GREENHOUSE GAS EMISSIONS INVENTORY FOR PENNSYLVANIA PHASE I REPORT

Adam Rose
Brent Yarnal
Robert Neff
Howard Greenberg

with

Mohammed Kharbach
Cheng-Hau Peng

Center for Integrated Regional Assessment
EMS Environment Institute
320 Earth-Engineering Sciences Building
The Pennsylvania State University
University Park, PA 16802

Report to

Pennsylvania Department of Environmental Protection
Harrisburg, PA

June 2003

GREENHOUSE GAS EMISSIONS INVENTORY FOR PENNSYLVANIA
PHASE I REPORT

TABLE OF CONTENTS

GREENHOUSE GAS EMISSIONS INVENTORY FOR PENNSYLVANIA

I. INTRODUCTION

This report summarizes Phase I of a Greenhouse Gas Emissions Inventory for Pennsylvania. It provides provisional estimates for two years, as well as background data and a preliminary interpretation of the results.

The overall goals of this project at the completion of Phase II are:

- To compile a statewide emission inventory for six categories of greenhouse gases for 1990 and for the most recent year possible (1999), supplemented by background data to provide perspective on the estimates for these two years.

- To develop a methodology for updating the inventory, including enhancements in the established EPA guidelines for estimating emissions.

The completed Inventory will provide valuable information to government, business, and the public. It explains how the activities of everyone in Pennsylvania contribute to the generation of greenhouse gases. It is also a necessary first step in assessing whether the State should develop a mitigation action plan, and, if so, what form the plan should take.

The research is being performed under a contract with the Department of Environmental Protection to Penn State University as a project of the Pennsylvania Consortium for Interdisciplinary Environmental Policy (PCIEP) Committee on Energy and Climate Change. The research team consists of Penn State University faculty members and graduate assistants with the aid of Don Brown, Director, Pennsylvania Consortium for Interdisciplinary Environmental Policy. During Phase II of the project, staff of national and state environmental agencies and an External Advisory Panel comprised of members of government, industry, and other non-governmental organizations, will assist the research team.

The emission inventory reports on six categories of GHGs:

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs); and
- Sulfur hexafluoride (SF_6).

The estimates are organized by major emissions categories, such as fossil fuel consumption, biomass fuel consumption, production processes, agriculture and livestock production, and waste disposal, treatment, and recovery. These major categories are broken down into subcategories in those cases where more than one GHG is emitted and where the emissions are widespread. For instance, fossil fuel consumption has five subcategories for CO_2 emissions: commercial/institutional, industrial/manufacturing, residential, utilities, and transportation.

Phase I of the project follows the United States Environmental Protection Agency (EPA) methodology in the Emission Inventory Improvement Program's manual, *Estimating Greenhouse Gas Emissions* (EIIP 1999). This methodology provides a valuable organizing framework, as well as guidelines, shortcuts and parameters for computations. Using the standardized methodology also makes it easy to compare the Pennsylvania Inventory with inventories of other states. At the same time, although the standardized EPA methodology applies to all states, it does not always provide the best possible techniques for estimating Pennsylvania emissions.

Consequently, Phase II will build upon the EPA methodology to improve the accuracy of GHG emission estimates for Pennsylvania. The enhanced methodology will enable staff of the Pennsylvania Department of Environmental Protection to update the inventory on an annual basis. Phase II is scheduled for completion in 2003.

Again, we emphasize that the GHG estimates presented in this Phase I report are provisional. Moreover, most of the estimates are presented for only two years and may not be indicative of long-term trends.

II. BACKGROUND

Everyday human activities can lead to climate change. Agriculture, forestry, fossil fuel production and combustion, chemical manufacture and use, and waste disposal release CO_2, CH_4, N_2O and other greenhouse gases. These GHGs accumulate in the atmosphere, increase radiative forcing, and eventually change Earth's surface climate. It is important to note that atmospheric GHGs and radiative forcing are normal and necessary to life, but that human activities are raising GHG concentrations and radiative forcing above natural levels. The ensuing short-term climate variability and long-term climate change have already been found to have adverse effects on flora, fauna, human health and various natural systems. They may have potentially catastrophic effects if GHG emissions are not curtailed significantly in the coming decades (IPCC, 2001).

Until the 1990s, most efforts to identify the human activities producing GHGs and to measure their emissions focused on the global level. At the global scale, greenhouse gases diffuse and mix regardless of their points of origin. This universal mixing makes it difficult to use instruments for measuring greenhouse gas emissions at sub-global scales. Instead, analysts must infer GHG emissions from the human activity responsible. Most countries keep broad records of land in forestry and agriculture, production and consumption of fossil fuels, chemical manufacture and use, waste disposal, and other major human activities within their boundaries. It is relatively simple, therefore, to construct national inventories of GHG emissions from general human activity data. The United States has compiled GHG emissions inventories since before 1990 (see EIA 2001a; EPA 2001).

In a large, diverse country like the United States, however, the mix of human activities and resulting GHG emissions varies from region to region and state to state. For instance, states dominated by agriculture, heavy manufacturing or coal mining, such as Kansas, Ohio and West Virginia, respectively, emit markedly different bundles of GHGs. If the United States were to develop a national action plan to reduce emissions, but failed to account for state-by-state differences, then it is unlikely that the action plan would succeed because it would lack the detail to be cost-effective and to be equitable within regions. To develop an effective action plan for greenhouse gas abatement, states must compile emissions inventories.

Recognizing the need for state-level action to decrease GHG emissions, for more than a decade, EPA has encouraged states to compile emissions inventories. Pennsylvania, for example, assembled its first state inventory and action plan nearly ten years ago (CUP 1993). The state-level emissions inventory protocols (EIIP 1999) use the international reporting standard established by the Intergovernmental Panel on Climate Change (IPCC 1997) and expanded by EPA (2001). The GHGs cataloged by United States emissions inventories include CO_2, CH_4, N_2O and certain manufactured fluorinated gases commonly known as Ozone Depleting Compounds (ODCs) and their substitutes (ODSs). ODCs include chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), which were banned under the Montreal Protocol and are no longer included in GHG emissions inventories. ODSs include HFCs, PFCs and SF_6. The sectors tracked by greenhouse gas emission inventories include the activities associated with agricultural production, forestry, energy production and consumption, other industrial processes, and waste disposal.

