half that rate.

- *Country-Specific Assumptions.* In the Czech Republic, production at a 10,000 ton capacity magnesium recycling plant started in mid-2002 (USGS, 2002). This analysis assumes that approximately 60 percent of its capacity will be utilized in 2002, after which production output will grow at 8.6 percent annually.

<u>Global Activity Growth Rates</u>

Table 7-14 presents the growth rates used in this analysis:

Table 7-14. Annual Growth Rates for Primary Casting and Recycling Production (Annual Percent Increase)[a]

Year	Primary Production Annual Growth Rates (percent)			Casting Annual Growth Rates (percent)					Recycling Annual Growth Rates (percent)	
	U.S.	China	Rest of World	U.S.	Asia	China	Europe	Canada	U.S.	Rest of World
2001-2005	[a]	8.2	3.4	10.4	9.6	10	8.6	1.6	9.1	Same as Casting[b]
2006-2010	1[a]	5.9	3.4	10.4	9.6	10	8.6	1.6	9.1	Same as Casting[b]
2011-2020	1	5.9	1.7	5.2	4.8	10	4.3	0.8	4.6	Same as Casting[b]

[a] See text above.
[b] Source: Primary and casting growth rates are based on Webb (2005). For recycling, it is assumed that growth rates will be driven by increased use in automotive applications; consequently, growth rates will be the same as casting estimates. Chinese rates based on Edgar (2004).

Historical Emission Factors and Related Assumptions

In this analysis, SF_6 emissions are conservatively assumed to be equivalent to SF_6 consumption (i.e., it is assumed that no SF_6 is destroyed during the metal processes). This may overstate emissions, as recent EPA studies have shown that 5-20 percent of the SF_6 is degraded during its use as a cover gas during at least one type of casting process (Bartos et al., 2003). For the U.S., historical emission factors (i.e., SF_6 consumption per metric ton of magnesium produced) for each magnesium process were estimated based on information supplied by the U.S. EPA's SF_6 Emissions Reduction Partnership for the Magnesium Industry (U.S. EPA, 2002). For all other countries except China and the U.K., Table 7-15 summarizes the emission factors utilized to estimate historical emissions for each of the production processes. The emission factor for primary production was based on measurements made in 1994 and 1995 by U.S. producers. Due to the similarity between the primary and recycling production processes, the emission factor for recycling production was assumed to be the same as that for primary production. The emission factor for die-casting was drawn from a 1996 international survey of die-casters performed by Gjestland and Magers (1996).

Table 7-15. Historical (1990 and 1995) Emission Factors for Primary Casting and Recycling Production

Process	**Historical Emission Factors (kg SF_6/metric ton Mg produced)**	**Source**
Primary Production	1.1	U.S. EPA, 2002
Casting	4.1[a]	Gjestland and Magers, 1996
Recycling	1.1	U.S. EPA, 2002

[a]Emission factor applied to all countries except France, Germany, Italy, Portugal, Spain, Sweden and the U.K.. For these EU countries, estimates were derived from Harnisch and Schwarz (2003).

In China, in 1990 and 1995, the primary cover gas mechanism in primary production was sulfur dioxide (SO_2) generated from the application of solid sulfur powder. Consequently, Chinese emissions of SF_6 in those years are assumed to be zero for primary production. Similarly, magnesium recyclers in the U.K. have used SO_2 since 1990, and U.K. SF_6 emissions from magnesium recycling in 1990 and 1995 are therefore assumed to be zero.

Current and Projected Emission Factors – No-Action Baseline

In the No-Action Baseline, EPA assumed the emission factors remain constant from 2000 to 2020. The No-Action Baseline is intended to model the hypothetical scenario in which no action is taken by magnesium producers or processors to reduce their emission rates below the levels observed during the late 1990s. In fact, many producers and processors have already taken significant steps to reduce their emission rates and to achieve the IMA goal of eliminating SF_6 emissions from magnesium operations by the end of 2010. These include research programs in several countries and, in some cases, the adoption of alternative cover gases such as HFC-134a and SO_2. These actions make it unlikely that actual emissions will be as high as those presented in the No-Action Baseline. Nevertheless, the No-Action Baseline is presented to provide an upper-bound estimate of future emissions and to provide a reference to which the Technology-Adoption Baseline can be compared.

Table 7-16 summarizes the emission factors EPA used to estimate emissions for this scenario from 2000 to 2020 for all countries except the U.S., where data was obtained from the EPA's SF_6 Emission Reduction Partnership for the Magnesium Industry. The 2000 emission factor for primary production was based on measurements made recently by four producers (i.e., producers with domestic U.S. and international operations) (U.S. EPA, 2002).

In China, it is assumed that some Chinese magnesium producers have begun to utilize SF_6 in an effort to produce better quality magnesium for the world market. Between 2000 and 2005, the fraction of Chinese magnesium producers using SF_6 is assumed to have grown from zero to 10 percent. From 2005 through 2020, SF_6 cover use is assumed to remain at 10 percent of total market cover gas usage, with the remaining Chinese primary producers still using SO_2 (Edgar, 2006, Brandt, 2006). Those Chinese producers using SF_6 are assumed to emit at the rate shown in Table 7-16.

For all countries except the U.K. and the Czech Republic, the emission factor for recycling was conservatively assumed to be slightly higher than that for primary production. For the U.K. as well as the Czech Republic, SO_2 will be the primary cover gas system, so emissions from these sources will be zero. For all countries including China, the emission factors for die-casting were estimated based on reports from U.S. die-casters, an international report on emissions of fluorinated chemicals (IEA, 2001), and a report on emissions from European die-casters (Harnisch and Schwarz, 2003).

SF_6 sales trends provide support for the downward trend observed in the emission factors between 1995 and 2000. The RAND survey of global SF_6 sales shows that SF_6 sales to the magnesium sector declined by 60 percent between 1995 and 2000 (Smythe, 2002). Because the magnesium sector has grown internationally between 1995 and 2000, this indicates that emission factors fell significantly during that period.

Table 7-16. Current and Projected (2000-2020) Emission Factors for Primary, Casting, and Recycling Production, No-Action Baseline

Process	Current/Projected Emission Factors (kg SF_6/metric ton Mg produced)	Source
Primary Production	0.75	U.S. EPA, 2002
Casting	1 (0.85)[a]	U.S. EPA, 2002
Recycling	1	U.S. EPA, 2002

[a] Europe-specific casting emission factor (Schwarz, 2006)

Projected Emission Factors –Technology-Adoption Baseline

Industry is currently conducting laboratory evaluations and commercial trial studies of alternate melt protection technologies, such as Novec™ 612 (a proprietary fluoroketone produced by 3M) and HFC-134a. These studies, as well as recent improvements in the equipment and practices for handling SO_2, have led to a marked shift in industry's approach to addressing climate change, opening up the possibility of eliminating SF_6 from daily operations. In fact, the International Magnesium Association (IMA), which represents approximately 80 percent of magnesium production and processing outside of China, has committed to eliminate SF_6 emissions from magnesium operations by the end of 2010.

To reflect the likely adoption of alternate melt protection technologies by global facilities in the near future, EPA developed a Technology-Adoption Baseline for magnesium, which models increasing market penetration by alternative gases from 2002 through 2011 in all countries but China, the U.K., and the Czech Republic. Under this scenario, alternate gases are first introduced into the baseline in 2002 and increase linearly through 2011, at which time their market share represents 100 percent of country-specific cover gas use. Inversely, SF_6 cover gas use in magnesium facilities is assumed to decrease linearly from 100 percent in 2001 to 0 percent by year 2011. From 2011 to 2020, alternate cover gases are assumed to maintain 100 percent market share. Currently, three gases are leading candidates to replace SF_6: SO_2, with a global warming potential (GWP) of 0, a fluoroketone, with a GWP of 1, and HFC-134a, with a GWP of 1,300. An average GWP of 325 was used to reflect the approximate expected market shares of the three gases and to estimate the contribution of their emissions to the baseline.

In the U.K., the above approach was applied to casting; however, U.K. magnesium recyclers were assumed to continue their current practice of using SO_2, which has been the norm since 1990. It was assumed that, with no foreseeable shift to SF_6 or alternate cover gas compounds, the use of SO_2 would continue through 2020, and consequently, greenhouse gas emissions from this segment of the U.K. industry would remain zero. In the Czech Republic, as in the U.K., SO_2 was assumed to be the primary cover gas system utilized through 2020. In China, magnesium producers and processors were assumed to continue using SF_6, as in the No-Action Baseline. In the U.S., most producers and processors were expected to adopt alternative cover gases to meet the industry goal; however, some SF_6 emissions were projected to continue through 2020 because some U.S. casting and recycling firms have not committed to phase out use of the chemical (EPA, 2005).

Uncertainties and Sensitivities

In developing these emissions estimates, EPA used multiple international data sets and the most recent IPCC guidance on estimating emissions from this source. In the Technology-Adoption Baseline, EPA also attempted to reflect recent technological developments and industry emission reduction goals. Nevertheless, the resulting emissions estimates are subject to considerable uncertainty.

Historical and current emissions from this source are affected by both activity levels and emission rates. Although country-specific activity levels are fairly well known for primary production, they are less well known for recycling-based production (particularly the share consisting of magnesium-base alloys) and for casting. In addition, emission rates vary widely across different processes and over time. EPA has attempted to account for these variations (e.g., the decline in emission rates that occurred between 1995 and 2000), but it may have overlooked some regional and process-based differences.

To check its estimates of historical global emissions, EPA compared them to the total sales of SF_6 to the magnesium industry reported by SF_6 manufacturers under the RAND survey (Smythe, 2004). Because the RAND survey did not include SF_6 producers from Russia and China, and Russia and China together accounted for 15 to 20 percent of global emissions from magnesium production and processing between 1990 and the present, one would expect total global emissions to slightly exceed the total sales reported by RAND. In fact, the 1990, 1995 and 2003 emissions estimates in this study are 20 to 35 percent higher than the RAND sales estimates for those years. However, the emissions estimate for 2000 is over twice as high as the RAND sales estimate for that year. This clearly implies that EPA may have overestimated emissions in 2000. However, because EPA's 2000 emissions estimate is already significantly lower than either its 1995 or 2003 emissions estimate, it seems unlikely that the difference between the 2000 estimate and the 2000 sales figure is solely attributable to an overestimate of emissions in this analysis. Instead, at least part of the difference is likely to be attributable to the magnesium industry's increased use of SF_6 from Russia and China, whose SF_6 manufacturers, as noted above, have not been included in the results of the RAND survey. With the exception of the year 2000, there is surprisingly good agreement between the RAND survey and this analysis.

Projected emissions from magnesium production and processing are quite sensitive to (1) estimated activity growth rates, and (2) assumptions regarding the adoption and/or retention of alternate melt protection technologies. EPA has used relatively high activity growth rates to project emissions; therefore, slight changes in these rates can lead to large changes in projected emissions. Assumptions regarding the penetration of alternate melt protection technologies are similarly important. First, the Technology-Adoption Baseline assumes that virtually all IMA members will phase out use of SF_6 by 2011. However, recent discussions with industry representatives indicate that some IMA members may continue to use SF_6 for the foreseeable future. If this is the case, emissions are likely to be higher than those projected in the Technology-Adoption Baseline, but not so high as those projected in the No-Action Baseline. Second, this analysis assumes that some but not all Chinese magnesium producers have adopted SF_6 in place of solid sulfur as they seek to increase the quality of their metal. Because China is currently the world's largest producer of magnesium, greater penetration of the Chinese market by SF_6 could significantly increase both Chinese and global emissions. On the other hand, penetration of the Chinese casting market by alternate cover gases would lower Chinese emissions below those projected here.

Finally, this analysis does not account for the potentially significant impact of yet unannounced mitigation projects funded by developed countries under the Clean Development Mechanism (CDM) of the Kyoto Protocol. CDM projects could significantly decrease SF_6 emissions from magnesium production and processing in China and other developing countries.

Appendices D-11 and D11-b present historical and projected emissions for all countries for this source for the Technology-Adoption and No-Action Baselines.

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Appendix A-1: Combined Methane, Nitrous Oxide, and High GWP Emissions by Country ($MtCO_2eq$)[1]

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	2.47	2.52	3.23	4.28	5.32	6.35	7.37
Algeria	28.82	30.57	37.65	40.96	47.93	56.32	66.22
Argentina	135.62	142.28	155.00	172.32	195.19	222.56	259.20
Armenia	3.81	2.20	2.49	2.96	3.25	3.41	3.57
Australia	139.64	139.29	160.35	166.79	177.58	187.28	196.73
Austria	16.09	15.97	14.92	15.10	14.59	14.34	14.27
Azerbaijan	17.26	14.98	12.85	15.01	17.04	25.37	29.12
Bangladesh	76.39	86.68	94.53	103.34	112.27	123.25	134.31
Belarus	27.90	19.19	20.12	21.01	21.84	22.49	23.13
Belgium	23.94	24.42	23.65	22.76	22.76	23.32	23.15
Bolivia	24.96	25.73	48.41	50.01	51.65	53.52	55.97
Brazil	481.60	508.64	613.27	661.32	718.81	775.36	838.74
Bulgaria	34.55	22.72	16.17	19.50	23.16	26.25	29.35
Cambodia	13.53	16.00	16.01	19.03	22.09	27.11	32.12
Canada	139.87	190.82	160.15	170.84	184.48	202.08	220.07
Chile	18.13	20.14	20.84	23.08	25.34	27.80	30.79
China	1,277.98	1,438.83	1,483.09	1,637.58	1,734.29	1,891.57	2,019.23
Colombia	77.66	84.54	102.36	111.31	121.27	131.76	143.55
Croatia	8.50	6.78	7.07	8.12	8.76	9.25	9.57
Czech Republic	28.16	21.86	19.56	20.04	19.93	18.78	18.55
Democratic Republic of Congo (Kinshasa)	46.63	49.01	88.35	91.04	94.15	97.54	101.30
Denmark	16.66	16.22	15.28	14.36	14.37	14.80	14.66
Ecuador	16.71	18.55	15.21	16.59	18.01	19.39	20.90
Egypt	36.40	43.53	50.91	57.30	63.82	71.12	79.06
Estonia	5.43	3.01	2.86	3.05	2.98	2.88	2.68
Ethiopia	48.24	50.18	61.22	67.94	75.52	82.84	90.99
Finland	14.19	13.69	12.31	12.24	11.98	11.89	11.81
France	171.72	170.77	152.23	151.16	156.84	158.53	164.50
Georgia	6.75	4.81	4.76	4.83	4.98	5.10	5.22
Germany	224.83	196.48	155.58	148.04	137.15	142.16	140.49
Greece	25.60	25.27	26.24	24.88	23.03	23.96	25.07
Hungary	31.37	23.02	23.49	24.67	25.14	25.87	26.64
Iceland	0.99	0.96	1.01	1.03	1.22	1.24	1.25
India	482.39	518.81	572.10	630.60	681.31	737.27	788.12
Indonesia	175.08	195.61	211.99	226.92	238.54	245.81	253.44
Iran	61.21	75.75	87.17	119.24	146.89	178.54	218.53
Iraq	18.06	17.62	18.84	20.54	23.48	26.38	29.52
Ireland	22.36	23.71	24.86	23.49	22.41	21.71	20.92
Israel	9.63	11.35	14.44	17.25	20.46	22.89	25.98
Italy	85.00	86.54	88.77	88.31	87.61	93.05	95.18
Japan	80.03	92.41	100.23	91.82	105.23	111.41	119.88
Jordan	1.45	2.06	2.26	2.65	3.12	3.50	3.90
Kazakhstan	72.74	57.37	36.35	35.21	37.90	41.83	45.51
Kuwait	6.09	6.54	10.39	10.93	14.00	16.12	18.87
Kyrgyzstan	6.08	3.72	3.61	3.82	4.00	4.19	4.38
Laos	10.21	10.59	15.08	15.94	16.86	17.82	18.77
Latvia	6.74	3.45	3.24	3.18	3.53	3.74	4.16
Liechtenstein	0.03	0.04	0.05	0.05	0.05	0.05	0.05
Lithuania	12.13	8.80	7.44	5.67	5.95	6.14	6.35
Luxembourg	0.67	0.71	0.83	0.85	0.87	0.92	0.92
Macedonia	2.54	2.16	2.10	2.15	2.18	2.22	2.24
Mexico	154.45	156.07	189.99	219.27	254.71	301.17	359.39
Moldova	8.32	5.86	4.22	4.36	4.51	4.69	4.88
Monaco	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Mongolia	15.26	17.02	19.19	20.61	22.08	23.63	25.22
Myanmar	60.27	71.30	85.78	92.98	98.82	105.27	111.92
Nepal	29.68	32.41	34.23	37.23	40.46	43.61	47.04
Netherlands	55.60	54.22	43.65	40.16	38.04	37.74	36.06
New Zealand	36.87	37.52	39.20	42.08	43.72	46.58	49.71

Appendix A-1: Combined Methane, Nitrous Oxide, and High GWP Emissions by Country ($MtCO_2eq$)[1]

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Nigeria	111.96	132.52	171.35	198.82	228.32	263.22	302.46
North Korea	44.46	39.59	41.50	41.27	41.26	41.23	41.41
Norway	15.68	13.33	13.58	12.53	12.29	12.45	12.67
Pakistan	79.58	90.68	103.16	113.20	125.36	137.16	150.89
Peru	29.18	34.05	40.58	44.53	48.90	53.46	58.49
Philippines	48.04	53.19	52.56	58.45	64.80	70.46	76.52
Poland	88.03	77.27	70.87	72.41	74.59	77.70	80.82
Portugal	16.64	17.62	16.90	15.54	14.06	14.96	15.80
Romania	68.29	43.22	34.40	36.40	40.81	45.74	50.70
Russian Federation	704.13	485.14	375.92	389.11	406.69	422.74	439.39
Saudi Arabia	26.79	29.53	35.16	41.28	48.37	54.89	61.87
Senegal	11.63	13.41	14.63	15.65	16.81	18.04	19.44
Singapore	1.37	2.58	3.74	5.23	7.64	7.65	8.23
Slovak Republic	12.60	9.57	8.76	10.22	11.18	11.39	11.56
Slovenia	3.80	3.61	3.86	4.10	4.38	4.55	4.73
South Africa	75.66	72.66	80.74	85.36	90.97	95.09	100.10
South Korea	61.88	52.72	59.63	70.71	82.35	93.61	104.42
Spain	60.49	60.70	70.16	71.62	71.35	74.42	75.38
Sweden	15.93	15.72	14.73	14.70	14.93	14.62	14.36
Switzerland	8.12	7.57	7.40	7.39	7.44	7.45	7.45
Tajikistan	9.34	6.39	5.24	4.04	4.15	4.29	4.45
Thailand	98.10	102.68	111.80	118.11	124.91	132.70	142.11
Turkey	121.06	124.67	131.97	152.87	169.36	186.33	211.13
Turkmenistan	23.75	20.27	27.68	49.72	75.82	87.13	98.03
Uganda	19.70	20.35	24.96	28.27	32.20	36.60	41.80
Ukraine	242.18	193.51	171.32	181.63	188.99	201.34	213.91
United Arab Emirates	21.31	29.32	36.03	43.05	53.08	59.33	67.36
United Kingdom	150.35	133.14	102.47	100.99	99.01	97.29	91.26
United States	1,066.20	1,072.84	1,076.76	1,054.29	1,114.42	1,188.43	1,278.57
Uruguay	25.90	26.12	32.88	36.22	39.94	43.64	47.72
Uzbekistan	51.48	54.66	62.05	68.56	74.98	77.82	81.08
Venezuela	87.70	90.02	98.00	111.34	123.50	142.02	170.59
Viet Nam	60.70	68.24	75.43	81.42	87.54	94.87	102.34
Rest of Africa	517.50	557.46	725.89	788.17	861.39	938.24	1,023.80
Rest of China/CPA	3.21	3.96	3.91	4.86	5.31	5.78	6.40
Rest of Latin America	105.77	111.61	122.99	132.42	144.57	157.19	171.89
Rest of Middle East	45.41	55.49	81.02	91.40	109.40	123.04	139.46
Rest of Non-EU Eastern Europe	29.88	28.14	27.25	26.55	28.01	29.75	31.85
Rest of Non-EU FSU	5.83	3.90	3.14	2.66	2.86	3.03	3.14
Rest of OECD90 & EU	1.54	1.36	1.48	1.66	1.95	2.17	2.42
Rest of SE Asia	119.97	138.53	134.87	151.96	164.15	181.19	200.84
Africa	896.54	969.69	1,255.71	1,373.52	1,511.10	1,659.01	1,825.18
China/CPA	1,425.36	1,594.22	1,654.21	1,820.72	1,929.45	2,102.02	2,245.51
Latin America	1,157.70	1,217.74	1,439.52	1,578.41	1,741.89	1,927.87	2,157.24
Middle East	189.96	227.65	285.31	346.35	418.80	484.71	565.49
Non-EU Eastern Europe	43.39	39.60	39.65	41.10	44.28	47.56	51.03
Non-EU FSU	1,179.55	872.00	729.75	782.92	847.01	903.43	955.82
OECD90 & EU	2,801.23	2,752.53	2,645.42	2,644.78	2,758.39	2,912.25	3,079.32
SE Asia	1,232.76	1,345.18	1,464.41	1,608.73	1,740.60	1,877.99	2,017.83
World Totals	8,926.48	9,018.62	9,513.97	10,196.53	10,991.52	11,914.83	12,897.41

[1] Projected estimates incorporate the planned reductions from the "Technology-Adoption" Baselines for the industrial sources of high GWP emissions, and reductions from U.S. voluntary programs for landfills, coal mining activities, and natural gas and oil systems.

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix A-2: Methane Emissions by Country ($MtCO_2eq$)[1]

Country	MtCO₂eq 1990	1995	2000	2005	2010	2015	2020
Albania	2.34	2.41	2.51	2.93	3.37	3.77	4.17
Algeria	19.10	20.93	26.24	27.58	32.06	38.03	45.24
Argentina	78.09	83.65	90.26	95.11	102.11	109.78	120.77
Armenia	3.46	1.95	2.24	2.69	2.98	3.14	3.30
Australia	114.11	112.63	124.55	128.85	137.51	144.02	150.23
Austria	9.87	9.16	8.19	8.10	7.45	6.96	6.64
Azerbaijan	15.60	13.90	11.88	13.99	15.98	24.26	27.96
Bangladesh	43.68	44.68	48.65	53.56	58.53	63.36	68.23
Belarus	16.99	14.03	13.45	13.75	14.06	14.23	14.36
Belgium	10.79	10.75	9.79	9.14	8.51	8.03	7.67
Bolivia	19.08	19.99	31.57	33.10	34.66	36.46	38.84
Brazil	291.17	305.18	365.55	389.07	416.31	439.33	463.32
Bulgaria	21.49	14.33	9.17	10.32	12.79	14.52	16.29
Cambodia	9.46	10.58	11.47	13.52	15.62	18.73	21.83
Canada	77.67	118.89	96.56	102.00	107.99	116.33	124.18
Chile	12.58	13.46	13.63	14.80	15.89	17.12	18.71
China	749.03	802.04	788.11	853.26	924.19	992.20	1,057.99
Colombia	49.74	53.40	58.44	62.35	66.64	71.02	75.95
Croatia	4.19	3.49	3.60	4.12	4.58	4.60	4.73
Czech Republic	16.82	12.91	10.76	10.54	9.61	8.37	7.97
Democratic Republic of Congo (Kinshasa)	33.06	35.28	55.51	58.03	60.96	64.15	67.69
Denmark	5.82	6.15	5.99	5.58	5.30	5.09	4.87
Ecuador	13.74	15.75	14.25	15.46	16.68	17.90	19.22
Egypt	24.41	29.39	34.32	37.96	42.00	46.55	51.40
Estonia	4.37	2.57	2.41	2.50	2.43	2.30	2.10
Ethiopia	41.11	42.00	49.10	54.31	60.17	65.56	71.50
Finland	6.49	6.27	5.49	5.22	5.04	4.67	4.31
France	69.97	69.80	64.54	60.92	57.30	56.66	56.01
Georgia	4.70	3.90	3.56	3.53	3.52	3.55	3.57
Germany	132.63	105.05	83.10	68.53	58.37	57.08	55.14
Greece	10.43	10.77	10.39	9.73	8.75	8.84	9.74
Hungary	12.06	10.19	10.25	10.86	11.26	11.88	12.50
Iceland	0.43	0.49	0.51	0.51	0.51	0.51	0.51
India	428.62	460.43	498.12	547.69	597.11	643.76	687.90
Indonesia	138.16	158.60	170.66	183.02	192.40	197.41	202.50
Iran	46.92	59.98	68.65	95.71	118.65	144.47	177.30
Iraq	11.65	11.55	12.34	13.13	15.03	16.75	18.55
Ireland	12.25	12.95	13.23	11.86	10.91	10.08	9.36
Israel	8.02	9.42	10.52	11.56	12.50	13.30	13.99
Italy	39.30	38.47	38.26	34.57	30.69	28.92	28.34
Japan	24.81	23.43	20.90	20.89	20.87	20.94	21.00
Jordan	1.32	1.83	1.94	2.16	2.40	2.62	2.84
Kazakhstan	50.14	41.78	28.17	26.89	29.39	33.11	36.53
Kuwait	5.98	6.34	9.85	9.76	11.82	13.18	14.90
Kyrgyzstan	5.89	3.59	3.49	3.68	3.85	4.03	4.21
Laos	8.27	8.44	11.95	12.77	13.65	14.53	15.44
Latvia	3.68	2.29	2.10	1.86	1.90	1.95	2.15
Liechtenstein	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Lithuania	7.97	5.63	3.83	3.94	4.01	4.09	4.18
Luxembourg	0.48	0.47	0.56	0.56	0.56	0.56	0.56
Macedonia	2.40	2.00	1.94	1.98	2.01	2.04	2.06
Mexico	133.12	137.22	161.09	184.82	217.61	258.27	311.64
Moldova	4.40	3.18	2.62	2.70	2.79	2.92	3.05
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	6.43	6.89	7.12	7.52	7.97	8.37	8.81
Myanmar	50.83	60.44	69.39	74.91	79.08	83.42	87.92
Nepal	20.54	22.43	23.93	25.59	27.29	28.74	30.24
Netherlands	25.77	23.92	19.62	17.33	14.91	13.31	11.68
New Zealand	25.30	25.52	26.18	27.30	27.20	27.80	28.70

Appendix A-2: Methane Emissions by Country ($MtCO_2eq$)[1]

Country	1990	1995	2000	2005	2010	2015	2020
	$MtCO_2eq$						
Nigeria	77.85	96.65	130.08	150.54	171.74	196.89	224.56
North Korea	33.51	35.16	34.73	33.67	32.64	31.66	30.77
Norway	5.16	5.38	5.31	5.36	5.40	5.43	5.46
Pakistan	68.92	77.08	88.32	97.75	108.78	119.54	132.11
Peru	16.91	17.65	19.14	20.60	22.17	23.72	25.35
Philippines	35.66	37.75	37.47	41.16	44.83	48.28	51.72
Poland	59.24	51.99	46.26	46.40	46.66	47.91	49.20
Portugal	10.47	11.30	10.50	8.62	6.75	6.87	7.00
Romania	44.61	30.81	24.64	26.62	30.35	34.16	37.97
Russian Federation	561.55	409.60	306.82	314.46	326.21	337.45	348.61
Saudi Arabia	18.17	20.96	24.41	27.72	31.60	35.28	39.09
Senegal	6.85	7.68	8.22	9.14	10.15	11.20	12.32
Singapore	0.84	1.22	1.38	1.68	1.77	1.96	2.17
Slovak Republic	6.39	5.23	4.59	4.68	4.75	4.83	4.95
Slovenia	2.19	2.04	2.05	2.05	2.05	2.05	2.04
South Africa	50.48	50.17	53.45	55.30	55.93	55.97	56.52
South Korea	46.04	33.20	31.52	33.40	36.25	38.48	40.20
Spain	29.38	31.33	35.60	36.63	37.29	38.12	38.93
Sweden	6.59	6.52	5.84	5.70	5.57	4.85	4.13
Switzerland	4.48	4.05	3.75	3.65	3.44	3.37	3.29
Tajikistan	4.57	3.24	2.86	2.96	3.06	3.19	3.32
Thailand	79.92	82.34	87.78	91.60	95.10	100.24	106.22
Turkey	74.76	82.62	90.79	105.26	114.45	123.16	138.20
Turkmenistan	23.07	19.68	27.09	49.08	75.15	86.43	97.29
Uganda	9.54	10.55	12.14	13.41	14.92	16.45	18.17
Ukraine	195.32	161.78	148.08	153.41	157.40	164.15	171.08
United Arab Emirates	20.84	29.00	35.65	41.29	50.28	56.02	63.43
United Kingdom	77.52	66.02	49.99	46.23	43.10	41.42	39.42
United States	599.29	592.91	546.42	521.02	528.98	534.79	549.12
Uruguay	15.27	17.97	18.41	19.88	21.48	22.89	24.39
Uzbekistan	40.07	43.91	48.37	53.84	59.19	60.98	63.01
Venezuela	56.95	64.51	73.59	83.78	92.14	107.04	131.61
Viet Nam	50.59	56.95	63.49	68.59	73.81	79.13	84.55
Rest of Africa	300.94	321.67	414.43	447.16	484.32	521.59	562.45
Rest of Latin America	64.97	70.07	79.68	85.49	91.62	98.11	105.96
Rest of Middle East	31.87	40.77	64.12	71.97	86.06	96.08	108.50
Rest of Non-EU Eastern Europe	17.26	17.64	17.64	18.20	18.94	19.86	21.15
Rest of OECD90 & EU	0.96	0.91	0.94	0.98	1.03	1.07	1.11
Rest of SE Asia	80.32	94.42	92.10	104.09	112.08	124.20	138.02
Africa	563.33	614.30	783.49	853.42	932.24	1,016.39	1,109.84
China/CPA	857.29	920.07	916.87	989.34	1,067.87	1,144.61	1,219.38
Latin America	751.64	798.86	925.60	1,004.46	1,097.29	1,201.64	1,335.78
Middle East	144.77	179.87	227.47	273.29	328.35	377.70	438.60
Non-EU Eastern Europe	26.19	25.54	25.69	27.22	28.89	30.27	32.11
Non-EU FSU	925.74	720.52	598.64	640.97	693.59	737.43	776.27
OECD90 & EU	1,553.58	1,513.82	1,393.08	1,364.36	1,373.70	1,400.99	1,445.00
SE Asia	993.53	1,072.59	1,149.32	1,254.44	1,353.21	1,449.40	1,547.24
World Totals	5,816.07	5,845.57	6,020.16	6,407.49	6,875.14	7,358.43	7,904.22

[1] Projected estimates include reductions from U.S. voluntary programs for landfills, coal mining activities, and natural gas and oil systems.

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix A-3: Nitrous Oxide Emissions by Country ($MtCO_2eq$)

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.12	0.10	0.71	1.33	1.94	2.56	3.18
Algeria	9.70	9.56	11.02	12.40	13.99	15.82	18.01
Argentina	56.61	58.18	63.96	75.64	90.52	109.51	134.39
Armenia	0.33	0.24	0.24	0.25	0.25	0.25	0.25
Australia	20.50	22.65	30.36	32.05	33.05	35.03	37.02
Austria	5.74	6.14	5.77	5.76	5.78	5.79	5.80
Azerbaijan	1.35	0.88	0.78	0.78	0.77	0.77	0.78
Bangladesh	32.69	41.98	45.84	49.64	53.49	59.54	65.64
Belarus	10.82	5.10	6.53	6.91	7.24	7.60	7.99
Belgium	13.06	13.10	12.88	12.14	12.42	12.60	12.78
Bolivia	5.87	5.74	16.83	16.89	16.95	17.01	17.07
Brazil	183.07	194.28	241.42	264.46	291.18	321.69	357.36
Bulgaria	12.98	8.28	6.77	8.67	9.58	10.76	11.88
Cambodia	4.07	5.42	4.53	5.51	6.48	8.39	10.30
Canada	52.33	62.75	52.05	57.70	62.37	68.03	73.76
Chile	5.51	6.62	7.05	7.86	8.77	9.77	10.90
China	521.04	626.40	645.36	684.05	725.29	767.51	811.94
Colombia	27.85	31.04	43.62	48.18	53.30	59.01	65.41
Croatia	4.00	3.18	3.30	3.80	3.95	4.38	4.54
Czech Republic	11.30	8.79	8.21	8.06	8.10	8.01	7.99
Democratic Republic of Congo (Kinshasa)	13.56	13.73	32.84	32.99	33.17	33.36	33.58
Denmark	10.78	9.69	8.65	7.81	7.86	7.94	8.02
Ecuador	2.96	2.78	0.89	0.95	1.01	1.06	1.12
Egypt	11.46	13.81	15.96	17.67	19.59	21.76	24.24
Estonia	1.06	0.44	0.44	0.53	0.53	0.56	0.56
Ethiopia	7.13	8.18	12.11	13.61	15.32	17.25	19.44
Finland	7.65	7.25	6.55	6.64	6.46	6.62	6.79
France	93.55	92.62	80.95	79.93	86.11	82.99	89.43
Georgia	2.03	0.89	1.13	1.15	1.18	1.20	1.23
Germany	86.58	80.94	62.26	63.57	61.09	61.24	61.39
Greece	14.29	13.16	13.45	12.99	13.29	13.78	13.98
Hungary	19.13	12.62	12.80	12.98	12.60	12.44	12.27
Iceland	0.37	0.34	0.35	0.35	0.35	0.35	0.35
India	51.11	54.36	67.06	71.29	75.97	81.01	86.64
Indonesia	36.53	36.72	40.84	42.43	44.26	46.12	48.25
Iran	14.06	15.57	18.31	22.82	27.40	33.06	40.02
Iraq	6.37	6.03	6.46	7.36	8.39	9.56	10.89
Ireland	10.03	10.55	11.31	11.14	10.97	10.91	10.85
Israel	1.39	1.50	1.67	1.90	2.17	2.45	2.77
Italy	40.22	41.09	43.07	44.67	46.11	48.75	51.38
Japan	40.15	40.57	37.41	35.57	40.71	38.81	40.51
Jordan	0.12	0.20	0.23	0.24	0.26	0.27	0.29
Kazakhstan	22.37	15.23	7.91	8.08	8.29	8.53	8.78
Kuwait	0.07	0.12	0.16	0.18	0.20	0.22	0.24
Kyrgyzstan	0.17	0.11	0.11	0.11	0.12	0.13	0.14
Laos	1.94	2.15	3.13	3.16	3.20	3.27	3.31
Latvia	3.06	1.10	0.99	1.03	1.16	1.21	1.32
Liechtenstein	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Lithuania	4.15	3.11	3.44	1.40	1.40	1.39	1.39
Luxembourg	0.18	0.20	0.22	0.22	0.22	0.22	0.22
Macedonia	0.13	0.15	0.15	0.15	0.16	0.16	0.17
Mexico	19.89	17.42	24.47	26.78	28.82	31.06	33.54
Moldova	3.89	2.66	1.58	1.59	1.62	1.65	1.69
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	8.83	10.12	12.06	13.07	14.09	15.24	16.39
Myanmar	9.43	10.85	16.38	18.03	19.69	21.79	23.92
Nepal	9.15	9.98	10.29	11.61	13.12	14.80	16.72
Netherlands	21.34	22.43	19.91	19.96	19.86	19.99	19.92
New Zealand	10.41	11.38	12.29	13.95	15.58	17.69	19.77

Appendix A-3: Nitrous Oxide Emissions by Country ($MtCO_2eq$)

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Nigeria	34.09	35.85	41.21	48.13	56.31	65.94	77.36
North Korea	10.88	4.36	6.55	7.03	7.59	8.21	8.91
Norway	5.06	4.80	5.22	5.21	5.21	5.21	5.21
Pakistan	10.59	13.50	14.59	14.74	15.42	16.14	16.93
Peru	12.25	16.36	21.30	23.57	26.10	28.92	32.08
Philippines	12.34	15.31	14.33	15.30	16.26	17.20	18.20
Poland	28.50	25.00	24.03	25.01	26.29	27.68	28.92
Portugal	6.12	6.11	6.05	6.40	6.67	7.16	7.88
Romania	20.07	11.18	8.26	9.20	9.68	10.61	11.55
Russian Federation	119.99	60.39	54.50	57.51	59.59	61.14	62.53
Saudi Arabia	8.51	8.33	9.87	11.22	12.76	14.51	16.49
Senegal	4.78	5.73	6.39	6.48	6.59	6.75	7.02
Singapore	0.16	0.77	0.90	1.00	1.12	1.20	1.29
Slovak Republic	6.07	4.20	3.83	5.01	5.70	5.73	5.64
Slovenia	1.51	1.45	1.54	1.57	1.60	1.63	1.67
South Africa	23.84	20.79	21.93	23.05	24.24	25.50	26.87
South Korea	13.20	14.45	15.41	16.86	18.47	19.73	21.11
Spain	24.33	22.94	27.77	28.85	28.92	29.04	29.16
Sweden	8.90	8.70	8.26	8.19	8.38	8.52	8.65
Switzerland	3.36	3.25	3.19	3.00	2.94	2.85	2.75
Tajikistan	0.49	0.42	0.40	0.41	0.41	0.43	0.44
Thailand	18.10	20.13	23.20	24.30	25.60	26.42	27.27
Turkey	45.97	41.78	40.62	46.31	53.02	60.84	70.05
Turkmenistan	0.66	0.58	0.58	0.60	0.63	0.66	0.69
Uganda	10.16	9.80	12.82	14.85	17.27	20.13	23.62
Ukraine	45.34	30.85	22.66	27.01	30.30	35.77	41.24
United Arab Emirates	0.10	0.12	0.14	0.15	0.17	0.20	0.23
United Kingdom	67.93	57.12	44.89	45.70	45.87	41.84	37.81
United States	376.40	385.07	395.60	375.84	379.57	388.36	399.39
Uruguay	10.62	8.13	14.38	16.10	18.03	20.18	22.59
Uzbekistan	11.32	10.66	13.48	14.19	14.97	15.86	16.91
Venezuela	27.72	23.56	22.54	24.48	26.65	29.06	31.76
Viet Nam	10.09	11.26	11.85	12.55	13.25	15.10	16.96
Rest of Africa	215.41	234.89	308.78	338.49	372.88	411.40	454.93
Rest of China/CPA	3.21	3.96	3.91	4.86	5.31	5.78	6.40
Rest of Latin America	40.72	41.37	42.51	44.86	49.27	54.31	59.92
Rest of Middle East	13.13	14.39	16.32	17.70	19.88	22.35	25.13
Rest of Non-EU Eastern Europe	9.53	9.48	8.39	7.87	8.57	9.34	10.11
Rest of Non-EU FSU	5.83	3.90	3.14	2.66	2.86	3.03	3.14
Rest of OECD90 & EU	0.57	0.43	0.44	0.44	0.49	0.55	0.62
Rest of SE Asia	38.95	43.02	36.89	38.92	42.28	45.86	49.90
Africa	330.12	352.34	463.08	507.68	559.36	617.91	685.05
China/CPA	560.06	663.66	687.40	730.23	775.21	823.49	874.22
Latin America	393.08	405.46	498.97	549.77	610.60	681.59	766.14
Middle East	43.75	46.27	53.15	61.58	71.23	82.61	96.05
Non-EU Eastern Europe	13.79	12.91	12.56	13.14	14.62	16.45	18.00
Non-EU FSU	224.60	131.93	113.03	121.26	128.23	137.01	145.81
OECD90 & EU	1,073.63	1,041.23	999.86	997.86	1,029.95	1,055.14	1,096.70
SE Asia	232.26	261.05	285.72	304.11	325.69	349.82	375.86
World Totals	2,871.28	2,914.86	3,113.76	3,285.63	3,514.88	3,764.03	4,057.84

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix A-4: High GWP Emissions by Country ($MtCO_2eq$)[1]