Not only is there great diversity from state to state, but also there is tremendous variation within most states. In Pennsylvania, various cities, counties and regions are known for their agriculture, forestry, coal mining, transportation systems, manufacturing or refuse disposal. Even in one small place, Centre County, for example, each of these activities is important. Ultimately, sub-state-level entities, such as metropolitan regions, counties and universities, will need to compile inventories and formulate action plans (Wilbanks and Kates 1999). Several recent efforts have recognized that need. The Global Change in Local Places project (Kates and Torrie 1998) adapted the EPA state-level methodology (Kates et al. 1998) to conduct GHG inventories for select counties in North Carolina, Kansas, Ohio and central Pennsylvania (Easterling et al. 1998). The International Council for Local Environmental Initiatives-Cities for Climate Protection (ICLEI-CCP) campaign independently developed tools to inventory GHGs from communities and institutions (Kates et al. 1998). Lachman (1999) used this instrument to compile a GHG emissions inventory for the Penn State University Park Campus.

Despite the importance of sub-state inventories to the formulation of future GHG mitigation action plans, pragmatism dictates that state-level inventories will form the basis of today's mitigation planning. The following section outlines the methodology used to compile the Pennsylvania GHG emissions inventory.

III. METHODOLOGY

The GHG emission figures presented in this report are based on the EPA methodology for estimating GHG emissions (EIIP 1999). It should be noted at the outset that the figures presented in this report are not based on direct measurement with the use of scientific instruments, but rather are estimates of emissions based on socioeconomic data. Therefore, our GHG emissions estimates are only as accurate as the underlying socioeconomic data and the accounting practices, transformations, and emissions and conversion factors applied to those data. The appendices of this report presents details of the methods used to calculate GHG emissions estimates from each sector.

We work through an example here to demonstrate the process of estimating emissions from socioeconomic data. In the case of municipal waste management, GHG emissions and sequestration have three sources: CH_4 emitted from waste at each landfill; CO_2 and N_2O emitted from the annual combustion of municipal solid waste; and carbon sequestered by the annual addition of waste to landfills (see Appendix B.5). Calculation of emissions from combustion of municipal solid waste and carbon sequestration from land filling are relatively simple because annual data on waste combustion and landfilling are available. Multiplying these quantities by coefficients that reflect the average emissions and sequestration per ton of waste provides reliable estimates of the emissions and sequestration resulting from each activity.

CH_4 emissions from municipal solid waste are less straightforward, however. Once placed in a landfill, municipal solid waste can emit CH_4 for as long as 30 years. Thus, to calculate CH_4 emissions, it is necessary to know how much waste is in place at each landfill in the state and the age of that waste. These data are not readily available. In this case, the EPA methodology provides a formula for estimating waste in place using gross population data, the average waste disposal per capita, and a 30-year multiplier. Although this methodology is imprecise, the resulting figure provides a reasonable approximation of CH_4 emissions that does not require costly data collection from each landfill dating from 1960.

Throughout this report, with one exception, we have estimated Pennsylvania GHG emissions using the EPA methodology. In some cases, the estimates are the best available; in other cases, we believe the estimates for Pennsylvania could be improved with marginal increases in time and money (see Appendix C for some issues that we identify in the EPA methodology and suggestions for addressing them). While improving the accuracy of the methodology used to estimate Pennsylvania GHGs is important, it is equally important to generate estimates based on the EPA methodology, despite any flaws or shortcomings. Assuming all 50 states eventually complete inventories of GHG emissions, those inventories must be directly comparable, not only with each other, but with national-scale inventories. Consistency in methodology is critical to achieving this goal. Towards that goal, this report summarizes our major findings based on the EPA methodology.

IV. RESULTS

The results of the Phase I Inventory are presented in Tables 1 through 11, which are distinguished by category of GHG and emissions source. Descriptions of the processes by which the GHGs are emitted and the data and formulas used to calculate the emissions are presented in Appendix A. Spreadsheets of the actual calculations are presented in Appendix B. Throughout this report, emissions of all GHGs are expressed in million metric tons of carbon equivalents (MMTCE). This is a common denominator for the different radiative forcings, or warming potentials, of the various GHGs.

A summary of Pennsylvania GHG emissions is provided in Table 1. This table indicates that CO_2 emissions from fossil fuels clearly dominate the picture. In 1999, for example, this category contributed 72.23 million metric tons of carbon equivalent (MMTCE) of the total of 79.79 MMTCE generated in Pennsylvania, or 90.53 percent of the total. Still, several other emission categories are significant. Note also that Forestry and Land Use Change has negative net additions to CO_2 emissions. This reflects the fact that plants absorb CO_2 from the atmosphere during their respiration process, and that additional forest growth (through natural process or replanting) sequesters even more of these GHGs.

To put the totals from Table 1 into perspective, Pennsylvania's population was 4.8 percent of the United States total in 1990, and 4.4 percent of the total in 1999. Using the data to calculate carbon equivalent GHG emissions in Table 1, Pennsylvania's contribution to the national total of GHGs is 5.6 percent and 4.9 percent for years 1990 and 1999, respectively. Thus, despite an increase in the overall level of GHG emissions in Pennsylvania between 1990 and 1999, we see a downward trend in our share of the national total of GHGs being emitted.

None of the categories of GHGs, other than CO_2 from fossil fuel combustion, generates more than five percent of total emissions. The most notable of these minor sources are GHGs from Non-Energy Industrial Sources (all six categories combined); CH_4 leakages from Oil and Natural Gas extraction, transportation and storage; CH_4 releases from Coal Mining; and GHG emission (primarily CH_4) from Municipal Waste Management and from Manure Management. All other non-carbon emissions amount to about one percent or less of the Pennsylvania total emissions.

A breakdown of CO_2 emissions from fossil fuel combustion by customer (Table 2) indicates that electricity generation is the dominant source of this GHG. The remaining tables provide similar disaggregations by emission types and sources. For example, Table 4 provides disaggregations of GHG emissions from Non-Energy Industrial Processes by gas and by source. This category increased more than any other, over 50 percent between 1990 and 1999. The most prominent contributors to this total are CO_2 from Cement, and HFCs and PFCs from ODSs. None of the other sources contributed more than 10 percent of the 2.95 MMTCE from Non-Energy Industrial Processes by 1999 listed in Table 2.