Country	1990	1995	2000	2005	2010	2015	2020
	$MtCO_2eq$						
Albania	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Algeria	0.03	0.07	0.39	0.99	1.87	2.47	2.97
Argentina	0.92	0.45	0.77	1.57	2.56	3.27	4.04
Armenia	0.02	0.01	0.01	0.03	0.02	0.02	0.02
Australia	5.04	4.02	5.44	5.89	7.02	8.23	9.48
Austria	0.47	0.66	0.96	1.24	1.36	1.59	1.83
Azerbaijan	0.31	0.21	0.19	0.24	0.28	0.33	0.39
Bangladesh	0.01	0.02	0.05	0.13	0.24	0.34	0.44
Belarus	0.08	0.06	0.14	0.35	0.55	0.66	0.79
Belgium	0.10	0.58	0.98	1.48	1.84	2.69	2.70
Bolivia	0.00	0.01	0.01	0.03	0.04	0.05	0.06
Brazil	7.37	9.18	6.30	7.79	11.32	14.33	18.07
Bulgaria	0.08	0.11	0.23	0.50	0.79	0.97	1.18
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	9.87	9.18	11.53	11.14	14.11	17.72	22.12
Chile	0.04	0.05	0.15	0.42	0.68	0.90	1.18
China	7.91	10.39	49.62	100.27	84.81	131.86	149.30
Colombia	0.07	0.10	0.30	0.78	1.34	1.73	2.19
Croatia	0.31	0.12	0.16	0.20	0.23	0.26	0.30
Czech Republic	0.04	0.16	0.59	1.44	2.23	2.39	2.59
Democratic Republic of Congo (Kinshasa)	0.01	0.01	0.01	0.02	0.02	0.02	0.03
Denmark	0.06	0.37	0.64	0.97	1.21	1.77	1.77
Ecuador	0.01	0.02	0.07	0.19	0.33	0.43	0.55
Egypt	0.53	0.34	0.62	1.68	2.23	2.80	3.43
Estonia	0.00	0.00	0.01	0.02	0.02	0.03	0.03
Ethiopia	0.00	0.00	0.01	0.02	0.03	0.04	0.05
Finland	0.05	0.17	0.28	0.38	0.48	0.59	0.72
France	8.20	8.35	6.74	10.30	13.42	18.88	19.06
Georgia	0.02	0.02	0.07	0.15	0.28	0.35	0.42
Germany	5.62	10.50	10.23	15.94	17.69	23.84	23.95
Greece	0.89	1.33	2.40	2.17	0.99	1.35	1.35
Hungary	0.17	0.21	0.45	0.82	1.28	1.56	1.87
Iceland	0.20	0.13	0.15	0.17	0.36	0.37	0.39
India	2.66	4.03	6.92	11.61	8.24	12.50	13.58
Indonesia	0.39	0.29	0.50	1.48	1.88	2.28	2.69
Iran	0.24	0.19	0.22	0.72	0.84	1.02	1.21
Iraq	0.04	0.04	0.04	0.05	0.06	0.07	0.08
Ireland	0.08	0.20	0.33	0.49	0.53	0.72	0.72
Israel	0.22	0.43	2.25	3.79	5.79	7.14	9.23
Italy	5.49	6.97	7.44	9.08	10.81	15.38	15.45
Japan	15.07	28.41	41.91	35.36	43.65	51.66	58.37
Jordan	0.01	0.02	0.10	0.25	0.46	0.61	0.77
Kazakhstan	0.23	0.37	0.27	0.24	0.22	0.19	0.19
Kuwait	0.04	0.08	0.38	1.00	1.97	2.72	3.73
Kyrgyzstan	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Laos	0.00	0.00	0.00	0.01	0.02	0.02	0.02
Latvia	0.01	0.06	0.15	0.29	0.48	0.58	0.69
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.01	0.06	0.16	0.33	0.54	0.66	0.77
Luxembourg	0.01	0.03	0.05	0.08	0.10	0.14	0.14
Macedonia	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Mexico	1.45	1.43	4.44	7.67	8.28	11.84	14.21
Moldova	0.02	0.01	0.03	0.06	0.10	0.12	0.15
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.01	0.00	0.01	0.01	0.02	0.02	0.03
Myanmar	0.00	0.01	0.01	0.04	0.05	0.07	0.08
Nepal	0.00	0.00	0.01	0.03	0.05	0.06	0.09
Netherlands	8.48	7.86	4.12	2.87	3.27	4.44	4.46
New Zealand	1.15	0.62	0.73	0.82	0.94	1.09	1.25

Appendix A-4: High GWP Emissions by Country ($MtCO_2eq$)[1]

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Nigeria	0.02	0.03	0.06	0.16	0.27	0.38	0.55
North Korea	0.07	0.07	0.22	0.57	1.04	1.36	1.73
Norway	5.46	3.15	3.05	1.96	1.68	1.81	2.00
Pakistan	0.07	0.10	0.25	0.71	1.16	1.48	1.85
Peru	0.02	0.04	0.14	0.37	0.63	0.82	1.06
Philippines	0.04	0.14	0.76	2.00	3.72	4.98	6.60
Poland	0.29	0.27	0.57	1.00	1.64	2.11	2.69
Portugal	0.05	0.21	0.35	0.52	0.64	0.93	0.93
Romania	3.61	1.24	1.50	0.58	0.79	0.96	1.18
Russian Federation	22.60	15.15	14.59	17.14	20.89	24.16	28.25
Saudi Arabia	0.12	0.24	0.88	2.34	4.00	5.10	6.29
Senegal	0.00	0.00	0.02	0.04	0.07	0.09	0.10
Singapore	0.37	0.58	1.46	2.55	4.75	4.49	4.76
Slovak Republic	0.15	0.14	0.33	0.53	0.72	0.83	0.97
Slovenia	0.10	0.12	0.27	0.49	0.73	0.87	1.02
South Africa	1.34	1.70	5.36	7.01	10.80	13.62	16.72
South Korea	2.65	5.06	12.70	20.45	27.62	35.41	43.12
Spain	6.78	6.43	6.79	6.14	5.14	7.26	7.29
Sweden	0.43	0.50	0.63	0.81	0.98	1.26	1.58
Switzerland	0.29	0.27	0.46	0.74	1.06	1.24	1.41
Tajikistan	4.28	2.72	1.98	0.68	0.67	0.68	0.69
Thailand	0.08	0.21	0.83	2.22	4.21	6.04	8.62
Turkey	0.33	0.28	0.57	1.30	1.89	2.33	2.87
Turkmenistan	0.02	0.01	0.01	0.04	0.04	0.04	0.05
Uganda	0.00	0.00	0.00	0.01	0.01	0.02	0.02
Ukraine	1.52	0.88	0.57	1.21	1.29	1.42	1.60
United Arab Emirates	0.37	0.20	0.25	1.61	2.62	3.12	3.70
United Kingdom	4.91	10.00	7.59	9.06	10.04	14.03	14.02
United States	90.52	94.86	134.74	157.44	205.87	265.29	330.06
Uruguay	0.01	0.02	0.09	0.24	0.43	0.57	0.74
Uzbekistan	0.09	0.09	0.21	0.53	0.82	0.98	1.17
Venezuela	3.03	1.95	1.86	3.08	4.71	5.92	7.23
Viet Nam	0.02	0.03	0.09	0.28	0.47	0.64	0.83
Rest of Africa	1.16	0.90	2.68	2.52	4.20	5.25	6.41
Rest of Latin America	0.08	0.17	0.80	2.07	3.68	4.77	6.00
Rest of Middle East	0.41	0.32	0.58	1.73	3.46	4.62	5.82
Rest of Non-EU Eastern Europe	3.08	1.02	1.22	0.49	0.51	0.55	0.59
Rest of OECD90 & EU	0.01	0.02	0.10	0.24	0.43	0.55	0.68
Rest of SE Asia	0.69	1.10	5.88	8.95	9.79	11.12	12.91
Africa	3.09	3.04	9.14	12.43	19.50	24.70	30.28
China/CPA	8.01	10.49	49.94	101.15	86.37	133.91	151.91
Latin America	12.99	13.42	14.95	24.19	34.00	44.63	55.32
Middle East	1.44	1.52	4.69	11.49	19.21	24.40	30.83
Non-EU Eastern Europe	3.41	1.15	1.40	0.73	0.78	0.85	0.93
Non-EU FSU	29.21	19.55	18.08	20.69	25.20	29.00	33.74
OECD90 & EU	174.02	197.48	252.48	282.55	354.74	456.12	537.61
SE Asia	6.98	11.54	29.37	50.18	61.71	78.77	94.73
World Totals	239.14	258.19	380.04	503.41	601.50	792.37	935.36

[1] Projected estimates incorporate the planned reductions from the "Technology-Adoption" Baselines for the industrial sources of high GWP emissions.

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-1: Methane Emissions from Fugitives from Natural Gas and Oil Systems

	MtCO2eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.19	0.02	0.02	0.03	0.04	0.04	0.05
Algeria	9.37	10.71	14.94	15.15	18.30	22.71	27.76
Argentina	8.13	11.10	15.13	15.13	16.96	21.07	28.36
Armenia	1.68	0.48	0.73	1.13	1.30	1.49	1.67
Australia	6.96	7.04	5.84	7.55	9.27	12.00	14.72
Austria	0.27	0.29	0.30	0.31	0.30	0.29	0.29
Azerbaijan	9.30	7.78	5.57	7.63	9.55	17.74	21.32
Bangladesh	0.15	0.24	0.31	0.32	0.34	0.43	0.54
Belarus	2.12	2.32	2.52	2.74	2.99	3.11	3.18
Belgium	0.45	0.44	0.40	0.39	0.38	0.37	0.37
Bolivia	1.70	1.94	2.00	2.36	2.64	3.28	4.42
Brazil	0.99	1.13	2.05	3.68	7.21	11.34	15.45
Bulgaria	0.62	0.65	0.60	0.67	0.83	0.92	1.01
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	26.18	35.09	38.27	38.27	39.12	40.82	42.09
Chile	0.72	0.73	1.17	1.45	1.63	2.02	2.72
China	2.20	2.60	4.07	6.28	10.20	16.70	19.75
Colombia	1.38	1.48	1.85	1.91	2.14	2.65	3.55
Croatia	1.19	1.10	1.11	1.33	1.56	1.67	1.89
Czech Republic	0.68	0.80	0.60	0.63	0.66	0.74	0.74
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Denmark	0.04	0.06	0.08	0.08	0.08	0.08	0.08
Ecuador	0.44	0.50	0.56	0.66	0.73	0.90	1.16
Egypt	3.11	4.72	6.88	8.30	10.01	12.42	15.16
Estonia	0.79	0.38	0.43	0.39	0.36	0.35	0.34
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.01	0.08	0.06	0.06	0.06	0.06	0.06
France	2.47	2.02	1.92	1.82	1.72	1.71	1.69
Georgia	1.06	0.87	0.52	0.59	0.66	0.75	0.84
Germany	7.01	7.54	7.35	7.70	7.72	7.91	8.09
Greece	0.04	0.03	0.18	0.18	0.19	0.20	0.21
Hungary	1.13	1.56	1.59	1.59	1.59	1.59	1.59
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	8.08	12.62	15.95	26.02	35.95	49.86	61.79
Indonesia	32.49	42.37	44.02	48.61	49.78	47.97	46.53
Iran	20.73	30.74	35.79	58.66	76.25	99.12	128.85
Iraq	3.74	3.00	3.20	2.80	3.40	3.81	4.33
Ireland	0.15	0.13	0.10	0.10	0.10	0.10	0.10
Israel	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Italy	6.63	5.67	5.37	5.41	5.74	6.09	6.57
Japan	0.37	0.42	0.45	0.45	0.44	0.43	0.43
Jordan	0.05	0.11	0.11	0.11	0.14	0.15	0.17
Kazakhstan	3.19	2.65	3.79	5.88	8.64	12.44	15.95
Kuwait	5.32	5.73	9.08	8.87	10.82	12.07	13.69
Kyrgyzstan	0.47	0.17	0.13	0.17	0.19	0.21	0.24
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.27	0.22	0.17	0.18	0.19	0.20	0.22
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.55	0.50	0.44	0.55	0.62	0.70	0.79
Luxembourg	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	41.54	44.61	60.65	77.16	102.70	136.69	183.36
Moldova	1.08	0.53	0.80	0.91	1.02	1.16	1.30
Monaco	0.00	0.00	0.00				
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.41	0.62	1.02	1.90	1.98	2.51	3.20
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	2.04	1.97	1.06	1.06	1.06	1.06	1.06
New Zealand	0.32	0.29	0.39	0.46	0.47	0.55	0.76
Nigeria	13.40	18.53	39.56	51.29	61.90	76.67	93.58

Appendix B-1: Methane Emissions from Fugitives from Natural Gas and Oil Systems

	MtCO2eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Norway	0.35	0.59	0.65	0.66	0.67	0.69	0.70
Pakistan	3.60	4.82	6.38	6.29	6.54	8.30	10.56
Peru	0.09	0.15	0.06	0.06	0.07	0.09	0.12
Philippines	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Poland	4.10	3.90	4.32	5.78	7.24	9.59	11.95
Portugal	0.04	0.04	0.20	0.23	0.26	0.27	0.28
Romania	20.07	11.39	8.34	9.28	12.01	14.65	17.30
Russian Federation	336.00	241.50	165.90	172.65	179.40	186.70	194.01
Saudi Arabia	1.60	2.00	2.61	2.77	3.38	3.76	4.27
Senegal	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Singapore	0.01	0.29	0.29	0.49	0.51	0.64	0.81
Slovak Republic	0.51	0.61	0.72	0.72	0.88	1.02	1.19
Slovenia	0.01	0.01	0.01	0.01	0.01	0.01	0.01
South Africa	0.01	0.21	0.18	0.21	0.25	0.31	0.38
South Korea	0.58	1.64	3.24	4.07	6.08	7.58	8.57
Spain	0.58	0.73	0.83	0.93	1.04	1.17	1.30
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.31	0.27	0.26	0.24	0.23	0.23	0.23
Tajikistan	0.79	0.19	0.05	0.06	0.07	0.08	0.08
Thailand	2.86	3.73	6.88	7.72	8.04	10.19	12.96
Turkey	20.70	29.18	39.22	50.88	57.20	63.50	76.12
Turkmenistan	19.51	16.72	24.35	46.20	72.13	83.27	93.99
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	78.72	82.08	87.22	90.77	94.32	98.15	101.99
United Arab Emirates	19.98	27.91	34.35	39.83	48.65	54.20	61.41
United Kingdom	10.66	10.04	8.33	8.00	7.67	7.51	7.35
United States[1]	148.32	152.08	149.61	127.61	142.37	155.03	169.29
United States[2]	148.32	152.08	149.61	150.78	169.88	190.74	216.19
Uruguay	0.00	0.00	0.01	0.01	0.02	0.02	0.02
Uzbekistan	27.26	30.37	34.84	39.65	44.32	45.43	46.81
Venezuela	29.98	35.12	37.93	45.44	50.96	63.26	85.11
Viet Nam	0.01	0.15	0.24	0.28	0.29	0.36	0.45
Rest of Africa	6.39	6.54	7.52	8.23	9.92	12.28	14.96
Rest of Latin America	1.97	2.95	4.89	5.58	6.25	7.77	10.45
Rest of Middle East	18.00	25.11	45.95	51.39	62.78	69.95	79.22
Rest of Non-EU Eastern Europe	0.17	0.80	0.24	0.26	0.36	0.42	0.46
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	9.11	11.46	15.02	19.72	20.51	26.01	33.05
Africa	32.29	40.72	69.10	83.18	100.40	124.41	151.85
China/CPA	2.22	2.75	4.32	6.56	10.49	17.07	20.21
Latin America	86.93	99.71	126.31	153.44	191.30	249.10	334.72
Middle East	69.43	94.63	131.10	164.45	205.44	243.09	291.97
Non-EU Eastern Europe	1.55	1.92	1.37	1.62	1.95	2.13	2.41
Non-EU FSU	481.18	385.66	326.43	368.38	414.57	450.53	481.40
OECD90 & EU	262.68	274.04	278.11	272.23	300.53	329.91	366.97
SE Asia	57.29	77.81	93.12	115.16	129.74	153.51	178.05
World Totals	993.57	977.25	1,029.87	1,165.03	1,354.42	1,569.74	1,827.58

[1] US emissions INCLUDING reductions from voluntary programs; included in OECD90 & EU and World totals

[2] US emissions NOT INCLUDING the effect of voluntary programs; not included in OECD90 & EU and World totals

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-2: Methane Emissions from Fugitives from Coal Mining Activities

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.07	0.06	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Argentina	0.19	0.10	0.25	0.23	0.21	0.19	0.19
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	15.82	17.48	19.64	21.82	26.38	28.18	29.67
Austria	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.04	0.03	0.02	0.02	0.02	0.02	0.02
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	1.24	1.11	1.32	1.22	1.12	1.03	0.95
Bulgaria	1.59	1.45	1.20	1.34	1.65	1.84	2.01
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	1.91	1.71	0.95	0.88	0.88	0.85	0.82
Chile	0.61	0.29	0.10	0.12	0.11	0.10	0.10
China	126.13	149.10	117.57	135.66	153.75	171.84	189.93
Colombia	1.86	1.99	2.95	3.44	4.02	4.68	5.46
Croatia	0.05	0.02	0.00	0.00	0.00	0.00	0.00
Czech Republic	7.60	5.81	5.02	4.82	3.91	3.11	2.97
Democratic Republic of Congo (Kinshasa)	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Denmark	0.07	0.13	0.06	0.09	0.09	0.09	0.09
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.41	0.25	0.24	0.21	0.20	0.19	0.19
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.01	0.01	0.01	0.00	0.00	0.00	0.00
France	4.33	4.43	2.56	2.60	2.63	2.66	2.69
Georgia	0.07	0.01	0.00	0.00	0.00	0.00	0.00
Germany	25.77	17.59	10.18	8.39	7.75	7.15	5.90
Greece	1.10	1.22	1.35	1.32	1.40	1.47	1.53
Hungary	1.12	0.70	0.57	0.49	0.43	0.38	0.33
India	10.87	13.65	15.84	19.46	23.08	28.37	33.65
Indonesia	0.33	0.43	0.45	0.49	0.50	0.49	0.47
Iran	0.29	0.30	0.37	0.39	0.42	0.45	0.47
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	0.12	0.06	0.07	0.07	0.08	0.08	0.09
Japan	2.81	1.34	0.77	0.76	0.75	0.74	0.73
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	24.87	17.19	9.98	6.67	6.38	6.10	5.81
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.30	0.04	0.03	0.03	0.03	0.02	0.02
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.12	0.13	0.13	0.14	0.15	0.16	0.17
Mexico	1.48	1.76	2.15	2.47	2.84	3.26	3.74
Moldova	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.20	0.10	0.07	0.05	0.04	0.03	0.03
Myanmar	0.01	0.01	0.09	0.13	0.19	0.28	0.41
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.03	0.03	0.02	0.02	0.02	0.02	0.02
New Zealand	0.27	0.28	0.34	0.41	0.41	0.48	0.67
Nigeria	1.83	2.86	1.24	0.02	0.00	0.00	0.00
North Korea	25.26	27.23	26.91	25.56	24.28	23.07	21.91
Norway	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Pakistan	0.90	0.99	1.03	1.06	1.09	1.12	1.15
Peru	0.04	0.02	0.02	0.00	0.00	0.00	0.00
Philippines	0.16	0.22	0.22	0.22	0.23	0.23	0.23

Appendix B-2: Methane Emissions from Fugitives from Coal Mining Activities

	MtCO2eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Poland	16.77	15.57	11.90	11.33	10.77	10.26	9.75
Portugal	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Romania	3.66	3.93	2.67	2.77	2.76	2.75	2.74
Russian Federation	60.90	36.75	28.98	26.25	27.51	26.91	26.30
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.57	0.62	0.61	0.46	0.49	0.50	0.49
Slovenia	0.30	0.27	0.25	0.25	0.25	0.25	0.25
South Africa	6.72	6.66	7.08	7.40	7.21	7.10	7.44
South Korea	4.83	1.61	1.17	0.91	0.71	0.56	0.44
Spain	1.79	1.43	1.20	1.20	0.98	0.71	0.44
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tajikistan	0.10	0.01	0.00	0.00	0.00	0.00	0.00
Thailand	0.22	0.34	0.32	0.36	0.39	0.43	0.48
Turkey	1.63	1.56	1.70	1.83	1.96	2.10	2.25
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	55.34	30.12	28.33	26.32	24.48	23.77	23.23
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	18.29	12.59	7.00	6.73	6.60	6.41	6.22
United States[1]	81.89	65.78	56.22	55.33	51.09	46.44	46.42
United States[2]	81.89	65.78	56.22	71.50	75.86	73.82	76.67
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.46	0.27	0.26	0.24	0.23	0.22	0.21
Venezuela	0.02	0.04	0.08	0.11	0.15	0.19	0.25
Viet Nam	0.46	0.83	1.00	1.19	1.42	1.69	2.02
Rest of Africa	1.16	1.15	0.96	0.96	1.00	1.08	1.20
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.81	0.75	1.72	2.16	2.82	3.77	5.16
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.82	1.04	1.64	1.64	1.65	1.66	1.69
Africa	9.74	10.69	9.31	8.41	8.25	8.22	8.68
China/CPA	152.05	177.26	145.55	162.47	179.50	196.63	213.89
Latin America	5.44	5.33	6.89	7.60	8.44	9.46	10.70
Middle East	0.29	0.30	0.37	0.39	0.42	0.45	0.47
Non-EU Eastern Europe	1.05	0.96	1.85	2.30	2.97	3.93	5.34
Non-EU FSU	142.04	84.40	67.59	59.51	58.63	57.02	55.58
OECD90 & EU	187.99	154.31	124.56	123.17	121.50	116.71	116.31
SE Asia	18.13	18.28	20.75	24.28	27.85	33.14	38.52
World Totals	516.74	451.55	376.88	388.14	407.56	425.56	449.48

[1] US emissions INCLUDING reductions from voluntary programs; included in OECD90 & EU and World totals

[2] US emissions NOT INCLUDING the effect of voluntary programs; not included in OECD90 & EU and World totals

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-3: Methane Emissions from Stationary and Mobile Combustion

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.12	0.01	0.01	0.01	0.01	0.01	0.01
Algeria	0.13	0.11	0.13	0.15	0.18	0.20	0.24
Argentina	0.20	0.68	0.77	0.91	1.07	1.23	1.43
Armenia	0.03	0.03	0.02	0.02	0.03	0.03	0.04
Australia	2.39	2.43	2.21	2.41	2.67	2.99	3.32
Austria	0.47	0.41	0.30	0.31	0.30	0.29	0.29
Azerbaijan	0.09	0.06	0.06	0.06	0.06	0.07	0.08
Bangladesh	0.11	0.11	0.11	0.16	0.22	0.30	0.41
Belarus	0.55	0.45	0.35	0.40	0.42	0.45	0.47
Belgium	0.26	0.24	0.21	0.21	0.21	0.21	0.21
Bolivia	0.01	0.01	0.02	0.02	0.03	0.03	0.04
Brazil	0.58	0.74	0.92	1.09	1.29	1.43	1.61
Bulgaria	0.10	0.08	0.06	0.07	0.08	0.09	0.10
Cambodia	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Canada	4.50	4.58	5.32	5.32	5.44	5.68	5.85
Chile	0.08	0.10	0.13	0.15	0.18	0.20	0.23
China	1.30	2.11	2.72	3.44	4.39	5.31	6.45
Colombia	0.18	0.24	0.25	0.30	0.36	0.42	0.48
Croatia	0.19	0.11	0.13	0.16	0.19	0.20	0.23
Czech Republic	1.25	0.67	0.41	0.39	0.31	0.25	0.25
Democratic Republic of Congo (Kinshasa)	0.02	0.02	0.02	0.02	0.03	0.03	0.03
Denmark	0.19	0.47	0.58	0.55	0.52	0.49	0.46
Ecuador	0.05	0.06	0.05	0.06	0.06	0.06	0.06
Egypt	0.23	0.25	0.33	0.33	0.34	0.35	0.36
Estonia	0.09	0.12	0.11	0.10	0.09	0.09	0.09
Ethiopia	0.15	0.18	0.24	0.27	0.31	0.36	0.41
Finland	0.48	0.48	0.46	0.46	0.46	0.46	0.46
France	4.93	4.62	4.08	3.87	3.66	3.63	3.61
Georgia	0.06	0.01	0.03	0.03	0.03	0.03	0.03
Germany	4.56	1.68	1.26	1.26	1.15	1.10	1.05
Greece	0.41	0.44	0.47	0.41	0.40	0.40	0.41
Hungary	0.85	0.73	0.68	0.71	0.71	0.71	0.71
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.15	0.19	0.20	0.25	0.32	0.39	0.49
Indonesia	0.16	0.22	0.28	0.31	0.43	0.50	0.76
Iran	1.05	1.51	1.82	2.07	2.36	2.75	3.21
Iraq	0.18	0.21	0.22	0.25	0.28	0.33	0.38
Ireland	0.15	0.10	0.11	0.11	0.12	0.13	0.14
Israel	0.06	0.08	0.10	0.11	0.12	0.14	0.16
Italy	1.55	1.82	1.73	1.74	1.85	1.96	2.11
Japan	0.60	0.62	0.62	0.62	0.62	0.63	0.63
Jordan	0.03	0.03	0.04	0.04	0.04	0.04	0.04
Kazakhstan	0.13	0.13	0.10	0.10	0.11	0.11	0.12
Kuwait	0.04	0.08	0.10	0.11	0.13	0.15	0.17
Kyrgyzstan	0.04	0.03	0.03	0.03	0.04	0.04	0.05
Latvia	0.27	0.28	0.25	0.26	0.28	0.30	0.32
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.11	0.20	0.25	0.25	0.25	0.25	0.25
Luxembourg	0.05	0.05	0.07	0.07	0.07	0.07	0.07
Macedonia	0.00	0.01	0.01	0.01	0.02	0.02	0.02
Mexico	0.71	0.81	0.88	1.06	1.10	1.14	1.17
Moldova	0.15	0.09	0.03	0.03	0.03	0.03	0.04
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.01	0.02	0.02	0.03	0.03	0.03	0.03
Nepal	0.00	0.01	0.01	0.01	0.01	0.02	0.02
Netherlands	0.67	0.66	0.62	0.68	0.70	0.74	0.74
New Zealand	0.21	0.18	0.12	0.14	0.15	0.17	0.24
Nigeria	0.22	0.25	0.28	0.32	0.37	0.43	0.49
North Korea	0.41	0.43	0.41	0.45	0.49	0.53	0.57

Appendix B-3: Methane Emissions from Stationary and Mobile Combustion

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Norway	0.25	0.26	0.28	0.28	0.28	0.28	0.28
Pakistan	0.07	0.09	0.11	0.14	0.18	0.23	0.29
Peru	0.07	0.07	0.08	0.09	0.11	0.12	0.14
Philippines	0.18	0.25	0.28	0.33	0.34	0.35	0.36
Poland	0.79	1.16	1.00	1.04	1.09	1.14	1.19
Portugal	0.45	0.44	0.43	0.48	0.54	0.56	0.58
Romania	0.44	1.07	0.76	0.76	0.76	0.76	0.76
Russian Federation	4.20	3.53	4.12	4.12	4.70	5.04	5.38
Saudi Arabia	0.32	0.39	0.46	0.51	0.58	0.67	0.77
Senegal	0.07	0.14	0.24	0.29	0.34	0.40	0.47
Singapore	0.05	0.06	0.07	0.09	0.10	0.12	0.14
Slovak Republic	0.37	0.21	0.17	0.17	0.18	0.18	0.16
Slovenia	0.15	0.14	0.13	0.13	0.13	0.13	0.13
South Africa	0.75	0.86	0.69	0.75	0.82	0.87	0.94
South Korea	0.49	0.67	0.90	1.12	1.40	1.67	2.01
Spain	1.18	1.09	1.01	0.96	0.91	0.90	0.89
Sweden	0.56	0.57	0.48	0.43	0.38	0.35	0.33
Switzerland	0.17	0.13	0.11	0.10	0.10	0.09	0.09
Tajikistan	0.13	0.01	0.00	0.00	0.00	0.00	0.00
Thailand	0.04	0.07	0.08	0.09	0.09	0.09	0.10
Turkey	1.06	0.97	0.76	0.70	0.66	0.65	0.65
Turkmenistan	0.05	0.05	0.06	0.06	0.07	0.08	0.10
Uganda	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Ukraine	4.12	1.51	0.74	0.88	0.97	1.02	1.07
United Arab Emirates	0.07	0.09	0.10	0.12	0.13	0.16	0.19
United Kingdom	2.51	1.91	2.05	2.46	2.46	2.46	2.46
United States	12.62	12.58	10.71	9.19	8.89	8.91	9.14
Uruguay	0.01	0.01	0.01	0.02	0.02	0.02	0.03
Uzbekistan	0.26	0.22	0.22	0.24	0.26	0.29	0.33
Venezuela	0.25	0.29	0.31	0.37	0.45	0.54	0.65
Viet Nam	0.04	0.04	0.06	0.08	0.10	0.12	0.15
Rest of Africa	2.16	2.39	2.40	2.73	3.11	3.53	4.00
Rest of Latin America	0.67	0.70	0.92	1.07	1.25	1.42	1.61
Rest of Middle East	0.18	0.25	0.29	0.32	0.36	0.41	0.47
Rest of Non-EU Eastern Europe	0.00	0.15	0.15	0.16	0.17	0.19	0.21
Rest of OECD90 & EU	0.01	0.02	0.02	0.02	0.02	0.03	0.03
Rest of SE Asia	0.34	0.46	0.64	0.80	1.00	1.21	1.48
Africa	3.74	4.22	4.33	4.88	5.52	6.18	6.95
China/CPA	1.75	2.58	3.20	3.97	4.98	5.96	7.18
Latin America	2.81	3.72	4.36	5.14	5.91	6.62	7.44
Middle East	1.93	2.65	3.12	3.53	4.01	4.64	5.38
Non-EU Eastern Europe	0.31	0.27	0.31	0.34	0.38	0.42	0.47
Non-EU FSU	9.81	6.12	5.75	5.98	6.73	7.20	7.69
OECD90 & EU	44.64	41.37	37.81	36.68	36.44	37.10	38.01
SE Asia	1.60	2.14	2.73	3.32	4.11	4.91	6.07
World Totals	66.58	63.08	61.60	63.84	68.09	73.03	79.20

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-4: Methane Emissions from Biomass Combustion

	MtCO₂eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.10	0.02	0.02	0.02	0.02	0.02	0.02
Algeria	0.00	0.01	0.02	0.02	0.02	0.03	0.03
Argentina	0.08	0.14	0.18	0.18	0.19	0.19	0.20
Armenia	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	3.40	3.74	4.07	4.28	4.50	4.65	4.81
Bolivia	0.15	0.15	0.16	0.16	0.17	0.17	0.18
Brazil	5.95	5.49	5.48	5.76	6.05	6.24	6.44
Cambodia	0.39	0.50	0.71	0.80	0.89	0.99	1.09
Chile	0.52	0.66	0.76	0.78	0.80	0.82	0.84
China	43.34	45.10	46.70	47.41	48.12	48.56	48.99
Colombia	1.26	1.38	0.93	0.95	0.97	1.00	1.03
Democratic Republic of Congo (Kinshasa)	2.11	2.37	2.73	3.00	3.30	3.58	3.89
Ecuador	0.38	0.39	0.41	0.42	0.43	0.44	0.45
Egypt	1.55	1.75	1.96	2.15	2.37	2.57	2.79
Ethiopia	3.33	3.93	4.44	4.88	5.36	5.82	6.33
Georgia	0.01	0.01	0.02	0.02	0.02	0.02	0.02
India	31.42	34.36	37.19	38.70	40.28	41.21	42.17
Indonesia	6.66	7.29	7.20	7.30	7.67	8.05	8.23
Iran	0.18	0.18	0.19	0.21	0.23	0.32	0.46
Iraq	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.48	0.50	0.51	0.52	0.53	0.54	0.54
Macedonia	0.05	0.05	0.04	0.04	0.04	0.04	0.05
Mexico	1.56	1.59	1.61	1.65	1.69	1.74	1.78
Moldova	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Mongolia	0.24	0.28	0.29	0.30	0.31	0.32	0.34
Myanmar	2.34	2.38	2.44	2.54	2.64	2.76	2.87
Nepal	1.49	1.66	1.82	1.92	2.01	2.08	2.15
Netherlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nigeria	8.29	9.34	10.65	11.70	12.85	13.96	15.16
North Korea	0.25	0.27	0.27	0.28	0.29	0.30	0.31
Pakistan	2.80	3.08	3.35	3.52	3.70	3.83	3.96
Peru	0.85	0.91	0.97	1.00	1.02	1.05	1.08
Philippines	2.41	1.65	1.03	1.07	1.12	1.16	1.21
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.23	0.26	0.29	0.32	0.35	0.39	0.42
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	1.64	1.80	1.96	2.16	2.37	2.57	2.80
South Korea	0.04	0.04	0.04	0.05	0.05	0.05	0.05
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	9.46	9.65	9.89	10.29	10.71	11.15	11.62
Turkey	1.90	1.79	1.83	2.19	2.61	2.99	3.41
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	1.56	1.76	1.97	2.17	2.38	2.59	2.81
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Uruguay	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Viet Nam	2.45	2.49	2.55	2.66	2.77	2.88	3.00
Rest of Africa	17.90	16.50	18.57	20.37	22.35	24.29	26.41
Rest of Latin America	2.68	2.66	2.77	2.84	2.91	2.99	3.07
Rest of Middle East	0.03	0.03	0.04	0.04	0.04	0.06	0.09
Rest of Non-EU Eastern Europe	0.09	0.10	0.10	0.10	0.10	0.10	0.10
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	1.20	1.20	1.24	1.30	1.36	1.41	1.46

Appendix B-4: Methane Emissions from Biomass Combustion

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Africa	36.63	37.74	42.60	46.77	51.35	55.80	60.64
China/CPA	47.14	49.14	51.03	51.96	52.90	53.59	54.28
Latin America	13.57	13.53	13.41	13.89	14.39	14.80	15.22
Middle East	0.22	0.23	0.23	0.26	0.28	0.40	0.57
Non-EU Eastern Europe	0.24	0.16	0.16	0.16	0.16	0.16	0.16
Non-EU FSU	0.05	0.05	0.06	0.06	0.06	0.06	0.06
OECD90 & EU	1.90	1.79	1.84	2.19	2.61	2.99	3.41
SE Asia	61.23	65.05	68.28	70.97	74.03	76.35	78.52
World Totals	160.98	167.68	177.61	186.25	195.79	204.15	212.87

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-5: Methane Emissions from Other Industrial Non-Agricultural Sources

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Australia	0.07	0.08	0.07	0.07	0.07	0.07	0.07
Austria	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Belarus	0.02	0.02	0.03	0.03	0.04	0.04	0.04
Belgium	0.03	0.03	0.04	0.02	0.02	0.02	0.01
Brazil	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Bulgaria	0.06	0.07	0.07	0.07	0.07	0.07	0.07
Croatia	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Czech Republic	0.12	0.08	0.07	0.07	0.07	0.07	0.07
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.01	0.01	0.01	0.01	0.01	0.01	0.01
France	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.34	0.33	0.38	0.38	0.38	0.38	0.38
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Indonesia	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Iran	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	0.11	0.11	0.06	0.07	0.07	0.08	0.08
Japan	0.34	0.30	0.16	0.16	0.16	0.16	0.16
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Netherlands	0.30	0.30	0.30	0.30	0.30	0.30	0.30
New Zealand	0.02	0.06	0.10	0.10	0.10	0.10	0.10
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Philippines	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Poland	0.27	0.24	0.17	0.13	0.13	0.13	0.13
Portugal	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Romania	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Russian Federation	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Saudi Arabia	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Slovenia	0.00	0.00	0.01	0.01	0.00	0.00	0.00
South Africa	0.07	0.03	0.03	0.03	0.03	0.03	0.03
South Korea	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Spain	0.06	0.07	0.07	0.07	0.07	0.07	0.07
Sweden	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Switzerland	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Thailand	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ukraine	0.10	0.03	0.23	0.23	0.23	0.23	0.23
United Kingdom	0.18	0.15	0.08	0.08	0.08	0.08	0.08
United States	2.52	2.86	2.90	2.58	2.59	2.59	2.62
Venezuela	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Rest of Africa	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Rest of SE Asia	0.00	0.00	0.01	0.06	0.06	0.06	0.06
Africa	0.15	0.11	0.11	0.11	0.11	0.11	0.11
China/CPA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latin America	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Middle East	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Non-EU Eastern Europe	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Non-EU FSU	0.61	0.52	0.74	0.74	0.74	0.75	0.75
OECD90 & EU	4.54	4.80	4.62	4.25	4.26	4.26	4.29
SE Asia	0.49	0.49	0.49	0.55	0.55	0.55	0.55
World Totals	6.31	6.44	6.47	6.16	6.17	6.17	6.20

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-6: Methane Emissions from Enteric Fermentation

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	1.22	1.59	1.58	1.57	1.57	1.56	1.56
Algeria	3.43	3.32	3.98	4.45	5.12	6.03	7.55
Argentina	54.89	56.44	51.78	55.67	59.86	62.53	65.33
Armenia	0.93	0.72	0.74	0.78	0.84	0.82	0.80
Australia	67.51	63.00	64.36	63.74	64.97	65.28	65.60
Austria	3.57	3.44	3.24	3.19	3.10	3.01	2.92
Azerbaijan	3.44	3.23	3.30	3.27	3.25	3.23	3.24
Bangladesh	10.89	10.78	10.68	11.72	12.88	13.93	15.08
Belarus	9.90	7.53	6.22	6.07	5.93	5.78	5.65
Belgium	4.49	4.50	4.24	4.13	4.02	3.91	3.80
Bolivia	9.19	9.85	10.86	11.82	12.87	13.81	14.82
Brazil	184.95	200.40	208.03	226.28	246.35	262.07	278.91
Bulgaria	3.78	1.79	1.66	2.17	2.26	2.19	2.24
Cambodia	2.94	3.45	3.60	4.79	5.97	8.02	10.07
Canada	18.68	21.26	20.83	23.41	25.68	28.67	31.66
Chile	5.60	6.48	6.86	7.43	8.06	8.63	9.24
China	186.30	221.32	230.79	258.88	291.32	320.23	352.74
Colombia	25.95	29.06	28.93	30.83	32.86	34.65	36.54
Croatia	1.34	0.85	0.75	0.87	0.97	0.97	0.97
Czech Republic	3.27	2.05	1.70	1.72	1.78	1.81	1.85
Democratic Republic of Congo (Kinshasa)	1.52	1.30	1.08	1.22	1.38	1.54	1.72
Denmark	3.11	3.08	2.87	2.70	2.57	2.53	2.48
Ecuador	5.90	6.74	6.94	7.56	8.24	8.83	9.48
Egypt	6.79	7.58	8.46	8.85	9.26	9.58	9.92
Estonia	1.09	0.56	0.38	0.61	0.69	0.71	0.72
Ethiopia	28.82	28.04	32.12	35.97	40.33	44.16	48.37
Finland	1.87	1.63	1.58	1.43	1.43	1.43	1.43
France	30.89	29.62	29.23	29.14	29.04	29.13	29.22
Georgia	1.55	1.16	1.18	1.15	1.12	1.10	1.08
Germany	34.29	28.52	26.55	22.31	18.81	18.87	18.93
Greece	2.86	2.83	2.88	2.90	2.89	2.88	2.87
Hungary	2.99	1.82	1.77	2.23	2.68	3.37	4.06
Iceland	0.27	0.25	0.24	0.24	0.24	0.24	0.24
India	179.84	190.62	201.89	217.80	235.03	246.41	258.38
Indonesia	17.68	18.93	17.97	20.41	23.21	25.02	26.98
Iran	9.75	10.87	13.03	15.83	19.60	20.71	21.88
Iraq	2.58	1.94	2.01	2.16	2.34	2.46	2.60
Ireland	9.18	9.65	9.93	8.70	7.78	6.95	6.21
Israel	0.62	0.68	0.69	0.70	0.71	0.71	0.71
Italy	12.34	12.48	12.25	11.97	11.52	11.17	10.83
Japan	7.25	7.12	6.76	6.97	7.18	7.39	7.60
Jordan	0.36	0.54	0.45	0.48	0.51	0.54	0.57
Kazakhstan	14.55	14.05	7.09	7.11	7.21	7.33	7.47
Kuwait	0.05	0.06	0.09	0.10	0.11	0.12	0.12
Kyrgyzstan	2.57	1.61	1.65	1.71	1.77	1.82	1.87
Laos	2.06	2.47	2.26	2.52	2.80	3.08	3.38
Latvia	2.06	0.83	0.56	0.53	0.56	0.61	0.65
Liechtenstein	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lithuania	3.30	2.22	1.31	1.31	1.31	1.31	1.31
Luxembourg	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Macedonia	0.98	0.67	0.56	0.55	0.55	0.55	0.54
Mexico	47.27	44.59	41.53	44.89	48.58	51.90	55.48
Moldova	1.74	1.47	0.78	0.77	0.76	0.74	0.73
Mongolia	4.93	5.41	5.95	6.32	6.72	7.07	7.45
Myanmar	8.33	9.27	10.22	11.41	12.75	14.06	15.50
Nepal	10.18	11.07	11.75	12.43	13.12	13.81	14.50
Netherlands	7.32	7.02	6.45	6.28	6.02	5.82	5.63
New Zealand	21.53	22.18	23.07	23.87	23.66	23.96	24.26
Nigeria	23.06	25.27	30.87	34.10	37.67	40.97	44.57
North Korea	1.19	1.00	0.89	0.94	0.99	1.03	1.06

Appendix B-6: Methane Emissions from Enteric Fermentation

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Norway	1.71	1.76	1.75	1.77	1.79	1.81	1.82
Pakistan	40.50	44.86	51.34	57.12	63.86	68.74	74.72
Peru	7.33	7.74	8.58	9.42	10.36	11.28	12.30
Philippines	5.51	5.64	6.04	6.79	7.62	8.42	9.29
Poland	16.66	11.86	9.08	8.35	7.68	7.07	6.50
Portugal	2.59	2.57	2.57	2.61	2.66	2.72	2.77
Romania	11.15	6.62	5.69	6.37	7.08	7.95	8.82
Russian Federation	93.03	68.27	43.61	47.84	52.07	57.02	61.96
Saudi Arabia	1.57	1.85	1.85	1.95	2.06	2.13	2.21
Senegal	2.82	3.23	3.61	4.04	4.53	5.05	5.62
Singapore	0.01	0.00	0.00	0.00	0.01	0.01	0.01
Slovak Republic	2.44	1.55	1.10	1.22	1.17	1.13	1.09
Slovenia	0.73	0.71	0.69	0.69	0.69	0.69	0.69
South Africa	19.25	17.54	17.96	18.51	19.07	19.19	19.32
South Korea	2.58	3.75	2.83	3.07	3.34	3.59	3.86
Spain	12.65	12.86	14.26	14.60	14.95	15.31	15.67
Sweden	3.03	3.11	2.90	2.83	2.75	2.75	2.75
Switzerland	2.77	2.65	2.52	2.48	2.42	2.36	2.30
Tajikistan	2.58	2.05	1.79	1.84	1.88	1.92	1.97
Thailand	13.04	12.74	10.35	11.71	13.26	14.62	16.13
Turkey	25.52	23.90	21.36	22.26	23.23	23.91	24.62
Turkmenistan	2.38	1.81	1.50	1.54	1.60	1.64	1.68
Uganda	4.15	4.48	5.10	5.65	6.27	6.81	7.39
Ukraine	36.50	28.79	16.19	18.38	19.11	20.83	22.56
United Arab Emirates	0.24	0.34	0.45	0.52	0.60	0.70	0.82
United Kingdom	18.17	17.96	17.30	17.11	16.83	16.61	16.38
United States	117.86	122.97	115.60	112.88	114.72	110.54	108.64
Uruguay	12.38	13.73	13.35	14.63	16.03	17.27	18.60
Uzbekistan	5.84	6.38	6.09	6.27	6.46	6.63	6.80
Venezuela	13.44	15.03	16.13	17.72	19.48	21.03	22.71
Viet Nam	6.51	7.22	7.67	8.62	9.68	10.71	11.85
Rest of Africa	123.87	133.48	150.23	167.29	186.59	204.43	224.41
Rest of Latin America	29.78	31.41	31.15	34.06	37.30	40.14	43.24
Rest of Middle East	4.56	4.44	5.17	5.57	6.02	6.36	6.75
Rest of Non-EU Eastern Europe	4.07	4.17	3.33	3.26	3.20	3.13	3.05
Rest of OECD90 & EU	0.17	0.18	0.18	0.20	0.21	0.22	0.23
Rest of SE Asia	9.45	9.91	9.53	10.38	11.31	12.16	13.08
Africa	213.71	224.25	253.41	280.08	310.23	337.76	368.87
China/CPA	203.93	240.87	251.17	282.06	317.48	350.14	386.56
Latin America	396.68	421.49	424.13	460.31	499.99	532.14	566.63
Middle East	19.73	20.70	23.74	27.31	31.96	33.73	35.66
Non-EU Eastern Europe	7.62	7.27	6.21	6.26	6.29	6.20	6.12
Non-EU FSU	175.01	137.08	90.15	96.73	101.99	108.86	115.80
OECD90 & EU	457.46	434.86	417.20	413.26	414.72	414.64	417.14
SE Asia	298.01	317.58	332.60	362.85	396.38	420.76	447.52
World Totals	1,772.14	1,804.10	1,798.61	1,928.87	2,079.05	2,204.23	2,344.30

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-7: Methane Emissions from Rice Cultivation

	MtCO2eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.32	0.79	0.80	0.84	0.89	0.93	0.97
Australia	0.49	0.65	0.74	0.74	0.74	0.74	0.74
Azerbaijan	0.00	0.01	0.01	0.01	0.01	0.01	0.02
Bangladesh	16.11	15.36	16.52	18.27	20.01	21.72	23.37
Belgium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolivia	0.09	0.11	0.13	0.14	0.16	0.17	0.18
Brazil	5.03	6.03	5.06	5.38	5.68	5.95	6.18
Bulgaria	0.09	0.01	0.03	0.04	0.04	0.04	0.04
Cambodia	3.08	3.16	3.32	3.74	4.19	4.65	5.10
Chile	0.13	0.13	0.11	0.11	0.12	0.13	0.13
China	237.30	220.23	215.95	223.92	231.13	237.47	242.07
Colombia	3.53	3.05	3.30	3.57	3.83	4.08	4.33
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	2.47	3.00	2.27	2.62	3.03	3.47	3.95
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	2.21	3.24	3.12	3.36	3.58	3.80	4.01
Egypt	3.99	5.38	6.04	6.67	7.36	8.02	8.63
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	0.10	0.13	0.10	0.10	0.10	0.10	0.10
Greece	0.07	0.11	0.08	0.08	0.08	0.08	0.08
Hungary	0.05	0.02	0.01	0.02	0.02	0.02	0.02
India	85.66	85.89	89.50	96.54	103.31	109.69	115.49
Indonesia	41.25	47.90	48.25	51.39	54.37	57.12	59.54
Iran	2.23	2.40	2.58	2.65	2.71	2.77	2.84
Iraq	0.47	1.03	0.76	0.87	0.99	1.12	1.24
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	1.54	1.71	1.57	1.57	1.57	1.57	1.57
Japan	7.08	7.20	6.02	6.20	6.39	6.58	6.76
Kazakhstan	1.22	1.44	1.24	1.22	1.20	1.21	1.22
Kyrgyzstan	0.01	0.04	0.05	0.06	0.06	0.06	0.07
Laos	3.34	2.82	3.47	3.89	4.34	4.79	5.24
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.35	0.26	0.33	0.35	0.37	0.40	0.41
Myanmar	27.89	35.34	35.15	37.48	39.47	41.23	42.79
Nepal	5.94	6.43	6.91	7.39	7.87	8.08	8.29
Nigeria	15.33	22.80	26.16	29.69	33.27	36.87	40.39
North Korea	3.02	2.70	2.49	2.55	2.60	2.65	2.70
Pakistan	4.57	4.67	5.00	5.65	6.37	7.17	7.97
Peru	1.06	1.16	1.71	1.85	1.98	2.11	2.24
Philippines	12.60	14.27	15.33	16.76	18.15	19.50	20.79
Portugal	0.26	0.16	0.18	0.18	0.19	0.19	0.19
Romania	0.17	0.03	0.01	0.01	0.01	0.01	0.01
Russian Federation	2.41	1.44	1.45	1.41	1.37	1.33	1.29
Senegal	0.11	0.10	0.14	0.16	0.18	0.20	0.22
South Africa	0.01	0.01	0.01	0.01	0.01	0.01	0.01
South Korea	8.61	7.30	7.21	7.42	7.56	7.65	7.70
Spain	0.23	0.14	0.29	0.29	0.29	0.29	0.29
Tajikistan	0.08	0.11	0.13	0.14	0.15	0.16	0.17
Thailand	42.79	44.32	45.30	45.72	46.16	46.62	47.12
Turkey	0.27	0.29	0.35	0.38	0.40	0.42	0.44
Turkmenistan	0.08	0.06	0.15	0.16	0.17	0.18	0.20
Uganda	0.49	0.70	0.91	1.07	1.28	1.53	1.81
Ukraine	0.41	0.17	0.11	0.00	0.00	0.00	0.00
United States	7.12	7.62	7.49	7.64	6.83	6.89	6.86
Uruguay	1.45	2.72	3.44	3.57	3.69	3.79	3.90
Uzbekistan	0.26	0.29	0.11	0.12	0.13	0.14	0.15
Venezuela	0.47	0.73	0.62	0.68	0.73	0.79	0.84

Appendix B-7: Methane Emissions from Rice Cultivation

	MtCO₂eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Viet Nam	29.18	32.75	37.06	39.64	42.27	44.93	47.47
Rest of Africa	7.28	11.73	13.82	15.88	18.19	20.76	23.58
Rest of Latin America	2.34	2.44	2.61	2.79	2.95	3.10	3.23
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	8.53	8.25	8.03	8.86	9.67	10.40	11.13
Africa	29.69	43.72	49.36	56.11	63.32	70.86	78.59
China/CPA	275.92	261.66	262.28	273.75	284.53	294.49	302.58
Latin America	16.99	20.67	21.22	22.64	23.99	25.26	26.42
Middle East	2.69	3.43	3.34	3.51	3.70	3.89	4.08
Non-EU Eastern Europe	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	4.48	3.55	3.26	3.12	3.09	3.11	3.10
OECD90 & EU	17.46	18.06	16.89	17.27	16.67	16.94	17.12
SE Asia	253.94	269.74	277.20	295.48	312.95	329.19	344.22
World Totals	601.19	620.84	633.55	671.89	708.25	743.74	776.12

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-8: Methane Emissions from Manure Management

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.07	0.12	0.31	0.49	0.67	0.76	0.84
Algeria	0.17	0.17	0.20	0.22	0.25	0.29	0.36
Argentina	2.16	2.36	2.05	2.21	2.39	2.52	2.65
Armenia	0.06	0.04	0.05	0.05	0.05	0.05	0.05
Australia	1.54	1.72	1.98	1.95	2.00	2.00	2.02
Austria	1.02	0.99	0.90	0.89	0.86	0.84	0.82
Azerbaijan	0.63	0.59	0.60	0.59	0.59	0.58	0.58
Bangladesh	1.53	1.52	1.50	1.66	1.83	1.98	2.16
Belarus	1.22	0.94	0.79	0.78	0.77	0.76	0.76
Belgium	2.57	2.75	2.67	2.66	2.64	2.63	2.62
Bolivia	0.38	0.42	0.47	0.50	0.55	0.58	0.62
Brazil	7.10	7.87	7.98	8.67	9.45	10.08	10.76
Bulgaria	1.50	0.72	0.57	0.74	0.77	0.75	0.77
Cambodia	0.38	0.47	0.49	0.65	0.81	1.09	1.37
Canada	3.13	3.36	3.32	3.80	4.10	4.59	5.07
Chile	0.21	0.26	0.30	0.33	0.36	0.39	0.42
China	15.70	18.89	19.76	21.91	24.35	26.24	28.32
Colombia	0.63	0.73	0.73	0.78	0.83	0.87	0.92
Croatia	0.23	0.16	0.16	0.18	0.20	0.20	0.20
Czech Republic	1.02	0.76	0.69	0.70	0.72	0.73	0.74
Democratic Republic of Congo (Kinshasa)	0.10	0.10	0.09	0.10	0.11	0.13	0.14
Denmark	0.74	0.86	0.94	0.89	0.82	0.77	0.71
Ecuador	0.19	0.22	0.25	0.27	0.30	0.32	0.34
Egypt	0.49	0.61	0.68	0.71	0.75	0.78	0.81
Estonia	0.37	0.19	0.06	0.09	0.10	0.11	0.11
Ethiopia	1.07	1.04	1.19	1.33	1.49	1.62	1.78
Finland	0.21	0.23	0.22	0.20	0.20	0.20	0.20
France	13.79	13.66	13.30	13.25	13.21	13.25	13.29
Georgia	0.28	0.21	0.21	0.21	0.21	0.20	0.20
Germany	27.10	23.76	23.27	19.63	16.54	16.59	16.65
Greece	0.50	0.48	0.49	0.49	0.49	0.49	0.49
Hungary	0.84	0.50	0.50	0.73	0.76	0.77	0.78
Iceland	0.02	0.02	0.02	0.02	0.02	0.02	0.02
India	18.83	20.13	21.52	23.20	25.01	26.22	27.48
Indonesia	1.08	1.25	1.01	1.13	1.28	1.37	1.47
Iran	0.39	0.44	0.60	0.69	0.82	0.87	0.92
Iraq	0.14	0.08	0.09	0.10	0.10	0.11	0.11
Ireland	1.26	1.36	1.43	1.25	1.12	1.00	0.89
Israel	0.18	0.21	0.22	0.23	0.24	0.25	0.25
Italy	4.03	3.88	3.86	3.96	4.06	4.16	4.26
Japan	1.07	0.99	0.93	0.96	0.99	1.01	1.04
Jordan	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Kazakhstan	1.72	1.04	0.54	0.55	0.56	0.57	0.58
Kuwait	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Kyrgyzstan	0.36	0.25	0.27	0.28	0.29	0.29	0.30
Laos	0.30	0.37	0.31	0.34	0.38	0.41	0.45
Latvia	0.28	0.11	0.08	0.07	0.08	0.08	0.09
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.49	0.33	0.20	0.20	0.20	0.20	0.20
Luxembourg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Macedonia	0.07	0.05	0.05	0.05	0.05	0.05	0.05
Mexico	0.94	1.17	1.29	1.39	1.49	1.59	1.69
Moldova	0.31	0.21	0.13	0.12	0.12	0.12	0.12
Mongolia	0.18	0.20	0.22	0.24	0.25	0.27	0.29
Myanmar	0.91	1.11	1.31	1.43	1.56	1.69	1.82
Nepal	0.65	0.71	0.76	0.80	0.85	0.89	0.94
Netherlands	2.97	3.04	2.67	2.54	2.41	2.29	2.17
New Zealand	0.57	0.58	0.55	0.62	0.61	0.65	0.68
Nigeria	1.20	1.33	1.59	1.75	1.93	2.09	2.27
North Korea	0.16	0.09	0.09	0.10	0.11	0.12	0.12

Appendix B-8: Methane Emissions from Manure Management

Country	1990	1995	2000	2005	2010	2015	2020
	$MtCO_2eq$						
Norway	0.30	0.31	0.32	0.32	0.32	0.32	0.32
Pakistan	3.70	4.11	4.85	5.40	6.03	6.51	7.12
Peru	0.23	0.24	0.27	0.29	0.32	0.35	0.39
Philippines	1.38	1.41	1.51	1.73	1.99	2.21	2.46
Poland	1.16	1.03	0.76	0.74	0.72	0.70	0.68
Portugal	1.56	1.45	1.43	1.45	1.48	1.51	1.54
Romania	3.90	2.37	1.94	2.09	2.29	2.49	2.70
Russian Federation	10.50	7.98	5.12	5.82	6.01	6.53	7.05
Saudi Arabia	0.18	0.20	0.24	0.25	0.27	0.28	0.29
Senegal	0.12	0.15	0.17	0.19	0.21	0.23	0.26
Singapore	0.05	0.03	0.03	0.03	0.04	0.04	0.04
Slovak Republic	0.37	0.28	0.20	0.28	0.31	0.31	0.31
Slovenia	0.27	0.21	0.19	0.19	0.19	0.19	0.19
South Africa	1.75	1.64	1.69	1.74	1.80	1.81	1.82
South Korea	0.22	0.30	0.31	0.34	0.37	0.40	0.43
Spain	6.22	7.07	8.44	9.00	9.42	9.97	10.52
Sweden	0.36	0.42	0.40	0.38	0.37	0.37	0.37
Switzerland	0.45	0.43	0.40	0.40	0.39	0.39	0.38
Tajikistan	0.17	0.14	0.12	0.12	0.12	0.13	0.13
Thailand	2.74	2.90	2.74	3.09	3.49	3.85	4.26
Turkey	8.41	8.28	7.59	7.88	8.18	8.39	8.61
Turkmenistan	0.43	0.34	0.26	0.27	0.28	0.28	0.29
Uganda	0.15	0.16	0.19	0.21	0.23	0.25	0.27
Ukraine	4.63	3.46	2.20	2.50	2.62	2.86	3.11
United Arab Emirates	0.01	0.02	0.03	0.03	0.04	0.04	0.05
United Kingdom	2.92	2.88	2.76	2.55	2.47	2.53	2.55
United States	31.19	36.07	38.08	39.18	40.07	42.32	43.83
Uruguay	0.29	0.31	0.30	0.33	0.36	0.39	0.41
Uzbekistan	0.80	0.87	0.82	0.84	0.87	0.89	0.91
Venezuela	0.53	0.63	0.71	0.78	0.85	0.92	0.99
Viet Nam	2.21	2.85	3.47	3.92	4.42	4.86	5.33
Rest of Africa	5.74	6.14	6.87	7.64	8.51	9.33	10.26
Rest of Latin America	1.08	1.12	1.17	1.27	1.37	1.46	1.57
Rest of Middle East	0.21	0.22	0.26	0.28	0.29	0.31	0.34
Rest of Non-EU Eastern Europe	0.70	0.66	0.60	0.60	0.60	0.60	0.60
Rest of OECD90 & EU	0.13	0.15	0.16	0.16	0.18	0.18	0.19
Rest of SE Asia	2.35	2.72	2.27	2.47	2.69	2.88	3.08
Africa	10.79	11.33	12.66	13.89	15.27	16.54	17.96
China/CPA	18.93	22.87	24.35	27.16	30.33	32.98	35.88
Latin America	13.74	15.32	15.53	16.83	18.27	19.47	20.76
Middle East	1.15	1.22	1.48	1.64	1.82	1.92	2.02
Non-EU Eastern Europe	1.07	0.99	1.11	1.32	1.53	1.61	1.69
Non-EU FSU	21.10	16.07	11.11	12.13	12.47	13.27	14.07
OECD90 & EU	122.29	121.27	121.32	120.31	119.12	122.83	125.84
SE Asia	33.44	36.20	37.81	41.29	45.14	48.04	51.25
World Totals	222.52	225.26	225.38	234.57	243.95	256.65	269.47

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-9: Methane Emissions from Other Agricultural Sources

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.02	0.02	0.03	0.03	0.03	0.03	0.03
Algeria	0.27	0.22	0.02	0.02	0.02	0.02	0.02
Argentina	2.47	1.81	8.28	8.28	8.28	8.28	8.28
Armenia	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Australia	9.59	9.52	19.19	19.19	19.19	19.19	19.19
Austria	0.08	0.03	0.05	0.05	0.05	0.05	0.05
Azerbaijan	0.05	0.03	0.04	0.04	0.04	0.04	0.04
Bangladesh	0.12	0.01	1.09	1.09	1.09	1.09	1.09
Belarus	0.12	0.10	0.10	0.10	0.10	0.10	0.10
Belgium	0.17	0.12	0.12	0.12	0.12	0.12	0.12
Bolivia	6.40	6.20	16.45	16.45	16.45	16.45	16.45
Brazil	54.34	48.44	98.40	98.40	98.40	98.40	98.40
Bulgaria	0.14	0.12	0.15	0.15	0.15	0.15	0.15
Cambodia	1.57	1.71	1.87	1.87	1.87	1.87	1.87
Canada	4.37	32.13	4.61	4.61	4.61	4.61	4.61
Chile	1.70	1.53	0.70	0.70	0.70	0.70	0.70
China	1.97	0.40	1.71	1.71	1.71	1.71	1.71
Colombia	4.16	3.57	6.50	6.50	6.50	6.50	6.50
Croatia	0.07	0.05	0.05	0.05	0.05	0.05	0.05
Czech Republic	0.11	0.09	0.10	0.10	0.10	0.10	0.10
Democratic Republic of Congo (Kinshasa)	18.82	18.90	38.68	38.68	38.68	38.68	38.68
Denmark	0.12	0.03	0.03	0.03	0.03	0.03	0.03
Ecuador	2.50	2.29	0.37	0.37	0.37	0.37	0.37
Egypt			0.00	0.00	0.00	0.00	0.00
Estonia	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ethiopia	3.35	3.70	5.30	5.30	5.30	5.30	5.30
Finland	0.07	0.06	0.01	0.01	0.01	0.01	0.01
France	1.34	0.40	0.28	0.28	0.28	0.28	0.28
Georgia	0.04	0.03	0.04	0.04	0.04	0.04	0.04
Germany	-0.14	-0.51	-0.45	-0.45	-0.45	-0.45	-0.45
Greece	0.45	0.24	0.07	0.07	0.07	0.07	0.07
Hungary	0.20	0.16	0.17	0.17	0.17	0.17	0.17
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	1.27	0.98	4.38	4.38	4.38	4.38	4.38
Indonesia	12.70	12.24	21.48	21.48	21.48	21.48	21.48
Iran	0.63	0.66	0.41	0.41	0.41	0.41	0.41
Iraq			0.00	0.00	0.00	0.00	0.00
Ireland	0.03	0.01	0.01	0.01	0.01	0.01	0.01
Israel	0.11	0.11	0.10	0.10	0.10	0.10	0.10
Italy	1.13	0.22	0.30	0.30	0.30	0.30	0.30
Japan	0.15	0.16	0.22	0.22	0.22	0.22	0.22
Jordan	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.44	0.21	0.60	0.60	0.60	0.60	0.60
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.04	0.02	0.04	0.04	0.04	0.04	0.04
Laos	1.44	1.53	4.55	4.55	4.55	4.55	4.55
Latvia	0.03	0.01	0.01	0.01	0.01	0.01	0.01
Liechtenstein			0.00	0.00	0.00	0.00	0.00
Lithuania	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Luxembourg	0.00		0.01	0.01	0.01	0.01	0.01
Macedonia	0.12	0.02	0.03	0.03	0.03	0.03	0.03
Mexico	3.11	2.84	9.69	9.69	9.69	9.69	9.69
Moldova	0.06	0.06	0.07	0.07	0.07	0.07	0.07
Monaco			0.00	0.00	0.00	0.00	0.00
Mongolia	0.59	0.59	0.24	0.24	0.24	0.24	0.24
Myanmar	4.22	4.14	10.76	10.76	10.76	10.76	10.76
Nepal	0.28	0.28	0.08	0.08	0.08	0.08	0.08
Netherlands	0.08	0.02	0.02	0.02	0.02	0.02	0.02
New Zealand	0.05	0.05	0.04	0.04	0.04	0.04	0.04
Nigeria	3.85	3.95	5.57	5.57	5.57	5.57	5.57

Appendix B-9: Methane Emissions from Other Agricultural Sources

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea			0.08	0.08	0.08	0.08	0.08
Norway	0.02	0.00	0.01	0.01	0.01	0.01	0.01
Pakistan	0.34	0.28	0.04	0.04	0.04	0.04	0.04
Peru	2.80	2.50	2.14	2.14	2.14	2.14	2.14
Philippines	3.38	3.08	0.61	0.61	0.61	0.61	0.61
Poland	0.45	0.42	0.44	0.44	0.44	0.44	0.44
Portugal	0.75	0.88	0.07	0.07	0.07	0.07	0.07
Romania	0.26	0.30	0.31	0.31	0.31	0.31	0.31
Russian Federation	6.78	2.42	12.76	12.76	12.76	12.76	12.76
Saudi Arabia	0.17	0.19	0.19	0.19	0.19	0.19	0.19
Senegal	1.30	1.29	0.94	0.94	0.94	0.94	0.94
Singapore	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Slovak Republic	0.06	0.05	0.05	0.05	0.05	0.05	0.05
Slovenia	0.02	0.01	0.01	0.01	0.01	0.01	0.01
South Africa	2.87	2.58	3.56	3.56	3.56	3.56	3.56
South Korea	0.41	0.47	0.39	0.39	0.39	0.39	0.39
Spain	1.59	0.81	0.25	0.25	0.25	0.25	0.25
Sweden	0.08	0.02	0.02	0.02	0.02	0.02	0.02
Switzerland	0.03	0.01	0.01	0.01	0.01	0.01	0.01
Tajikistan	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Thailand	2.80	2.18	5.38	5.38	5.38	5.38	5.38
Turkey	1.37	1.45	1.50	1.50	1.50	1.50	1.50
Turkmenistan	0.04	0.04	0.05	0.05	0.05	0.05	0.05
Uganda	1.72	1.73	1.98	1.98	1.98	1.98	1.98
Ukraine	0.64	0.52	0.58	0.58	0.58	0.58	0.58
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.32	0.08	0.10	0.10	0.10	0.10	0.10
United States	0.69	0.66	0.79	0.82	0.87	0.92	0.97
Uruguay	0.07	0.09	0.15	0.15	0.15	0.15	0.15
Uzbekistan	0.17	0.14	0.15	0.15	0.15	0.15	0.15
Venezuela	5.03	4.58	8.88	8.88	8.88	8.88	8.88
Viet Nam	1.82	1.79	1.89	1.89	1.89	1.89	1.89
Rest of Africa	70.83	70.02	130.34	130.34	130.34	130.34	130.34
Rest of Latin America	7.78	7.55	13.22	13.22	13.22	13.22	13.22
Rest of Middle East	0.14	0.20	0.15	0.15	0.15	0.15	0.15
Rest of Non-EU Eastern Europe	0.16	0.15	0.20	0.20	0.20	0.20	0.20
Rest of OECD90 & EU	0.16	0.02	0.02	0.02	0.02	0.02	0.02
Rest of SE Asia	7.73	8.30	5.58	5.58	5.58	5.58	5.58
Africa	103.01	102.39	186.39	186.39	186.39	186.39	186.39
China/CPA	7.39	6.03	10.35	10.35	10.35	10.35	10.35
Latin America	90.36	81.39	164.77	164.77	164.77	164.77	164.77
Middle East	1.07	1.18	0.85	0.85	0.85	0.85	0.85
Non-EU Eastern Europe	0.36	0.24	0.31	0.31	0.31	0.31	0.31
Non-EU FSU	8.41	3.61	14.45	14.45	14.45	14.45	14.45
OECD90 & EU	23.81	47.63	28.57	28.60	28.65	28.70	28.75
SE Asia	33.24	31.97	49.79	49.79	49.79	49.79	49.79
World Totals	267.64	274.43	455.48	455.51	455.56	455.61	455.66

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-10: Methane Emissions from Landfilling of Solid Waste

	MtCO$_2$eq						
Country	1990	1995	2000	2005	2010	2015	2020
Albania	0.26	0.29	0.32	0.56	0.80	1.10	1.41
Algeria	3.69	4.11	4.46	4.85	5.24	5.62	5.97
Argentina	5.51	5.89	6.28	6.66	7.02	7.36	7.68
Armenia	0.50	0.39	0.41	0.42	0.47	0.46	0.46
Australia	7.47	8.31	7.97	8.69	9.42	10.64	11.87
Austria	4.14	3.67	3.06	3.01	2.54	2.22	2.03
Azerbaijan	1.35	1.41	1.47	1.54	1.62	1.71	1.78
Bangladesh	0.92	1.19	1.32	1.58	1.74	1.88	2.03
Belarus	2.35	1.94	2.72	2.92	3.12	3.31	3.50
Belgium	2.63	2.45	1.67	1.27	0.87	0.60	0.41
Bolivia	0.38	0.42	0.47	0.52	0.56	0.61	0.66
Brazil	12.98	14.54	15.56	16.56	17.47	18.29	19.00
Bulgaria	12.20	8.39	4.23	4.44	6.08	7.42	8.67
Cambodia	0.11	0.12	0.14	0.16	0.18	0.20	0.22
Canada	18.53	20.36	22.86	25.29	27.72	30.66	33.61
Chile	1.43	1.55	1.66	1.76	1.86	1.96	2.06
China	40.38	42.63	44.58	46.01	47.50	48.80	49.75
Colombia	6.55	7.21	7.88	8.53	9.16	9.77	10.34
Croatia	0.79	0.86	1.08	1.20	1.29	1.20	1.08
Czech Republic	1.96	1.99	1.60	1.54	1.49	0.99	0.70
Democratic Republic of Congo (Kinshasa)	4.96	5.89	6.44	7.44	8.58	9.84	11.20
Denmark	1.33	1.29	1.19	1.00	0.96	0.87	0.78
Ecuador	0.84	0.93	1.01	1.09	1.16	1.24	1.30
Egypt	4.07	4.49	4.94	5.46	6.02	6.56	7.06
Estonia	1.42	0.93	0.98	0.88	0.77	0.66	0.47
Ethiopia	0.50	0.59	0.68	0.77	0.86	0.97	1.08
Finland	3.68	3.62	3.01	2.91	2.73	2.36	2.00
France	11.21	13.80	11.72	8.49	5.27	4.49	3.71
Georgia	1.07	1.05	1.03	0.98	0.95	0.92	0.90
Germany	31.48	25.26	14.37	9.12	6.28	5.35	4.41
Greece	2.65	3.33	3.42	2.82	1.79	1.83	2.68
Hungary	3.63	3.54	3.82	3.82	3.82	3.82	3.82
Iceland	0.11	0.19	0.22	0.22	0.22	0.22	0.22
India	10.69	12.22	13.95	15.93	17.05	18.10	19.06
Indonesia	7.80	8.44	9.05	9.64	10.20	10.72	11.17
Iran	5.67	6.24	6.64	7.07	7.55	8.14	8.67
Iraq	2.78	3.24	3.73	4.26	4.86	5.49	6.10
Ireland	1.23	1.46	1.39	1.41	1.50	1.59	1.69
Israel	6.56	7.77	8.78	9.71	10.55	11.29	11.90
Italy	10.35	10.86	11.36	7.84	3.87	1.91	0.94
Japan	4.04	4.24	3.93	3.49	3.06	2.72	2.38
Jordan	0.52	0.68	0.81	0.92	1.02	1.12	1.21
Kazakhstan	2.29	3.35	3.17	3.11	3.07	3.11	3.12
Kuwait	0.34	0.27	0.36	0.43	0.49	0.54	0.59
Kyrgyzstan	1.64	0.95	0.78	0.84	0.89	0.94	0.99
Laos	0.24	0.27	0.30	0.34	0.38	0.41	0.45
Latvia	0.42	0.64	0.83	0.61	0.58	0.56	0.69
Liechtenstein	0.02	0.02	0.02	0.02	0.03	0.03	0.03
Lithuania	3.40	2.24	1.28	1.28	1.28	1.28	1.28
Luxembourg	0.00	0.00	0.05	0.05	0.05	0.05	0.05
Macedonia	0.92	0.94	0.97	0.99	1.01	1.03	1.04
Mexico	26.04	28.51	30.95	33.28	35.45	37.42	39.16
Moldova	0.73	0.48	0.47	0.47	0.47	0.46	0.46
Monaco	0.00	0.00	0.00				
Mongolia	0.07	0.07	0.09	0.10	0.11	0.11	0.12
Myanmar	2.60	3.01	3.50	4.06	4.28	4.47	4.63
Nepal	0.13	0.19	0.25	0.31	0.39	0.50	0.64
Netherlands	12.04	10.54	8.14	6.09	4.04	2.72	1.41
New Zealand	2.18	1.75	1.40	1.49	1.57	1.66	1.75
Nigeria	3.86	4.47	5.15	5.84	6.55	7.25	7.95

Appendix B-10: Methane Emissions from Landfilling of Solid Waste

Country	1990	1995	2000	2005	2010	2015	2020
	$MtCO_2eq$						
North Korea	1.18	1.26	1.31	1.35	1.37	1.40	1.43
Norway	2.46	2.39	2.24	2.25	2.27	2.27	2.27
Pakistan	1.57	1.93	2.22	2.65	2.99	3.36	3.73
Peru	1.84	2.01	2.19	2.36	2.53	2.70	2.86
Philippines	3.80	4.25	4.71	5.15	5.58	5.99	6.39
Poland	16.11	15.94	17.00	17.00	17.00	17.00	17.00
Portugal	3.89	4.84	4.79	3.05	1.32	1.32	1.32
Romania	3.33	3.27	3.22	3.35	3.47	3.61	3.74
Russian Federation	37.80	37.80	35.13	34.15	33.18	32.19	31.13
Saudi Arabia	12.55	14.38	16.79	19.43	22.12	24.81	27.48
Senegal	1.61	1.82	2.05	2.31	2.59	2.88	3.15
Singapore	0.42	0.48	0.56	0.61	0.64	0.65	0.67
Slovak Republic	1.06	1.07	1.01	1.02	1.02	1.03	1.07
Slovenia	0.51	0.53	0.58	0.58	0.58	0.58	0.58
South Africa	14.05	15.16	16.29	16.78	16.64	16.39	16.18
South Korea	23.47	12.40	10.24	10.68	10.88	11.01	11.09
Spain	3.46	5.14	6.82	6.90	6.98	7.06	7.15
Sweden	2.55	2.40	2.04	2.04	2.04	1.34	0.64
Switzerland	0.71	0.53	0.41	0.36	0.24	0.24	0.24
Tajikistan	0.14	0.13	0.13	0.13	0.14	0.15	0.16
Thailand	0.39	0.41	0.43	0.46	0.48	0.49	0.51
Turkey	8.16	8.93	9.67	10.38	11.04	11.64	12.14
Turkmenistan	0.19	0.22	0.24	0.26	0.28	0.30	0.32
Uganda	0.05	0.06	0.07	0.08	0.10	0.12	0.14
Ukraine	14.23	14.48	12.09	13.39	14.75	16.36	17.98
United Arab Emirates	0.33	0.40	0.45	0.50	0.54	0.58	0.61
United Kingdom	23.76	19.70	11.60	8.41	6.09	4.93	3.48
United States[1]	172.23	162.40	130.68	130.58	125.43	124.15	123.51
United States[2]	172.23	162.40	130.68	156.60	157.30	160.20	164.30
Uruguay	0.60	0.62	0.64	0.67	0.69	0.71	0.73
Uzbekistan	2.92	3.05	3.34	3.60	3.87	4.12	4.33
Venezuela	4.70	5.28	5.85	6.42	6.98	7.52	8.03
Viet Nam	1.17	1.39	1.56	1.80	1.92	2.04	2.16
Rest of Africa	40.65	45.70	51.84	57.86	64.13	70.69	77.50
Rest of Latin America	11.03	12.85	13.79	14.72	15.62	16.46	17.26
Rest of Middle East	5.53	6.63	7.68	8.83	10.13	11.55	13.09
Rest of Non-EU Eastern Europe	10.24	9.89	10.29	10.43	10.46	10.43	10.35
Rest of OECD90 & EU	0.42	0.45	0.47	0.49	0.50	0.52	0.53
Rest of SE Asia	34.66	43.94	39.95	44.21	48.18	51.89	55.56
Africa	73.43	82.30	91.93	101.39	110.72	120.32	130.22
China/CPA	43.14	45.75	47.99	49.76	51.46	52.97	54.13
Latin America	71.89	79.83	86.30	92.59	98.53	104.05	109.09
Middle East	34.28	39.62	45.23	51.15	57.27	63.52	69.66
Non-EU Eastern Europe	12.22	11.99	12.66	13.17	13.57	13.76	13.87
Non-EU FSU	65.21	65.26	60.99	61.82	62.79	64.05	65.14
OECD90 & EU	374.78	356.49	299.03	282.21	263.91	260.33	259.26
SE Asia	86.44	88.48	86.18	95.28	102.38	109.06	115.48
World Totals	761.40	769.71	730.32	747.38	760.63	788.07	816.86

[1] US emissions INCLUDING reductions from voluntary programs; included in OECD90 & EU and World totals

[2] US emissions NOT INCLUDING the effect of voluntary programs; not included in OECD90 & EU and World totals

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix B-11: Methane Emissions from Wastewater

	MtCO2eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.23	0.22	0.22	0.23	0.23	0.24	0.25
Algeria	2.03	2.26	2.47	2.70	2.91	3.10	3.30
Argentina	3.95	4.22	4.49	4.77	5.03	5.28	5.50
Armenia	0.25	0.26	0.26	0.26	0.27	0.27	0.26
Australia	2.27	2.40	2.55	2.68	2.80	2.92	3.03
Austria	0.29	0.30	0.30	0.29	0.25	0.22	0.20
Azerbaijan	0.73	0.78	0.82	0.85	0.87	0.89	0.91
Bangladesh	10.44	11.73	13.04	14.48	15.94	17.38	18.76
Belarus	0.72	0.72	0.71	0.70	0.68	0.67	0.66
Belgium	0.08	0.08	0.08	0.06	0.04	0.03	0.02
Bolivia	0.80	0.90	1.01	1.13	1.24	1.36	1.48
Brazil	17.95	19.35	20.67	21.97	23.23	24.43	25.55
Bulgaria	1.40	1.04	0.59	0.62	0.85	1.04	1.22
Cambodia	0.98	1.16	1.34	1.51	1.70	1.90	2.09
Canada	0.36	0.38	0.40	0.41	0.43	0.44	0.46
Chile	1.59	1.72	1.85	1.96	2.06	2.17	2.28
China	94.40	99.65	104.25	108.04	111.73	115.34	118.29
Colombia	4.24	4.68	5.11	5.53	5.96	6.39	6.79
Croatia	0.31	0.32	0.32	0.33	0.32	0.32	0.32
Czech Republic	0.83	0.65	0.58	0.57	0.57	0.56	0.56
Democratic Republic of Congo (Kinshasa)	3.02	3.66	4.16	4.91	5.82	6.86	8.05
Denmark	0.20	0.22	0.22	0.22	0.22	0.22	0.22
Ecuador	1.25	1.39	1.53	1.67	1.81	1.93	2.05
Egypt	4.18	4.61	5.05	5.49	5.89	6.28	6.67
Estonia	0.19	0.13	0.22	0.21	0.20	0.19	0.18
Ethiopia	3.88	4.52	5.13	5.79	6.52	7.32	8.24
Finland	0.15	0.15	0.13	0.13	0.13	0.13	0.13
France	0.71	0.95	1.15	1.17	1.19	1.20	1.21
Georgia	0.56	0.55	0.54	0.52	0.51	0.49	0.47
Germany	2.23	0.89	0.17	0.17	0.17	0.17	0.17
Greece	2.36	2.09	1.45	1.45	1.44	1.43	1.41
Hungary	1.25	1.15	1.11	1.08	1.06	1.03	1.01
Iceland	0.02	0.02	0.02	0.02	0.02	0.02	0.02
India	81.77	89.73	97.65	105.36	112.66	119.09	124.98
Indonesia	18.01	19.51	20.94	22.25	23.47	24.69	25.85
Iran	5.96	6.59	7.18	7.69	8.25	8.89	9.54
Iraq	1.76	2.05	2.34	2.69	3.05	3.42	3.78
Ireland	0.25	0.25	0.27	0.28	0.29	0.31	0.32
Israel	0.46	0.55	0.62	0.68	0.74	0.79	0.83
Italy	1.34	1.39	1.43	1.38	1.38	1.35	1.33
Japan	1.10	1.03	1.03	1.04	1.05	1.05	1.04
Jordan	0.33	0.43	0.50	0.58	0.66	0.73	0.81
Kazakhstan	1.71	1.70	1.65	1.62	1.61	1.63	1.64
Kuwait	0.22	0.17	0.20	0.22	0.25	0.28	0.31
Kyrgyzstan	0.45	0.47	0.50	0.53	0.56	0.60	0.63
Laos	0.42	0.48	0.54	0.60	0.67	0.75	0.82
Latvia	0.35	0.20	0.20	0.19	0.19	0.18	0.18
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.08	0.12	0.33	0.33	0.33	0.33	0.33
Luxembourg	0.03	0.03	0.03	0.03	0.03	0.04	0.04
Macedonia	0.13	0.14	0.14	0.14	0.14	0.14	0.14
Mexico	10.02	10.98	11.91	12.78	13.59	14.35	15.05
Moldova	0.30	0.30	0.30	0.30	0.29	0.29	0.29
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.23	0.25	0.26	0.27	0.29	0.31	0.34
Myanmar	4.13	4.53	4.87	5.16	5.41	5.64	5.89
Nepal	1.85	2.09	2.35	2.64	2.95	3.28	3.62
Netherlands	0.32	0.28	0.26	0.27	0.27	0.28	0.28
New Zealand	0.16	0.16	0.16	0.17	0.17	0.18	0.18
Nigeria	6.80	7.85	9.01	10.26	11.63	13.08	14.58

Appendix B-11: Methane Emissions from Wastewater

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	2.04	2.18	2.27	2.35	2.42	2.49	2.57
Norway	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Pakistan	10.88	12.25	13.99	15.89	17.97	20.24	22.57
Peru	2.62	2.86	3.11	3.37	3.63	3.87	4.10
Philippines	6.23	6.97	7.72	8.47	9.17	9.78	10.35
Poland	2.93	1.86	1.60	1.59	1.58	1.57	1.56
Portugal	0.87	0.90	0.82	0.52	0.23	0.23	0.23
Romania	1.60	1.81	1.68	1.66	1.64	1.61	1.58
Russian Federation	9.44	9.43	9.26	8.97	8.72	8.49	8.26
Saudi Arabia	1.57	1.74	2.08	2.43	2.82	3.24	3.68
Senegal	0.60	0.68	0.77	0.87	0.98	1.10	1.23
Singapore	0.31	0.35	0.41	0.45	0.47	0.49	0.50
Slovak Republic	1.01	0.85	0.74	0.75	0.65	0.60	0.58
Slovenia	0.19	0.14	0.18	0.17	0.17	0.17	0.17
South Africa	3.36	3.69	4.00	4.15	4.17	4.12	4.06
South Korea	4.37	4.59	4.77	4.93	5.06	5.17	5.25
Spain	1.25	1.48	1.80	1.80	1.79	1.76	1.73
Sweden	IE	IE	IE	IE	IE	IE	IE
Switzerland	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Tajikistan	0.54	0.59	0.62	0.64	0.68	0.72	0.78
Thailand	5.59	5.99	6.41	6.79	7.11	7.40	7.66
Turkey	5.72	6.27	6.80	7.27	7.67	8.06	8.46
Turkmenistan	0.37	0.43	0.48	0.53	0.58	0.62	0.66
Uganda	1.41	1.64	1.90	2.23	2.66	3.16	3.74
Ukraine	0.63	0.63	0.39	0.37	0.36	0.34	0.33
United Arab Emirates	0.21	0.24	0.27	0.29	0.31	0.33	0.34
United Kingdom	0.70	0.72	0.77	0.78	0.79	0.79	0.79
United States	24.85	29.89	34.34	35.21	36.13	36.99	37.84
Uruguay	0.38	0.39	0.40	0.42	0.43	0.45	0.46
Uzbekistan	2.09	2.33	2.54	2.72	2.91	3.12	3.32
Venezuela	2.37	2.65	2.93	3.21	3.48	3.75	3.99
Viet Nam	6.74	7.43	7.97	8.51	9.05	9.63	10.23
Rest of Africa	24.88	27.92	31.81	35.78	40.10	44.77	49.71
Rest of Latin America	7.63	8.38	9.15	9.95	10.76	11.56	12.33
Rest of Middle East	3.22	3.89	4.59	5.38	6.28	7.29	8.40
Rest of Non-EU Eastern Europe	1.01	0.97	1.01	1.03	1.03	1.02	1.02
Rest of OECD90 & EU	0.08	0.08	0.09	0.09	0.10	0.10	0.10
Rest of SE Asia	6.13	7.12	8.19	9.07	10.07	10.95	11.85
Africa	50.15	56.83	64.29	72.19	80.66	89.79	99.56
China/CPA	104.81	111.15	116.63	121.29	125.86	130.42	134.33
Latin America	52.78	57.51	62.17	66.76	71.23	75.54	79.58
Middle East	13.74	15.67	17.76	19.96	22.36	24.97	27.69
Non-EU Eastern Europe	1.69	1.66	1.70	1.72	1.73	1.73	1.73
Non-EU FSU	17.80	18.18	18.08	18.02	18.03	18.12	18.20
OECD90 & EU	55.20	57.97	61.56	62.71	63.89	65.27	66.62
SE Asia	149.72	164.86	180.35	195.48	210.27	224.10	237.27
World Totals	445.87	483.82	522.54	558.11	594.04	629.93	664.97

Regional country groupings are defined in Table 1-4 and Appendix H.