Note that our estimates are based on the latest data from Energy Information Agency (EIA) (2002b) on coal use in Pennsylvania (unpublished data released in late October 2002). EIA implemented major modifications in its methodology, primarily to account for the reclassification of many electric utilities as non-utility generators accompanying electricity industry deregulation. We have distinguished these two sub-categories of electricity generation in Table 12. Note that the revised coal use estimate for electricity generation for 1999 is significantly higher than the previously published standard data (EIA, 2001d), which failed to include non-utility generation.[3]

A major caveat relates to the transportation sector, which is experiencing significant growth in CO_2 emissions. Motor vehicle traffic generates a large part of total transportation emissions. Emissions were calculated for motor vehicle traffic by following the EPA methodology and using EIA data detailing motor fuel sales in the Commonwealth. Although the report shows growth in CO_2 emissions from motor vehicles of nearly 17 percent from 1990 to 1999, other available data suggest that emission growth is higher. For instance, annual vehicle miles traveled (VMT) in Pennsylvania grew by 20 percent from 1990 to 1999. Fuel efficiency standards for new light-duty cars and trucks declined nationally by about four percent over the same time period, but consumers demonstrated a growing preference for purchasing sport-utility vehicles over more fuel-efficient vehicles. All of these factors may well have contributed to a higher rate in CO_2 emissions growth than described in this report. Transportation emissions will need to be investigated further in any future analysis, and the methodology and growth rates in this report will need to be improved to generate a more accurate estimate of emissions from the transportation sector.[4,5]

Several important causal trends can be identified despite these caveats; that is, these trends hold generally over the course of the 1990s even if we take into account data omissions. Recent studies have identified underlying “sources” of change in GHGs (e.g., economic growth, population growth, change in fuel mix, change in a sectoral intensity of total economic activity) and have utilized a formal methodology called structural decomposition analysis to identify their relative contributions over time (see, e.g., Casler and Rose, 1998; Zhang and Ang, 2001). Here we use this concept to isolate major explanatory factors and discuss their influence on a less formal basis.

For example, had only economic growth taken place during the 1990s, with no changes in any of the other underlying causal factors, overall CO_2 emissions would have grown at a commensurate rate of 24 percent. Yet, overall CO_2 emissions have increased only slightly over the decade. The good news is that Pennsylvania has "de-coupled" certain types of economic activity from economic growth. Many analysts were previously convinced that electricity use had to move in lockstep with economic activity, but this conclusion is clearly no longer valid, as other factors have offset the upward pressure of economic growth on electricity use and hence on CO_2 emissions. Some of these causal factors exerting downward pressure on emissions include a relative decrease in manufacturing from 21 percent of Gross State Product in 1990 to 19 percent in 1999, as well as a significant increase in energy conservation in this sector.

V. SUMMARY AND CONCLUSIONS

The results of the Phase I Inventory demonstrate that Pennsylvania's total GHG emissions have increased three percent -- from 77.44 MMTCE in 1990 to 79.79 MMTCE in 1999. However, Pennsylvania's contribution to the national GHG emissions total has decreased from 5.6 percent to 4.9 percent for the years 1990 and 1999, respectively.

While Pennsylvania's share of the national total of GHG emissions has been declining, its contribution is still above the national average on a per capita basis. In 1999, Pennsylvania emissions were 6.46 MTCE per person. The U.S. per person average for 1999 was 6.10 MTCE. Further, in economic terms, Pennsylvania's 1999 emissions represented 0.47 pounds of carbon equivalent per dollar of state economic output compared to the national average of 0.40 pounds.

The Inventory indicates that CO_2 emissions from fossil fuels are, by far, the most significant GHG. In 1999, this category contributed 72.23 MMTCE of the total 79.79 MMTCE generated in Pennsylvania, or 90.53 percent of the total. Despite their large contribution to the total, GHGs from fossil fuels increased less than one percent between 1990 and 1999. Of the fossil fuels consumed, bituminous coal is the largest fuel category contributing to Pennsylvania's GHG emissions. In 1999, bituminous coal use among all sectors contributed 30.62 MMTCE, or 38 percent of all GHGs reported in the Inventory.

The Inventory also demonstrates that motor vehicles are the fastest growing source of GHGs in Pennsylvania. Although the Commonwealth's population is essentially static, total vehicle miles are rising, which in turn means that per capita vehicle miles traveled (VMT) are rising (OHIM, 1994; OHIM, 1999). This fact, in conjunction with consumer preferences for larger, less efficient vehicles, is primarily responsible for the rise in total GHG emissions from the transportation sector, both in the Commonwealth and in the United States (EIA, 2001c).

The Pennsylvania Greenhouse Gas Emissions Inventory highlights other activities that produce GHGs. For instance, the Commonwealth has plentiful, relatively pure limestone available for lime calcining and cement manufacturing—production processes that emit disproportionately high quantities of CO_2. Still, the dominance of fossil fuel use, especially for energy production and transportation, overwhelms all other sources of GHGs in Pennsylvania.

VI. ENDNOTES

[1] Due to data limitations, we were not able to include emissions from sources such as methane flaring in the Phase I analysis. In addition, we were not able to identify all emissions within Pennsylvania from mobile sources associated with interstate and international transportation such as marine vessels, railroads and aircraft. We have computed emissions from fuels purchased in Pennsylvania for these transport modes, but this is unlikely to correspond to GHGs actually emitted within the Commonwealth's boundaries. This problem of measuring transportation sector emissions also applies to motor vehicles such as large trucks involved in interstate commerce.

[2] Separate tables are provided only in cases where additional detail is warranted, (i.e., where the sources generate more than one GHG).

[3]The revised EIA data are similar to those published in EIA (2002a).

[4]Several other shortcomings arise in the EPA methodology. For example, nitrous oxide generated from nitric acid production for Pennsylvania is calculated as a percentage of U.S. production on the basis of Pennsylvania's share of U.S. total population. Thus, even though Pennsylvania's nitric acid production capacity was the same in 1999 as in 1990, it is estimated that the generation of nitrous oxide from nitric acid production in the Commonwealth declined from 107.8 thousand MTCE to 101.3 thousand MTCE over the decade because Pennsylvania's population share decreased (see Table 4). This case points out the limitations of using population ratios to estimate greenhouse gas emissions. Similar problems will likely be found under "GHGs from Non-Energy Industrial Sources."

[5]The EPA methodology also contains an important omission relating to chlorofluorocarbons (CFCs). CFCs are greenhouse gases, but were not included in the Kyoto Protocol. Since they were banned by the earlier Montreal Protocol, it was felt that they would be phased out anyway before the Kyoto compliance period of 2008-12. However, substitutes for these ozone-depleting substances

(ODSs) generate HFCs and PFCs, which are in fact GHGs, and which increased from 14.3 thousand MTCE in 1990 to 814.8 thousand MTCE in 1999. This dramatic increase, however, was offset a bit by the decline in CFCs, which we estimate were 28.8 thousand MTCE in 1990 and only 6.6 thousand MTCE in 1999. This net improvement of 22.2 thousand MTCE does not show up in Table 1 or Table 4 because CFCs are not incorporated into the official U.S. GHG Inventory. Inclusion of CFCs in our assessment, however, would have an imperceptible effect on our results. The total GHG emissions in Table 1 in 1999 would be 79.81 MMTCE (as opposed to 79.79) and would still represent a three percent increase over the revised 1990 level of 77.47 MMTCE.

VII. ACKNOWLEDGEMENT

The authors acknowledge funding for research done in connection with this Report from the Pennsylvania Department of Environmental Protection (Contract FRL-6964-2). The authors are grateful to the following people for their contributions, data, assistance and/or comments: Mark Linstedt (Pennsylvania Agricultural Statistics Service); Richard Birdsey (U. S. Forestry Service); Clark Talkington (Coalbed Methane Outreach Program, EPA); Scott Bartos (Global Programs Division, EPA); Laurel Belding (Communication Department, PaCBI); Thomas Kevin Swift (American Chemistry Council); Carolyn Read (Directory of Chemical Producers Program), and Julia Hutchins (U.S. EIA). The authors also acknowledge the helpful comments and other assistance of Don Brown, Patrick McDonnell, Joseph Sherrick and Chris Trostle (Pennsylvania Department of Environmental Protection). The views expressed in this report, however, are those of the authors and do not necessarily represent the position of any of the persons or organizations named above. The authors are solely responsible for any errors and omissions.

VIII. REFERENCES

Casler, S., and A. Rose, 1998. Carbon dioxide emissions in the U.S. economy. *Environmental and Resource Economics* 11: 349-63.

CUP, 1993. *Greenhouse Gas Emissions in Pennsylvania: An Inventory*. California, PA: Earth Systems Laboratory, California University of Pennsylvania. California, PA.

Denny, A., B. Yarnal, C. Polsky, and S. Lachman, 2003. Global change and Central Pennsylvania: Local resources and impacts of mitigation. In: *Global Change in Local Places*: Estimating, Understanding, and Reducing Greenhouse Gases, Association of American Geographers Global Change in Local Places Research Group, editors, Cambridge University Press, Cambridge, England (in press).

Easterling, W., C. Polsky, W. Muraco, D. Goodin, M. Mayfield, and B. Yarnal, 1998. Changing places, changing emissions: The cross-scale reliability of greenhouse gas emissions in the U.S. *Local Environment* 3: 249-264.

EIIP, 1999. *Estimating Greenhouse Gas Emissions*. EIIP Documentation Series, Volume VIII. Washington, DC: Greenhouse Gas Committee, Emission Inventory Improvement Program, and US Environmental Protection Agency. http://www.epa.gov/ttn/chief/eiip/techreport/volume08/index.html.

EIA, 2001a. *Emissions of Greenhouse Gases in the United States 2000.* Washington, DC: Energy Information Administration, U.S. Department of Energy, Report No. EIA/DOE 0573(2000), http://www.eia.doe.gov/oiaf/1605/1605a.html#links.

EIA, 2001b. *Electric Power Annual 2000, Vol. 1.* Washington, DC: Energy Information Administration, U.S. Department of Energy. http://www.eia.doe.gov/cneaf/electricity/epav1/epav1_sum.html.

EIA, 2001c. *Annual Energy Review 2000.* Washington, DC: Energy Information Administration, U.S. Department of Energy, Report No. DOE/EIA-0384(2000), http://www.eia.doe.gov/emeu/aer/pdf/038400.pdf.

EIA, 2001d. *State Energy Data Report, 1999*. Washington, DC: Energy Information Administration, U.S. Department of Energy, Report No. EIA/DOE. http://www.eia.doe.gov/emev/sedr/contents.html.

EIA, 2002a. *State Electricity Profiles (Pennsylvania)*. Washington, DC: Energy Information Administration, U.S. Department of Energy, http://www.eia.doe.gov/cneaf/electricity/st_profiles/pennsylvania/pa.html.

EIA, 2002b. "Revised Energy Consumption Data for Pennsylvania" (unpublished), Energy Information Administration, U.S. Department of Energy.

EPA, 2001. *U.S. Inventory of Greenhouse Gas Emissions and Sinks, 1990-1999*. Washington, DC: Report No. EPA 236-R-01-001, Office of Atmospheric Programs, U.S. Environmental Protection Agency. http://www.epa.gov/globalwarming/publications/emissions/us2001/index. html#toc.

IPCC, 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (3 Volumes). Kanagawa, Japan: Technical Support Unit at the Institute for Global Environmental Strategies, National Greenhouse Gas Inventories Programme, Intergovernmental Panel on Climate Change. http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm.

IPCC, 2001. *Climate Change 2001,* Report of the Intergovernmental Panel on Climate Change, Cambridge, UK: Cambridge University Press.

Kates, R., and R. Torrie, 1998. Global change in local places. *Environment* 40 (2): 5 and 39-41.

Kates, R., M. Mayfield, R. Torrie, and B. Witcher, 1998. Methods for estimating greenhouse gases from local places. *Local Environment* 3: 279-297.

Lachman, S., 1999. A greenhouse gas inventory of the University Park campus of the Pennsylvania State University. Unpublished M.S. Thesis, Department of Geography, The Pennsylvania State University, University Park, PA.

OHIM, 1994. *Highway Statistics 1994.* Washington, DC: Office of Highway Information Management, Department of Transportation. http://www.fhwa.dot.gov/ohim/ohimstat.htm

OHIM, 1999. *Highway Statistics 1999.* Washington, DC: Office of Highway Information Management, Department of Transportation. http://www.fhwa.dot.gov/ohim/ohimstat.htm

Wilbanks, T., and R. Kates, 1999. Global change in local places: How scale matters. *Climatic Change* 43: 601-628.

Zhang, F. and B. Ang, 2001. Methodological issues in cross/country/region decomposition of energy and environmental indicators. *Energy Economics* 23: 179-90.

Table 1: Summary of All PA GHG Emissions (MMTCE)

Emission Source	1990	% of 1990	1999	% of 1999
CO_2 from Fossil Fuels	71.57	92.42	72.23	90.53
GHGs from Non-Energy Industrial Processes	1.92	2.48	2.95	3.70
CH_4 from Oil and Natural Gas	1.43	1.85	1.47	1.84
CH_4 from Coal Mining	1.98	2.56	2.27	2.84
CH_4 from Domestic Animals	0.08	0.10	0.07	0.09
GHGs from Municipal Waste Management	1.25	1.61	1.16	1.45
GHGs from Manure Management	0.79	1.02	0.81	1.02
CO_2 from Forestry and Land-use Change	-2.40	-3.10	-2.01	-2.52
GHGs from Burning Agricultural Waste	*	*	*	*
GHGs from Municipal Waste Water	0.15	0.19	0.15	0.19
CH_4 & N_2O from Mobile Combustion	0.42	0.54	0.44	0.55
CH_4 & N_2O from Stationary Combustion	0.25	0.32	0.25	0.31
Total	77.44	100.00	79.79	100.00

* Less than .005
Source: See Appendix B.1-B.14.