Codes:
IE - Estimated, but included elsewhere.

Appendix B-12: Methane Emissions from Other Non-Agricultural Sources (Waste and Other)

Country	MtCO2eq 1990	1995	2000	2005	2010	2015	2020
Albania	0.07	0.06	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Argentina	0.19	0.10	0.25	0.23	0.21	0.19	0.19
Austria	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Belgium	0.06	0.11	0.35	0.27	0.18	0.13	0.09
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Denmark	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	0.18	0.17	0.20	0.20	0.20	0.20	0.20
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	0.16	0.27	0.25	0.25	0.25	0.25	0.25
Japan	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moldova	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.07	0.08	0.07	0.06	0.06	0.05
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spain	0.37	0.52	0.62	0.62	0.62	0.62	0.62
Switzerland	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Africa	0.00	0.01	0.01	0.01	0.01	0.01	0.01
China/CPA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latin America	0.19	0.10	0.25	0.23	0.21	0.19	0.19
Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU Eastern Europe	0.07	0.06	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	0.02	0.02	0.02	0.02	0.02	0.02	0.02
OECD90 & EU	0.83	1.22	1.57	1.48	1.39	1.33	1.28
SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
World Totals	1.12	1.42	1.86	1.75	1.64	1.55	1.51

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix C-1: Nitrous Oxide Emissions from Stationary and Mobile Combustion

	MtCO2eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.02	0.00	0.00	0.00	0.00	0.01	0.01
Algeria	0.09	0.09	0.10	0.12	0.15	0.17	0.21
Argentina	1.39	1.53	1.94	2.56	3.41	4.34	5.56
Armenia	0.04	0.02	0.02	0.03	0.03	0.04	0.04
Australia	2.35	3.79	5.19	7.05	7.63	9.49	11.35
Austria	0.67	0.83	0.79	0.79	0.79	0.79	0.79
Azerbaijan	0.07	0.05	0.04	0.04	0.04	0.04	0.05
Bangladesh	0.01	0.01	0.01	0.02	0.02	0.03	0.04
Belarus	0.24	0.19	0.13	0.14	0.14	0.16	0.17
Belgium	2.09	2.28	2.39	1.81	2.02	2.12	2.23
Bolivia	0.01	0.02	0.04	0.05	0.06	0.08	0.09
Brazil	0.57	0.71	0.90	1.05	1.24	1.38	1.56
Bulgaria	3.65	3.03	2.41	2.75	3.09	3.53	3.96
Cambodia	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Canada	8.44	10.95	11.39	13.37	14.55	16.06	17.59
Chile	0.33	0.47	0.62	0.74	0.89	1.03	1.20
China	9.32	12.39	12.47	14.77	17.60	20.32	23.55
Colombia	0.12	0.19	0.19	0.23	0.29	0.34	0.40
Croatia	0.08	0.08	0.15	0.15	0.15	0.15	0.15
Czech Republic	1.42	1.33	1.48	1.32	1.35	1.26	1.23
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.59	0.76	0.79	0.85	0.92	1.01	1.10
Ecuador	0.11	0.14	0.15	0.15	0.16	0.16	0.17
Egypt	3.54	3.80	4.92	5.06	5.21	5.36	5.50
Estonia	0.05	0.04	0.04	0.04	0.04	0.04	0.04
Ethiopia	0.07	0.10	0.13	0.15	0.17	0.20	0.22
Finland	0.90	1.30	1.15	1.29	1.42	1.53	1.64
France	4.53	5.62	6.96	4.88	10.25	6.60	12.52
Georgia	0.09	0.01	0.04	0.04	0.05	0.05	0.05
Germany	10.42	11.06	10.26	11.53	11.89	12.94	14.00
Greece	3.09	3.18	3.71	3.89	4.24	4.70	5.15
Hungary	2.89	2.74	2.62	2.62	2.62	2.62	2.62
Iceland	0.03	0.04	0.06	0.06	0.06	0.06	0.06
India	2.06	2.91	3.29	4.04	4.97	5.90	7.02
Indonesia	0.22	0.29	0.62	0.73	0.97	1.38	2.01
Iran	2.11	2.68	3.09	3.47	3.91	4.44	5.07
Iraq	0.15	0.17	0.18	0.20	0.22	0.25	0.28
Ireland	0.95	1.13	1.50	1.63	1.76	1.98	2.19
Israel	0.12	0.17	0.22	0.27	0.33	0.38	0.45
Italy	8.53	8.62	9.72	11.23	12.73	15.28	17.84
Japan	6.22	7.87	8.97	5.23	8.80	5.13	5.08
Jordan	0.06	0.13	0.14	0.15	0.15	0.15	0.16
Kazakhstan	0.62	0.64	0.48	0.49	0.50	0.51	0.53
Kuwait	0.03	0.09	0.13	0.14	0.16	0.17	0.19
Kyrgyzstan	0.09	0.03	0.03	0.04	0.04	0.04	0.05
Latvia	0.17	0.12	0.13	0.13	0.13	0.13	0.13
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.29	0.21	0.17	0.16	0.16	0.16	0.16
Luxembourg	0.03	0.05	0.06	0.06	0.06	0.06	0.06
Macedonia	0.00	0.04	0.04	0.04	0.05	0.05	0.06
Mexico	2.20	2.57	2.82	3.39	3.52	3.64	3.76
Moldova	0.18	0.04	0.02	0.02	0.02	0.02	0.02
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.02	0.02	0.03	0.03	0.03	0.03
Nepal	0.00	0.01	0.01	0.01	0.02	0.02	0.02
Netherlands	0.52	0.72	0.76	0.85	0.91	0.99	1.07
New Zealand	0.14	0.18	0.22	0.25	0.25	0.28	0.28
Nigeria	1.13	1.29	1.42	1.64	1.90	2.18	2.51
North Korea	0.89	0.95	0.91	0.99	1.10	1.23	1.38

Appendix C-1: Nitrous Oxide Emissions from Stationary and Mobile Combustion

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Norway	0.31	0.46	0.74	0.74	0.74	0.74	0.74
Pakistan	0.18	0.19	0.19	0.24	0.29	0.35	0.42
Peru	0.05	0.07	0.08	0.09	0.10	0.12	0.13
Philippines	0.35	0.46	0.51	0.59	0.61	0.62	0.64
Poland	1.80	2.09	2.23	2.72	3.17	4.07	4.96
Portugal	0.51	0.66	0.84	1.03	1.17	1.49	1.82
Romania	0.36	0.48	0.35	0.35	0.35	0.35	0.35
Russian Federation	5.27	3.41	3.38	3.38	3.38	3.38	3.38
Saudi Arabia	0.40	0.47	0.55	0.61	0.69	0.77	0.87
Senegal	0.01	0.01	0.02	0.02	0.03	0.03	0.03
Singapore	0.13	0.17	0.19	0.22	0.26	0.30	0.34
Slovak Republic	0.26	0.26	0.26	0.28	0.33	0.38	0.31
Slovenia	0.15	0.17	0.22	0.26	0.29	0.32	0.36
South Africa	1.09	1.19	1.30	1.45	1.61	1.77	1.94
South Korea	0.66	0.91	1.24	1.53	1.88	2.25	2.68
Spain	1.74	2.49	3.42	3.49	3.49	3.53	3.56
Sweden	1.52	1.68	1.70	1.77	2.09	2.26	2.42
Switzerland	0.23	0.30	0.32	0.23	0.18	0.12	0.07
Tajikistan	0.03	0.03	0.03	0.03	0.04	0.05	0.05
Thailand	0.14	0.29	0.36	0.42	0.43	0.44	0.45
Turkey	0.43	0.51	0.58	0.57	0.57	0.56	0.55
Turkmenistan	0.12	0.12	0.12	0.13	0.15	0.16	0.18
Uganda	1.25	1.45	1.68	1.91	2.17	2.47	2.82
Ukraine	1.54	0.68	0.46	0.46	0.46	0.46	0.46
United Arab Emirates	0.07	0.08	0.09	0.10	0.12	0.14	0.16
United Kingdom	5.47	6.36	8.26	9.77	10.53	7.12	3.71
United States	55.99	66.65	67.16	50.65	43.79	44.71	47.04
Uruguay	0.06	0.07	0.08	0.09	0.11	0.12	0.14
Uzbekistan	0.11	0.11	0.12	0.13	0.15	0.16	0.18
Venezuela	0.20	0.24	0.24	0.30	0.37	0.44	0.53
Viet Nam	0.07	0.07	0.13	0.15	0.19	0.23	0.29
Rest of Africa	0.65	0.82	1.04	1.19	1.36	1.54	1.76
Rest of Latin America	0.58	0.86	1.07	1.23	1.43	1.62	1.84
Rest of Middle East	0.18	0.24	0.29	0.32	0.36	0.40	0.45
Rest of Non-EU Eastern Europe	0.00	0.18	0.17	0.19	0.22	0.24	0.26
Rest of OECD90 & EU	0.03	0.03	0.03	0.04	0.04	0.04	0.05
Rest of SE Asia	0.60	0.78	1.12	1.37	1.67	2.00	2.41
Africa	7.82	8.76	10.62	11.54	12.59	13.71	14.99
China/CPA	10.27	13.41	13.51	15.92	18.90	21.78	25.22
Latin America	5.63	6.87	8.13	9.90	11.59	13.28	15.39
Middle East	3.12	4.03	4.67	5.25	5.93	6.71	7.63
Non-EU Eastern Europe	0.10	0.30	0.37	0.40	0.42	0.45	0.48
Non-EU FSU	8.41	5.33	4.88	4.94	4.99	5.07	5.16
OECD90 & EU	126.77	147.97	156.90	143.69	152.38	152.44	167.04
SE Asia	4.37	6.05	7.57	9.19	11.15	13.31	16.07
World Totals	166.47	192.71	206.64	200.83	217.95	226.76	251.97

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix C-2: Nitrous Oxide Emissions from Biomass Combustion

	MtCO2eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Argentina	0.06	0.11	0.13	0.14	0.14	0.14	0.15
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.68	0.75	0.82	0.86	0.90	0.93	0.96
Bolivia	0.04	0.04	0.05	0.05	0.05	0.05	0.05
Brazil	1.55	1.62	1.82	1.91	2.01	2.08	2.14
Cambodia	0.08	0.10	0.13	0.15	0.17	0.19	0.22
Chile	0.13	0.17	0.19	0.20	0.20	0.21	0.21
China	10.58	10.58	10.96	11.13	11.29	11.40	11.50
Colombia	0.29	0.35	0.26	0.26	0.27	0.28	0.29
Democratic Republic of Congo (Kinshasa)	0.51	0.57	0.66	0.73	0.80	0.87	0.94
Ecuador	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Egypt	0.08	0.09	0.10	0.11	0.12	0.13	0.14
Ethiopia	0.55	0.83	0.94	1.03	1.13	1.23	1.33
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.57	0.62	0.67	0.70	0.73	0.74	0.76
Indonesia	1.35	1.48	1.29	1.33	1.38	1.43	1.45
Iran	0.05	0.05	0.06	0.06	0.07	0.10	0.14
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Macedonia	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mexico	0.39	0.41	0.37	0.38	0.39	0.40	0.41
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.03	0.03	0.03	0.03	0.03	0.04	0.04
Myanmar	0.25	0.26	0.27	0.28	0.29	0.30	0.31
Nepal	0.30	0.33	0.36	0.38	0.40	0.42	0.43
Netherlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nigeria	0.91	1.02	1.16	1.28	1.40	1.52	1.66
North Korea	0.05	0.05	0.05	0.05	0.06	0.06	0.06
Pakistan	0.00	1.09	1.20	1.26	1.33	1.37	1.42
Peru	0.19	0.20	0.21	0.22	0.22	0.23	0.23
Philippines	0.51	0.47	0.36	0.38	0.39	0.41	0.43
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.05	0.06	0.06	0.07	0.08	0.08	0.09
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.37	0.41	0.45	0.49	0.54	0.58	0.64
South Korea	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.28	0.28	0.29	0.30	0.32	0.33	0.34
Turkey	0.37	0.35	0.36	0.43	0.51	0.59	0.67
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	1.46	1.64	1.84	2.02	2.22	2.41	2.62
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uruguay	0.03	0.03	0.02	0.03	0.03	0.03	0.03
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Viet Nam	0.47	0.48	0.49	0.51	0.53	0.55	0.58
Rest of Africa	2.72	3.03	3.41	3.74	4.11	4.47	4.85
Rest of Latin America	0.84	0.72	0.74	0.76	0.78	0.80	0.82
Rest of Middle East	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Rest of Non-EU Eastern Europe	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.26	0.25	0.29	0.30	0.31	0.33	0.34

Appendix C-2: Nitrous Oxide Emissions from Biomass Combustion

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Africa	6.64	7.66	8.62	9.47	10.40	11.30	12.28
China/CPA	11.25	11.28	11.71	11.91	12.12	12.28	12.43
Latin America	3.60	3.72	3.88	4.02	4.17	4.29	4.42
Middle East	0.05	0.06	0.06	0.07	0.08	0.11	0.15
Non-EU Eastern Europe	0.05	0.03	0.03	0.03	0.03	0.03	0.03
Non-EU FSU	0.01	0.01	0.01	0.01	0.01	0.01	0.01
OECD90 & EU	0.37	0.35	0.36	0.43	0.51	0.59	0.67
SE Asia	4.21	5.54	5.56	5.80	6.06	6.26	6.45
World Totals	26.18	28.65	30.23	31.75	33.39	34.87	36.45

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix C-3: Nitrous Oxide Emissions from Adipic Acid and Nitric Acid Production

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Algeria	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Argentina	0.17	0.19	0.31	0.31	0.31	0.31	0.31
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	IE	IE	IE	IE	IE	IE	IE
Austria	0.91	0.86	0.95	0.98	1.03	1.07	1.12
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.35	0.26	0.31	0.31	0.31	0.31	0.31
Belgium	3.93	4.64	4.56	4.72	4.89	5.06	5.23
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	2.48	4.34	5.03	5.53	6.09	6.40	6.73
Bulgaria	2.26	1.92	1.31	2.28	2.67	2.90	3.40
Canada	11.50	11.51	1.70	1.76	1.87	1.87	1.93
Chile	0.31	0.25	0.31	0.31	0.31	0.31	0.31
China	19.55	27.52	30.10	32.00	34.05	35.49	36.99
Colombia	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Croatia	0.93	0.84	0.85	0.85	0.85	0.85	0.85
Czech Republic	1.21	1.13	1.12	1.12	1.12	1.12	1.12
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	1.04	0.90	1.00	1.00	1.00	1.00	1.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	1.60	1.39	1.32	1.50	1.50	1.55	1.60
France	24.14	26.17	11.46	12.90	14.35	14.40	14.46
Georgia	0.50	0.16	0.16	0.16	0.16	0.16	0.16
Germany	23.48	24.99	5.55	5.72	5.89	6.06	6.23
Greece	0.71	0.56	0.50	0.50	0.50	0.50	0.50
Hungary	3.21	1.35	1.80	1.32	1.32	1.32	1.32
Iceland	0.05	0.04	0.02	0.02	0.02	0.02	0.02
India	2.43	2.79	3.01	3.19	3.39	3.60	3.82
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	1.04	0.81	0.81	0.81	0.81	0.81	0.81
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	6.75	7.15	7.80	8.22	8.64	9.10	9.57
Japan	7.42	7.37	4.25	4.59	4.59	4.78	4.96
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.43	1.11	1.88	0.51	0.51	0.51	0.51
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.65	0.85	0.95	1.01	1.08	1.15	1.23
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	7.57	7.52	7.14	7.49	7.69	8.08	8.28
New Zealand	IE	IE	IE	IE	IE	IE	IE
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	2.06	1.64	1.73	1.72	1.72	1.72	1.72
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.19	0.19	0.19	0.19	0.19	0.19
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	5.00	4.90	4.35	4.35	4.35	4.35	4.35
Portugal	0.57	0.60	0.44	0.44	0.44	0.44	0.44
Romania	8.94	3.63	2.89	2.89	2.89	2.89	2.89

Appendix C-3: Nitrous Oxide Emissions from Adipic Acid and Nitric Acid Production

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Russian Federation	0.93	0.31	0.31	0.31	0.31	0.31	0.31
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.59	0.68	0.76	0.83	0.88	0.92
Slovak Republic	0.51	0.63	0.70	0.70	0.70	0.70	0.70
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	1.81	2.25	2.25	2.25	2.25	2.25	2.25
South Korea	5.71	6.09	7.13	7.87	8.69	9.13	9.60
Spain	2.88	2.38	2.33	2.32	2.32	2.32	2.32
Sweden	0.83	0.72	0.65	0.54	0.43	0.40	0.37
Switzerland	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	5.20	1.45	2.29	2.41	2.41	2.41	2.41
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	29.27	18.99	6.25	6.25	6.25	6.25	6.25
United States	33.05	37.09	25.63	22.41	23.90	25.48	27.18
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Venezuela	0.06	0.07	0.08	0.09	0.09	0.10	0.10
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of China/CPA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU FSU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.18	0.17	0.11	0.11	0.11	0.11	0.11
Africa	2.43	2.87	2.87	2.87	2.87	2.87	2.87
China/CPA	19.55	27.52	30.10	32.00	34.05	35.49	36.99
Latin America	3.67	5.97	6.87	7.44	8.07	8.46	8.87
Middle East	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Non-EU Eastern Europe	0.94	0.85	0.87	0.87	0.87	0.87	0.87
Non-EU FSU	7.29	2.49	3.38	3.50	3.50	3.50	3.50
OECD90 & EU	180.46	170.11	98.25	97.18	101.51	104.80	108.38
SE Asia	8.33	9.64	10.94	11.94	13.03	13.73	14.46
World Totals	223.36	220.12	153.97	156.48	164.58	170.40	176.62

Regional country groupings are defined in Table 1-4 and Appendix H.

Codes:
IE - Estimated, but included elsewhere.

Appendix C-4: Nitrous Oxide Emissions from Other Industrial Non-Agricultural Sources

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Australia	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Belgium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.94	0.83	0.72	0.70	0.70	0.70	0.70
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sweden	0.04	0.04	0.05	0.05	0.05	0.05	0.05
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China/CPA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OECD90 & EU	1.02	0.90	0.81	0.78	0.78	0.78	0.78
SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
World Totals	1.02	0.90	0.81	0.78	0.78	0.78	0.78

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix C-5: Nitrous Oxide Emissions from Agricultural Soils

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Algeria	7.97	7.75	9.22	10.43	11.81	13.37	15.14
Argentina	52.07	54.27	58.81	69.80	83.75	101.75	125.36
Armenia	0.05	0.01	0.01	0.02	0.02	0.02	0.02
Australia	15.18	15.45	19.03	18.85	19.21	19.31	19.40
Austria	3.07	3.34	2.85	2.81	2.78	2.75	2.72
Azerbaijan	0.61	0.25	0.02	0.02	0.02	0.02	0.02
Bangladesh	30.40	39.55	42.15	45.72	49.32	55.13	60.99
Belarus	9.95	4.42	5.81	6.11	6.44	6.79	7.17
Belgium	5.68	4.41	4.15	4.08	4.01	3.95	3.88
Bolivia	0.04	0.04	0.05	0.06	0.06	0.07	0.08
Brazil	132.06	147.56	154.44	176.00	201.08	230.40	264.79
Bulgaria	5.77	2.62	2.40	3.01	3.20	3.72	3.92
Cambodia	1.66	2.21	2.17	2.64	3.10	4.03	4.96
Canada	26.86	29.78	32.85	35.92	38.84	42.37	45.91
Chile	3.76	4.93	5.43	6.09	6.82	7.64	8.56
China	412.72	497.16	509.26	536.10	563.92	595.25	627.74
Colombia	23.16	26.72	37.01	41.46	46.45	52.05	58.32
Croatia	2.46	1.87	1.97	2.47	2.63	3.06	3.21
Czech Republic	7.57	5.40	4.73	4.73	4.73	4.73	4.73
Democratic Republic of Congo (Kinshasa)	0.34	0.34	0.31	0.37	0.43	0.51	0.60
Denmark	8.31	7.27	6.15	5.35	5.35	5.35	5.35
Ecuador	0.02	0.03	0.04	0.04	0.05	0.06	0.06
Egypt	6.54	8.51	9.42	10.87	12.54	14.47	16.69
Estonia	0.95	0.36	0.37	0.45	0.45	0.48	0.48
Ethiopia	4.96	5.49	9.23	10.54	12.04	13.76	15.72
Finland	4.29	3.81	3.42	3.23	2.96	2.96	2.96
France	56.05	52.52	54.36	53.78	53.20	53.61	54.01
Georgia	0.94	0.29	0.45	0.48	0.52	0.55	0.59
Germany	43.88	37.59	39.22	39.57	36.97	35.91	34.85
Greece	9.75	8.74	8.55	7.91	7.87	7.90	7.65
Hungary	10.43	6.81	6.74	6.80	6.35	6.17	5.99
Iceland	0.25	0.23	0.24	0.24	0.24	0.24	0.24
India	42.99	45.26	54.62	57.68	61.00	64.71	68.82
Indonesia	16.28	16.23	17.20	18.08	19.00	19.97	20.99
Iran	9.31	10.11	12.59	16.59	20.57	25.52	31.66
Iraq	6.01	5.64	6.04	6.89	7.85	8.96	10.22
Ireland	7.29	7.84	8.17	7.86	7.55	7.27	6.99
Israel	0.93	0.93	1.03	1.18	1.37	1.58	1.82
Italy	18.87	19.33	19.23	18.79	18.24	17.78	17.31
Japan	9.75	8.80	8.14	8.34	8.54	8.74	8.94
Jordan	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Kazakhstan	18.62	12.13	5.76	5.91	6.09	6.29	6.50
Latvia	2.52	0.74	0.68	0.73	0.85	0.90	1.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	3.35	1.55	1.10	0.45	0.45	0.45	0.45
Luxembourg	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Mexico	12.88	10.04	12.84	14.39	16.12	18.06	20.23
Moldova	2.77	1.81	0.87	0.88	0.91	0.94	0.98
Mongolia	8.19	9.46	11.45	12.42	13.39	14.50	15.61
Myanmar	2.08	3.36	4.65	6.05	7.44	9.30	11.16
Nepal	7.66	8.37	8.84	10.03	11.40	12.95	14.72
Netherlands	10.88	11.91	9.92	9.55	9.18	8.83	8.49
New Zealand	10.02	10.94	11.80	13.43	15.05	17.13	19.21
Nigeria	29.08	30.26	34.19	40.51	48.01	56.94	67.58
North Korea	9.00	2.72	4.93	5.27	5.68	6.13	6.64
Norway	2.42	2.41	2.44	2.44	2.44	2.44	2.44
Pakistan	7.68	9.27	10.19	10.34	10.50	10.68	10.94
Peru	7.90	12.12	17.84	19.98	22.39	25.09	28.11
Philippines	5.68	8.68	10.66	11.21	11.78	12.38	13.01
Poland	12.60	9.73	10.71	11.03	11.57	11.89	12.12

Appendix C-5: Nitrous Oxide Emissions from Agricultural Soils

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Portugal	3.51	3.24	3.16	3.21	3.25	3.31	3.38
Romania	10.05	6.46	4.44	5.39	5.87	6.81	7.75
Russian Federation	86.65	35.22	27.31	28.12	29.50	30.33	30.91
Saudi Arabia	7.31	6.98	8.28	9.41	10.70	12.17	13.85
Senegal	4.17	5.09	5.91	5.96	6.04	6.17	6.39
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	4.16	2.55	2.34	3.41	4.06	4.05	4.04
Slovenia	0.89	0.91	0.95	0.95	0.95	0.95	0.95
South Africa	18.51	15.52	16.25	17.15	18.12	19.18	20.34
South Korea	4.24	4.00	3.66	3.85	4.05	4.25	4.47
Spain	16.26	14.82	18.76	19.67	19.67	19.67	19.67
Sweden	5.39	5.26	4.95	4.93	4.91	4.91	4.91
Switzerland	2.41	2.25	2.16	2.05	2.03	2.00	1.97
Thailand	8.70	10.98	13.52	14.21	14.94	15.70	16.50
Turkey	41.71	37.26	36.08	41.56	48.03	55.68	64.69
Turkmenistan	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	6.55	5.74	8.34	9.89	11.77	14.06	16.90
Ukraine	27.52	20.04	14.28	18.00	21.10	26.15	31.19
United Kingdom	30.41	29.08	27.63	26.92	26.32	25.69	25.07
United States	252.99	244.72	263.86	263.98	272.43	278.21	284.70
Uruguay	10.41	7.90	14.11	15.81	17.71	19.85	22.24
Uzbekistan	10.22	9.85	12.67	13.35	14.12	14.98	16.00
Venezuela	21.03	17.24	14.88	16.67	18.68	20.92	23.44
Viet Nam	7.00	8.06	9.12	9.69	10.25	11.95	13.64
Rest of Africa	181.13	200.59	226.85	255.16	288.09	325.27	367.26
Rest of China/CPA	3.21	3.96	3.91	4.86	5.31	5.78	6.40
Rest of Latin America	30.83	31.37	31.80	33.82	37.86	42.46	47.71
Rest of Middle East	12.48	13.52	15.40	16.67	18.73	21.05	23.68
Rest of Non-EU Eastern Europe	8.35	7.69	6.71	6.16	6.87	7.63	8.40
Rest of Non-EU FSU	5.83	3.90	3.14	2.66	2.86	3.03	3.14
Rest of OECD90 & EU	0.33	0.34	0.31	0.31	0.36	0.41	0.48
Rest of SE Asia	26.16	28.88	28.01	29.49	32.24	35.25	38.63
Africa	259.24	279.30	319.73	360.87	408.85	463.72	526.62
China/CPA	441.78	523.56	540.83	570.98	601.65	637.64	675.00
Latin America	294.15	312.21	347.24	394.11	450.98	518.34	598.90
Middle East	36.04	37.19	43.34	50.74	59.23	69.29	81.24
Non-EU Eastern Europe	10.81	9.56	8.68	8.63	9.50	10.68	11.61
Non-EU FSU	163.17	87.93	70.33	75.57	81.57	89.09	96.51
OECD90 & EU	643.98	598.57	622.04	631.87	648.07	666.73	686.78
SE Asia	151.88	174.58	193.52	206.66	221.66	240.34	260.24
World Totals	2,001.05	2,022.90	2,145.71	2,299.43	2,481.50	2,695.83	2,936.92

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix C-6: Nitrous Oxide Emissions from Manure Management

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.02	0.03	0.64	1.25	1.86	2.48	3.10
Algeria	0.83	0.93	1.05	1.16	1.32	1.53	1.88
Argentina	0.15	0.18	0.25	0.27	0.29	0.31	0.33
Armenia	0.20	0.16	0.16	0.15	0.15	0.14	0.14
Australia	0.52	0.93	1.31	1.30	1.33	1.33	1.34
Austria	0.79	0.77	0.73	0.73	0.73	0.73	0.73
Azerbaijan	0.57	0.47	0.62	0.61	0.60	0.59	0.59
Bangladesh	0.51	0.59	0.62	0.68	0.75	0.82	0.89
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.95	0.98	0.97	0.94	0.91	0.89	0.86
Bolivia	0.24	0.28	0.33	0.36	0.39	0.42	0.45
Brazil	5.89	6.20	5.68	6.18	6.73	7.18	7.66
Bulgaria	1.03	0.50	0.43	0.43	0.43	0.43	0.43
Cambodia	0.64	1.20	1.24	1.71	2.17	3.10	4.03
Canada	3.45	3.85	3.88	4.38	4.80	5.37	5.93
Chile	0.14	0.20	0.31	0.33	0.36	0.39	0.42
China	49.51	60.01	62.34	69.12	76.80	82.76	89.32
Colombia	0.35	0.38	0.40	0.43	0.46	0.48	0.51
Croatia	0.38	0.25	0.22	0.22	0.22	0.22	0.22
Czech Republic	0.66	0.48	0.42	0.43	0.44	0.45	0.46
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.68	0.64	0.60	0.51	0.49	0.48	0.47
Ecuador	0.26	0.31	0.38	0.41	0.45	0.49	0.52
Egypt	0.05	0.07	0.08	0.08	0.09	0.09	0.09
Estonia	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Ethiopia	0.22	0.23	0.26	0.29	0.32	0.35	0.39
Finland	0.62	0.50	0.48	0.45	0.41	0.41	0.41
France	6.90	6.64	6.51	6.43	6.36	6.41	6.45
Georgia	0.41	0.34	0.40	0.39	0.38	0.38	0.37
Germany	4.47	3.14	3.00	2.53	2.13	2.14	2.15
Greece	0.30	0.28	0.29	0.29	0.29	0.29	0.29
Hungary	2.15	1.30	1.29	1.89	1.95	1.98	2.00
Iceland	0.03	0.03	0.03	0.03	0.03	0.03	0.03
India	0.29	0.31	0.34	0.36	0.39	0.41	0.43
Indonesia	3.02	3.62	3.22	3.64	4.11	4.40	4.72
Iran	0.14	0.16	0.18	0.20	0.21	0.22	0.24
Iraq	0.05	0.02	0.02	0.02	0.03	0.03	0.03
Ireland	0.63	0.67	0.70	0.70	0.70	0.70	0.70
Israel	0.21	0.24	0.26	0.28	0.29	0.29	0.30
Italy	3.83	3.98	4.05	4.15	4.25	4.36	4.47
Japan	13.55	12.65	12.00	12.30	12.59	12.89	13.18
Jordan	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Kazakhstan	2.78	2.19	1.32	1.34	1.36	1.39	1.41
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.28	0.37	0.34	0.37	0.40	0.47	0.50
Latvia	0.30	0.18	0.12	0.12	0.12	0.13	0.14
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.17	0.23	0.21	0.21	0.21	0.21
Macedonia	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Mexico	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Moldova	0.50	0.38	0.26	0.26	0.25	0.25	0.25
Mongolia	0.48	0.50	0.49	0.53	0.57	0.60	0.64
Myanmar	1.73	1.89	2.17	2.37	2.59	2.79	3.01
Nepal	0.57	0.62	0.71	0.77	0.84	0.91	0.99
Netherlands	0.67	0.74	0.74	0.74	0.74	0.74	0.74
New Zealand	0.04	0.05	0.06	0.06	0.05	0.05	0.05
Nigeria	0.64	0.76	0.89	0.98	1.08	1.17	1.27
North Korea	0.72	0.41	0.40	0.44	0.47	0.50	0.53
Norway	0.13	0.15	0.14	0.14	0.14	0.14	0.14

Appendix C-6: Nitrous Oxide Emissions from Manure Management

	MtCO₂eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Pakistan	0.57	0.65	0.73	0.33	0.39	0.45	0.49
Peru	0.59	0.61	0.70	0.76	0.84	0.92	1.00
Philippines	1.12	1.29	1.56	1.79	2.05	2.28	2.53
Poland	8.13	7.33	5.78	5.95	6.24	6.42	6.54
Portugal	0.94	0.95	1.02	1.12	1.22	1.32	1.65
Romania	0.28	0.16	0.14	0.14	0.14	0.14	0.14
Russian Federation	21.30	16.60	17.20	19.50	20.30	21.10	22.00
Saudi Arabia	0.03	0.04	0.06	0.06	0.06	0.06	0.07
Senegal	0.05	0.06	0.08	0.09	0.10	0.11	0.12
Singapore	0.03	0.02	0.02	0.02	0.02	0.03	0.03
Slovak Republic	1.09	0.73	0.50	0.59	0.58	0.56	0.55
Slovenia	0.36	0.29	0.25	0.25	0.25	0.25	0.25
South Africa	0.43	0.02	0.02	0.02	0.02	0.02	0.02
South Korea	1.70	2.48	2.48	2.69	2.91	3.14	3.38
Spain	1.63	1.56	1.61	1.71	1.79	1.90	2.00
Sweden	0.80	0.67	0.63	0.63	0.62	0.62	0.62
Switzerland	0.45	0.42	0.41	0.40	0.40	0.39	0.39
Tajikistan	0.40	0.34	0.31	0.31	0.31	0.31	0.31
Thailand	5.56	5.83	5.25	5.56	6.08	6.08	6.08
Turkey	1.97	2.04	1.89	1.96	2.04	2.09	2.14
Turkmenistan	0.47	0.38	0.37	0.37	0.38	0.39	0.40
Uganda	0.21	0.24	0.28	0.31	0.34	0.37	0.40
Ukraine	9.26	7.35	4.31	4.87	5.10	5.57	6.04
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	1.51	1.50	1.44	1.44	1.44	1.44	1.44
United States	16.26	17.13	17.81	17.40	17.83	18.09	18.39
Uruguay	0.04	0.05	0.06	0.07	0.07	0.08	0.09
Uzbekistan	0.31	0.30	0.28	0.29	0.29	0.30	0.31
Venezuela	0.26	0.37	0.47	0.51	0.56	0.60	0.65
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	2.47	2.59	2.66	3.11	3.52	3.76	4.14
Rest of Latin America	0.93	1.05	1.18	1.27	1.36	1.55	1.61
Rest of Middle East	0.03	0.09	0.09	0.09	0.09	0.09	0.09
Rest of Non-EU Eastern Europe	0.90	1.33	1.21	1.21	1.18	1.18	1.15
Rest of OECD90 & EU	0.03	0.03	0.06	0.06	0.06	0.06	0.06
Rest of SE Asia	2.01	2.36	1.46	1.60	1.76	1.87	1.98
Africa	4.90	4.90	5.31	6.04	6.78	7.41	8.32
China/CPA	51.62	62.49	64.82	72.16	80.41	87.43	95.02
Latin America	8.84	9.64	9.77	10.61	11.54	12.42	13.24
Middle East	0.47	0.56	0.63	0.66	0.69	0.72	0.74
Non-EU Eastern Europe	1.39	1.70	2.16	2.77	3.35	3.97	4.56
Non-EU FSU	36.21	28.51	25.21	28.09	29.14	30.43	31.83
OECD90 & EU	75.21	71.45	69.52	70.40	71.74	73.45	75.37
SE Asia	17.11	19.67	18.55	19.80	21.90	23.17	24.53
World Totals	195.76	198.93	195.97	210.53	225.56	238.99	253.61

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix C-7: Nitrous Oxide Emissions from Other Agricultural Sources

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Algeria	0.22	0.16	0.00	0.00	0.00	0.00	0.00
Argentina	2.17	1.24	1.82	1.82	1.82	1.82	1.82
Armenia	0.01	0.00	0.01	0.01	0.01	0.01	0.01
Australia	1.91	1.91	4.24	4.24	4.24	4.24	4.24
Austria	0.03	0.01	0.01	0.01	0.01	0.01	0.01
Azerbaijan	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Bangladesh	0.14	0.02	1.06	1.06	1.06	1.06	1.06
Belarus	0.04	0.03	0.04	0.04	0.04	0.04	0.04
Belgium	0.02	0.24	0.23	0.01	0.01	0.01	0.01
Bolivia	5.48	5.27	16.28	16.28	16.28	16.28	16.28
Brazil	36.79	30.13	69.56	69.56	69.56	69.56	69.56
Bulgaria	0.05	0.04	0.05	0.05	0.05	0.05	0.05
Cambodia	1.59	1.77	0.83	0.83	0.83	0.83	0.83
Canada	0.74	5.25	0.75	0.75	0.75	0.75	0.75
Chile	0.84	0.61	0.19	0.19	0.19	0.19	0.19
China	1.80	0.20	0.84	0.84	0.84	0.84	0.84
Colombia	3.56	2.91	5.31	5.31	5.31	5.31	5.31
Croatia	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Czech Republic	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Democratic Republic of Congo (Kinshasa)	12.57	12.64	31.67	31.67	31.67	31.67	31.67
Denmark	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Ecuador	2.42	2.13	0.14	0.14	0.14	0.14	0.14
Egypt			0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	1.02	1.22	1.21	1.21	1.21	1.21	1.21
Finland	0.04	0.06	0.00	0.00	0.00	0.00	0.00
France	0.42	0.14	0.12	0.12	0.12	0.12	0.12
Georgia	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Germany	0.19	0.05	0.06	0.06	0.06	0.06	0.06
Greece	0.11	0.05	0.02	0.02	0.02	0.02	0.02
Hungary	0.07	0.06	0.06	0.06	0.06	0.06	0.06
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.79	0.29	2.77	2.77	2.77	2.77	2.77
Indonesia	13.53	12.80	16.03	16.03	16.03	16.03	16.03
Iran	0.47	0.46	0.15	0.15	0.15	0.15	0.15
Iraq			0.00	0.00	0.00	0.00	0.00
Ireland	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Italy	0.31	0.07	0.09	0.09	0.09	0.09	0.09
Japan	0.08	0.09	0.06	0.06	0.06	0.06	0.06
Jordan	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.14	0.06	0.13	0.13	0.13	0.13	0.13
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Laos	1.58	1.70	2.69	2.69	2.69	2.69	2.69
Latvia	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein			0.00	0.00	0.00	0.00	0.00
Lithuania	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Luxembourg	0.00		0.00	0.00	0.00	0.00	0.00
Macedonia	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Mexico	2.45	2.11	5.92	5.92	5.92	5.92	5.92
Moldova	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Monaco			0.00	0.00	0.00	0.00	0.00
Mongolia	0.10	0.10	0.05	0.05	0.05	0.05	0.05
Myanmar	4.84	4.75	8.66	8.66	8.66	8.66	8.66
Nepal	0.34	0.34	0.02	0.02	0.02	0.02	0.02
Netherlands	0.03	0.01	0.01	0.01	0.01	0.01	0.01
New Zealand	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Nigeria	1.35	1.39	2.25	2.25	2.25	2.25	2.25

Appendix C-7: Nitrous Oxide Emissions from Other Agricultural Sources

Country	1990	1995	2000	2005	2010	2015	2020
	$MtCO_2eq$						
North Korea			0.02	0.02	0.02	0.02	0.02
Norway	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	0.39	0.31	0.01	0.01	0.01	0.01	0.01
Peru	3.18	2.79	1.88	1.88	1.88	1.88	1.88
Philippines	3.83	3.44	0.18	0.18	0.18	0.18	0.18
Poland	0.16	0.15	0.16	0.16	0.16	0.16	0.16
Portugal	0.14	0.15	0.02	0.02	0.02	0.02	0.02
Romania	0.10	0.12	0.11	0.11	0.11	0.11	0.11
Russian Federation	1.41	0.58	2.37	2.37	2.37	2.37	2.37
Saudi Arabia	0.06	0.07	0.07	0.07	0.07	0.07	0.07
Senegal	0.42	0.41	0.21	0.21	0.21	0.21	0.21
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Slovenia	0.01	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.89	0.57	0.76	0.76	0.76	0.76	0.76
South Korea	0.19	0.25	0.14	0.14	0.14	0.14	0.14
Spain	0.38	0.15	0.07	0.07	0.07	0.07	0.07
Sweden	0.03	0.01	0.01	0.01	0.01	0.01	0.01
Switzerland	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Tajikistan	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Thailand	2.90	2.17	3.17	3.17	3.17	3.17	3.17
Turkey	0.49	0.53	0.54	0.54	0.54	0.54	0.54
Turkmenistan	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Uganda	0.54	0.54	0.47	0.47	0.47	0.47	0.47
Ukraine	0.23	0.19	0.20	0.20	0.20	0.20	0.20
United Arab Emirates		0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.12	0.03	0.03	0.03	0.03	0.03	0.03
United States	0.37	0.38	0.46	0.48	0.50	0.54	0.57
Uruguay	0.03	0.03	0.04	0.04	0.04	0.04	0.04
Uzbekistan	0.06	0.05	0.05	0.05	0.05	0.05	0.05
Venezuela	5.78	5.22	6.40	6.40	6.40	6.40	6.40
Viet Nam	1.53	1.52	0.90	0.90	0.90	0.90	0.90
Rest of Africa	25.41	24.47	71.01	71.01	71.01	71.01	71.01
Rest of Latin America	6.97	6.73	7.04	7.04	7.04	7.04	7.04
Rest of Middle East	0.09	0.12	0.05	0.05	0.05	0.05	0.05
Rest of Non-EU Eastern Europe	0.06	0.05	0.06	0.06	0.06	0.06	0.06
Rest of OECD90 & EU	0.16	0.01	0.01	0.01	0.01	0.01	0.01
Rest of SE Asia	8.66	9.35	4.57	4.57	4.57	4.57	4.57
Africa	42.43	41.42	107.60	107.60	107.60	107.60	107.60
China/CPA	6.60	5.29	5.33	5.33	5.33	5.33	5.33
Latin America	69.65	59.17	114.58	114.58	114.58	114.58	114.58
Middle East	0.67	0.69	0.31	0.31	0.31	0.31	0.31
Non-EU Eastern Europe	0.11	0.09	0.10	0.10	0.10	0.10	0.10
Non-EU FSU	1.98	0.99	2.88	2.88	2.88	2.88	2.88
OECD90 & EU	6.12	9.61	7.21	7.01	7.03	7.07	7.10
SE Asia	35.61	33.72	36.60	36.60	36.60	36.60	36.60
World Totals	163.17	150.97	274.61	274.40	274.42	274.46	274.49

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix C-8: Nitrous Oxide Emissions from Human Sewage

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Algeria	0.28	0.31	0.34	0.37	0.40	0.43	0.45
Argentina	0.62	0.66	0.70	0.74	0.78	0.82	0.86
Armenia	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Australia	0.48	0.51	0.54	0.57	0.59	0.62	0.64
Austria	0.02	0.06	0.16	0.16	0.16	0.15	0.15
Azerbaijan	0.09	0.09	0.10	0.10	0.10	0.11	0.11
Bangladesh	0.95	1.06	1.18	1.31	1.44	1.58	1.70
Belarus	0.24	0.20	0.23	0.23	0.22	0.22	0.22
Belgium	0.11	0.28	0.30	0.30	0.30	0.30	0.30
Bolivia	0.07	0.08	0.09	0.09	0.10	0.11	0.12
Brazil	3.72	3.72	3.97	4.22	4.47	4.70	4.91
Bulgaria	0.22	0.18	0.16	0.15	0.14	0.14	0.13
Cambodia	0.11	0.13	0.16	0.18	0.20	0.23	0.25
Canada	0.87	0.92	0.96	1.00	1.04	1.08	1.11
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	17.56	18.54	19.39	20.10	20.78	21.45	22.00
Colombia	0.37	0.41	0.45	0.48	0.52	0.56	0.60
Croatia	0.14	0.13	0.08	0.08	0.08	0.08	0.08
Czech Republic	0.20	0.20	0.20	0.20	0.20	0.20	0.19
Democratic Republic of Congo (Kinshasa)	0.14	0.17	0.19	0.22	0.27	0.31	0.37
Denmark	0.09	0.09	0.07	0.06	0.06	0.06	0.06
Ecuador	0.10	0.12	0.13	0.14	0.15	0.16	0.17
Egypt	0.94	1.04	1.13	1.23	1.32	1.41	1.50
Estonia	0.03	0.03	0.03	0.02	0.02	0.02	0.02
Ethiopia	0.31	0.31	0.35	0.40	0.45	0.50	0.57
Finland	0.14	0.13	0.11	0.11	0.11	0.11	0.11
France	1.27	1.29	1.36	1.39	1.41	1.42	1.43
Georgia	0.06	0.06	0.06	0.06	0.06	0.06	0.05
Germany	2.21	2.18	2.24	2.24	2.23	2.21	2.19
Greece	0.33	0.35	0.38	0.38	0.38	0.37	0.37
Hungary	0.17	0.16	0.16	0.16	0.15	0.15	0.15
Iceland	0.01	0.01	0.01	0.01	0.01	0.01	0.01
India	1.98	2.17	2.36	2.55	2.72	2.88	3.02
Indonesia	2.12	2.30	2.47	2.62	2.76	2.91	3.04
Iran	1.30	1.44	1.57	1.68	1.80	1.94	2.08
Iraq	0.17	0.19	0.22	0.25	0.29	0.32	0.36
Ireland	0.11	0.11	0.13	0.13	0.14	0.15	0.15
Israel	0.09	0.11	0.13	0.14	0.15	0.16	0.17
Italy	1.04	1.05	1.06	1.05	1.04	1.02	0.99
Japan	1.10	1.09	1.05	1.06	1.06	1.06	1.04
Jordan	0.04	0.06	0.07	0.08	0.09	0.10	0.11
Kazakhstan	0.21	0.21	0.21	0.20	0.20	0.20	0.21
Kuwait	0.04	0.03	0.03	0.04	0.04	0.05	0.05
Kyrgyzstan	0.07	0.07	0.06	0.07	0.07	0.07	0.08
Laos	0.04	0.05	0.05	0.06	0.06	0.07	0.08
Latvia	0.06	0.05	0.05	0.05	0.05	0.05	0.05
Lithuania	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Luxembourg	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	1.31	1.44	1.56	1.67	1.78	1.88	1.97
Moldova	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.03	0.03	0.03	0.04	0.04	0.04	0.04
Myanmar	0.52	0.57	0.61	0.65	0.68	0.71	0.74
Nepal	0.28	0.31	0.35	0.39	0.44	0.49	0.54
Netherlands	0.52	0.47	0.43	0.44	0.44	0.45	0.45
New Zealand	0.15	0.15	0.16	0.16	0.17	0.17	0.17
Nigeria	0.98	1.13	1.29	1.47	1.67	1.88	2.09
North Korea	0.22	0.24	0.25	0.26	0.26	0.27	0.28

Appendix C-8: Nitrous Oxide Emissions from Human Sewage

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Norway	0.09	0.10	0.11	0.11	0.11	0.11	0.11
Pakistan	1.76	1.98	2.27	2.57	2.91	3.28	3.65
Peru	0.34	0.37	0.41	0.44	0.47	0.50	0.53
Philippines	0.85	0.95	1.06	1.16	1.26	1.34	1.42
Poland	0.80	0.81	0.81	0.80	0.80	0.79	0.79
Portugal	0.45	0.52	0.55	0.56	0.56	0.55	0.55
Romania	0.34	0.33	0.33	0.32	0.32	0.31	0.31
Russian Federation	3.72	3.57	3.41	3.30	3.21	3.12	3.04
Saudi Arabia	0.70	0.77	0.92	1.07	1.25	1.44	1.63
Senegal	0.08	0.10	0.11	0.12	0.14	0.16	0.17
Slovak Republic	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Slovenia	0.06	0.05	0.06	0.06	0.06	0.06	0.06
South Africa	0.74	0.82	0.89	0.93	0.93	0.92	0.91
South Korea	0.68	0.72	0.75	0.77	0.79	0.81	0.82
Spain	1.00	1.05	1.09	1.09	1.08	1.07	1.05
Sweden	0.20	0.19	0.15	0.15	0.14	0.14	0.14
Switzerland	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tajikistan	0.05	0.05	0.05	0.06	0.06	0.06	0.07
Thailand	0.53	0.57	0.60	0.64	0.67	0.70	0.72
Turkey	0.99	1.09	1.18	1.26	1.33	1.40	1.47
Turkmenistan	0.05	0.06	0.07	0.07	0.08	0.09	0.09
Uganda	0.16	0.18	0.21	0.25	0.29	0.35	0.41
Ukraine	1.56	1.13	1.11	1.06	1.01	0.97	0.93
United Arab Emirates	0.04	0.04	0.05	0.05	0.06	0.06	0.06
United Kingdom	1.03	1.04	1.17	1.18	1.19	1.20	1.20
United States	13.02	14.22	15.56	15.74	15.93	16.12	16.29
Uruguay	0.06	0.06	0.06	0.06	0.06	0.07	0.07
Uzbekistan	0.30	0.05	0.05	0.05	0.05	0.05	0.06
Venezuela	0.34	0.38	0.42	0.47	0.50	0.54	0.58
Viet Nam	1.03	1.13	1.22	1.30	1.38	1.47	1.56
Rest of Africa	3.03	3.38	3.82	4.29	4.79	5.34	5.91
Rest of Latin America	0.58	0.63	0.69	0.74	0.80	0.85	0.91
Rest of Middle East	0.34	0.41	0.48	0.56	0.64	0.74	0.84
Rest of Non-EU Eastern Europe	0.21	0.21	0.21	0.22	0.22	0.21	0.21
Rest of OECD90 & EU	0.02	0.02	0.02	0.02	0.03	0.03	0.03
Rest of SE Asia	1.09	1.23	1.33	1.47	1.61	1.73	1.85
Africa	6.65	7.43	8.34	9.28	10.26	11.29	12.38
China/CPA	18.99	20.12	21.10	21.93	22.74	23.54	24.22
Latin America	7.51	7.87	8.48	9.07	9.65	10.20	10.72
Middle East	2.72	3.06	3.46	3.87	4.32	4.80	5.31
Non-EU Eastern Europe	0.40	0.38	0.34	0.35	0.35	0.35	0.35
Non-EU FSU	6.44	5.57	5.44	5.29	5.16	5.05	4.93
OECD90 & EU	27.22	28.83	30.67	31.03	31.34	31.59	31.80
SE Asia	10.75	11.86	12.98	14.13	15.28	16.41	17.51
World Totals	80.68	85.12	90.81	94.95	99.09	103.23	107.22

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix C-9: Nitrous Oxide Emissions from Other Non-Agricultural Sources (Waste and Other)

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Australia	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Austria	0.26	0.28	0.28	0.28	0.28	0.28	0.28
Belarus	0.00	0.00	0.00	0.08	0.08	0.08	0.08
Belgium	0.28	0.26	0.28	0.28	0.28	0.28	0.28
Canada	0.47	0.50	0.52	0.53	0.53	0.53	0.53
Czech Republic	0.20	0.21	0.21	0.22	0.22	0.22	0.22
Denmark	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Finland	0.06	0.06	0.06	0.06	0.06	0.06	0.06
France	0.23	0.23	0.19	0.43	0.43	0.43	0.43
Germany	1.92	1.92	1.92	1.92	1.92	1.92	1.92
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	0.22	0.20	0.14	0.14	0.14	0.14	0.14
Iceland	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	0.88	0.89	1.12	1.12	1.12	1.12	1.12
Japan	2.04	2.71	2.93	3.98	5.07	6.15	7.24
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moldova	0.37	0.36	0.36	0.36	0.36	0.36	0.36
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.23	0.24	0.18	0.18	0.18	0.18	0.18
New Zealand	0.04	0.04	0.05	0.05	0.05	0.05	0.05
Norway	0.04	0.04	0.05	0.05	0.05	0.05	0.05
Portugal	0.00	0.00	0.03	0.03	0.03	0.03	0.03
Russian Federation	0.71	0.71	0.53	0.53	0.53	0.53	0.53
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	IE	IE	IE	0.00	0.00	0.00	0.00
Slovenia	0.04	0.02	0.04	0.04	0.04	0.04	0.04
Spain	0.42	0.48	0.49	0.49	0.49	0.49	0.49
Sweden	0.09	0.13	0.13	0.13	0.13	0.13	0.13
Switzerland	0.14	0.16	0.18	0.20	0.22	0.21	0.20
Ukraine	0.02	0.02	0.01	0.01	0.01	0.01	0.01
United Kingdom	0.11	0.11	0.10	0.10	0.10	0.10	0.10
United States	4.72	4.88	5.12	5.18	5.19	5.21	5.22
Venezuela	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China/CPA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latin America	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	1.10	1.09	0.90	0.99	0.99	0.99	0.99
OECD90 & EU	12.47	13.44	14.10	15.47	16.59	17.69	18.78
SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
World Totals	13.59	14.55	15.02	16.48	17.60	18.70	19.79

Regional country groupings are defined in Table 1-4 and Appendix H.

Codes:
IE - Estimated, but included elsewhere.

Appendix D-1: HFC and PFC Emissions from ODS Substitutes - Aerosols (MDI)

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.02	0.19	0.37	0.41
Argentina	0.00	0.00	0.00	0.00	0.05	0.09	0.10
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.12	0.15	0.16	0.23	0.29	0.32
Austria	0.00	0.01	0.02	0.02	0.04	0.05	0.06
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.04	0.07	0.09
Belarus	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Belgium	0.00	0.05	0.06	0.06	0.08	0.11	0.11
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.00	0.00	0.00	0.01	0.06	0.12	0.15
Bulgaria	0.00	0.00	0.01	0.01	0.02	0.03	0.04
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.00	0.00	0.01	0.02	0.16	0.30	0.33
Chile	0.00	0.00	0.00	0.00	0.00	0.01	0.01
China	0.00	0.00	0.01	0.08	0.72	1.60	2.17
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.00	0.00	0.00	0.00	0.02	0.03	0.03
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.03	0.04	0.04	0.06	0.07	0.07
Ecuador	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.02	0.02	0.02	0.03	0.03	0.03
France	0.00	0.29	0.34	0.37	0.51	0.65	0.68
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.00	0.40	0.47	0.51	0.71	0.89	0.94
Greece	0.00	0.02	0.02	0.03	0.04	0.05	0.05
Hungary	0.00	0.00	0.00	0.00	0.01	0.02	0.02
Iceland	0.00	0.00	0.00	0.01	0.01	0.01	0.01
India	0.00	0.00	0.00	0.02	0.23	0.48	0.57
Indonesia	0.00	0.00	0.00	0.00	0.06	0.12	0.14
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.01	0.01	0.01	0.02	0.02	0.03
Israel	0.00	0.00	0.00	0.01	0.07	0.14	0.18
Italy	0.00	0.27	0.31	0.34	0.47	0.59	0.63
Japan	0.00	0.00	0.06	0.12	0.95	1.65	1.64
Jordan	0.00	0.00	0.00	0.00	0.02	0.04	0.04
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.03	0.06	0.08
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.00	0.01	0.03	0.29	0.58	0.67
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.07	0.08	0.09	0.12	0.15	0.16
New Zealand	0.00	0.02	0.02	0.03	0.03	0.04	0.04
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.01

Appendix D-1: HFC and PFC Emissions from ODS Substitutes - Aerosols (MDI)

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.01	0.03	0.03
Norway	0.00	0.02	0.05	0.07	0.11	0.11	0.12
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Poland	0.00	0.02	0.04	0.08	0.13	0.16	0.19
Portugal	0.00	0.02	0.02	0.02	0.03	0.04	0.04
Romania	0.00	0.01	0.02	0.04	0.06	0.08	0.09
Russian Federation	0.00	0.19	0.40	0.69	1.13	1.35	1.54
Saudi Arabia	0.00	0.00	0.00	0.00	0.05	0.09	0.11
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.02	0.04	0.05
Slovak Republic	0.00	0.00	0.00	0.00	0.01	0.02	0.02
Slovenia	0.00	0.00	0.00	0.00	0.01	0.01	0.01
South Africa	0.00	0.00	0.00	0.01	0.12	0.23	0.26
South Korea	0.00	0.00	0.00	0.01	0.03	0.05	0.08
Spain	0.00	0.12	0.14	0.15	0.21	0.27	0.28
Sweden	0.00	0.07	0.08	0.08	0.10	0.11	0.12
Switzerland	0.00	0.01	0.02	0.03	0.04	0.05	0.06
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.01	0.11	0.22	0.27
Turkey	0.00	0.00	0.00	0.00	0.01	0.02	0.02
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.01	0.01	0.02	0.04	0.05	0.05
United Arab Emirates	0.00	0.00	0.00	0.00	0.01	0.02	0.02
United Kingdom	0.00	0.24	0.28	0.30	0.42	0.53	0.56
United States	0.00	0.00	0.14	0.33	2.70	5.09	5.49
Uruguay	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Uzbekistan	0.00	0.00	0.00	0.00	0.01	0.02	0.02
Venezuela	0.00	0.00	0.00	0.00	0.02	0.03	0.04
Viet Nam	0.00	0.00	0.00	0.00	0.03	0.07	0.08
Rest of Africa	0.00	0.00	0.00	0.01	0.07	0.15	0.17
Rest of Latin America	0.00	0.00	0.00	0.01	0.05	0.11	0.13
Rest of Middle East	0.00	0.00	0.00	0.01	0.10	0.20	0.24
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Rest of SE Asia	0.00	0.00	0.00	0.01	0.04	0.08	0.11
Africa	0.00	0.00	0.01	0.04	0.38	0.75	0.85
China/CPA	0.00	0.00	0.01	0.08	0.76	1.69	2.28
Latin America	0.00	0.00	0.01	0.05	0.49	0.97	1.14
Middle East	0.00	0.00	0.01	0.03	0.28	0.55	0.66
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Non-EU FSU	0.00	0.19	0.41	0.72	1.18	1.43	1.63
OECD90 & EU	0.00	1.81	2.41	2.98	7.35	11.52	12.22
SE Asia	0.00	0.00	0.01	0.07	0.53	1.07	1.33
World Totals	0.00	2.00	2.87	3.97	10.99	17.99	20.12

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-2: HFC and PFC Emissions from ODS Substitutes - Aerosols (Non-MDI)

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Argentina	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.55	0.67	0.74	0.82	0.90	1.00
Austria	0.00	0.23	0.26	0.28	0.29	0.31	0.33
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.27	0.32	0.34	0.36	0.38	0.40
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulgaria	0.00	0.04	0.10	0.17	0.27	0.32	0.37
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	0.00	0.00	0.01	0.02	0.03	0.04	0.05
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.01	0.02	0.03	0.05	0.06	0.07
Czech Republic	0.00	0.09	0.21	0.37	0.57	0.66	0.77
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.18	0.21	0.22	0.23	0.25	0.26
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.07	0.08	0.09	0.09	0.10	0.11
France	0.00	1.67	1.93	2.05	2.17	2.31	2.45
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.00	2.29	2.64	2.81	2.98	3.17	3.36
Greece	0.00	0.12	0.13	0.14	0.15	0.16	0.17
Hungary	0.00	0.08	0.19	0.32	0.50	0.59	0.68
Iceland	0.00	0.00	0.01	0.01	0.01	0.01	0.02
India	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.06	0.07	0.08	0.08	0.09	0.09
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	0.00	1.53	1.76	1.87	1.99	2.11	2.24
Japan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.04	0.08	0.13	0.20	0.23	0.26
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.04	0.09	0.15	0.23	0.26	0.30
Luxembourg	0.00	0.01	0.02	0.02	0.02	0.02	0.02
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.00	0.00	0.01	0.01	0.01	0.02
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.40	0.46	0.49	0.52	0.55	0.58
New Zealand	0.00	0.05	0.06	0.06	0.07	0.07	0.08
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-2: HFC and PFC Emissions from ODS Substitutes - Aerosols (Non-MDI)

	$MTCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.02	0.04	0.06	0.09	0.09	0.10
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.08	0.19	0.33	0.52	0.60	0.70
Portugal	0.00	0.09	0.11	0.12	0.12	0.13	0.14
Romania	0.00	0.02	0.05	0.08	0.13	0.15	0.17
Russian Federation	0.00	0.75	1.60	2.74	4.18	4.77	5.45
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.00	0.03	0.08	0.13	0.21	0.24	0.28
Slovenia	0.00	0.04	0.09	0.16	0.25	0.29	0.34
South Africa	0.00	0.00	0.00	0.00	0.00	0.01	0.01
South Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spain	0.00	0.69	0.80	0.85	0.90	0.96	1.01
Sweden	0.00	0.10	0.11	0.12	0.13	0.14	0.14
Switzerland	0.00	0.08	0.17	0.28	0.39	0.42	0.44
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.03	0.07	0.12	0.19	0.22	0.25
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.00	1.36	1.57	1.67	1.77	1.88	2.00
United States	0.00	8.11	9.95	10.98	12.13	13.39	14.78
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Africa	0.00	0.00	0.01	0.01	0.02	0.02	0.02
China/CPA	0.00	0.00	0.01	0.02	0.03	0.04	0.05
Latin America	0.00	0.00	0.01	0.01	0.02	0.02	0.03
Middle East	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Non-EU Eastern Europe	0.00	0.01	0.02	0.03	0.05	0.06	0.07
Non-EU FSU	0.00	0.79	1.67	2.87	4.37	4.99	5.70
OECD90 & EU	0.00	18.33	22.44	25.12	28.20	30.78	33.62
SE Asia	0.00	0.00	0.01	0.01	0.02	0.02	0.03
World Totals	0.00	19.14	24.16	28.08	32.71	35.94	39.53

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-3: HFC and PFC Emissions from ODS Substitutes - Fire Extinguishing

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.01	0.01	0.01	0.02
Argentina	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.00	0.01	0.01	0.02	0.03	0.03
Austria	0.00	0.00	0.00	0.01	0.01	0.02	0.02
Azerbaijan	0.00	0.00	0.00	0.01	0.03	0.05	0.07
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Belgium	0.00	0.00	0.00	0.02	0.04	0.05	0.07
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.00	0.02	0.04	0.08	0.10	0.11	0.12
Chile	0.00	0.00	0.00	0.01	0.01	0.01	0.02
China	0.00	0.01	0.31	1.01	2.04	3.40	4.86
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.01	0.02	0.03	0.04
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.02	0.06	0.11	0.16	0.20
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.01	0.02	0.03	0.04
France	0.00	0.00	0.02	0.10	0.23	0.34	0.45
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.00	0.00	0.03	0.14	0.30	0.43	0.57
Greece	0.00	0.00	0.00	0.01	0.02	0.02	0.03
Hungary	0.00	0.00	0.00	0.01	0.03	0.04	0.06
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.00	0.00	0.01	0.03	0.05	0.08	0.10
Indonesia	0.00	0.00	0.01	0.03	0.05	0.07	0.10
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Israel	0.00	0.00	0.03	0.08	0.14	0.21	0.27
Italy	0.00	0.00	0.02	0.09	0.21	0.31	0.41
Japan	0.00	0.01	0.15	0.37	0.61	0.81	0.94
Jordan	0.00	0.00	0.00	0.01	0.02	0.02	0.03
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.01	0.02	0.03	0.05	0.06
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.00	0.01	0.02	0.04	0.06	0.08
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.00	0.01	0.02	0.05	0.07	0.10
New Zealand	0.00	0.00	0.01	0.03	0.05	0.06	0.07
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-3: HFC and PFC Emissions from ODS Substitutes - Fire Extinguishing

	$MTCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.00	0.00	0.01	0.02	0.03	0.04
Pakistan	0.00	0.00	0.01	0.02	0.04	0.06	0.08
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.01	0.01	0.02	0.03
Poland	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Portugal	0.00	0.00	0.00	0.01	0.01	0.02	0.03
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	0.00	0.00	0.01	0.04	0.11	0.20	0.30
Saudi Arabia	0.00	0.00	0.03	0.09	0.16	0.24	0.31
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.01	0.03	0.06	0.09	0.12
Slovak Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.00	0.00	0.04	0.11	0.20	0.29	0.37
South Korea	0.00	0.00	0.07	0.21	0.38	0.58	0.77
Spain	0.00	0.00	0.01	0.04	0.10	0.14	0.19
Sweden	0.00	0.00	0.00	0.01	0.03	0.04	0.05
Switzerland	0.00	0.00	0.00	0.01	0.02	0.02	0.03
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Turkey	0.00	0.00	0.01	0.02	0.04	0.06	0.08
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Arab Emirates	0.00	0.00	0.00	0.01	0.03	0.04	0.05
United Kingdom	0.00	0.00	0.02	0.06	0.11	0.14	0.17
United States	0.00	0.34	0.73	1.24	1.64	1.76	1.92
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.00	0.00	0.00	0.01	0.01	0.02	0.02
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.01	0.01	0.02	0.02
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Rest of Middle East	0.00	0.00	0.00	0.01	0.01	0.02	0.02
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.02	0.05	0.10	0.15	0.20
Africa	0.00	0.00	0.06	0.19	0.33	0.48	0.61
China/CPA	0.00	0.01	0.31	1.01	2.04	3.40	4.86
Latin America	0.00	0.00	0.01	0.05	0.09	0.13	0.17
Middle East	0.00	0.00	0.07	0.21	0.39	0.58	0.74
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Non-EU FSU	0.00	0.00	0.01	0.06	0.14	0.25	0.38
OECD90 & EU	0.00	0.37	1.07	2.32	3.71	4.60	5.50
SE Asia	0.00	0.00	0.12	0.38	0.70	1.07	1.41
World Totals	0.00	0.39	1.67	4.22	7.41	10.52	13.68

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-4: HFC and PFC Emissions from ODS Substitutes - Foams

	$MTCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.00	0.00	0.02	0.08	0.11	0.17
Austria	0.00	0.02	0.03	0.11	0.13	0.17	0.25
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.02	0.03	0.15	0.18	0.23	0.34
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.00	0.01	0.02	0.13	0.38	0.53	0.76
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	0.00	0.00	0.00	0.01	0.02	0.04	0.05
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.01	0.02	0.10	0.12	0.15	0.22
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.01	0.01	0.04	0.05	0.06	0.09
France	0.00	0.12	0.21	0.88	1.08	1.42	2.08
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.00	0.17	0.29	1.21	1.48	1.95	2.86
Greece	0.00	0.01	0.01	0.06	0.07	0.10	0.14
Hungary	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.01	0.03	0.04	0.05	0.08
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	0.00	0.11	0.19	0.81	0.99	1.30	1.91
Japan	0.00	0.00	0.01	2.39	3.26	3.95	4.81
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.01	0.01	0.01	0.02
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.03	0.05	0.21	0.26	0.34	0.49
New Zealand	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-4: HFC and PFC Emissions from ODS Substitutes - Foams

	$MTCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.00	0.00	0.01	0.02	0.02	0.03
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Portugal	0.00	0.01	0.01	0.05	0.06	0.08	0.12
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	0.00	0.00	0.01	0.01	0.02	0.03	0.04
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spain	0.00	0.05	0.09	0.37	0.45	0.59	0.86
Sweden	0.00	0.01	0.02	0.07	0.09	0.12	0.18
Switzerland	0.00	0.00	0.00	0.02	0.03	0.04	0.06
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.00	0.10	0.17	0.72	0.88	1.16	1.70
United States	0.00	0.15	0.29	2.00	5.67	7.94	11.31
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China/CPA	0.00	0.00	0.00	0.01	0.02	0.04	0.05
Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	0.00	0.00	0.01	0.01	0.03	0.03	0.04
OECD90 & EU	0.00	0.84	1.47	9.42	15.33	20.39	28.54
SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
World Totals	0.00	0.84	1.48	9.44	15.38	20.46	28.64

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-5: HFC and PFC Emissions from ODS Substitutes - Refrigeration/Air Conditioning

	$MTCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.05	0.35	0.86	1.55	1.94	2.37
Argentina	0.00	0.05	0.39	0.99	1.82	2.36	3.01
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.30	1.20	1.98	2.94	3.97	5.03
Austria	0.00	0.10	0.36	0.55	0.72	0.88	1.01
Azerbaijan	0.00	0.00	0.03	0.07	0.12	0.16	0.19
Bangladesh	0.00	0.00	0.03	0.07	0.13	0.18	0.25
Belarus	0.00	0.01	0.10	0.24	0.43	0.54	0.66
Belgium	0.00	0.12	0.44	0.83	1.11	1.85	1.71
Bolivia	0.00	0.00	0.00	0.01	0.02	0.03	0.03
Brazil	0.00	0.20	1.46	3.68	6.90	9.12	11.99
Bulgaria	0.00	0.01	0.08	0.20	0.38	0.50	0.65
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.00	0.87	3.44	5.76	8.76	12.03	15.51
Chile	0.00	0.01	0.10	0.25	0.46	0.62	0.84
China	0.00	0.53	4.12	11.88	25.81	39.91	61.73
Colombia	0.00	0.03	0.24	0.61	1.14	1.47	1.88
Croatia	0.00	0.00	0.02	0.04	0.07	0.09	0.11
Czech Republic	0.00	0.02	0.16	0.40	0.74	0.95	1.18
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.08	0.29	0.55	0.73	1.22	1.13
Ecuador	0.00	0.01	0.06	0.15	0.27	0.36	0.47
Egypt	0.00	0.04	0.30	0.75	1.35	1.69	2.06
Estonia	0.00	0.00	0.00	0.01	0.01	0.01	0.02
Ethiopia	0.00	0.00	0.01	0.02	0.03	0.04	0.04
Finland	0.00	0.03	0.12	0.19	0.27	0.34	0.42
France	0.00	0.18	1.51	5.01	7.95	12.97	12.22
Georgia	0.00	0.01	0.06	0.14	0.25	0.32	0.39
Germany	0.00	0.99	3.66	6.94	9.30	15.50	14.31
Greece	0.00	0.05	0.18	0.35	0.47	0.78	0.72
Hungary	0.00	0.02	0.14	0.36	0.65	0.82	1.02
Iceland	0.00	0.00	0.00	0.01	0.03	0.04	0.06
India	0.00	0.07	0.49	1.30	2.60	3.73	5.40
Indonesia	0.00	0.02	0.15	0.38	0.72	0.95	1.22
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.03	0.10	0.19	0.26	0.43	0.40
Israel	0.00	0.10	0.78	1.98	3.85	5.38	7.56
Italy	0.00	0.66	2.44	4.63	6.20	10.34	9.54
Japan	0.00	4.75	16.37	24.68	32.59	39.45	45.10
Jordan	0.00	0.01	0.08	0.21	0.39	0.51	0.65
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.04	0.33	0.84	1.63	2.27	3.18
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.01	0.06	0.14	0.26	0.33	0.41
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.01	0.07	0.17	0.30	0.37	0.45
Luxembourg	0.00	0.01	0.02	0.04	0.06	0.10	0.09
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.19	1.41	3.55	6.61	8.66	11.24
Moldova	0.00	0.00	0.02	0.05	0.09	0.11	0.14
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Myanmar	0.00	0.00	0.00	0.01	0.02	0.03	0.03
Nepal	0.00	0.00	0.01	0.02	0.04	0.05	0.07
Netherlands	0.00	0.17	0.63	1.20	1.61	2.68	2.48
New Zealand	0.00	0.03	0.10	0.17	0.28	0.40	0.53
Nigeria	0.00	0.01	0.04	0.10	0.20	0.30	0.45

Appendix D-5: HFC and PFC Emissions from ODS Substitutes - Refrigeration/Air Conditioning

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.03	0.19	0.50	0.95	1.24	1.59
Norway	0.00	0.00	0.03	0.08	0.23	0.38	0.54
Pakistan	0.00	0.02	0.16	0.42	0.79	1.04	1.33
Peru	0.00	0.02	0.11	0.28	0.53	0.70	0.90
Philippines	0.00	0.09	0.70	1.81	3.49	4.70	6.27
Poland	0.00	0.02	0.15	0.40	0.84	1.21	1.67
Portugal	0.00	0.04	0.15	0.29	0.38	0.64	0.59
Romania	0.00	0.00	0.04	0.11	0.26	0.40	0.58
Russian Federation	0.00	0.18	1.27	3.31	6.95	9.86	13.40
Saudi Arabia	0.00	0.09	0.69	1.74	3.19	4.06	5.06
Senegal	0.00	0.00	0.01	0.04	0.07	0.08	0.10
Singapore	0.00	0.02	0.14	0.37	0.80	1.29	2.10
Slovak Republic	0.00	0.01	0.06	0.15	0.27	0.36	0.45
Slovenia	0.00	0.01	0.07	0.18	0.32	0.41	0.51
South Africa	0.00	0.23	1.70	4.20	7.65	9.72	12.18
South Korea	0.00	0.50	3.73	9.69	18.59	24.99	33.18
Spain	0.00	0.30	1.10	2.09	2.81	4.68	4.32
Sweden	0.00	0.04	0.17	0.29	0.49	0.72	0.96
Switzerland	0.00	0.01	0.10	0.24	0.44	0.56	0.67
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.09	0.67	1.76	3.56	5.18	7.60
Turkey	0.00	0.04	0.29	0.72	1.34	1.76	2.27
Turkmenistan	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Uganda	0.00	0.00	0.00	0.01	0.01	0.02	0.02
Ukraine	0.00	0.01	0.06	0.15	0.29	0.40	0.53
United Arab Emirates	0.00	0.01	0.08	0.20	0.40	0.58	0.85
United Kingdom	0.00	0.59	2.18	4.13	5.53	9.22	8.51
United States	0.00	14.61	58.01	97.30	148.60	204.75	264.59
Uruguay	0.00	0.01	0.08	0.21	0.39	0.51	0.67
Uzbekistan	0.00	0.02	0.14	0.35	0.63	0.79	0.97
Venezuela	0.00	0.09	0.63	1.60	2.99	3.94	5.16
Viet Nam	0.00	0.01	0.05	0.14	0.27	0.37	0.51
Rest of Africa	0.00	0.05	0.41	1.03	1.91	2.49	3.22
Rest of Latin America	0.00	0.10	0.71	1.78	3.29	4.23	5.36
Rest of Middle East	0.00	0.04	0.31	0.80	1.51	2.01	2.67
Rest of Non-EU Eastern Europe	0.00	0.00	0.03	0.08	0.14	0.18	0.23
Rest of OECD90 & EU	0.00	0.01	0.09	0.23	0.42	0.53	0.66
Rest of SE Asia	0.00	0.10	0.77	2.00	3.88	5.28	7.15
Africa	0.00	0.38	2.83	7.01	12.77	16.27	20.44
China/CPA	0.00	0.56	4.37	12.52	27.03	41.52	63.84
Latin America	0.00	0.71	5.21	13.10	24.42	32.00	41.55
Middle East	0.00	0.30	2.27	5.76	10.97	14.81	19.96
Non-EU Eastern Europe	0.00	0.01	0.05	0.11	0.21	0.27	0.33
Non-EU FSU	0.00	0.24	1.67	4.31	8.78	12.19	16.31
OECD90 & EU	0.00	24.12	93.79	160.54	237.57	331.58	400.31
SE Asia	0.00	0.91	6.85	17.84	34.62	47.42	64.60
World Totals	0.00	27.22	117.04	221.20	356.36	496.07	627.35

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-6: HFC and PFC Emissions from ODS Substitutes - Solvents

	MTCO$_2$eq						
Country	1990	1995	2000	2005	2010	2015	2020
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.06	0.14	0.07	0.07	0.08	0.08
Austria	0.00	0.01	0.02	0.01	0.01	0.01	0.01
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.03	0.05	0.03	0.02	0.03	0.03
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.00	0.01	0.05	0.04	0.05	0.06	0.07
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.00	0.08	0.17	0.09	0.08	0.09	0.10
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	0.00	0.01	3.97	2.66	1.37	0.08	0.11
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.02	0.03	0.02	0.02	0.02	0.02
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.01	0.01	0.01	0.01	0.01	0.01
France	0.00	0.16	0.88	0.53	0.33	0.16	0.17
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.00	0.21	1.18	2.03	1.11	0.22	0.23
Greece	0.00	0.01	0.02	0.01	0.01	0.01	0.01
Hungary	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Israel	0.00	0.00	0.02	0.01	0.02	0.02	0.03
Italy	0.00	0.14	0.69	0.41	0.27	0.14	0.15
Japan	0.00	1.04	3.54	1.99	1.37	0.87	0.89
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.04	0.08	0.04	0.04	0.04	0.04
New Zealand	0.00	0.01	0.02	0.01	0.01	0.01	0.01
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-6: HFC and PFC Emissions from ODS Substitutes - Solvents

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.01	0.02	0.01	0.01	0.01	0.01
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.66	0.45	0.24	0.02	0.03
Slovak Republic	0.00	0.00	0.05	0.03	0.02	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.01
South Africa	0.00	0.00	0.02	0.01	0.02	0.02	0.02
South Korea	0.00	0.01	1.56	1.05	0.57	0.07	0.09
Spain	0.00	0.06	0.13	0.07	0.06	0.07	0.07
Sweden	0.00	0.01	0.02	0.01	0.01	0.01	0.01
Switzerland	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.01	0.03	0.02	0.03	0.04	0.05
Turkey	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.00	0.13	0.57	0.34	0.23	0.13	0.14
United States	0.00	1.10	2.36	1.63	1.67	1.85	2.04
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Africa	0.00	0.01	0.02	0.02	0.02	0.03	0.03
China/CPA	0.00	0.01	3.97	2.66	1.37	0.08	0.11
Latin America	0.00	0.01	0.05	0.04	0.06	0.07	0.08
Middle East	0.00	0.00	0.02	0.02	0.02	0.02	0.03
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	0.00	0.00	0.00	0.00	0.01	0.01	0.01
OECD90 & EU	0.00	3.13	10.02	7.35	5.37	3.78	4.07
SE Asia	0.00	0.02	2.26	1.53	0.84	0.15	0.18
World Totals	0.00	3.19	16.35	11.62	7.70	4.14	4.51

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-7: HFC-23 Emissions from HCFC-22 Production (Technology-Adoption)

	MTCO$_2$eq						
Country	1990	1995	2000	2005	2010	2015	2020
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	1.28	1.61	0.14	0.17	0.20	0.24	0.21
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	3.58	5.27	33.26	64.43	27.01	57.12	47.79
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	5.92	4.35	0.18	0.14	0.09	0.05	0.05
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	2.64	4.79	0.20	0.15	0.10	0.05	0.06
Greece	0.54	0.89	1.78	1.33	0.00	0.00	0.00
Hungary	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	1.13	2.41	4.71	6.13	1.14	3.54	2.35
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	2.09	2.36	0.18	0.14	0.09	0.05	0.06
Japan	9.85	16.15	13.64	0.77	0.80	0.84	0.89
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	1.06	0.90	2.63	3.24	0.26	1.19	0.57
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	2.96	4.44	0.26	0.19	0.13	0.07	0.08
New Zealand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-7: HFC-23 Emissions from HCFC-22 Production (Technology-Adoption)