Table 2: PA CO_2 Emissions from Fossil Fuel Combustion (MMTCE)

Emission Source	1990	% of 1990 Fossil Fuel	1999	% of 1999 Fossil Fuel
Residential	6.00	8.38	6.38	8.83
Commercial	3.42	4.78	3.25	4.50
Industrial	18.69	26.11	14.97	20.73
Transportation	16.03	22.40	18.71	25.90
Electricity	27.43	38.33	28.92	40.04
Total	71.57	100.00	72.23	100.00

Source: See Appendix B.1.

Table 3: Extended Presentation of PA CO_2 Emissions by Sector and Fuel Type (MMTCE)

	Residential		Commercial		Industrial		Transportation		Electricity	
	1990	1999	1990	1999	1990	1999	1990	1999	1990	1999
Asphalt					1.01	0.68				
Aviation Gasoline							0.01	0.02		
Distillate Fuel Oil	1.96	2.22	0.64	0.55	0.73	0.58	2.74	3.90	0.14	0.13
Jet Fuel							1.33	1.77		
Kerosene	0.15	0.28	0.02	0.04	0.01	0.02				
Liq. Petrol Gas	0.16	0.23	0.03	0.04	0.20	0.07	0.01	0.01		
Lubricants					0.34	0.35				
Motor Gasoline			0.07	0.02	0.12	0.07	10.66	11.67		
Other Oil					2.25	2.42				
Petroleum Coke									0.17	0.12
Residual Fuel Oil			0.11	0.09	0.78	0.31	0.76	0.80	0.72	0.59
Bituminous Coal	0.15	0.05	0.68	0.38	2.57	2.26			26.37	27.93
Coke					7.09	4.56				
Natural Gas	3.58	3.60	1.88	2.14	3.60	3.65	0.51	0.55	0.03	0.15
Total	6.00	6.38	3.42	3.25	18.69	14.97	16.03	18.71	27.43	28.92

Source: See Appendix B.1.

Table 4: PA GHG Emissions from Non-Energy Industrial Processes, by Activity (MTCE)

Process	1990	1999
CO_2 from Cement	712,522	969,401
CO_2 from Lime	302,553	251,198
CO_2 from Limestone	35,656	56,958
CO2 from Soda Ash	35,217	32,001
CO_2 from Manufacturing	10,404	19,193
N_2O from Nitric Acid	107,817	101,285
HFC_{23} from $HCFC_{22}$	452,570	364,666
HFCs and PFCs from substitutes of ODS*	14,300	814,800
SF_6 from Electric Utilities	220,400	256,900
SF_6 from Magnesium	31,508	78,860
Total	1,922,947	2,945,262

*Ozone Depleting Substances.
Source: See Appendix B.2.

Table 5: PA GHG Emissions from Oil and Natural Gas (MTCE)

Emission Type	1990	1999
CH_4 Emissions from Oil	8,778	8,807
CH_4 Emissions from Natural Gas	1,422,679	1,464,393
Total	1,431,457	1,473,199

Source: See Appendix B.3.

Table 6: PA GHG Emissions from Municipal Waste Management (MTCE)

Emission Type	1990	1999
CH_4 Emitted by Landfills	1,518,383	1,349,864
Carbon Sequestered by Landfills	-562,227	-435,578
CO_2 Emitted by Combustion of MSW	272,898	232,567
N_2O Emissions from Combustion of MSW	21,150	18,024
Total	1,250,204	1,164,877

Source: See Appendix B.5.

Table 7: PA GHG Emissions from Manure Management (MTCE)

Emission Type	1990	1999
CH_4 Emissions	111	124
N_2O Emissions	786,855	807,694
Total	786,966	807,819

Source: See Appendix B.7.

Table 8: PA GHG Emissions from Burning of Agricultural Waste (MTCE)

Emission Type	1990	1999
CH_4 Emissions	0.14	0.14
N_2O Emissions	0.02	0.02
Total	0.16	0.16

Source: See Appendix B.11.

Table 9: PA GHG Emissions from Municipal Waste Water (MTCE)

Emission Type	1990	1999
CH_4 Emissions	51,172	51,596
N_2O Emissions	100,672	101,505
Total	151,845	153,101

Source: See Appendix B.12.

Table 10: PA GHG Emissions from Mobile Combustion (MTCE)

Emission Type	1990	1999
CH_4 Emissions	24,254	25,494
N_2O Emissions	397,639	416,743
Total	421,893	442,237

Source: See Appendix B.13.

Table 11: PA GHG Emissions from Stationary Combustion (MTCE)

Emission Type	1990	1999
CH_4 Emissions	49,381	49,977
N_2O Emissions	204,180	200,180
Total	253,561	250,157

Source: See Appendix B.13.

Table 12: Fuel Utilization in Electricity in Pennsylvania, 1990-1999 (in trillion Btu)

Fuel Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Coal										
Utilities	1,012	992	998	994	936	966	1,009	1,043	1,056	862
Non-Utilities	33	53	65	74	81	94	111	103	103	267
Natural Gas	2	2	3	9	13	25	7	8	7	11
Petroleum	47	44	28	53	62	39	42	29	50	39
Nuclear	617	617	642	634	718	708	730	719	650	753
Hydro	18	7	13	12	17	5	18	13	16	12
Total	1,729	1,715	1,750	1,776	1,828	1,837	1,918	1,915	1,882	1,943

Source: EIA 2001d; revised data for 1999 supplemented by Julia Hutchins, EIA 2002b.

For consistency purposes all the fuel consumption data in standard quantity units (e.g., short tons, barrels, cubic feet, trillion Btu) have been converted using coefficients developed from the EIA, *State Energy Data Report 1999*. 1999 data were used to arrive at the following coefficients for each type of fuel, though this assumes a constant mix of fuels within each category:

	Coal	Gas	Petroleum	Nuclear	Hydro
	TBtu/thousand short tons	TBtu/billion cubit feet	TBtu/thousand barrels	TBtu/million Kwh	
Conversion Factors	0.024943573	1.07	0.00b174794	0.0106228	0.0103181