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	3.34	1.41	1.08	0.89	0.69	0.50	0.32
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.14	0.43	0.00	0.00	0.00	0.00	0.00
South Korea	1.22	2.35	3.67	4.60	4.36	5.81	4.92
Spain	2.07	2.84	2.37	1.78	0.06	0.03	0.04
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	3.49	6.39	1.53	0.68	0.13	0.07	0.08
United States	34.98	27.03	29.79	17.21	9.34	8.43	8.53
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.66	0.67	0.20	0.23	0.26	0.29	0.25
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Africa	0.14	0.43	0.00	0.00	0.00	0.00	0.00
China/CPA	3.58	5.27	33.26	64.43	27.01	57.12	47.79
Latin America	3.20	3.18	2.97	3.64	0.72	1.73	1.03
Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	3.34	1.41	1.08	0.89	0.69	0.50	0.32
OECD90 & EU	64.54	69.23	49.93	22.39	10.75	9.59	9.78
SE Asia	2.35	4.76	8.39	10.73	5.50	9.35	7.27
World Totals	77.16	84.27	95.62	102.07	44.67	78.29	66.19

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-7b : HFC-23 Emissions from HCFC-22 Production (No-Action)

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	1.28	1.61	0.14	0.17	0.20	0.24	0.21
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	3.58	5.27	33.26	64.43	70.20	100.31	90.98
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	5.92	4.35	0.18	0.14	0.09	0.05	0.05
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	2.64	4.79	0.20	0.15	0.10	0.05	0.06
Greece	0.54	0.89	1.78	1.33	0.00	0.00	0.00
Hungary	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	1.13	2.41	4.71	6.13	7.98	10.38	9.18
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	2.09	2.36	0.18	0.14	0.09	0.05	0.06
Japan	9.85	16.15	13.64	0.77	0.80	0.84	0.89
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	1.06	0.90	2.63	3.24	4.00	4.94	4.32
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	2.96	4.44	0.26	0.19	0.13	0.07	0.08
New Zealand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-7b : HFC-23 Emissions from HCFC-22 Production (No-Action)

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	3.34	1.41	1.08	0.89	0.69	0.50	0.32
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.14	0.43	0.00	0.00	0.00	0.00	0.00
South Korea	1.22	2.35	3.67	4.60	5.76	7.21	6.32
Spain	2.07	2.84	2.37	1.78	1.20	0.63	0.71
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	3.49	6.39	1.53	0.68	0.13	0.07	0.08
United States	34.98	27.03	29.79	34.85	26.32	23.75	24.04
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.66	0.67	0.20	0.23	0.26	0.29	0.25
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Africa	0.14	0.43	0.00	0.00	0.00	0.00	0.00
China/CPA	3.58	5.27	33.26	64.43	70.20	100.31	90.98
Latin America	3.20	3.18	2.97	3.64	4.46	5.48	4.78
Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	3.34	1.41	1.08	0.89	0.69	0.50	0.32
OECD90 & EU	64.54	69.23	49.93	40.03	28.87	25.51	25.97
SE Asia	2.35	4.76	8.39	10.73	13.73	17.58	15.50
World Totals	77.16	84.27	95.62	119.72	117.96	149.39	137.55

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-8: SF_6 Emissions from Electric Power Systems (Technology-Adoption)

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Algeria	0.03	0.03	0.03	0.10	0.11	0.14	0.16
Argentina	0.09	0.10	0.12	0.31	0.38	0.48	0.59
Armenia	0.02	0.01	0.01	0.02	0.02	0.02	0.02
Australia	0.27	0.25	0.26	0.71	0.71	0.71	0.71
Austria	0.08	0.06	0.05	0.04	0.03	0.03	0.02
Azerbaijan	0.04	0.02	0.02	0.07	0.07	0.07	0.07
Bangladesh	0.01	0.02	0.02	0.06	0.07	0.09	0.10
Belarus	0.08	0.05	0.04	0.11	0.11	0.11	0.11
Belgium	0.09	0.08	0.06	0.05	0.04	0.03	0.03
Bolivia	0.00	0.00	0.01	0.02	0.02	0.02	0.02
Brazil	0.45	0.46	0.52	1.37	1.63	1.99	2.42
Bulgaria	0.08	0.06	0.04	0.11	0.11	0.11	0.11
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.85	0.75	0.73	1.85	1.85	1.85	1.85
Chile	0.04	0.04	0.05	0.17	0.20	0.26	0.31
China	1.12	1.47	1.78	6.79	9.00	11.69	14.94
Colombia	0.07	0.06	0.06	0.16	0.20	0.25	0.30
Croatia	0.02	0.02	0.02	0.06	0.06	0.06	0.06
Czech Republic	0.03	0.03	0.04	0.05	0.04	0.03	0.03
Democratic Republic of Congo (Kinshasa)	0.01	0.01	0.01	0.02	0.02	0.02	0.03
Denmark	0.06	0.05	0.05	0.04	0.03	0.02	0.02
Ecuador	0.01	0.01	0.01	0.04	0.05	0.06	0.07
Egypt	0.08	0.08	0.10	0.29	0.35	0.41	0.47
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.05	0.04	0.03	0.03	0.02	0.02	0.01
France	0.53	0.44	0.37	0.30	0.24	0.19	0.17
Georgia	0.02	0.01	0.01	0.01	0.03	0.03	0.03
Germany	0.20	0.17	0.18	0.21	0.24	0.21	0.18
Greece	0.05	0.04	0.04	0.03	0.02	0.02	0.01
Hungary	0.03	0.03	0.04	0.04	0.03	0.03	0.03
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.50	0.60	0.71	2.00	2.42	2.92	3.46
Indonesia	0.08	0.09	0.12	0.39	0.47	0.55	0.63
Iran	0.10	0.12	0.15	0.49	0.58	0.68	0.79
Iraq	0.04	0.04	0.04	0.05	0.06	0.07	0.08
Ireland	0.05	0.04	0.03	0.03	0.02	0.02	0.01
Israel	0.03	0.04	0.05	0.15	0.18	0.21	0.24
Italy	0.44	0.37	0.31	0.25	0.20	0.16	0.14
Japan	1.43	1.43	0.52	0.30	0.30	0.30	0.30
Jordan	0.01	0.01	0.01	0.03	0.04	0.04	0.05
Kazakhstan	0.18	0.10	0.07	0.07	0.19	0.19	0.19
Kuwait	0.04	0.03	0.04	0.13	0.16	0.18	0.21
Kyrgyzstan	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Laos	0.00	0.00	0.00	0.01	0.02	0.02	0.02
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Luxembourg	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Macedonia	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Mexico	0.21	0.22	0.26	0.77	1.01	1.27	1.57
Moldova	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.01	0.00	0.00	0.01	0.01	0.02	0.02
Myanmar	0.00	0.01	0.01	0.03	0.03	0.04	0.04
Nepal	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Netherlands	0.16	0.13	0.11	0.09	0.07	0.05	0.05
New Zealand	0.06	0.05	0.05	0.13	0.13	0.13	0.13

Appendix D-8: SF_6 Emissions from Electric Power Systems (Technology-Adoption)

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Nigeria	0.02	0.02	0.02	0.06	0.07	0.08	0.09
North Korea	0.07	0.04	0.03	0.07	0.08	0.09	0.11
Norway	0.10	0.08	0.06	0.03	0.03	0.03	0.03
Pakistan	0.07	0.08	0.08	0.27	0.33	0.39	0.45
Peru	0.02	0.02	0.03	0.08	0.10	0.12	0.15
Philippines	0.04	0.05	0.06	0.17	0.21	0.24	0.28
Poland	0.09	0.09	0.11	0.13	0.11	0.09	0.08
Portugal	0.05	0.04	0.03	0.03	0.02	0.02	0.01
Romania	0.13	0.09	0.07	0.16	0.16	0.16	0.16
Russian Federation	1.87	1.19	1.09	2.88	2.88	2.88	2.88
Saudi Arabia	0.12	0.15	0.16	0.50	0.60	0.70	0.81
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.03	0.03	0.04	0.11	0.11	0.11	0.11
Slovak Republic	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Slovenia	0.01	0.01	0.01	0.01	0.01	0.01	0.01
South Africa	0.28	0.26	0.26	0.76	0.91	1.10	1.29
South Korea	0.18	0.28	0.33	1.18	1.39	1.59	1.77
Spain	0.24	0.20	0.17	0.14	0.11	0.09	0.08
Sweden	0.09	0.07	0.06	0.05	0.04	0.03	0.03
Switzerland	0.15	0.12	0.09	0.05	0.04	0.04	0.04
Tajikistan	0.03	0.02	0.02	0.05	0.05	0.05	0.05
Thailand	0.08	0.11	0.12	0.41	0.50	0.58	0.67
Turkey	0.10	0.12	0.16	0.44	0.44	0.44	0.44
Turkmenistan	0.02	0.01	0.01	0.03	0.03	0.03	0.03
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.46	0.27	0.21	0.54	0.54	0.54	0.54
United Arab Emirates	0.03	0.04	0.05	0.14	0.17	0.20	0.23
United Kingdom	0.58	0.48	0.41	0.33	0.26	0.21	0.18
United States	28.89	21.13	14.96	13.94	12.83	12.29	11.81
Uruguay	0.01	0.01	0.01	0.03	0.04	0.05	0.05
Uzbekistan	0.09	0.07	0.06	0.17	0.17	0.17	0.17
Venezuela	0.10	0.11	0.11	0.31	0.37	0.47	0.57
Viet Nam	0.02	0.02	0.03	0.14	0.17	0.20	0.23
Rest of Africa	0.12	0.11	0.11	0.31	0.37	0.45	0.52
Rest of Latin America	0.08	0.07	0.09	0.27	0.33	0.42	0.51
Rest of Middle East	0.05	0.06	0.08	0.25	0.30	0.35	0.41
Rest of Non-EU Eastern Europe	0.10	0.06	0.05	0.17	0.17	0.17	0.17
Rest of OECD90 & EU	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Rest of SE Asia	0.22	0.26	0.32	0.95	1.15	1.35	1.56
Africa	0.53	0.50	0.52	1.52	1.82	2.20	2.56
China/CPA	1.22	1.54	1.85	7.03	9.28	12.02	15.32
Latin America	1.08	1.12	1.27	3.52	4.33	5.39	6.57
Middle East	0.42	0.49	0.59	1.75	2.08	2.44	2.83
Non-EU Eastern Europe	0.13	0.09	0.09	0.26	0.26	0.26	0.26
Non-EU FSU	2.85	1.79	1.57	4.00	4.14	4.14	4.14
OECD90 & EU	34.92	26.51	19.10	19.64	18.18	17.36	16.72
SE Asia	1.22	1.52	1.81	5.59	6.69	7.87	9.08
World Totals	42.36	33.55	26.78	43.30	46.77	51.69	57.48

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-8b : SF_6 Emissions from Electric Power Systems (No-Action)

	$MtCO_2eq$						
Country	1990	1995	2000	2005	2010	2015	2020
Albania	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Algeria	0.03	0.03	0.03	0.10	0.11	0.14	0.16
Argentina	0.09	0.10	0.12	0.31	0.38	0.48	0.59
Armenia	0.02	0.01	0.01	0.02	0.02	0.02	0.02
Australia	0.27	0.25	0.26	0.71	0.71	0.71	0.71
Austria	0.08	0.06	0.05	0.05	0.05	0.05	0.05
Azerbaijan	0.04	0.02	0.02	0.07	0.07	0.07	0.07
Bangladesh	0.01	0.02	0.02	0.06	0.07	0.09	0.10
Belarus	0.08	0.05	0.04	0.11	0.11	0.11	0.11
Belgium	0.09	0.08	0.06	0.06	0.06	0.06	0.06
Bolivia	0.00	0.00	0.01	0.02	0.02	0.02	0.02
Brazil	0.45	0.46	0.52	1.37	1.63	1.99	2.42
Bulgaria	0.08	0.06	0.04	0.11	0.11	0.11	0.11
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.85	0.75	0.73	1.85	1.85	1.85	1.85
Chile	0.04	0.04	0.05	0.17	0.20	0.26	0.31
China	1.12	1.47	1.78	6.79	9.00	11.69	14.94
Colombia	0.07	0.06	0.06	0.16	0.20	0.25	0.30
Croatia	0.02	0.02	0.02	0.06	0.06	0.06	0.06
Czech Republic	0.03	0.03	0.04	0.04	0.05	0.05	0.05
Democratic Republic of Congo (Kinshasa)	0.01	0.01	0.01	0.02	0.02	0.02	0.03
Denmark	0.06	0.05	0.05	0.04	0.04	0.04	0.04
Ecuador	0.01	0.01	0.01	0.04	0.05	0.06	0.07
Egypt	0.08	0.08	0.10	0.29	0.35	0.41	0.47
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.05	0.04	0.03	0.03	0.03	0.03	0.03
France	0.53	0.44	0.37	0.33	0.33	0.33	0.33
Georgia	0.02	0.01	0.01	0.01	0.03	0.03	0.03
Germany	0.20	0.17	0.18	0.24	0.34	0.34	0.34
Greece	0.05	0.04	0.04	0.03	0.03	0.03	0.03
Hungary	0.03	0.03	0.04	0.04	0.05	0.05	0.05
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.50	0.60	0.71	2.00	2.42	2.92	3.46
Indonesia	0.08	0.09	0.12	0.39	0.47	0.55	0.63
Iran	0.10	0.12	0.15	0.49	0.58	0.68	0.79
Iraq	0.04	0.04	0.04	0.05	0.06	0.07	0.08
Ireland	0.05	0.04	0.03	0.03	0.03	0.03	0.03
Israel	0.03	0.04	0.05	0.15	0.18	0.21	0.24
Italy	0.44	0.37	0.31	0.27	0.28	0.28	0.28
Japan	1.43	1.43	0.52	0.33	0.42	0.42	0.42
Jordan	0.01	0.01	0.01	0.03	0.04	0.04	0.05
Kazakhstan	0.18	0.10	0.07	0.07	0.19	0.19	0.19
Kuwait	0.04	0.03	0.04	0.13	0.16	0.18	0.21
Kyrgyzstan	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Laos	0.00	0.00	0.00	0.01	0.02	0.02	0.02
Latvia	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Luxembourg	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Macedonia	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Mexico	0.21	0.22	0.26	0.77	1.01	1.27	1.57
Moldova	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.01	0.00	0.00	0.01	0.01	0.02	0.02
Myanmar	0.00	0.01	0.01	0.03	0.03	0.04	0.04
Nepal	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Netherlands	0.16	0.13	0.11	0.10	0.10	0.10	0.10
New Zealand	0.06	0.05	0.05	0.13	0.13	0.13	0.13

Appendix D-8b : SF_6 Emissions from Electric Power Systems (No-Action)

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Nigeria	0.02	0.02	0.02	0.06	0.07	0.08	0.09
North Korea	0.07	0.04	0.03	0.07	0.08	0.09	0.11
Norway	0.10	0.08	0.06	0.04	0.04	0.04	0.04
Pakistan	0.07	0.08	0.08	0.27	0.33	0.39	0.45
Peru	0.02	0.02	0.03	0.08	0.10	0.12	0.15
Philippines	0.04	0.05	0.06	0.17	0.21	0.24	0.28
Poland	0.09	0.09	0.11	0.13	0.15	0.15	0.15
Portugal	0.05	0.04	0.03	0.03	0.03	0.03	0.03
Romania	0.13	0.09	0.07	0.16	0.16	0.16	0.16
Russian Federation	1.87	1.19	1.09	2.88	2.88	2.88	2.88
Saudi Arabia	0.12	0.15	0.16	0.50	0.60	0.70	0.81
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.03	0.03	0.04	0.11	0.11	0.11	0.11
Slovak Republic	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Slovenia	0.01	0.01	0.01	0.01	0.02	0.02	0.02
South Africa	0.28	0.26	0.26	0.76	0.91	1.10	1.29
South Korea	0.18	0.28	0.33	1.18	1.39	1.59	1.77
Spain	0.24	0.20	0.17	0.15	0.15	0.15	0.15
Sweden	0.09	0.07	0.06	0.06	0.06	0.06	0.06
Switzerland	0.15	0.12	0.09	0.06	0.05	0.05	0.05
Tajikistan	0.03	0.02	0.02	0.05	0.05	0.05	0.05
Thailand	0.08	0.11	0.12	0.41	0.50	0.58	0.67
Turkey	0.10	0.12	0.16	0.44	0.44	0.44	0.44
Turkmenistan	0.02	0.01	0.01	0.03	0.03	0.03	0.03
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.46	0.27	0.21	0.54	0.54	0.54	0.54
United Arab Emirates	0.03	0.04	0.05	0.14	0.17	0.20	0.23
United Kingdom	0.58	0.48	0.41	0.36	0.36	0.36	0.36
United States	28.89	21.13	14.96	17.01	17.62	18.24	18.89
Uruguay	0.01	0.01	0.01	0.03	0.04	0.05	0.05
Uzbekistan	0.09	0.07	0.06	0.17	0.17	0.17	0.17
Venezuela	0.10	0.11	0.11	0.31	0.37	0.47	0.57
Viet Nam	0.02	0.02	0.03	0.14	0.17	0.20	0.23
Rest of Africa	0.12	0.11	0.11	0.31	0.37	0.45	0.52
Rest of Latin America	0.08	0.07	0.09	0.27	0.33	0.42	0.50
Rest of Middle East	0.05	0.06	0.08	0.25	0.30	0.35	0.41
Rest of Non-EU Eastern Europe	0.10	0.06	0.05	0.17	0.17	0.17	0.17
Rest of OECD90 & EU	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Rest of SE Asia	0.22	0.26	0.32	0.95	1.15	1.35	1.56
Africa	0.53	0.50	0.52	1.52	1.82	2.20	2.56
China/CPA	1.22	1.54	1.85	7.03	9.28	12.02	15.32
Latin America	1.08	1.12	1.27	3.52	4.33	5.39	6.57
Middle East	0.42	0.49	0.59	1.75	2.08	2.44	2.83
Non-EU Eastern Europe	0.13	0.09	0.09	0.26	0.26	0.26	0.26
Non-EU FSU	2.85	1.79	1.57	4.00	4.14	4.14	4.14
OECD90 & EU	34.92	26.51	19.10	22.91	23.73	24.35	25.00
SE Asia	1.22	1.52	1.81	5.59	6.69	7.87	9.08
World Totals	42.36	33.55	26.78	46.57	52.32	58.68	65.76

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-9: PFC Emissions from Primary Aluminum Production (Technology-Adoption)

Country	1990	1995	2000	2005	2010	2015	2020
	$MTCO_2eq$						
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.63	0.30	0.25	0.26	0.29	0.32	0.32
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	4.76	2.72	3.00	2.15	2.11	2.11	2.11
Austria	0.36	0.18	0.16	0.17	0.08	0.08	0.08
Azerbaijan	0.27	0.18	0.13	0.09	0.05	0.05	0.05
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	5.30	6.40	3.89	2.31	2.41	2.77	3.20
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	8.07	5.70	5.06	2.70	2.51	2.64	3.33
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	2.93	2.56	5.21	9.18	6.48	6.62	6.75
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.29	0.09	0.11	0.07	0.04	0.04	0.04
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.46	0.22	0.20	0.57	0.42	0.55	0.69
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	1.59	0.88	0.89	0.61	0.61	0.59	0.59
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	2.23	0.66	0.69	1.10	1.01	1.03	1.06
Greece	0.30	0.19	0.21	0.21	0.21	0.21	0.20
Hungary	0.13	0.06	0.06	0.06	0.03	0.03	0.03
Iceland	0.19	0.12	0.13	0.14	0.30	0.30	0.29
India	0.81	0.63	0.75	1.69	1.17	1.22	1.26
Indonesia	0.32	0.19	0.22	0.67	0.57	0.59	0.61
Iran	0.14	0.07	0.07	0.22	0.26	0.33	0.42
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	2.84	1.35	1.24	0.30	0.24	0.24	0.24
Japan	0.03	0.04	0.05	0.11	0.08	0.09	0.11
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.12	0.16	0.19
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.14	0.06	0.06	0.06	0.06	0.06	0.06
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	5.32	2.53	2.32	0.45	0.42	0.42	0.42
New Zealand	1.10	0.47	0.47	0.39	0.36	0.36	0.36
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-9: PFC Emissions from Primary Aluminum Production (Technology-Adoption)

	$MTCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	3.84	2.03	1.97	1.54	1.15	1.14	1.13
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.20	0.06	0.07	0.05	0.03	0.03	0.03
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Romania	3.48	1.12	1.33	0.19	0.18	0.18	0.18
Russian Federation	15.40	10.03	7.46	4.93	3.34	3.33	3.32
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.14	0.09	0.13	0.19	0.19	0.20	0.20
Slovenia	0.09	0.07	0.09	0.13	0.13	0.14	0.14
South Africa	0.89	0.72	3.24	1.81	1.77	2.14	2.51
South Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spain	4.45	2.13	1.95	0.64	0.44	0.45	0.45
Sweden	0.33	0.17	0.16	0.16	0.09	0.09	0.09
Switzerland	0.12	0.02	0.02	0.07	0.06	0.06	0.07
Tajikistan	4.25	2.70	1.96	0.62	0.62	0.63	0.64
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.23	0.11	0.10	0.11	0.05	0.05	0.05
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.43	0.29	0.22	0.25	0.20	0.20	0.21
United Arab Emirates	0.34	0.15	0.11	0.72	1.27	1.66	2.05
United Kingdom	0.64	0.41	0.44	0.45	0.44	0.43	0.42
United States	18.34	11.83	8.95	4.69	4.56	4.50	4.45
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	2.27	1.08	0.92	0.94	1.06	1.15	1.17
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	1.04	0.73	2.15	1.17	1.83	2.15	2.47
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.36	0.22	0.17	0.66	1.54	2.03	2.48
Rest of Non-EU Eastern Europe	2.99	0.95	1.14	0.24	0.19	0.19	0.19
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.00	0.06	0.06	0.06
Africa	2.38	1.67	5.59	3.55	4.02	4.84	5.67
China/CPA	2.93	2.56	5.21	9.18	6.48	6.62	6.75
Latin America	8.34	7.84	5.12	3.57	3.82	4.31	4.75
Middle East	0.83	0.44	0.35	1.60	3.18	4.18	5.15
Non-EU Eastern Europe	3.27	1.04	1.24	0.31	0.24	0.23	0.23
Non-EU FSU	20.35	13.20	9.77	5.90	4.21	4.21	4.22
OECD90 & EU	58.78	32.95	29.51	16.60	15.29	15.38	16.03
SE Asia	1.12	0.82	0.97	2.37	1.81	1.87	1.94
World Totals	98.01	60.51	57.78	43.07	39.06	41.64	44.73

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-9b : PFC Emissions from Primary Aluminum Production (No-Action)

	MtCO$_2$eq						
Country	1990	1995	2000	2005	2010	2015	2020
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.63	0.30	0.25	0.31	0.37	0.41	0.41
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	4.76	2.72	3.00	2.34	2.34	2.34	2.34
Austria	0.36	0.18	0.16	0.27	0.24	0.24	0.24
Azerbaijan	0.27	0.18	0.13	0.14	0.14	0.13	0.13
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	5.30	6.40	3.89	2.94	3.47	4.06	4.72
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	8.07	5.70	5.06	4.11	4.42	4.67	4.92
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	2.93	2.56	5.21	13.49	13.16	13.32	13.49
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.29	0.09	0.11	0.11	0.11	0.11	0.11
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.46	0.22	0.20	0.87	1.01	1.30	1.65
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	1.59	0.88	0.89	0.64	0.64	0.63	0.62
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	2.23	0.66	0.69	1.23	1.16	1.20	1.23
Greece	0.30	0.19	0.21	0.22	0.22	0.22	0.21
Hungary	0.13	0.06	0.06	0.10	0.09	0.09	0.09
Iceland	0.19	0.12	0.13	0.14	0.32	0.31	0.31
India	0.81	0.63	0.75	2.39	2.21	2.29	2.36
Indonesia	0.32	0.19	0.22	0.80	0.73	0.76	0.78
Iran	0.14	0.07	0.07	0.27	0.32	0.41	0.52
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Italy	2.84	1.35	1.24	0.38	0.37	0.37	0.37
Japan	0.03	0.04	0.05	0.16	0.15	0.18	0.20
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.12	0.16	0.20
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.14	0.06	0.06	0.06	0.06	0.06	0.06
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	5.32	2.53	2.32	0.53	0.53	0.53	0.53
New Zealand	1.10	0.47	0.47	0.46	0.46	0.46	0.46
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-9b : PFC Emissions from Primary Aluminum Production (No-Action)

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	3.84	2.03	1.97	2.01	1.89	1.89	1.89
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.20	0.06	0.07	0.08	0.08	0.08	0.07
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Romania	3.48	1.12	1.33	0.23	0.23	0.23	0.23
Russian Federation	15.40	10.03	7.46	7.45	7.40	7.35	7.30
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.14	0.09	0.13	0.20	0.20	0.21	0.21
Slovenia	0.09	0.07	0.09	0.14	0.14	0.14	0.15
South Africa	0.89	0.72	3.24	2.17	2.46	2.98	3.51
South Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spain	4.45	2.13	1.95	0.89	0.83	0.84	0.84
Sweden	0.33	0.17	0.16	0.24	0.22	0.22	0.22
Switzerland	0.12	0.02	0.02	0.09	0.08	0.08	0.09
Tajikistan	4.25	2.70	1.96	0.68	0.69	0.71	0.72
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.23	0.11	0.10	0.17	0.15	0.15	0.16
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.43	0.29	0.22	0.36	0.38	0.39	0.41
United Arab Emirates	0.34	0.15	0.11	0.80	1.41	1.84	2.28
United Kingdom	0.64	0.41	0.44	0.47	0.47	0.47	0.46
United States	18.34	11.83	8.95	14.67	14.67	14.67	14.67
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	2.27	1.08	0.92	1.12	1.35	1.47	1.49
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	1.04	0.73	2.15	1.61	2.54	3.00	3.46
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.36	0.22	0.17	0.69	1.60	2.11	2.58
Rest of Non-EU Eastern Europe	2.99	0.95	1.14	0.33	0.32	0.32	0.32
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.00	0.06	0.07	0.07
Africa	2.38	1.67	5.59	4.65	6.01	7.28	8.62
China/CPA	2.93	2.56	5.21	13.49	13.16	13.32	13.49
Latin America	8.34	7.84	5.12	4.43	5.25	6.00	6.69
Middle East	0.83	0.44	0.35	1.76	3.46	4.53	5.59
Non-EU Eastern Europe	3.27	1.04	1.24	0.44	0.43	0.43	0.42
Non-EU FSU	20.35	13.20	9.77	8.63	8.62	8.58	8.55
OECD90 & EU	58.78	32.95	29.51	29.76	29.90	30.21	30.51
SE Asia	1.12	0.82	0.97	3.19	3.01	3.11	3.20
World Totals	98.01	60.51	57.78	66.36	69.84	73.47	77.07

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-10: HFC, PFC, SF_6 Emissions from Semiconductor Manufacturing (Technology-Adoption)

	$MTCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Armenia	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Australia	0.01	0.02	0.03	0.03	0.04	0.03	0.03
Austria	0.04	0.06	0.07	0.06	0.04	0.04	0.04
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.04	0.06	0.00	0.00	0.00	0.00	0.00
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.14	0.22	0.32	0.13	0.19	0.16	0.13
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	0.25	0.38	0.76	3.10	10.68	8.90	7.12
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.01	0.02	0.18	0.61	0.86	0.72	0.57
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	0.13	0.21	0.37	0.28	0.19	0.19	0.19
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.30	0.46	0.54	0.54	0.38	0.38	0.38
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	0.01	0.02	0.02	0.02	0.03	0.02	0.02
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.21	0.33	0.23	0.44	0.61	0.51	0.41
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.03	0.05	0.09	0.14	0.09	0.09	0.09
Israel	0.19	0.29	0.58	1.00	1.39	1.16	0.93
Italy	0.08	0.12	0.23	0.18	0.13	0.13	0.13
Japan	2.66	4.10	7.37	4.57	3.69	3.69	3.69
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.04	0.06	0.06	0.00	0.00	0.00	0.00
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.04	0.06	0.13	0.09	0.06	0.06	0.06
New Zealand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-10: HFC, PFC, SF_6 Emissions from Semiconductor Manufacturing (Technology-Adoption)

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	0.19	0.30	0.78	1.03	1.45	1.20	0.96
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.34	0.53	0.61	1.59	3.52	2.93	2.34
Slovak Republic	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.03	0.05	0.10	0.10	0.14	0.11	0.09
South Korea	1.25	1.92	3.34	3.71	2.31	2.31	2.31
Spain	0.01	0.02	0.02	0.00	0.00	0.00	0.00
Sweden	0.02	0.03	0.01	0.01	0.01	0.01	0.01
Switzerland	0.02	0.03	0.04	0.03	0.02	0.02	0.02
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Arab Emirates	0.00	0.00	0.00	0.54	0.75	0.63	0.50
United Kingdom	0.19	0.29	0.40	0.37	0.26	0.26	0.26
United States	2.93	5.00	6.39	5.30	5.49	4.44	4.14
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.48	0.74	4.78	5.88	4.54	4.18	3.82
Africa	0.03	0.05	0.10	0.10	0.14	0.11	0.09
China/CPA	0.25	0.38	0.76	3.10	10.68	8.90	7.12
Latin America	0.08	0.12	0.06	0.00	0.00	0.00	0.00
Middle East	0.19	0.29	0.58	1.54	2.15	1.79	1.43
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	0.19	0.30	0.78	1.05	1.45	1.21	0.97
OECD90 & EU	6.65	10.73	16.21	12.39	11.50	10.26	9.78
SE Asia	2.28	3.51	8.96	11.62	10.98	9.94	8.89
World Totals	9.67	15.38	27.45	29.79	36.90	32.21	28.28

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-10b : HFC, PFC, SF_6 Emissions from Semiconductor Manufacturing (No-Action)

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Armenia	0.00	0.00	0.00	0.01	0.03	0.04	0.05
Australia	0.01	0.02	0.03	0.03	0.04	0.05	0.06
Austria	0.04	0.06	0.07	0.08	0.18	0.23	0.29
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.01	0.01	0.01	0.01	0.03	0.04	0.05
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.04	0.06	0.00	0.00	0.00	0.00	0.00
Bulgaria	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.14	0.22	0.32	0.13	0.19	0.24	0.30
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	0.25	0.38	0.76	3.10	10.68	19.98	37.47
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.01	0.02	0.18	0.61	0.86	1.09	1.37
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.01	0.01	0.01
France	0.13	0.21	0.37	0.39	0.88	1.11	1.41
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.30	0.46	0.54	0.76	1.69	2.15	2.72
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	0.01	0.02	0.02	0.02	0.03	0.03	0.04
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.21	0.33	0.23	0.44	0.61	0.78	0.98
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.03	0.05	0.09	0.19	0.43	0.54	0.69
Israel	0.19	0.29	0.58	1.00	1.39	1.76	2.22
Italy	0.08	0.12	0.23	0.26	0.57	0.73	0.92
Japan	2.66	4.10	7.37	6.46	10.99	12.98	15.34
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.01	0.01	0.01	0.01	0.02	0.02	0.03
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.04	0.06	0.06	0.00	0.00	0.00	0.00
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.04	0.06	0.13	0.13	0.29	0.36	0.46
New Zealand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-10b : HFC, PFC, SF_6 Emissions from Semiconductor Manufacturing (No-Action)

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	0.19	0.30	0.78	1.03	1.45	1.83	2.31
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.34	0.53	0.61	1.59	3.52	4.87	6.74
Slovak Republic	0.00	0.00	0.00	0.02	0.04	0.05	0.06
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.03	0.05	0.10	0.10	0.14	0.17	0.22
South Korea	1.25	1.92	3.34	7.18	13.42	18.76	26.21
Spain	0.01	0.02	0.02	0.00	0.00	0.00	0.00
Sweden	0.02	0.03	0.01	0.01	0.03	0.03	0.04
Switzerland	0.02	0.03	0.04	0.05	0.11	0.14	0.17
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Arab Emirates	0.00	0.00	0.00	0.54	0.75	0.95	1.20
United Kingdom	0.19	0.29	0.40	0.52	1.17	1.48	1.88
United States	2.93	5.00	6.39	12.64	28.21	35.44	46.11
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.48	0.74	4.78	11.18	21.45	41.10	82.48
Africa	0.03	0.05	0.10	0.10	0.14	0.17	0.22
China/CPA	0.25	0.38	0.76	3.10	10.68	19.98	37.47
Latin America	0.08	0.12	0.06	0.00	0.00	0.00	0.00
Middle East	0.19	0.29	0.58	1.54	2.15	2.71	3.43
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	0.19	0.30	0.78	1.05	1.48	1.87	2.36
OECD90 & EU	6.65	10.73	16.21	22.32	45.74	56.72	71.97
SE Asia	2.28	3.51	8.96	20.39	39.01	65.51	116.42
World Totals	9.67	15.38	27.45	48.49	99.19	146.96	231.86

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-11: SF_6 Emissions from Magnesium Manufacturing (Technology-Adoption)

	$MTCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.30	0.44	0.24	0.20	0.05	0.01	0.01
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.81	1.53	1.74	0.38	0.08	0.01	0.01
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	0.04	0.16	0.18	1.11	1.65	2.47	3.74
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	0.03	0.04	0.04	0.03	0.01	0.00	0.00
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.24	0.35	0.35	0.30	0.08	0.01	0.02
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.00	0.00	0.79	0.56	0.14	0.02	0.02
Italy	0.04	0.06	0.06	0.05	0.01	0.00	0.00
Japan	1.09	0.89	0.22	0.04	0.01	0.00	0.00
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.04	0.26	0.20	0.17	0.04	0.01	0.01
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Zealand	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-11: SF_6 Emissions from Magnesium Manufacturing (Technology-Adoption)

	MTCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	1.52	1.00	0.90	0.15	0.04	0.01	0.01
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.01	0.01	0.01	0.00	0.00	0.00
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	1.80	1.09	0.89	0.60	0.14	0.02	0.02
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spain	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.63	0.27	0.00	0.12	0.03	0.00	0.00
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.01	0.02	0.01	0.01	0.00	0.00	0.00
United States	5.37	5.57	3.18	2.82	1.24	0.84	0.99
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.05	0.02	0.00	0.00
Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China/CPA	0.04	0.16	0.18	1.11	1.65	2.47	3.74
Latin America	0.30	0.44	0.24	0.20	0.05	0.01	0.01
Middle East	0.00	0.00	0.79	0.56	0.14	0.02	0.02
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	2.47	1.63	1.09	0.89	0.20	0.03	0.03
OECD90 & EU	9.13	9.47	6.54	3.81	1.49	0.88	1.04
SE Asia	0.00	0.00	0.00	0.05	0.02	0.00	0.00
World Totals	11.95	11.69	8.83	6.63	3.55	3.41	4.84

Regional country groupings are defined in Table 1-4 and Appendix H.

Appendix D-11b : SF_6 Emissions from Magnesium Manufacturing (No-Action)

	$MtCO_2eq$						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Albania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Algeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argentina	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Armenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Azerbaijan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belarus	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolivia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.30	0.44	0.24	0.33	0.48	0.58	0.71
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambodia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	0.81	1.53	1.74	0.63	0.73	0.78	0.83
Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China	0.04	0.16	0.18	1.11	1.65	2.47	3.74
Colombia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Croatia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Democratic Republic of Congo (Kinshasa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecuador	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Egypt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethiopia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	0.03	0.04	0.04	0.06	0.09	0.10	0.13
Georgia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Germany	0.24	0.35	0.35	0.49	0.75	0.92	1.13
Greece	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hungary	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indonesia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iran	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iraq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Israel	0.00	0.00	0.79	0.93	1.24	1.45	1.70
Italy	0.04	0.06	0.06	0.08	0.13	0.16	0.19
Japan	1.09	0.89	0.22	0.07	0.11	0.14	0.18
Jordan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kazakhstan	0.04	0.26	0.20	0.28	0.34	0.37	0.41
Kuwait	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyrgyzstan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laos	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liechtenstein	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macedonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mexico	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moldova	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monaco	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Zealand	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D-11b : SF_6 Emissions from Magnesium Manufacturing (No-Action)

	MtCO$_2$eq						
Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Nigeria	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	1.52	1.00	0.90	0.25	0.37	0.46	0.56
Pakistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Peru	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.01	0.01	0.01	0.01	0.02	0.02
Romania	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Russian Federation	1.80	1.09	0.89	0.99	1.22	1.37	1.53
Saudi Arabia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Senegal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Singapore	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovak Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spain	0.01	0.01	0.01	0.02	0.03	0.03	0.04
Sweden	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tajikistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Turkmenistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uganda	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ukraine	0.63	0.27	0.00	0.20	0.23	0.25	0.28
United Arab Emirates	0.00	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.01	0.02	0.01	0.02	0.03	0.03	0.04
United States	5.37	5.57	3.18	3.46	4.57	5.36	6.35
Uruguay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uzbekistan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Venezuela	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viet Nam	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Latin America	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Middle East	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of OECD90 & EU	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest of SE Asia	0.00	0.00	0.00	0.09	0.13	0.17	0.22
Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
China/CPA	0.04	0.16	0.18	1.11	1.65	2.47	3.74
Latin America	0.30	0.44	0.24	0.33	0.48	0.58	0.71
Middle East	0.00	0.00	0.79	0.93	1.24	1.45	1.70
Non-EU Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-EU FSU	2.47	1.63	1.09	1.47	1.80	1.99	2.22
OECD90 & EU	9.13	9.47	6.54	5.09	6.80	8.00	9.49
SE Asia	0.00	0.00	0.00	0.09	0.13	0.17	0.22
World Totals	11.95	11.69	8.83	9.02	12.10	14.66	18.07

Regional country groupings are defined in Table 1-4 and Appendix H.

Countries	Data Sources: Historical	Data Sources: Projected	Methodology/Adjustments
Albania, Bangladesh, Cambodia, Chile, Congo (Kinshasa) DPRC, Ethiopia, Georgia, Iraq, Jordan, Kuwait, Laos, Macedonia, Moldova, Myanmar, Nepal, North Korea, Singapore, Turkey, Uganda, United Arab Emirates	Estimated using IPCC Tier 1	EIA 2002 Reference Case	Used IPCC Tier 1 Methodology to develop historical estimates. Used 1997 IPCC default emission factors. Obtained historic natural gas and oil production and consumption data from 1980 through 2000 (EIA 2002). Missing historical estimates extrapolated from changes in oil and natural gas production and consumption (EIA 2002). Obtained EIA 'reference case' projections of natural gas production and oil production and consumption for the periods 2000-2005, 2005-2010, 2010-2015 and 2015-2020 from EIA 2002. Assumed growth rate for natural gas consumption the same as natural gas production. Created projections by applying the average annual consumption or production growth rate to emissions attributed to consumption or production.
Algeria, Armenia, Bolivia, Brazil, China, Columbia, Dominican Republic, Ecuador, Egypt, Indonesia, India, Iran, Israel, Kyrgyzstan, Nigeria, Pakistan, Peru, Philippines, South Africa, Saudia Arabia, Senegal, Tajikistan, Thailand, Taiwan, Uruguay, Venezuela, Viet Nam	First National Communication	EIA 2002 Reference Case	Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 methodology described below.
Argentina	Addendum to First National Communication	EIA 2002 Reference Case	Used reported data for 1990. Missing historical estimates extrapolated from changes in oil and natural gas production and consumption (EIA 2002). Obtained EIA 'reference case' projections of natural gas production and oil production and consumption for the periods 2000-2005, 2005-2010, 2010-2015 and 2015-2020 from EIA 2002. Assumed growth rate for natural gas consumption the same as natural gas production. Created projections by applying the average annual consumption or production growth rate to emissions attributed to consumption or production.
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Iceland, Italy, Japan, Latvia, Lithuania, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Azerbaijan, Kazakhstan, Turkmenistan, Uzbekistan	First National Communication	Oil and Gas Journal	Used reported data for 1990. Missing historical and projected estimates obtained from the Oil and Gas Journal.
Liechtenstein	Third National Communication	Third National Communication	Historical and projected emissions from Third National Communication.
Luxembourg	First National Communication	Not Applicable.	Used reported data for 1990-2000. Projections kept constant at 2000 levels.
Mexico	Second National Communication	EIA 2002 Reference Case	Used reported emissions from National Communication from 1994 and 1996. Interpolated 1995. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 methodology described above.