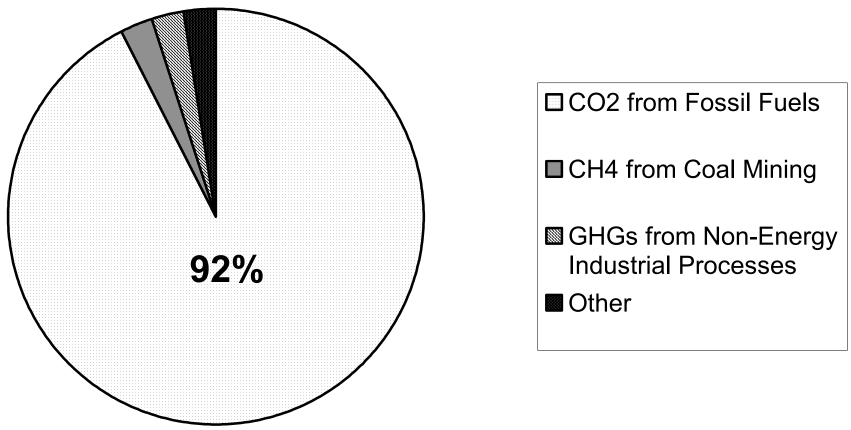

Figure 1: Relative Contribution of Each Sector to Total PA GHG Emissions, 1990

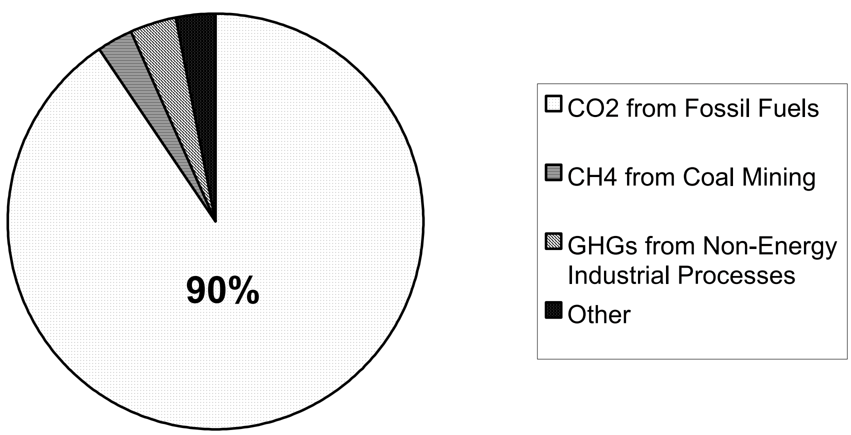

Figure 2: Relative Contribution of Each Sector to Total PA GHG Emissions, 1999

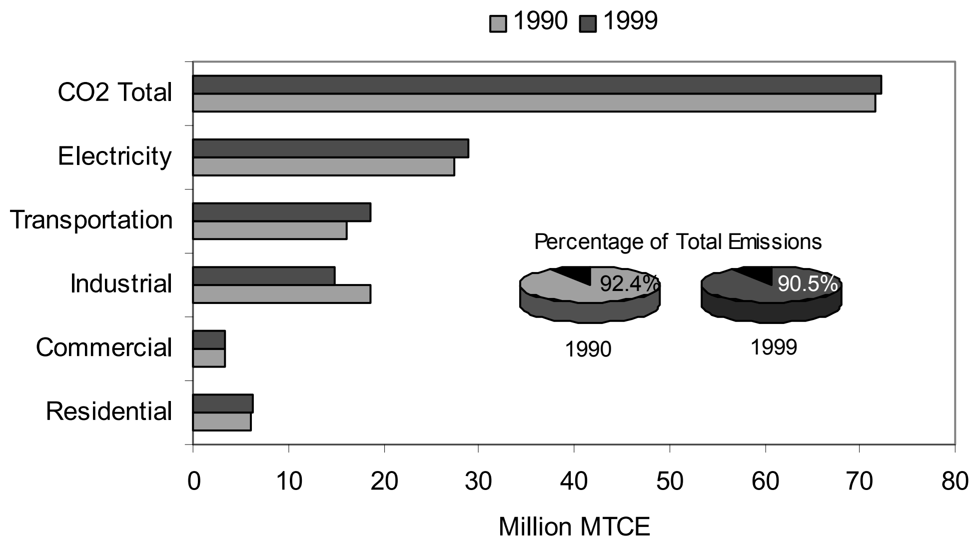

Figure 3: Sectoral Contributions to CO_2 Emissions from Fossil Fuel Combustion, 1990 and 1999

APPENDIX A:

DESCRIPTIONS OF METHODS USED TO CALCULATE EMISSIONS

CO_2 EMISSIONS FROM FOSSIL FUEL COMBUSTION

Process Description:

CO_2 from fossil fuels is the most important contributor to U.S. GHG emissions. CO_2 is emitted from each major economic sector (residential, commercial, industrial, transportation and electric utilities) during the combustion of fossil fuels (natural gas, coal, gasoline, etc.).

Required Data:

- fossil fuels consumed by energy type (natural gas, coal, gasoline, etc.) and by sector (residential, commercial, industrial, transportation and electric utilities) [(1)].

Estimation Method:

First, we obtained all fossil fuels consumed by each sector in MMBtu[(1)]. Second, we accessed the emissions factors and fraction rates (the proportions of carbon oxidized) for each activity listed in the EPA Guide Book [(2)] to calculate tons of carbon emissions of each fossil fuel type by sector. Third, we aggregated emissions of each fossil fuel by sector to obtain total CO_2 emissions from each sector.

*a. (emissions from coal = consumption of coal * emission factor*0.99)*
*b. (emissions from oil = consumption of oil * emission factor*0.99)*
*c. (emissions from gas = consumption of gas * emission factor*0.995)*
(annual CO_2 emissions from fossil fuel combustion in tons = a + b + c)

*To obtain the amount of emissions in metric tons of carbon equivalent (MTCE), the CO_2 emissions calculated above should be multiplied by 0.907*12/44, where 0.907 is the conversion factor from tons to metric tons and where 12/44 is the carbon fraction of a molecule of CO_2.*

Data Sources:

1. Energy Information Administration (EIA), 1999. *State Energy Data Report*.
2. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

CO_2 EMISSIONS FROM MANUFACTURE

Process Description:

CO_2 is consumed by some industries, such as food processing, chemical manufacturing, and carbonated beverages production (cola, beer etc.). These industries emit CO_2 while producing their products.

Required Data:

- National CO_2 emissions from manufacture in metric tons [(1)].
- National Population [(2)].
- State Population [(3)].

Estimation Method:

We used total emissions of CO_2 from manufacture in the United States and the Pennsylvania/ U.S. [(2,3)] population ratio to estimate the emissions in Pennsylvania. Total emissions of CO_2 from manufacture in the U.S. (1990 and 1999) are obtained from EPA data [(1)]. Metric tons of CO_2 from manufacture in Pennsylvania is calculated by multiplying total CO_2 emissions from manufacture in the U.S. by the Pennsylvania/ U.S. population ratio. Multiplying the result by the carbon conversion factor (12/44), we obtained total CO_2 emissions from manufacture in metric tons of carbon equivalent (MTCE).

*(annual CO_2 emissions from manufacture = national CO_2 emissions from manufacture *population ratio)*

To obtain the amount of emissions in metric tons of carbon equivalent (MTCE), the CO_2 emissions calculated above should be multiplied by 12/44.

Data Sources:

1. U.S. Environmental Protection Agency (EPA). 2000. *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-1999. Annual Energy Review 2000.*
2. U.S. Bureau of Census, 2000. *Historical National Population Estimates: July 1, 1990 to July 1, 1999.* Population Distribution and Population Estimates Branches.
3. U.S. Bureau of Census, 2000. *State Population Estimates and Demographic Components of Population Change: April 1, 1990 to April 1, 1999*. Population Estimates Program, Population Division.

CO_2 EMISSIONS FROM CEMENT PRODUCTION

Process Description:

Cement production is the most important source of CO_2 emissions among industrial processes. CO_2 is released as a by-product during the calcination process. The calcination process is a reaction through which calcium carbonate ($CaCO_3$) is heated in order to produce lime (CaO). The lime is then combined with some materials containing silica to form dicalcium or tricalciumsilicates. These two elements are among the four major compounds of the clinker. The clinker is an intermediate product, which is used to produce Portland and masonry cement. The production of masonry cement involves additional CO_2 emissions.

Required Data:

- Annual production of clinker in short tons in Pennsylvania [1,2].
- Annual production of masonry cement in short tons in Pennsylvania [1,2].

Estimation Method:

CO_2 from clinker production
Emissions are estimated using an emissions factor. This factor is equal to the amount of CO_2 released in tons per tons of clinker produced. The recommended factor is 0.507 tons of CO_2 per ton of clinker produced[3].the annual CO_2 emissions from clinker production is given by:

*(annual CO_2 emissions from clinker production)= 0.507 *(annual production of clinker).*

CO_2 from masonry cement production
Emissions are estimated using an emissions factor. This factor is equal to the amount of CO_2 released in tons per tons of masonry cement production. The recommended factor is 0.0224 tons of CO_2 per ton of masonry cement production. The annual CO_2 emissions from masonry cement production is given by:

*(annual CO_2 emissions from masonry cement production)= 0.0224 *(annual production of masonry cement).*

Total CO_2 emissions from cement production
The total CO_2 emissions from cement production is the sum of the two estimates above.

*(Total CO_2 emissions from cement production)= 0.507 *(annual production of clinker)+ 0.0224*(annual production of masonry cement).*

Data Sources:

1. U.S. Bureau of Mines. 1990. *Minerals Yearbook*.
2. U.S. Geological Survey. 1999. *Minerals Yearbook.*
3. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII*

CO_2 EMISSIONS FROM LIME PRODUCTION

Process Description:

Lime is among the most important chemicals produced in United States in terms of quantity. It is used in construction, pulp and paper manufacturing, and water and wastewater treatment. Lime manufacturing, through limestone heating, generates CO_2 emissions.

Required Data:

- Annual lime production in short tons in Pennsylvania.
- Amount of CO_2 recovered during manufacturing in tons in Pennsylvania.

Estimation Method:

Emissions are estimated using an emissions factor. This factor is equal to the amount of CO_2 released in tons per ton of lime produced. The recommended factor is 0.785. The annual CO_2 emissions from lime manufacturing is given by:

(CO_2 emissions from lime production in tons)=0.785(annual lime production in tons)-(amount of CO_2 recovered in tons).*

*To obtain the amount of emissions in MTCE, the total CO_2 emissions calculated above should be multiplied by 0.907*12/44.*

Data Sources:

1. U.S. Bureau of Mines. 1990. *Minerals Yearbook.*
2. U.S. Geological Survey. 1999. *Minerals Yearbook*.
3. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

CO_2 EMISSIONS FROM LIMESTONE USE

Process Description:

Limestone is a raw material used in different sectors such as construction, chemical, agriculture and metallurgical industries. CO_2 is generated as a by-product when limestone is heated during industrial processes. Two types of limestone are used: Calcite and Dolomite.

Required Data:

- The annual consumption of calcite in industrial processes in metric tons in Pennsylvania [1].
- The annual consumption of dolomite in industrial processes in metric tons in Pennsylvania [1].

Estimation Method:

CO_2 emissions from Calcite consumption
Emissions are estimated using an emissions factor[2]. This factor is equal to the amount of carbon released in tons per ton of Calcite consumed. The recommended factor is 0.12. A factor of 44/12 is used to give the results in terms of tons of CO_2 instead of tons of carbon. The annual CO_2 emissions from calcite consumption is given by:

*(CO_2 emissions from calcite consumption)=0.12*44/12*(annual calcite consumption).*

CO_2 emissions from Dolomite consumption

Emissions are estimated using an emissions factor. This factor is equal to the amount of carbon released in tons per ton of dolomite consumed. The recommended factor is 0.13. A factor of 44/12 is used to give the results in terms of tons of CO_2 instead of tons of carbon. The annual CO_2 emissions from dolomite consumption is given by:

*(CO_2 emissions from dolomite consumption)=0.13*44/12*(annual dolomite consumption).*

Total CO_2 emissions from limestone use

The annual CO_2 emissions from limestone use is the sum of the two estimates above.
*(Total CO_2 emissions from limestone use)=0.13*44/12*(annual dolomite consumption) + 0.12*44/12*(annual calcite consumption).*

To obtain the amount of emissions in MTCE, the total CO_2 emissions calculated above should be multiplied by 12/44.

Data Sources:

1. U.S. EPA. 2000. *U.S. Inventory of Greenhouse Gas and Sinks: 1990-1999.*
2. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

N_2O EMISSIONS FROM NITRIC ACID PRODUCTION

Process Description:

Nitric Acid is produced through the reaction of ammonia oxidation. This reaction also produces Nitrous Oxide (N_2O) as a by-product. Nitric Acid is used principally in the fertilizer industry and in the production of Adipic Acid, a feedstock for nylon.

Required Data:

- National emissions from Nitric Acid in MTCE [1,2].
- National capacity of Nitric Acid in tons [3].
- State capacity of Nitric Acid in tons [3].

Estimation Method:

Emissions are estimated using the ratio of Nitric Acid state capacity to national capacity. State emissions are derived from national emissions accordingly.

The annual N_2O emissions from Nitric Acid production is given by:

(annual state N_2O emissions from Nitric Acid production)=
(State capacity of Nitric Acid)/ (National capacity of Nitric Acid)(annual US N_2O emissions from Nitric Acid production).*

The emissions are given in metric tons of carbon equivalent (MTCE).

Data Sources:

1. U.S. EPA. 2000. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998.*
2. U.S. DOE. 2000. *U.S. Nitrous Oxide Emissions from Industrial Processes, 1990-1999.*
3. *Directory of Chemical Producers*.