	Data Sources		
Mongolia	ALGAS	EIA 2002 Reference Case	No oil/gas production or consumption.
Russia	Third National Communication	U.S. EPA	Used reported data for 1990-2000. Forecast emissions through 2010 using natural gas production. Growth rate for 2000-2010 used for 2010-2020.
South Korea	Second National Communication	EIA 2002 Reference Case	Used reported emissions from National Communication from 1990-2000. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 methodology described above.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	

Appendix E-2: Data Sources and Methodologies for Methane Emissions from Fugitives from Coal Mining Activities

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Albania	First National Communication	EIA 2002	Used reported 1995 emissions. Missing historical estimates extrapolated from changes in coal production using EIA 2002 data. Coal production was zero in 2000 and is expected to remain at zero.
Algeria, Armenia, Azerbaijan, Bangladesh, Bolivia, Cambodia, Chile, Democratic Republic of Congo (Kinshasa), Ecuador, Egypt, Ethiopia, Georgia, Iraq, Israel, Lao People's Democratic Republic, Macedonia, Moldova, Myanmar, Nepal, North Korea, Saudi Arabia, Senegal, Singapore, Turkey, Turkmenistan, Uganda, United Arab Emirates. Also estimated emissions for many smaller countries combined under "Rest Of" Africa, FSU, Latin America, Middle East, Non-EU Eastern Europe, OECD 90 & EU, and S&E Asia	IPCC Tier 1/ EIA 2000	IPCC Tier 1/ EIA 2002	Used IPCC Tier 1 methodology to develop historical and projected estimates. Calculated historical estimates by multiplying 1997 IPCC default emission factors for hard and soft coal by corresponding hard and soft coal production data. Obtained historic coal production data from 1980 through 2000 from EIA (2002). Extrapolated future coal production based on the change in production from 1995 to 2000. Projected emissions to 2020 using average emission factors based on high and low IPCC default values. (Note: If IEA (2002) and EIA indicated that a country did not produce coal, methane emissions were assumed to be zero.)
Argentina, Tajikistan	First National Communication	IPCC Tier 1/ EIA 2002	Used reported 1990 emissions. Missing historical estimates were extrapolated from changes in coal production using EIA 2002 data. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.
Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Iceland, Italy, Japan, Latvia, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Brazil, China, Indonesia, India, Iran, Malawi, Nigeria, Pakistan, Philippines, Taiwan, Venezuela, Viet Nam.	First National Communication	IPCC Tier 1	Used reported emissions from National Communication (1994 often used as proxy for 1995). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions were developed as described above.
Columbia	First National Communication/ EIA 2000	Estimated using IPCC Tier 1/ EIA 2000	Used reported 1990 and 1995 emissions. Missing historical estimate extrapolated from changes in coal production using EIA 2000 data. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions were developed as described above.
Kazakhstan	Tier 3/2 Inventory Project	Russian Trend	Used reported emissions for 1990 to 2000 from Tier 3/2 Inventory Project. Projections follow Russian trend.
Kyrgyzstan	First National Communication	IPCC Tier 1/ EIA 2002	Used reported 1990, 1995, and 2000 emissions. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.
Mexico	Country Studies Report	IPCC Tier 1/ EIA 2002	Used reported 1990 emissions. Missing historical estimates were extrapolated from changes in coal production using EIA 2002 data. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.
Mongolia	First National Communication	IPCC Tier 1/ EIA 2002	Used reported 1990 and 1995 emissions. Missing historical estimate extrapolated from changes in coal production using EIA 2002 data. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.
Peru, Swaziland	First National Communication	IPCC Tier 1/ EIA 2002	Used reported 1995 emissions. Missing historical estimates were extrapolated from changes in coal production using EIA 2002 data. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.

	Data Sources		
Russia	Third National Communication	Third National Communication/ EPA	Used reported emissions from 1990-2010. Projected to 2020 by scaling projected estimates from EPA internal report.
South Africa	Country Report on Coal Mining (PJD Lloyd)	Country Report on Coal Mining (PJD Lloyd)	Used reported emissions from 1990-2020.
South Korea	Second National Communication	IPCC Tier 1/ EIA 2002	Used reported emissions from 1990-2000. Developed projections by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below.
Thailand	National Communication/ ALGAS	IPCC Tier 1/ EIA 2002	Used reported 1990 and 1995 emissions. Missing historical estimate extrapolated from changes in coal production using EIA 2002 data. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	
Uruguay	First National Communication	IPCC Tier 1/ EIA 2002	Used reported 1990 and 1995 emissions. Coal production was zero in 2000 and is expected to remain at zero.
Uzbekistan	First National Communication	Russian Trend	Used reported 1990 and 1995 emissions. Missing historical estimates and projections filled in using trend from Russia's data.

Appendix E-3: Data Sources and Methodologies for Methane and Nitrous Oxide Emissions from Stationary and Mobile Combustion

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Albania, Algeria, Brazil, Congo (Kinshasa) DPRC, Iraq, Israel, Kuwait, Macedonia, Nepal, North Korea (DPRK), Peru, Saudi Arabia, Singapore, South Africa, Turkey, United Arab Emirates. Also estimated emissions for many smaller countries combined under "Rest Of" Africa, FSU, Latin America, Middle East, Non-EU Eastern Europe, OECD 90 & EU and S&E Asia.	IPCC Tier1/ IEA Energy Balances	IEA WEO 2000	Used IPCC Tier 1 methodology to develop historical estimates. Fuel consumption data from IEA Energy Balances are multiplied by IPCC nitrous oxide and methane uncontrolled emission factors for each fuel and sector. Projections are created by applying regional or country-specific annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Argentina	First National Communication	IEA WEO 2000	Used reported 1990, 1994, and 1997 emissions. Interpolated between values to estimate 1995 emissions. Applied the annual growth rates for fuel consumption by sector from IEA's Energy Balances to forecast emissions for 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Armenia, Cambodia, Dominican Republic, Ethiopia, Gambia, Indonesia, India, Iran, Kyrgyrzstan, Madagascar, Nigeria, Pakistan, Tajikistan, Taiwan, Viet Nam	First National Communication	IEA WEO 2000	Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions.
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Azerbaijan	First National Communication	IEA WEO 2000	Used reported 1990 and 1995 emissions; applied annual growth rates for fuel consumption by sector from IEA's Energy Balances to the given values to forecast emissions for 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Bangladesh	ALGAS	IEA WEO 2000	Used reported 1990 emissions. Applied the annual growth rates for fuel consumption by sector from IEA's Energy Balances to the given values to forecast emissions for 1995 and 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.

	Data Sources		
Bolivia, Jordan, Philippines, Senegal, Thailand	First National Communication	IEA WEO 2000	Used reported 1994 emissions; applied annual growth rates for fuel consumption by sector from IEA's Energy Balances to the given value to backcast to 1990 and forecast to 1995 and 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Chile	First National Communication	IEA WEO 2000	Used reported data for 1993 and 1994; applied annual growth rates for fuel consumption by sector from IEA's Energy Balances to the given value to backcast to 1990 and forecast to 1995 and 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
China	ALGAS (CH_4); IEA Energy Balances (N_2O)	IEA WEO 2000	For CH_4 used reported data for 1990. Applied the annual growth rates for fuel consumption by sector from IEA's Energy Balances to forecast emissions for 1995 and 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. For N2O, used fuel consumption data from IEA Energy Balances and IPCC Tier 1 methodology to estimate historical emissions. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Colombia	First National Communication	IEA WEO 2000	Used reported 1990 and 1994 emissions; applied annual growth rates for fuel consumption by sector from IEA's Energy Balances to the given values to forecast emissions for 1995 and 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Ecuador, Egypt, Uruguay	First National Communication	IEA WEO 2000	Used reported 1990 emissions. Applied the annual growth rates for fuel consumption by sector from IEA's Energy Balances to forecast emissions for 1995 and 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.

	Data Sources		
Georgia	First National Communication	IEA WEO 2000	Used reported 1990, 1995, and 1997 emissions; applied annual growth rates for fuel consumption by sector from IEA's Energy Balances to the given values to forecast emissions for 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Kazakhstan	First National Communication	IEA WEO 2000	Used reported 1990 emissions. Used regional fuel consumption growth rates by sector from IEA's WEO to forecast emissions for 1995 (IEA Energy Balance data not available for 1990). Applied the annual growth rates for fuel consumption by sector from IEA's Energy Balances to forecast emissions for 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Liechtenstein	2005 Common Reporting Format (CRF)	Third National Communication	Historical and projected Emissions from Third National Communication.
Luxembourg	Second National Communication	EPA	Projections kept constant at 2000 levels.
Mexico	First National Communication	IEA WEO 2000	Used reported 1994, 1996, and 1998 emissions. Interpolated to estimate 1995 emissions. Applied the annual growth rates for fuel consumption by sector from IEA's Energy Balances to the given values to backcast to 1990 and forecast to 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Moldova, Uzbekistan	IPCC Tier 1/ IEA Energy Balances	IEA WEO 2000	Used fuel consumption data from IEA Energy Balances and IPCC Tier 1 methodology to estimate historical emissions for 1995 and 1999. Estimated 1990 emissions by applying the country's share of FSU's total emissions in 1995 to FSU's emissions in 1990. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Mongolia	Not estimated.	Not estimated.	
Myanmar	ALGAS	IEA WEO 2000	Used reported 1990 emissions. Applied the annual growth rates for fuel consumption by sector from IEA's Energy Balances to forecast emissions for 1995 and 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.

	Data Sources		
Russia	Second National Communication / 2000 Inventory	EPA	
South Korea	Second National Communication	IEA WEO 2000	Used reported emissions from National Communication for 2000. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Turkmenistan	First National Communication	IEA WEO 2000	Used reported 1994 emissions; used regional fuel consumption growth rates by sector from IEA's WEO to backcast to 1990 and forecast to 1995 (IEA Energy Balance data not available for 1990). Applied annual growth rates for fuel consumption by sector from IEA's Energy Balances to the given value to forecast emissions for 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
Uganda, Venezuela	Country Study	IEA WEO 2000	Used reported 1990 emissions. Applied the regional fuel consumption growth rates by sector from IEA's WEO to forecast emissions for 1995 and 1999. Allocated 1999 emissions to primary fuel type using the proportion that these fuels were consumed in 1999 from IEA's Energy Balances. Applied regional annual growth rates for fuel consumption by sector and primary fuel type from IEA's WEO to project emissions. Used 1997-2010 growth rate to project to 2000, 2005, 2010; and used 2010-2020 growth rate to project to 2015 and 2020.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	

Appendix E-4: Data Sources and Methodologies for Methane and Nitrous Oxide Emissions from Biomass Combustion

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Albania, Algeria, Argentina, Azerbaijan, Brazil, Chile, Colombia, Congo (Kinshasa) DPRC, Georgia, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Macedonia, Mexico, Moldova, Nepal, North Korea, Peru, Philippines, Saudi Arabia, Senegal, Singapore, South Africa, Tajikistan, Turkey, Turkmenistan, United Arab Emirates, Uruguay, Uzbekistan, Venezuela. Also estimated emissions for many smaller countries combined under "Rest Of" Africa, FSU, Latin America, Middle East, Non-EU Eastern Europe, OECD90 & EU,and S&E Asia	IPCC Tier 1/ IEA Energy Statistics	IEA WEO 2000	Used IPCC Tier 1 methodology to develop historical estimates. Multiplied biomass fuel consumption by sector by default IPCC emission factors. Used IEA statistics for 1990-99 activity data (Section 7.3.4, IEA 2001b and 2001c). Created projections (2000-2020) by applying annual regional or country-specific growth rates from WEO 2000 (IEA 2001a).
Armenia, Ecuador, Egypt, Laos	First National Communication	IEA WEO 2000	Used reported 1990 emissions. Missing historical and projected estimates backcast/forecast from country-reported data by applying regional or country-specific annual growth rates (from WEO 2000) to the given estimates (IEA 2001a).
Bangladesh, Myanmar, Pakistan, South Korea, Thailand	ALGAS	IEA WEO 2000	Used reported 1990 emissions. Missing historical and projected estimates backcast/forecast from country-reported data by applying regional or country-specific annual growth rates (from WEO 2000) to the given estimates (IEA 2001a).
Bolivia, India, Madagascar, Nigeria, Iran, Viet Nam	First National Communication	IEA WEO 2000	Used reported data for 1994 (1994 used as proxy for 1995). Missing historical and projected estimates backcast/forecast from country-reported data by applying regional or country-specific annual growth rates (from WEO 2000) to the given estimates (IEA 2001a).
Cambodia	First National Communication	First National Communication	Used reported 1995 emissions. Backcast 1990. Used reported data for 2000, 2010, 2020. Interpolated 2005 and 2015.
China	First National Communication (CH_4); Estimated using IPCC Tier 1 (N_2O)	IEA WEO 2000	For methane, used reported data for 1994. Assumed 1995 emissions = 1994 emissions. Created projections by applying annual PRC growth rates (from WEO 2000) to the given estimates. For N_2O, used IPCC Tier 1 methodology to develop historical estimates. Multiplied biomass fuel consumption by sector by default IPCC emission factors. Used IEA statistics for 1990-99 activity data (IEA 2001b). Created projections by applying annual PRC growth rates from WEO 2000 (IEA 2001a).
Dominican Republic, Ethiopia, Malawi, Mongolia	First National Communication	IEA WEO 2000	Used reported data for 1990 and 1995. Missing historical and projected estimates backcast/forecast from country-reported data by applying regional or country-specific annual growth rates (from WEO 2000) to the given estimates (IEA 2001a).
Indonesia	First National Communication	IEA WEO 2000	Used reported emissions from 1990-2000. Created projections by applying regional annual growth rates (from WEO 2000) to the given estimates (IEA 2001a).
Uganda	Country Study	IEA WEO 2000	Used reported 1990 emissions. Missing historical and projected estimates backcast/forecast from country-reported data by applying regional or country-specific annual growth rates (from WEO 2000) to the given estimates (IEA 2001a).

Appendix E-5: Data Sources and Methodologies for Nitrous Oxide Emissions from Adipic Acid and Nitric Acid Production

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Algeria, Chile	First National Communication	Kept constant.	Used reported emissions for 1995. Missing historical years and projections kept constant at 1995 levels.
Albania, Columbia, India, Iran, Peru	First National Communication	IPCC Tier 1	Used reported emissions for 1995 (1994 often used as proxy for 1995). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions.
Argentina, Georgia	First National Communication	Kept constant.	Used reported emissions for 1990 and 1995. Projections kept constant at 1995 levels.
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	See Methodology Section 7.2.5.	Used reported data from1990-2000.
Brazil, Indonesia, South Africa	First National Communication	IPCC Tier 1	Used reported emissions for 1990 and 1994 (1994 used as proxy for 1995). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions.
Singapore	IPCC Tier 1	IPCC Tier 1	See Methodology Section 7.2.5.
Mexico	Second National Communication	IPCC Tier 1	Used reported emissions from 1994 and 1996. Interpolated 1995. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions.
Russia	Third National Communication	Kept constant.	Used reported emissions from 1990 to 2000. Projections held constant at 2000 levels.
South Korea	Second National Communication	IPCC Tier 1	Used reported emissions for 2001 (2001 used as proxy for 2000). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	
Uzbekistan	First National Communication	Kept constant.	Used reported emissions for 1990. Missing historical years and projections kept constant at 1990 levels.
Venezuela	First National Communication	IPCC Tier 1	Used reported emissions for 2000. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions.

Appendix E-6: Data Sources and Methodologies for Nitrous Oxide Emissions from Agricultural Soils

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Algeria, Brazil, Cambodia, Democratic Republic of the Congo (Kinshasa), Indonesia, India, Iran, Nepal, Pakistan, South Africa, Saudia Arabia, Thailand, Taiwan, Uruguay, Venezuela, Viet Nam	First National Communication	FAO	Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below.
Argentina, Uzbekistan	First National Communication	FAO	Used Tier 1 methodology. Projected activity data based on FAO fertilizer consumption 1995/1997 to 2015 growth rate, historical crop production growth rates, and 1990 to 2020 methane from manure growth rates. Calculated growth rates based on Tier 1 results for 1995 to 2020 and applied these growth rates to reported 1990 and 1995 (proxy year) values.
Armenia, Azerbaijan, Ecuador, Egypt	First National Communication	FAO	Used reported 1990 emissions, extrapolated to 2000 based on country-specific fertilizer consumption growth rate, and extrapolated to 2020 based on FAO 1995/1997 to 2015 regional fertilizer consumption growth rate.
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom.	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Bangladesh, China, Iraq, Kazakhstan, Liechtenstein, Luxembourg, Moldova, Mongolia, Nigeria, North Korea (DPRK), Senegal, Turkey, Uganda	IPCC Tier 1/ FAO	FAO	Used Tier 1 methodology for historical and projected estimates. Projected activity data based on FAO fertilizer consumption 1995/1997 to 2015 growth rate, historical crop production growth rates, and 1990 to 2020 methane from manure growth rates.
Bolivia, Chile, Ethiopia, Israel, Jordan, Peru, Turkmenistan	First National Communication	FAO	Used reported 1995 (or proxy year) value and applied country-specific fertilizer consumption growth rate to estimate 1990 and 2000, then extrapolated to 2020 based on FAO 1995/1997 to 2015 regional fertilizer consumption growth rate.
Colombia	First National Communication	FAO	Used reported 1990 and 1995 (proxy year) emissions, applied country-specific fertilizer consumption growth rate until 2000, and then extrapolated to 2020 based on FAO 1995/1997 to 2015 regional fertilizer consumption growth rate.
Georgia	First National Communication	FAO	Used reported 1990 and 1995 emissions, applied country-specific fertilizer consumption growth rate until 2000, and extrapolated to 2020 based on FAO 1995/1997 to 2015 regional fertilizer consumption growth rate.
Mexico	Second National Communication	FAO	Used reported 1994 and 1996 emissions. Interpolated 1995. Applied country-specific fertilizer consumption growth rate to estimate 1990 and 2000; extrapolated to 2020 based on FAO 1995/1997 to 2015 regional fertilizer consumption growth rate.
Myanmar	ALGAS	ALGAS	Used ALGAS estimates for 1990, 2000, 2010, and 2020, and interpolated 2005 and 2015.
Philippines	ALGAS & First National Communication	FAO	Used reported 1990 and 1995 (proxy year) emissions, applied country-specific fertilizer consumption growth rate until 2000, and then extrapolated to 2020 based on FAO 1995/1997 to 2015 regional fertilizer consumption growth rate.
Russia	Third National Communication	Second National Communication	Used reported emissions from 1990-2000. Projected to 2020 by scaling projected estimates extracted from Second National Communication to Third National Communication historical data.
Singapore	First National Communication	First National Communication	Used reported estimates and projections for 1990 to 2020.
South Korea	Second National Communication	FAO	Used reported emissions from 1990-2000. Extrapolated to 2020 based on FAO 1995/1997 to 2015 regional fertilizer consumption growth rate.

Appendix E-6: Data Sources and Methodologies for Nitrous Oxide Emissions from Agricultural Soils

	Data Sources		
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	

Appendix E-7: Data Sources and Methodologies for Methane Emissions from Enteric Fermentation

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Albania, Algeria, Bolivia, China, Democratic Republic of the Congo (Kinshasa), Gambia, India, Nigeria, Pakistan, Viet Nam	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1994 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below.
Argentina	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1990, 1994, and 1997. Interpolated for 1995 emissions using 1994 and 1997 reported estimates. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions and 1997 reported emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Armenia, Kyrgyrzstan	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions from National Communication from 1990-2000. Developed projections by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below.
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Azerbaijan	First National Communication	First National Communication	Used reported 1990 emissions. Determined the percent contribution of enteric fermentation to total agriculture CH_4 emissions in 1990 and applied this to total agriculture CH_4 estimates for 1995, 2000, 2005, 2010, 2015, and 2020 to project emissions.
Bangladesh	ALGAS	ALGAS	Used reported emissions for 1990. Determined the percent contribution of enteric fermentation to total livestock CH_4 emissions in 1990 and applied this to total agriculture CH_4 estimates for 2000, 2010, and 2020 to estimate emissions. Interpolated for 1995, 2005, 2015.
Brazil, Dominican Republic, Malawi, South Africa	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1990 and 1994 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions were developed as described below.
Cambodia	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1994 and 2000 emissions. Developed projections by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below.
Chile	First National Communication	IPCC Tier 1/ IFPRI	Determined the percent contribution of enteric fermentation to total agriculture CH_4 emissions in 1995 using Tier 1 methodology, and applied this to reported emissions from livestock in 1993 and 1994. Backcast 1990 and forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Colombia, Uzbekistan	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1990 and 1994. Forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Ecuador, Egypt, Laos, Saudi Arabia, Uruguay	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1990 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.

	Data Sources		
Ethiopia	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1990 and 1995 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below.
Georgia	First National Communication	National Communication and IFPRI	Applied the 1990 percent contribution of enteric fermentation to CH_4 emissions to emissions from livestock for 1990, 1995, 2000, 2005, and 2010 to estimate 1990, 1995, 2000, 2005, and 2010 methane emissions from enteric fermentation. Ranges of emissions were reported for 2000, 2005, and 2010 estimates; the midpoint of the range was applied. Projected from 2010 to 2015-2020 based on IFPRI growth rates.
Indonesia	National Communication and ALGAS	IPCC Tier 1/ IFPRI	Used National Communications reported total emissions of livestock for 1994 and applied the percent contribution by enteric fermentation from ALGAS. Backcast 1990 and forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Iran	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions from National Communication from 1994 and 2000. Developed projections by applying growth rates from the Tier 1 estimated emissions.
Iraq, North Korea, Singapore, Turkey	IPCC Tier1/ FAO	IPCC Tier 1/ IFPRI	Used IPCC Tier 1 methodology to develop historical estimates. Estimated emissions by multiplying IPCC default emission factors for each animal type (non-dairy and dairy cattle, swine, sheep, etc.) by livestock populations, and summing livestock-specific emissions. FAO provided historical livestock data. Developed projections by applying livestock population growth rates provided by IFPRI[1] to historical estimates.
Israel	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1996 emissions. Backcast to 1995 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Then backcast 1990 emissions based on 1990-1995 annual growth rate of emissions. Forecast 2000 emissions from 1996 reported estimate based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Jordan	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1994. Backcast 1990 and forecasted 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecasted 2000 emissions based on 1995-2000 Tier 1 growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Kazakhstan	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1990 and 1994. Forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Mexico	Second National Communication	IPCC Tier 1/ IFPRI	Used reported emissions from National Communication from 1994 and 1996. Interpolated 1995. Developed projections by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below.
Moldova	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1990, 1995, and 1998. Forecasted to 2000 using 1998 reported data and 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.

	Data Sources		
Mongolia	ALGAS	ALGAS	Applied 1990 contribution of enteric fermentation to total livestock CH_4 emissions in ALGAS to total reported methane from livestock in 1995, 2000, 2010, and 2020. Interpolated to find 2005 and 2015 emissions. (Although the NC is more recent, ALGAS reports the same historical data, and additionally projects emissions to 2020.)
Myanmar	ALGAS	ALGAS	Used reported emissions for 1990, 2000, 2010, and 2020. Interpolated for 1995, 2005, 2015.
Nepal, Sudan	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1995 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions.
Peru, Turkmenistan	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1994 emissions. Backcast 1990 and forecasted 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Philippines	First National Communications and ALGAS	ALGAS	Used 1994 NC reported estimate of domestic livestock methane emissions to adjust the available reported projections in ALGAS. Applied the ALGAS reported percent contribution of enteric fermentation to total livestock CH_4 emissions to the ALGAS reported livestock emission totals for 1990, 1995, 2000, 2005, 2010, 2015, and 2020.
Russia	Third National Communication		Used reported 1990, 1995, and 2000 emissions.
Senegal	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1991. Backcast 1990 and forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
South Korea	Second National Communication	IPCC Tier 1/ IFPRI	Used reported emissions from 1990-2000. Developed projections by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions were developed as described below.
Thailand	First National Communication	First National Communication	Used reported 1994, 2000, 2005, 2010, 2015, and 2020 estimates. Dairy cattle not included in estimates; therefore, projected the dairy cattle estimates at the same rate as reported cattle estimates (2000-2020) using 1994 reported dairy cattle methane estimate. Interpolated 1995 using 1994 and 2000 data. Used 1990-1995 Tier 1 annual growth rate of emissions to backcast to 1990 emissions.
Uganda	Country Study Report	IPCC Tier 1/ IFPRI	Used reported emissions for 1990. Forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	
Venezuela	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions from National Communication for 2000. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.

[1] IFPRI. 2004. International Food Policy Research Institute (IFPRI) provided herd size growth rates to EPA to project FAO herd size data.

Appendix E-8: Data Sources and Methodologies for Methane Emissions from Rice Cultivation

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Afghanistan, Algeria, Angola, Belize, Benin, Bhutan, Brunei Darussalam, Cameroon, Central African Republic, Comoros, Fiji, Gabon, Guinea-Bissau, Iraq, Jamaica, Kenya, Liberia, Mozambique, North Korea, Papua New Guinea, Paraguay, Reunion, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Suriname, Swaziland, Syrian Arab Republic, Trinidad and Tobago, Turkey, United Republic of Tanzania, Zambia, Zimbabwe	IPCC Tier 1/ FAO	IPCC Tier 1/ UN POP	Used IPCC Tier 1 methodology to develop historical and projected estimates. Tier 1 Emissions were estimated using FAO data on total area harvested for rice cultivation and IPCC emission factors based on water management regime. Breakdown of area harvested by water management regime obtained from IPCC or IRRI. Created projections by applying growth rates derived from UN population data to historical data.
Albania	First National Communication	First National Communication	National Communication states "Rice cultivation and production after 1990 practically stopped and therefore there are no reported statistical data of cultivation for this crop."
Argentina	Revision to the First National Communication	IPCC Tier 1/ UN POP	Used reported 1990 and 1995 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Iceland, Italy, Japan, Latvia, Netherlands, New Zealand, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Azerbaijan, Colombia, Cuba, Dominican Republic, Ghana, Indonesia, Kazakhstan, Malawi, Niger, Uzbekistan	First National Communication	IPCC Tier 1/ UN POP	Used reported 1990 and 1995 emissions (1994 often used as proxy for 1995). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Bangladesh, Myanmar	ALGAS	IPCC Tier 1/ UN POP	Used reported emissions from ALGAS Report for 1990. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Bolivia, Burkina Faso, Cambodia, Chile, Costa Rica, Côte d'Ivoire, Democratic Republic of Congo (Kinshasa), El Salvador, Gambia, Guinea, Guyana, Haiti, Honduras, India, Madagascar, Malaysia, Mali, Mauritania, Morocco, Nepal, Nicaragua, Nigeria, Pakistan, Panama, Peru, Republic of the Congo (Brazzaville), Sri Lanka, Togo, Turkmenistan, Viet Nam	First National Communication	IPCC Tier 1/ UN POP	Used reported 1995 emissions (1993 or 1994 often used as proxy for 1995). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Brazil	Inventory	IPCC Tier 1/ UN POP	Used reported emissions from Inventory from 1990 to 1995 (http://www.mct.gov.br/clima/ingles/comunic_old/in). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Burundi, Venezuela	First National Communication	IPCC Tier 1/ UN POP	Used reported 2000 emissions. Missing historical estimates and projections extrapolated from country-reported data, based on observed growth rates from the Tier 1 estimated emissions. Tier 1 emissions were developed as described above.
Chad, Egypt, Guatemala, Laos, Uruguay	First National Communication	IPCC Tier 1/ UN POP	Used reported 1990 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.

Appendix E-8: Data Sources and Methodologies for Methane Emissions from Rice Cultivation

	Data Sources		
China, Philippines	Nutrient Cycling in Agroecosystems Vol. 64, Nos. 1-2, 2002 pp ix - xv	IPCC Tier 1/ UN POP	Used reported 1990 emissions from Journal. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Ecuador, Uganda	Country Study	Country Study/ IPCC Tier 1	Used reported emissions from Country Study for 1990. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Iran, Thailand	First National Communication	IPCC Tier 1/ UN POP	Used reported 1995 and 2000 emissions (1994 used as proxy for 1995). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Kyrgyzstan, Tajikistan, Macedonia, Taiwan	First National Communication	IPCC Tier 1/ UN POP	Used reported 1990 and 2000 emissions. Projections extrapolated from country-reported data, based on observed growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Mexico	Second National Communication	IPCC Tier 1/ UN POP	Used reported 1994 and 1996 emissions. Interpolated 1995 emissions. Projections extrapolated from country-reported data, based on observed growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Russia	Third National Communication	UN POP	Used reported 1990, 1995, and 2000 emissions. Projections extrapolated from country-reported data, based on observed population growth rates.
South Korea	Second National Communication	IPCC Tier 1/ UN POP	Used reported 1990, 1995, and 2000 emissions. Projections extrapolated from country-reported data, based on observed growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	

Appendix E-9: Data Sources and Methodologies for Methane Emissions from Manure Management

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Albania, Algeria, China, Democratic Republic of the Congo (Kinshasa), India, Malawi, Nigeria, Pakistan	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1994 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below (under Ecuador).
Argentina	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1990, 1994, and 1997. Interpolated for 1995 emissions using 1994 and 1997 reported estimates. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions and 1997 reported emissions. Projected emissions from 2005-2020 by applying livestock population growth rates provided by IFPRI[1] to historical estimates.
Armenia, Kyrgyrzstan	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions from National Communication from 1990-2000. Developed projections by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below (under Ecuador).
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithaunia, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Azerbaijan	First National Communication	First National Communication	Used reported 1990 emissions. Determined the percent contribution of manure management to total agriculture emissions in 1990 and applied this to total agriculture estimates for 1995, 2000, 2005, 2010, 2015, and 2020 to project emissions.
Bangladesh	ALGAS	ALGAS	Used reported emissions for 1990. Determined the percent contribution of manure management to total livestock emissions in 1990 and applied this to total agriculture estimates for 2000, 2010, and 2020 to estimate emissions. Interpolated for 1995, 2005, 2015.
Bolivia	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1994. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below (under Ecuador).
Brazil, Dominican Republic, South Africa, Sudan, Viet Nam	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1990 and 1994 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below (under Ecuador).
Cambodia, Iran	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1994 and 2000 emissions. Interpolated 1995. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions were developed as described below (under Ecuador).
Chile	First National Communication	IPCC Tier 1/ IFPRI	Determined the percent contribution of manure management to total agriculture emissions in 1995 using Tier 1 methodology, and applied this to reported emissions from livestock in 1993 and 1994. Backcast 1990 and forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.

	Data Sources		
Colombia, Uzbekistan	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1990 and 1994 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below (under Ecuador).
Ecuador, Iraq, North Korea, Senegal, Singapore, Uruguay	IPCC Tier 1/ FAO	IPCC Tier 1/ IFPRI	Used IPCC Tier 1 methodology to develop historical estimates. Estimated emissions by multiplying IPCC default emission factors for each animal type (non-dairy and dairy cattle, swine, sheep, etc.) by livestock populations, and summing livestock-specific emissions. FAO provided historical livestock data. Developed projections by applying livestock population growth rates provided by IFPRI[1] to historical estimates.
Egypt	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1990 emissions. Forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates
Ethiopia	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions from National Communication from 1990 and 1995. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above (under Ecuador).
Georgia	First National Communication	National Communication and IFPRI	Applied the 1990 percent contribution of manure to total livestock emissions to emissions from livestock for 1990, 1995, 2000, 2005, and 2010 to estimate 1990, 1995, 2000, 2005, and 2010 methane emissions from manure management. Ranges of emissions were reported for 2000, 2005, and 2010 estimates; the midpoint of the range was applied. Projected from 2010 to 2015-2020 based on IFPRI growth rates.
Indonesia	First National Communication and ALGAS	IPCC Tier 1/ IFPRI	Used National Communication reported total emissions of livestock for 1994 and applied the percent contribution by manure from ALGAS. Backcast 1990 and forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Israel	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1996 emissions. Backcast to 1995 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Backcast 1990 emissions based on 1990-1995 annual growth rate of emissions. forecast 2000 emissions from 1996 reported estimate based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Jordan	First National Communication	IPCC Tier 1/ IFPRI	Used reported emissions for 1994. Backcast 1990 and forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Kazakhstan	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1990 and 1995 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above (under Ecuador).

	Data Sources		
Laos, Saudi Arabia	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1990 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above (under Ecuador).
Mexico	Second National Communication		Used reported 1994 and 1996 emissions . Interpolated 1995. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions were developed as described above (under Ecuador).
Moldova	First National Communication	IFPRI	Used reported emissions for 1990, 1995, and 1998. Forecast to 2000 using 1998 reported data and 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates.
Mongolia	ALGAS	ALGAS	Applied 1990 manure/enteric fermentation ratio in ALGAS to total reported methane from livestock in 1995, 2000, 2010, and 2020. Interpolated to find 2005 and 2015 emissions. (Although the NC is more recent, ALGAS reports the same historical data, and additionally projects emissions to 2020.)
Myanmar	ALGAS	ALGAS	Used reported emissions for 1990, 2000, 2010, and 2020. Interpolated for 1995, 2005, 2015.
Nepal, Sudan	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1995 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions were developed as described below (under Ecuador).
Peru, Turkmenistan	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1994 emissions. Backcast 1990 and forecast 1995 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on IFPRI growth rates
Philippines	First National Communication and ALGAS	ALGAS	Used 1994 NC reported estimate of domestic livestock methane emissions to adjust the available reported projections in ALGAS. Applied the ALGAS reported percent contribution of manure management to total livestock CH_4 emissions to the ALGAS reported livestock emission totals for 1990, 1995, 2000, 2005, 2010, 2015, and 2020.
Russia	Third National Communication		Used reported 1990, 1995, and 2000 emissions.
South Korea	Second National Communication		Used reported 2001 emissions from National Communication (2001 used as proxy for 2000). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions were developed as described above (under Ecuador).
Thailand	First National Communication	First National Communication	Used reported 1994, 2000, 2005, 2010, 2015, and 2020 estimates. Dairy cattle not included in estimates; therefore, projected the dairy cattle estimates at the same rate as reported cattle estimates (2000-2020) using 1994 reported dairy cattle methane estimate. Interpolated 1995 using 1994 and 2000 data. Used 1990-1995 Tier 1 annual growth rate of emissions to backcast to 1990 emissions.
Turkey	IPCC Tier 1/ FAO	IPCC Tier 1/ IFPRI	Used FAO data and Tier 1 methodology for 1990, 1995, 2000 emissions and Projected from 2000 to 2005-2020 based on growth rate for CH_4 emissions.

	Data Sources		
Uganda	Country Study Report	IPCC Tier 1/ IFPRI	Used reported 1990 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above (under Ecuador).
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	
Venezuela	First National Communication	IPCC Tier 1/ IFPRI	Used reported 1996 emissions. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above (under Ecuador).

[1] IFPRI. 2004. International Food Policy Research Institute (IFPRI) provided herd size growth rates to EPA to project FAO herd size data.

Appendix E-9b: Data Sources and Methodologies for Nitrous Oxide Emissions from Manure Management

Countries	Data Sources: Historical	Data Sources: Projected	Methodology/Adjustments
Albania, Algeria, Cambodia, Democratic Republic of the Congo (Kinshasa), India, Malawi, Nepal, Peru, Viet Nam	First National Communication	IPCC Tier 1/ CH_4 rate	Used reported emissions for 1995 (1994 often used as proxy for 1995). Missing historical emissions and projections backcast/forecast from country-reported data based on growth rates for CH_4 emissions.
Argentina	Revision to the First National Communication/ IPCC Tier 1	IPCC Tier / CH_4 rate	Used reported emissions for 1990, 1994, and 1997. Interpolated 1995 emissions. Forecast 2000-2020 emissions based on growth rate for CH_4 emissions.
Armenia, Azerbaijan, Bangladesh, Bolivia, Chile, China, Colombia, Ecuador, Egypt, Ethiopia, Georgia, Indonesia, Iran, Iraq, Jordan, Kazakhstan, Kuwait, Laos, Macedonia, Moldova, Mongolia, Myanmar, Nigeria, North Korea, Philippines, Russia, Saudi Arabia, Senegal, Singapore, Tajikistan, Turkey, Turkmenistan, Uganda, United Arab Emirates, Uruguay	IPCC Tier 1/ FAO	IPCC Tier 1/ CH_4 rate	Used IPCC Tier 1 methodology to develop historical estimates. Estimated 1990, 1995, and 2000 emissions by multiplying IPCC default emission factors for each manure management system by population for each animal type (non-dairy and dairy cattle, swine, sheep, poultry and others) and summed emissions for each system. FAO provided historical livestock data. Projected from 2000 to 2005-2020 based on growth rate for CH_4 emissions.
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Brazil, South Africa	First National Communication	IPCC Tier 1/ CH_4 rate	Used reported emissions for 1990 and 1995 (1994 used as proxy for 1995). Missing historical emissions and projections backcast/forecast from country-reported data based on growth rates for CH_4 emissions.
Israel	National Communication	IPCC Tier 1/ CH_4 rate	Used reported 1996 emissions. Backcast 1990 emissions based on 1990-1995 Tier 1 annual growth rate of emissions. Backcast to 1995 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Forecast 2000 emissions based on 1995-2000 Tier 1 annual growth rate of emissions. Projected from 2000 to 2005-2020 based on growth rate for Tier 1 estimated CH_4 emissions.
Kyrgyrzstan	First National Communication	IPCC Tier 1	Used reported emissions for 1990-2000. Projections extrapolated from country-reported data, based on calculated growth rates from the Tier 1 estimated emissions.
Liechtenstein	2005 Common Reporting Format (CRF)	N/A	No reported data.
Mexico	Second National Communication	IPCC Tier 1/ CH_4 rate	Country reported emissions for 1994 and 1996. Interpolated 1995 emissions. Missing historical emissions and projections backcast/forecast from country-reported data based on growth rates for CH_4 emissions.
Pakistan	ALGAS	ALGAS	Used 1990-2020 animal population data and projections from ALGAS and Tier 1 methodology to estimate emissions for 1990-2020.
South Korea	Second National Communication	IPCC Tier 1/ CH_4 rate	Used reported emissions for 2000. Missing historical emissions and projections backcast/forecast from country-reported data based on growth rates for Tier 1 estimated CH_4 emissions.

	Data Sources		
Thailand	First National Communication	First National Communication	Used reported 1994, 2000, 2005, 2010, 2015, and 2020 estimates. Dairy cattle not included in estimates; therefore, projected the dairy cattle estimates at the same rate as reported cattle estimates (2000-2020) using 1994 reported dairy cattle N_2O estimate. Interpolated 1995 using 1994 and 2000 data. Used 1990-1995 Tier 1 annual growth rate of emissions to backcast to 1990 emissions.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	
Uzbekistan	First National Communication	IPCC Tier 1/ CH_4 rate	Used reported emissions for 1990 and 1994. Forecast 1995-2020 based on growth rate for CH_4 emissions.
Venezuela	First National Communication	IPCC Tier 1/ CH_4 rate	Used reported emissions for 2000. Missing historical emissions and projections backcast/forecast from country-reported data based on growth rates for CH_4 emissions.

Appendix E-10: Data Sources and Methodologies for Methane Emissions from Landfilling of Solid Waste

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Albania, Armenia, China, Dominican Republic, Gambia, India, Jordan, Laos, Nigeria, Nepal, Pakistan, South Africa, Saudia Arabia, Senegal, Tajikistan, Venezuela, Viet Nam.	First National Communication	IPCC Tier 1/ UN POP	Used reported emissions from National Communication (1994 often used as proxy for 1995). Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described below.
Algeria, Azerbaijan, Bolivia, Brazil, Cambodia, Chile, Colombia, Democratic Republic of Congo (Kinshasa), Ecuador, Egypt, Ethiopia, Georgia, Indonesia, Iran, Israel, Kazakhstan, Kyrgyzstan, Macedonia, Mexico, Moldova, Peru, Philippines, Thailand, Turkmenistan, Uganda, Uruguay, Uzbekistan.	First National Communication	IPCC Tier 1/ UN POP	Used reported 1990 and 1995 emissions (1994 often used as proxy for 1995). Created missing historical estimates and projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described below.
Argentina, Iraq, Jordan, Kuwait, Liechtenstein, North Korea, Singapore, Turkey, United Arab Emirates. Also estimated emissions for many smaller countries combined under "Rest Of" Africa, Latin America, Middle East, Non-EU Eastern Europe, OECD90 & EU, and S&E Asia	IPCC Tier 1/ UN POP	IPCC Tier 1/ UN POP	Used IPCC Tier 1 methodology to develop historical estimates. Tier 1 Emissions were estimated using UN population data and IPCC or IEA MSW disposal rates. The methane correction factor was either the IEA or default IPCC value for uncategorized disposal sites or was calculated using country-specific proportions for each disposal site type and their corresponding IPCC defaults. The DOC fraction was calculated based on country-specific waste stream composition figures and IPCC default percent DOC values, otherwise, default IPCC DOC fractions or IEA default DOC fractions were used. IPCC defaults were used for the fractions of DOC dissimilated, methane in landfill gas, recovered methane, and for the oxidation factor. Emissions from 2005-2020 forecast by applying population growth rates to Tier 1 estimated emissions.
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Bangladesh, Myanmar	ALGAS	IPCC Tier 1/ UN POP	Used reported emissions for 1990-2005. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.
Luxembourg	2003 Inventory Submission	Not Applicable.	Used reported data for 2000. Projections kept constant at 2000 levels.
Mexico	Second National Communication	IPCC Tier 1/ UN POP	Used reported emissions from National Communication from 1994 and 1996. Interpolated 1995. Missing historical estimates and projections backcast/forecast from country-reported data by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
Mongolia	First National Communication	IPCC Tier 1/ UN POP	Used reported emissions for 1990-2005. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.
Russia	Third National Communication	IPCC Tier 1/ UN POP	Used reported 1990, 1995, and 2000 emissions. Developed projections by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
South Korea	Second National Communication	IPCC Tier 1/ UN POP	Used reported 1990, 1995, and 2000 emissions. Developed projections by applying growth rates from the Tier 1 estimated emissions. Tier 1 emissions are described above.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	

Appendix E-11: Data Sources and Methodologies for Methane Emissions from Wastewater

Countries	Data Sources		Methodology/Adjustments
	Historical	Projected	
Albania, Algeria, Argentina, Armenia, Azerbaijan, Bangladesh, Bolivia, Brazil, Cambodia, Chile, China, Colombia, Democratic Republic of Congo (Kinshasa), Ecuador, Egypt, Ethiopia, Georgia, Iceland, India, Indonesia, Iran, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Laos, Liechtenstein, Luxembourg, Macedonia, Mexico, Moldova, Mongolia, Myanmar, Nepal, Nigeria, North Korea, Peru, Philippines, Russia, Saudi Arabia, Senegal, South Africa, South Korea, Tajikistan, Thailand, Turkey, Turkmenistan, Uganda, United Arab Emirates, Uruguay, Uzbekistan, Venezuela, Viet Nam. Also estimated emissions for many smaller countries combined under "Rest Of" Africa, Latin America, Middle East, Non-EU Eastern Europe, OECD90 & EU, and S&E Asia	IPCC Tier 1	IPCC Tier 1/ UN POP	Used IPCC Tier 1 methodology for each country and/or region. The maximum methane producing capacity, part of the emission factor, used in this analysis is 0.6 kg CH_4/kg biological oxygen demand (BOD), the recommended factor in the IPCC Good Practice Guidance. Assuming that the emission factors do not change, the driver for determining methane emissions from wastewater is population.
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Latvia, Lithuania, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	IPCC Tier 1/ UN POP	IPCC Tier 1 estimates scaled to historical estimates.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	

Appendix E-12: Data Sources and Methodologies for Human Sewage
Nitrous Oxide Emissions from Human Sewage

Countries	Data Sources: Historical	Data Sources: Projected	Methodology/Adjustments
Albania, Algeria, Brazil, Cambodia, Democratic Republic of the Congo (Kinshasa), Ethiopia, India, Iran, Kyrgyzstan, Nepal, Pakistan, Philippines, Peru, South Africa, Saudi Arabia, Sudan, Venezuela, Viet Nam	First National Communication	IPCC Tier 1/ UN POP	IPCC Tier 1 estimates scaled to historical estimates.
Argentina, Armenia, Azerbaijan, Bangladesh, Bolivia, Chile, China, Colombia, Ecuador, Egypt, Estonia, Georgia, Hungary, Iceland, Indonesia, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Laos, Lithuania, Luxembourg, Macedonia, Mexico, Moldova, Mongolia, Myanmar, Nepal, Nigeria, North Korea, Peru, Russian Federation, Saudi Arabia, Senegal, South Korea, Tajikistan, Thailand, Turkey, Turkmenistan, Uganda, United Arab Emirates, Uruguay, Uzbekistan. Also estimated emissions for many smaller countries combined under "Rest Of" Africa, Latin America, Middle East, Non-EU Eastern Europe, OECD90 & EU, and S&E Asia	Estimated using IPCC Tier 1	IPCC Tier 1/ UN POP	Used IPCC Tier 1 methodology to develop historical and projected estimates. Tier 1 emissions were estimated using UN population data, 1999 FAO protein per capita per day intake (kg/person/year), the IPCC default emission factor (0.01 kg N2O-N/kg sewage N produced), and the IPCC default fraction of nitrogen in protein (0.16 kg/N/kg protein).
Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Latvia, Monaco, Netherlands, New Zealand, Norway, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom	2005 Common Reporting Format (CRF)	Third National Communication	Used reported emissions from CRF from 1990 to 2000. Projected emissions to 2020 by scaling projected estimates extracted from Third National Communication (or other country-reported data) to CRF historical estimates.
Poland	2005 Common Reporting Format (CRF)	IPCC Tier 1/ UN POP	2005 CRF supplied data for 2000; 1990 and 1995 backcast using Tier 1 rates. Created projections by applying growth rates from Tier 1 estimated emissions. Tier 1 emissions are described above.
Russia	Third National Communication		Used reported 1990, 1995, and 2000 emissions.
United States	Inventory of US GHG Emissions and Sinks: 1990-2003; 4/15/2005	U.S. EPA - Internal Draft 4th National Communication	

Appendix F: Methodology and Adjustments to Approaches Used to Estimate Nitrous Oxide Emissions from Agricultural Soils

This appendix presents the methodology and country-specific approaches the EPA used to estimate nitrous oxide emissions from agricultural soils. EPA estimated nitrous oxide for five components of nitrous oxide emissions from agricultural soils:

- Direct emissions from commercial synthetic fertilizer application
- Direct emissions from cultivation of nitrogen-fixing crops
- Direct emissions from the incorporation of crop residues
- Direct emissions from manure (pasture, range, and paddock and all applied manure)
- Indirect emissions from agricultural soils.

Direct Emissions from Commercial Synthetic Fertilizer Application

Historical Activity Data

EPA obtained commercial synthetic fertilizer consumption data from the FAO database of agricultural statistics, FAOSTAT. These data are available for most countries from 1990-2000. Specifically, EPA used the consumption of nitrogenous fertilizers data, reported in metric tons of N[1]. EPA used several assumptions for countries without complete data:

- Ethiopia before 1993. In 1993, the former Ethiopia divided into Ethiopia and Eritrea. To estimate the fertilizer consumption of the current Ethiopia in 1990-1992, EPA determined the ratio of the fertilizer consumption of the current Ethiopia to the fertilizer consumption of the former Ethiopia in 1993 (FAO reports consumption for both former Ethiopia and Ethiopia in 1993). This ratio (96 percent for fertilizer consumption) was then applied to the fertilizer consumption of the former Ethiopia for 1990-1992 to estimate the fertilizer consumption of the current Ethiopia for 1990-1992.
- Former Soviet Union (FSU) before 1992. In 1992, the Soviet Union divided into separate countries. The distribution of fertilizer consumption among the FSU countries in 1992 was assumed to be the same for 1990 and 1991. Consequently, Soviet Union consumption data in 1990 and 1991 were allocated among the FSU countries by their percentages in 1992.

Projected Activity Data

EPA estimated the growth rate of fertilizer consumption for 2005 to 2020 by using the regional growth rates available from FAO (2000) for 1995/1997 to 2015. These rates are not provided annually. EPA then projected nitrogenous fertilizer consumption data for 2005 to 2020 based on the regional growth rate from FAO.

Historical and Projected Emissions

As recommended in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC Guidelines) (IPCC, 1997) and *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC Good Practice Guidance) (IPCC, 2000), EPA assumed that

[1] In the FAO online database, fertilizer data appear to be reported in metric tons, but data are actually reported in metric tons of N. This was corroborated by paper copies of the FAO statistics.

1.25 percent of all nitrogen from fertilizer consumption, excluding the 10 percent of nitrogen in fertilizer that volatilizes as NO_x and NH_3, is directly emitted as nitrous oxide. Therefore, emissions were calculated as follows:

$$\text{Gg } N_2O = [\text{F country} - (\text{F country} * 0.10)] * 0.0125 * 44/28 * 1000$$

Where:

F country	= fertilizer consumption for the specified year and country in metric tons of N
0.10	= fraction of N volatilized
0.0125	= emissions factor in kg N_2O-N/kg N
44/28	= N to N_2O conversion
1000	= conversion from metric tons to Gg

Direct Emissions from Cultivation of Nitrogen-fixing Crops

The cultivation of nitrogen-fixing crops such as soybeans and pulses result in emissions of nitrous oxide.

Historical Activity Data

EPA obtained production statistics for soybeans and pulses from the FAOSTAT database. The availability of data and the assumptions for each category are discussed below:

- *Soybeans.* For 1990-2000, data on soybean production are available for all of the countries examined except Mongolia, Bangladesh, Singapore, Armenia, Turkmenistan, Uzbekistan, Chile, Algeria, Senegal, Israel, Jordan, and Saudi Arabia, which EPA assumed did not produce soybeans. For 1990 no data are available for any FSU countries (including Moldova), or Ethiopia, but the data are available for 1992 and after for FSU and 1993 and after for Ethiopia. For Ethiopia and FSU countries, data were estimated from 1990-1992 (for FSU) and 1990-1993 (for Ethiopia) using the same methodology used to estimate fertilizer consumption.

- *Total pulses.* For 1990-2000, pulses were produced in all of the countries examined except Singapore, which EPA assumed did not produce pulses.

Projected Activity Data

EPA estimated future production of soybeans and pulses using the following methodologies:

- *Soybeans*. Neither projected soybean production data nor regional growth rates were available for any countries. Therefore, country-specific growth rates were determined by taking historical soybean production and deriving an average annual growth rate where *i* = ((2000 production/1990 production)^(1/10)) – 1. This rate was applied to 2000 onwards to obtain projected production to 2020.

- *Total pulses*. Projections of pulses were not available. Country-specific annual growth rates were derived by applying the same methodology as for soybeans.

Historical and Projected Emissions

EPA first adjusted the crop production statistics to kg N by multiplying the crops' residue-to-crop-mass ratios and dry matter fractions for residue (Strehler and Stutzle, 1987). To convert to units of nitrogen, EPA applied the IPCC recommendation that 3 percent of the total crop dry mass for all crops was nitrogen (IPCC, 1997).[2] To convert to kg N and account for the aboveground biomass nitrogen, EPA used the following equation:

$$\text{kg N} = \text{Production (metric ton)} * (1+ \text{residue-to-crop ratio}) * \text{dry matter fraction} * \text{N content} * 1000$$

[2] For the pulse factors, EPA used an average of the residue-to-crop-mass ratios and dry matter fractions of peas, beans, and peanuts. Also, the crop production statistics account for only the mass of the crop rather than the entire aboveground plant.

Units in kg N were then multiplied by the emissions factor of 0.0125 kg N_2O-N/kg N and converted from kg to Gg by multiplying by 1/10^6. Finally Gg N_2O-N were converted to Gg N_2O by multiplying by 44/28, the molecular weight ratio of N_2O to N.

Direct Emissions from the Incorporation of Crop Residues

Residues from corn, wheat, beans, and pulses are typically incorporated into soils. Incorporation of crop residues directly adds nitrogen to the soil, resulting in an increase in nitrous oxide emissions.

Historical Activity Data

FAO provided historical production statistics for corn, wheat, beans, and pulses; residues of which are typically incorporated into soils. Bean and pulse production were estimated in the previous section. Historical production data for corn and wheat were available for all countries examined from 1990-2000, with the following exceptions: Viet Nam, Indonesia, Philippines, and Senegal (no wheat data), Mongolia (no corn data), and Singapore (no corn or wheat data) (FAO, 2002). For these countries EPA assumed zero production for these crops.

Historical Emissions

EPA assumed that 75 percent of all crop residues are returned to the soils in developing countries (IPCC, 1997). Crop residue biomass, in dry matter kg, was derived based on the following equation:

> Crop residue biomass (kg N) = Production (metric ton) * (residue-to-crop ratio) * dry matter fraction * N content * 75% applied to fields * 1000 kg/metric ton

The data for these calculations were obtained from Table 4.16 in the IPCC Good Practice Guidance. IPCC estimates that 1.25 percent of all nitrogen from incorporated residues is directly emitted as nitrous oxide, so crop residue biomass was multiplied by 0.0125 to convert from kg N to kg N_2O-N. The estimate was then converted from kg to Gg N_2O by multiplying the value in kg by 44/28, the molecular weight ratio of N_2O to N.

Projected Activity Data and Emissions

EPA assumed that nitrous oxide emissions from incorporation of crop residue grow in proportion to production. Using historical average annual growth rates from 1990-2000 (derived through same methodology as soybean growth rates), the production of corn and wheat was estimated for 2005-2020. EPA calculated projected crop residue biomass using the projected production estimates in the equation listed under historical emissions.

Direct Emissions from Manure (Pasture, Range, and Paddock, and All Applied Manure)

Direct nitrous oxide emissions result from livestock manure that is applied to soils either through daily spread operations (all applied manure) or direct deposition on pastures, range, and paddocks (PRP) by grazing livestock.

Historical Activity Data

EPA obtained animal population from FAOSTAT for most countries for 1990, 1995, and 2000 (FAO, 2001). The exceptions include FSU countries (including Moldova), and Ethiopia, none of which have data until 1995. The ratio of the current countries' animal populations to the former countries' animal populations in 1995 was established as described in previous sections. The animal populations from the former countries in 1990 were multiplied by this ratio to obtain an estimate for the animal population of the current country in 1990.

Historical Emissions

EPA calculated total livestock nitrogen excretion, for each animal type (non-dairy cattle, dairy cattle, swine, sheep, poultry, and others) and divided it among animal waste management systems using IPCC default assumptions. EPA assumed that 20 percent of total annual excreted livestock nitrogen was volatilized (IPCC, 1997). Finally, EPA separated the value of the remainder of the excreted livestock nitrogen into manure applied to soils and PRP manure. Each was then multiplied by the emission factor specific to the animal manure management systems; 0.0125 kg N_2O-N/kg N excreted for manure applied to soils and 0.02 kg N_2O-N/ kg N excreted for manure in PRP. The complete equations are as follows:

Emissions from manure applied to soils:
kg N_2O-N from manure applied to soils = kg N applied to soils * 0.8 non-volatilized N * 0.0125 kg N_2O-N/kg N

Emissions from manure applied to PRP:
kg N_20-N from PRP manure = kg N applied to PRP * 0.02 kg N_2O-N/kg N

Projected Emissions

EPA assumed that emissions would grow at the same rate as methane emissions from manure, as reported by five-year increments in the methane and nitrous oxide emissions from manure management section of this report (Section 7.2.9). This approach was taken as projections of animal populations are not available.

Indirect Emissions from Agricultural Soils

This component accounts for nitrous oxide that is emitted indirectly from nitrogen applied as fertilizer and excreted by livestock. Nitrous oxide enters the atmosphere indirectly through one of two pathways: 1) atmospheric deposition of NO_x and NH_3 (originating from fertilizer use and livestock excretion of nitrogen), and 2) leaching and runoff of nitrogen from fertilizer applied to agricultural fields and from livestock excretion. Emissions from each of these pathways are described below.

- *Emissions from fertilizer consumption.* Nitrogen consumption data and forecasts, determined for the fertilizer application section, were used to calculate indirect nitrous oxide emissions from fertilizer consumption. The IPCC recommends that 10 percent of the applied synthetic fertilizer nitrogen volatilizes to NH_3 and NO_x, and one percent of the total volatilized nitrogen was emitted as N_2O (IPCC, 1997). To estimate emissions from leaching and run-off, EPA uses the IPCC recommendation that 30 percent of the total nitrogen applied is lost to leaching and surface runoff, and 2.5 percent of this lost nitrogen is emitted as nitrous oxide (IPCC, 1997).

- *Emissions from livestock excretion.* Historical estimates of total livestock excretion, as calculated under the nitrous oxide emissions from livestock manure management section, were used to calculate historical nitrous oxide emissions from livestock excretion. According to the IPCC, 20 percent of nitrous oxide in livestock excretion volatilizes to NH_3 and NO_x, and that one percent of the total volatilized nitrogen is emitted as nitrous oxide (IPCC, 1997). To estimate emissions from leaching and runoff, EPA used the IPCC recommendation that 30 percent of the total nitrogen applied is lost to leaching and surface runoff, and 2.5 percent of this lost nitrogen is emitted as nitrous oxide (IPCC 1997). Livestock excretion projections for 2005-2020 were not available. Therefore, the indirect emissions from animal waste were expected to grow at the same rate as direct emissions from animal waste, as determined in the methane and nitrous oxide emissions from livestock manure management section (Section 7.2.9).

Appendix G: U.S. EPA Vintaging Model Framework

Vintaging Model Overview

The Vintaging Model estimates emissions from six industrial sectors: refrigeration and air-conditioning, foams, aerosols, solvents, fire extinguishing, and sterilization. Within these sectors, over 40 independently modeled end-uses exist. The model requires information on the market growth for each of the end-uses, as well as a history of the market transition from ozone-depleting substances (ODS) to alternatives. As ODS are phased out, a percentage of the market share originally filled by the ODS is allocated to each of its substitutes.

The model, named for its method of tracking the emissions of annual "vintages" of new equipment that enter into service, is a "bottom-up" model. It models the consumption of chemicals based on estimates of the quantity of equipment or products sold, serviced, and retired each year, and the amount of the chemical required to manufacture and/or maintain the equipment. The Vintaging Model makes use of this market information to build an inventory of the in-use stocks of the equipment in each of the end-uses. Emissions are estimated by applying annual leak rates, service emission rates, and disposal emission rates to each population of equipment. By aggregating the emission and consumption output from the different end-uses, the model produces estimates of total annual use and emissions of each chemical. For the purpose of projecting the use and emissions of chemicals into the future, the available information about probable evolutions of the end-use market is incorporated into the model.

The following sections discuss the forms of the estimation equations used in the Vintaging Model for each broad end-use category. These equations are applied separately for each chemical used within each of over 40 different end-uses. In the majority of these end-uses, more than one ODS substitute chemical is used.

In general, the modeled emissions are a function of the amount of chemical consumed in each end-use market. Estimates of the consumption of ODS alternatives can be inferred by extrapolating forward in time from the amount of regulated ODS used in the early 1990s, adjusted for factors that might affect ODS substitute consumption, such as different charge sizes and lower emission rates. Using data gleaned from a variety of sources, assessments are made regarding which alternatives will likely be used, and what fraction of the ODS market in each end-use will be captured by that alternative. By combining this information with estimates of the total end-use market growth, a consumption value is estimated for each chemical used within each end-use.

Emissions Equations

Refrigeration and Air-Conditioning

For refrigeration and air conditioning products, emission calculations are split into two categories: emissions during equipment lifetime, which arise from annual leakage and service losses, and disposal emissions, which occur at the time of discard. Equation 1 calculates the lifetime emissions from leakage and service, and Equation 2 calculates the emissions resulting from disposal of the equipment. These lifetime emissions and disposal emissions are added to calculate the total emissions from refrigeration and air-conditioning (Equation 3). As new technologies replace older ones, it is generally assumed that there are improvements in their leak, service, and disposal emission rates. In addition, the charge size assumed for equipment using an ODS substitute may be different than that for equipment using the ODS.

Lifetime emissions from any piece of equipment include both the amount of chemical leaked during equipment operation and during service, including recharges. Emissions from leakage and servicing can be expressed as follows:

$$Es_j = (l_a + l_s) \times \Sigma\, Qc_{j-i+1} \text{ for } i=1 \rightarrow k \qquad \text{Eq. 1}$$

Where:

- Es_j = *Emissions from equipment serviced*. Emissions in year j from normal leakage and servicing (recharging) of equipment.
- l_a = *Annual leak rate*. Average annual leak rate during normal equipment operation (expressed as a percentage of total chemical charge).
- l_s = *Service leak rate*. Average leakage during equipment servicing (expressed as a percentage of total chemical charge).
- Qc = *Quantity of chemical in new equipment*. Total amount of a specific chemical used to charge new equipment in a given year, by weight.
- k = *Lifetime.* The average lifetime of the equipment.
- j = *Year of emission.*
- i = *Counter.* Runs from 1 to lifetime (k).

The disposal emission equations assume that a certain percentage of the chemical charge will be emitted to the atmosphere when that vintage is discarded. Disposal emissions are thus a function of the quantity of chemical contained in the retiring equipment fleet and the proportion of chemical released at disposal:

$$Ed_j = Qc_{j-k} \times [1 - (rm \times rc)] \qquad \text{Eq. 2}$$

Where:

- Ed_j = *Emissions from equipment disposed*. Emissions in year j from the disposal of equipment.
- Qc = *Quantity of chemical in new equipment*. Total amount of a specific chemical used to charge new equipment one lifetime (k) ago (e.g., j – k), by weight.
- rm = *Chemical remaining.* Amount of chemical remaining in equipment at the time of disposal (expressed as a percentage of total chemical charge)
- rc = *Chemical recovery rate.* Amount of chemical that is recovered just prior to disposal (expressed as a percentage of chemical remaining at disposal (rm))
- k = *Lifetime*. The average lifetime of the equipment.
- j = *Year of emission.*

$$E_j = Es_j + Ed_j \qquad \text{Eq. 3}$$

Where:

- E_j = *Total emissions.* Emissions from refrigeration and air conditioning equipment in year j.
- Es = *Emissions from equipment serviced.* Emissions in a given year from normal leakage and servicing (recharging) of equipment.
- Ed = *Emissions from equipment disposed.* Emissions in a given year from the disposal of equipment.
- j = *Year of emission.*

Aerosols

All HFCs used in aerosols are assumed to be emitted in the year of manufacture. Since there is currently no aerosol recycling, it is assumed that all of the annual production of aerosol propellants is released to the atmosphere. Equation 4 describes the emissions from the aerosols sector.

$$E_j = Qc_j \qquad \text{Eq. 4}$$

Where:

- E_j = *Emissions.* Total emissions of a specific chemical in year j from use in aerosol products, by weight.
- Qc = *Quantity of chemical.* Total quantity of a specific chemical contained in aerosol products sold in a given year, by weight.
- j = *Year of Emission.*

Solvents

Generally during the solvent cleaning process, a portion of used solvent is assumed to remain in the liquid phase and is not emitted as gas. Thus, emissions are considered "incomplete," and are set as a percentage of the amount of solvent consumed in a year. The remainder of the consumed solvent is assumed to be reused or disposed without being released to the atmosphere. Equation 5 calculates emissions from solvent applications.

$$E_j = l \times Qc_j \qquad \text{Eq. 5}$$

Where:

E_j	=	*Emissions.* Total emissions of a specific chemical in year j from use in solvent applications, by weight.
l	=	*Percent leakage.* The percentage of the total chemical that is lost to the atmosphere, assumed to be 90 percent.
Qc	=	*Quantity of chemical.* Total quantity of a specific chemical sold for use in solvent applications in a given year, by weight.
j	=	*Year of emission.*

Fire Extinguishing

Total emissions from fire extinguishing are assumed, in aggregate, to equal a percentage of the total quantity of chemical in operation at a given time (Equation 6). For modeling purposes, it is assumed that fire extinguishing equipment leaks at a constant rate for an average equipment lifetime.

$$E_j = r \times \Sigma\, Qc_{j-i+1} \quad \text{for } i=1 \rightarrow k \qquad \text{Eq. 6}$$

Where:

E_j	=	*Emissions*. Total emissions of a specific chemical in year j for fire extinguishing equipment, by weight.
r	=	*Percent Released*. The percentage of the total chemical in operation that is released to the atmosphere.
Qc	=	*Quantity of chemical*. Total amount of a specific chemical used in new fire extinguishing equipment one lifetime (k) ago (e.g., j – k + 1), by weight.
i	=	*Counter*. Runs from 1 to lifetime (k).
j	=	*Year of emission*.
k	=	*Lifetime*. The average lifetime of the equipment.

Foam Blowing

Foams are given emission profiles depending on the foam type (open cell or closed cell). Open cell foams are assumed to be 100 percent emissive in the year of manufacture, as described in Equation 7 below. Closed cell foams are assumed to emit a portion of their total HFC content upon manufacture, a portion at a constant rate over the lifetime of the foam, a portion at disposal, and a portion post-disposal, as described in Equations 8 through 12, below.[1]

[1] Emissions from foams may vary because of handling and disposal of the foam; shredding of foams may increase emissions, while landfilling of foams may abate some emissions (Scheutz and Kjeldsen, 2002; Scheutz and Kjeldsen, 2003). Average annual emissions are assumed in the model, which may not fully account for the range of foam handling and disposal practices.

Open-Cell Foam

$$E_j = Qc_j \qquad \text{Eq. 7}$$

Where:

E_j	=	*Emissions.* Total emissions of a specific chemical in year j used for open-cell foam blowing, by weight.
Qc	=	*Quantity of chemical.* Total amount of a specific chemical used for open-cell foam blowing in a given year, by weight.
j	=	*Year of emission.*

Closed-Cell Foam

Emissions from foams occur at many different stages, including manufacturing, lifetime, disposal and post-disposal.

Manufacturing emissions occur in the year of foam manufacture, and are calculated as presented in Equation 8.

$$Em_j = lm \times Qc_j \qquad \text{Eq. 8}$$

Where:

Em_j	=	*Emissions from manufacturing.* Total emissions of a specific chemical in year j due to manufacturing losses, by weight.
lm	=	*Loss Rate.* Percent of original blowing agent emitted during foam manufacture.
Qc	=	*Quantity of chemical.* Total amount of a specific chemical used to manufacture closed-cell foams in a given year.
j	=	*Year of emission.*

Lifetime emissions occur annually from closed cell foams throughout the lifetime of the foam, as calculated using Equation 9.

$$Eu_j = lu \times \Sigma Qc_{j-i+I} \text{ for } i = 1 \rightarrow k \qquad \text{Eq. 9}$$

Where:

Eu_j	=	*Emissions from lifetime losses.* Total emissions of a specific chemical in year j due to lifetime losses during use, by weight.
lu	=	*Leak Rate.* Percent of original blowing agent emitted during lifetime use.
Qc	=	*Quantity of chemical.* Total amount of a specific chemical used to manufacture closed-cell foams in a given year.
k	=	*Lifetime.* Average lifetime of foam product.
i	=	*Counter*. Runs from 1 to lifetime (k).
j	=	*Year of Emission.*

Disposal emissions occur in the year the foam is disposed, and are calculated as presented in Equation 10.

$$Ed_j = ld \times Qc_{j-k} \qquad \text{Eq. 10}$$

Where:

Ed_j	=	*Emissions from disposal.* Total emissions of a specific chemical in year j at disposal, by weight.
ld	=	*Loss Rate.* Percent of original blowing agent emitted at disposal.
Qc	=	*Quantity of chemical.* Total amount of a specific chemical used to manufacture closed-cell foams in a given year.
k	=	*Lifetime.* Average lifetime of foam product.
j	=	*Year of emission.*

Post-disposal emissions occur in the years after the foam is disposed, and are assumed to occur while the disposed foam is in a landfill. Currently, the only foam type assumed to have post-disposal emissions is polyurethane appliance foam, which is expected to continue to emit for 32 years post-disposal, and are calculated as presented in Equation 11.

$$Ep_j = lp \times \Sigma Qc_{j-m} \text{ for } m = k \rightarrow k + 32 \qquad \text{Eq. 11}$$

Where:

Ep_j	=	*Emissions post disposal.* Total post-disposal emissions of a specific chemical in year j, by weight.
lp	=	*Leak rate.* Percent of original blowing agent emitted post disposal.
Qc	=	*Quantity of chemical.* Total amount of a specific chemical used in closed-cell foams in a given year.
k	=	*Lifetime.* Average lifetime of foam product.
m	=	*Counter*. Runs from lifetime (k) to (k + 32).
j	=	*Year of emission.*

To calculate total emissions from foams in any given year, emissions from all foam stages must be summed, as presented in Equation 12.

$$E_j = Em_j + Eu_j + Ed_j + Ep_j \qquad \text{Eq. 12}$$

Where:

E_j	=	*Total emissions.* Total emissions of a specific chemical in year j, by weight.
Em_j	=	*Emissions from manufacturing losses.* Total emissions of a specific chemical in year j due to manufacturing losses, by weight.
Eu_j	=	*Emissions from lifetime losses.* Total emissions of a specific chemical in year j due to lifetime losses during use, by weight.
Ed_j	=	*Emissions at disposal.* Total emissions of a specific chemical in year j due to disposal, by weight.
Ep_j	=	*Emissions post disposal.* Total post-disposal emissions of a specific chemical in year j, by weight.

Sterilization

For sterilization applications, all chemicals that are used in the equipment in any given year are assumed to be emitted in that year, as shown in Equation 13.

$$E_j = Qc_j \qquad \text{Eq. 13}$$

Where:

E_j	=	*Emissions.* Total emissions of a specific chemical in year j from use in sterilization equipment, by weight.
Qc	=	*Quantity of chemical.* Total quantity of a specific chemical used in sterilization equipment in a given year, by weight.
j	=	*Year of emission.*

Model Output

By repeating these calculations for each year from 1990-2020, the Vintaging Model creates annual profiles of use and emissions for ODS and ODS substitutes. The results can be shown for each year in two ways: 1) on a chemical-by-chemical basis, summed across the end-uses, or 2) on an end-use basis. Values for use and emissions are calculated both in metric tons and in million metric tons of carbon dioxide equivalents ($MtCO_2eq$). The conversion of metric tons of chemical to $MtCO_2eq$ is accomplished through a linear scaling of tonnage by the global warming potential (GWP) of each chemical. The GWP values that are used in the model correspond to those published in the IPCC Second Assessment Report (SAR) (IPCC, 1996).

Appendix H: Regional Definitions

Africa

Algeria
Democratic-Republic of-Congo (Kinshasa)
Egypt
Ethiopia
Nigeria
Senegal
South Africa
Uganda

Rest of Africa[1]

Angola
Benin
Botswana
Burundi
Burkina Faso
Cameroon
Cape Verde
Central African-Republic
Chad
Comoros
Coté d'Ivoire
Djibouti
Equatorial Guinea
Eritrea
Gabon
Gambia
Ghana
Guinea
Guinea Bissau
Kenya
Lesotho
Liberia
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Namibia
Niger
Republic of the-Congo-(Brazzaville)
Rwanda
Sao Tome and Principe
Sierra Leone
Somalia
Sudan
Swaziland
Togo
Tunisia
United Republic-of Tanzania
Zambia
Zimbabwe

China/CPA

Cambodia[2]
China
Democratic People's-Republic of Korea (North Korea)
Hong Kong
Laos[2]
Mongolia
Vietnam
Macau

Latin America

Argentina
Bolivia
Brazil
Chile
Colombia
Ecuador
Mexico
Peru
Uruguay
Venezuela

Rest of Latin America[1]

Antigua and-Barbuda
Bahamas
Barbados
Belize
Costa Rica
Cuba
Dominica
Dominican-Republic
El-Salvador
Grenada
Guatemala
Guyana
Haiti
Honduras
Jamaica
Nicaragua
Panama
Paraguay
St. Kitts and Nevis
St. Lucia
St. Vincent and-the Grenadines
Suriname
Trinidad and-Tobago

Middle East

Iran
Iraq
Israel
Jordan
Kuwait
Saudi Arabia
United Arab-Emirates

Rest of Middle East[1]

Bahrain
Lebanon
Oman
Qatar
Syria
Yemen

Appendix H. Regional Definitions (Cont.)

Non- EU Eastern Europe
Albania
Croatia [A]
The former Republic of Yugoslavia-Macedonia

Rest of Eastern Europe[1]
Bosnia & Herzegovina
Serbia & Montenegro

Non-EU FSU
Armenia
Azerbaijan
Belarus [A]
Georgia
Kazakhstan
Kyrgyzstan[2]
Moldova
Russian Federation [A]
Tajikistan[2]
Turkmenistan
Ukraine [A]
Uzbekistan

OECD1990 & EU[3]
Australia [A,O,T]
Canada [A,O]
Japan [A,O]
New Zealand [A,O,T]
United States [A,O,T]

EU-25:
Austria [A,O]
Belgium [A,O]
Czech Republic [A]
Denmark [A,O,T]
Estonia [A]
Finland [A,O]
France [A,O,T]
Germany [A,O]
Greece [A,O]
Hungary [A]
Ireland [A,O]
Italy [A,O]
Latvia [A]
Lithuania [A]
Luxembourg [A,O]
Netherlands [A,O]
Poland [A]
Portugal [A,O]
Slovak Republic [A]
Slovenia [A]
Spain [A,O]
Sweden [A,O]
United Kingdom (U.K.) [A,O,T]

EU Accession:
Bulgaria [A]
Romania [A]

Non-EU Western Europe:
Iceland [A,O]
Liechtenstein [A]
Monaco [A]
Norway [A,O,T]
Switzerland [A,O]
Turkey [A,O]

Rest of OECD1990 & EU[1]
Rest of EU-25:
Cyprus
Malta
Rest of Non-EU Western Europe:
Holy See
San Marino
Andorra

South & Southeast Asia
Bangladesh
India
Indonesia
Myanmar
Nepal
Pakistan
Philippines
Republic of Korea (South Korea)
Singapore
Thailand

Rest of South & Southeast Asia[1]
Afghanistan
Bhutan
Brunei Darussalam
East Timor
Fiji
Kiribati
Malaysia
Maldives
Marshall Islands
Micronesia
Nauru
Palau Islands
Papua New-Guinea
Samoa
Seychelles
Solomon Islands
Sri Lanka
Tonga
Taiwan
Tuvalu
Vanuatu

Codes:
- A – Annex I countries.
- O – OECD countries as of 1990.
- T – Countries with territories whose emissions are assumed included in country totals.

Notes:
1. In this report, when emissions totals are presented for a region, the regional sum includes the estimates for all of the individually reported countries AND the aggregated value for the "Rest Of" countries. Thus, the emissions total for the "Middle East" found in the graphs and Appendices A-D, includes the sum of Iran, Iraq, Israel, Jordan, Kuwait, Saudi Arabia, the United Arab Emirates AND the smaller emitters already aggregated under "Rest of Middle East."
2. Agricultural Soils includes emissions for Cambodia and Laos under "Rest of China/CPA" and emissions for Kyrgyzstan and Tajikistan under "Rest of non-EU FSU." For all other categories, these countries are reported independently.
3. The Holy See, Liechtenstein, Monaco, Andorra, and San Marino are also included in the OECD90 & EU grouping.

Appendix I-1. HCFC-22 Production Activity Data for Selected Countries (Metric Tons)

Country	1990	1995	2000	2005	2010	2020
United States	138,900	154,700	186,905	138,369	104,495	95,452
China	10,200	15,000	94,762	183,571	200,000	259,192
Japan	42,093	69,007	58,290	65,715	68,242	76,140
United Kingdom	14,904	27,299	22,765	17,112	11,532	6,825
Netherlands	12,642	18,958	22,132	16,637	11,211	6,635
Germany	11,276	20,475	17,074	12,834	8,649	5,119
Italy	8,934	10,097	15,809	11,883	8,008	4,740
France	25,319	18,579	15,493	11,646	7,848	4,645
India	3,226	6,855	13,430	17,469	22,724	26,163
Spain	8,842	12,133	10,118	7,605	5,125	3,033
South Korea	3,480	6,692	10,460	13,098	16,400	18,007
Greece	2,300	3,792	7,588	5,704	0	0
Mexico	3,011	2,570	7,487	9,241	11,406	12,302
Russia	9,524	4,019	3,079	2,522	1,974	911
Venezuela	1,872	1,903	562	643	734	720
Brazil	3,644	4,591	405	483	576	596
South Africa	411	1,239	N/A	N/A	N/A	N/A
Argentina	583	N/A	N/A	N/A	N/A	N/A

N/A = Data not available.

Sources: CEH, 2001; Oberthür, S., 2001; U.S. EPA, 2005; SROC, 2005; JICOP, 2006.

Appendix I-2. Activity Data for Electric Power Systems Net Electricity Consumption by Selected Countries (Billion Kilowatt Hours)

Country	1990	1995	2000	2003
United States[a]	2,837	3,164	3,592	3,656
Russia	955	740	761	812
Japan[a]	764	881	940	946
China	551	884	1,201	1,671
Germany[a]	489	473	502	510
Canada	435	468	511	521
France[a]	324	366	407	433
United Kingdom[a]	290	303	343	346
India	257	370	493	519
Brazil	229	288	361	371
Ukraine	235	169	145	153
Italy[a]	222	247	282	302
South Africa	144	161	184	197
Australia	136	153	182	201
Spain[a]	133	151	201	231

Sources: EIA, 2002.

[a] For the U.S., Japan, Germany, France, U.K, Italy and Spain (as well as other EU-25+3 countries) net electricity consumption is not used to estimate emissions. U.S. SF_6 emissions from electric power systems were obtained from U.S. EPA (U.S. EPA, 2005). EU-25+3 and Japan SF_6 emissions were obtained from Ecofys, 2005 and Yokota et al., 2005, respectively.

Estimated Global SF_6 Emissions

Year	Estimated Emissions[a] (metric tons)
1990	1,772
1995	1,404
2000	1,121
2003	1,737

[a] Estimates based on RAND survey of SF_6 manufacturers, including reported sales to utilities in a given year and reported sales to equipment manufacturers 40 years previous (Smythe, 2004). RAND data are adjusted upward by 16 percent to account for consumption and emissions in Russia and China. See methodology section for more detail.

Appendix I-2b. Developing Country-/Region-Specific Net Electricity Consumption Annual Growth Rates[a,b] (percent)

Country	2010	2020
China	5.9	5.5
India	3.9	3.8
South Korea	3.7	2.9
Other Asia	3.8	3.4
Middle East	3.2	3.1
Africa	3.7	3.6
Brazil	3.1	3.6
Other Central/South America	3.7	4.1

Source: EIA, 2002.

[a] Averaged over 10-year periods.

[b] Country-specific SF_6 emissions grow at different rates in developed and developing countries. For all developed countries, except the U.S., Japan, and EU-25+3, emissions remain constant from 2003 levels through 2020. For developing countries, emissions are estimated to grow at the same rate as country- or region-specific net electricity consumption projections.

Appendix I-3. Aluminum Production Activity Data for Selected Countries (Thousand Metric Tons)

Country	1990	1995	2000	2010	2020
United States	4,048	3,375	3,668	3,310	3,310
Russia	2,997	2,757	2,544	2,774	2,737
Canada	1,623	2,002	2,174	2,940	3,126
Australia	1,243	1,288	1,732	1,922	1,922
Brazil	923	1,177	1,130	1,534	2,069
Norway	817	831	994	1,108	1,093
China	812	1,141	2,794	6,390	6,505
Germany	638	509	608	979	1,026
Spain	411	258	308	222	227
France	363	445	532	528	509
United Kingdom	250	332	397	423	408
India	242	332	378	1,106	1,163
Greece	120	162	193	204	197
Ukraine	92	69	63	110	116
Slovakia	54	79	122	186	196

Sources: IEA, 2000; IAI, 2005 (China); U.S. EPA, 2005 (U.S.).

Appendix I-4. Magnesium Activity Data for Selected Countries (Includes Primary, Secondary, and Die Casting Production) (Metric Tons)

Country	1990	1995	2000	2010	2020
United States	169,610	179,631	141,983	211,410	298,727
Russia	64,062	38,612	48,456	65,351	80,791
Norway	50,817	30,642	55,010	30,927	47,016
Canada	26,768	50,792	94,409	37,050	42,773
Ukraine	23,896	10,076	104	12,857	15,294
France	14,000[b]	14,450[b]	2,000[a]	4,187	6,365
Germany	N/A	N/A	17,530[a]	36,697	55,787
Japan	13,293	10,157	9,045	4,756	7,593
Brazil	9,604	11,716	11,463	21,950	31,906
Italy	N/A	N/A	3,000[a]	6,280	9,547
China[c]	3,789	95,204	197,350	416,613	773,568
Kazakhstan	1,661	9,267	10,791	18,673	22,486
United Kingdom	N/A	N/A	600[a]	1,256	1,909
Spain	N/A	N/A	600[a]	1,256	1,909
Portugal	N/A	N/A	300[a]	628	916
Israel	0	0	41,119	61,329	82,220

[a] 2001 values. Includes only production/processing that uses SF_6.
[b] Includes primary production only. Casting emissions estimated separately.
[c] Figures for China include production/processing that uses SO_2 as well as production/processing that uses SF_6.
N/A = Not Applicable; emissions estimate derived without direct use of activity data.

Sources: USGS, 2002; Ward's, 2001; U.S. EPA, 2005 (U.S.); Harnisch and Schwarz, 2003 (France, Germany, Italy, U.K., Spain, and Portugal).

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