HFCs AND PFCs EMISSIONS FROM COSUMPTION OF SUBSTITUTES FOR OZONE - DEPLETING SUBSTANCES (ODS)

Process Description:

Following the Montreal Protocol and the Clean Air Act Amendments of 1990, the production of several ODS, primarily CFCs, will come to a halt. Such substances are mainly used in motor vehicle air conditioning, commercial and industrial refrigeration and aerosols. PFCs and HFCs emerge as ozone-friendly substitutes. Their disadvantage is their global warming effect.

Required Data:

- National emissions [(1)] of HFCs and PFCs used as ODS substitutes in MTCE.
- National population [(2,3,4)].
- State population [(5)].

Estimation Method:

(state emissions)=(per capita emissions)(state population)*

Where per capita emissions is defined by:
(per capita emissions) = (national emissions)/(national Population).

The emissions are given in metric tons of carbon equivalent (MTCE).

Data Sources:

1. U.S. EPA. 2000. *U.S. Inventory of Greenhouse Gas and Sinks: 1990-1998.*
2. U.S. Bureau of the Census. 2000. *Historical National Population Estimates: July 1, 1900 to July 1, 1999. Population Estimates Program, Population Division.*
3. U.S. Bureau of the Census. 1995. *Intercentanal Estimates of the Total Resident Population of States: 1970 to 1980 Population Distribution and Population Estimates Branches*.
4. U.S. Bureau of the Census. 1995. *Intercentanal Estimates of the Total Resident Population of States: 1970 to 1980.*
5. U.S. Bureau of The Census. 2000. *State Population Estimates and Demographic Components of Population Change*: *April 1, 1990 to July 1, 1999. Population Estimates Program, Population Division, Washington, DC 20233.*

CO_2 EMISSIONS FROM SODA ASH MANUFACTURE AND CONSUMPTION

Process Description:

Soda Ash emits CO_2 while being produced and consumed. In the U.S, only California and Wyoming produce Soda Ash, and all other states are consumers. Hence, to evaluate Soda Ash emissions in Pennsylvania, we just estimate the amount of CO_2 emitted from Soda Ash consumed in the State.

Required Data:

- U.S. Soda Ash consumption in metric tons[(1)].
- National Population [(2)].
- State Population[(3)].

Estimation Method:

The consumption of Soda Ash in Pennsylvania is calculated by multiplying total consumption in the U.S. by the population ratio in Pennsylvania and the U.S.[(2,3)]. Multiplying the amount of Soda Ash by the emissions factor (0.11) [(4)] and carbon conversion factor(12/44).

*(annual CO_2 emissions from soda ash consumption = soda ash consumption in U.S. *population ratio *0.11*12/44)*

The emissions are given in metric tons of carbon equivalent (MTCE).

Data Resources:

1. U.S. Geological Survey, 2000. *Minerals Information..*
2. U.S. Bureau of Census, 2000. *Historical National Population Estimates: July 1, 1990 to July 1, 1999.* Population Distribution and Population Estimates Branches.
3. U.S. Bureau of Census, 2000. *State Population Estimates and Demographic Components of Population Change: April 1, 1990 to April 1, 1999.* Population Estimates Program, Population Division.
4. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

SF_6 EMISSIONS FROM MAGNESIUM PRODUCTION AND PROCESSING

Process Description:

Primary production of magnesium occurs only in Utah and Washington, but magnesium casting occurs all over United States. Both of these activities use SF_6 as a protective means against oxidation of molten magnesium. Indeed, SF_6 is used in small quantities in addition to other components to form a protective layer around the molten magnesium.

Required Data:

- Annual production of magnesium metal in the state in metric tons [1,2].
- Annual quantity of magnesium cast in the state in metric tons [1,2].

Estimation Method:

SF_6 from primary production of magnesium
For primary production of magnesium, a recommended emissions factor [3] is 0.001 tons SF_6 per ton of magnesium produced. The annual amount of SF_6 emissions from primary production is given by:

(SF_6 emissions from primary production)=0.001(annual production of primary magnesium).*

SF_6 from magnesium casting
For magnesium casting, the recommended emissions factor is 0.0041 tons SF_6 per ton of cast magnesium. The annual amount of SF_6 emissions from magnesium casting is given by:

(SF_6 emissions from magnesium casting)=0.0041(annual production cast magnesium).*

Total SF_6 emissions from magnesium production and processing
(total SF_6 Emissions from magnesium production and processing) = 0.0041*(annual production of cast magnesium)+0.001*(annual production of primary magnesium).

*To obtain the amount of emissions in metric tons of carbon equivalent (MTCE), the total SF_6 emissions calculated above should be multiplied by 23900*12/44, where 23900 is the global warming potential in relation to carbon.*

Data Sources:

1. U.S. Geological Survey. 1990. *Minerals Yearbook.*
2. U.S. Geological Survey. 1999. *Minerals Yearbook.*
3. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

CH_4 EMISSIONS FROM NATURAL GAS

Process Description:

Methane is emitted from natural gas production, processing, transmission, and distribution.

Required Data:

- Number of wells and processing plants in Pennsylvania [1,2].
- Miles of distribution, transmission and gathering pipelines in Pennsylvania [1].
- The amount of services [1].

Estimation Method:

Methane emission activities are divided into four segments and we estimated each segment separately. For estimating production emissions, the data required is the total number of wells [1] and miles of gathering pipeline[1].

To estimate methane emissions from processing, the data required is the number of gas processing plants[2].

To estimate methane emitted from natural gas transmission, the data required is the total miles of transmission pipeline [1]. We used the default given by EPA Guide Book [3] to estimate the number of transmission stations and storage stations by the length of transmission pipeline [1]. Data on LNG storage stations is not available. This source, however, can be omitted since the emissions are minimal.

To estimate gas distribution emissions, the data required are the total number of services (i.e. amount of gas consumed) [1] and the miles of distribution pipeline[1].

After gathering the basic data, we accessed the emissions factors for each activity given by the EPA Guide Book to calculate the metric tons of methane emissions.

a. *(emissions from production = # of wells*2.5+ miles of gathering pipeline*0.37)*
b. *(emissions from processing = # of processing plants*948)*
c. *(emissions from transmission = miles of transmission pipeline*0.68+ # of transmission stations*891+ # of storage stations*914)*
d. *(emissions from distribution = # of services*0.014 +# of protected steel services*0.0035 + # of unprotected steel services*0.03+ miles of distribution pipeline*0.7)*
(annual methane emissions from natural gas = a + b + c + d)

*To obtain the amount of emissions in metric tons of carbon equivalent (MTCE), the CH_4 emissions calculated above should be multiplied by 21*12/44, where 21 is CH_4 Global Warming Potential in relation to carbon.*

Data Sources:

1. American Gas Association (AGA). 1991 & 2000. *Gas Facts*.
2. Energy Information Administration/Department of Energy (EIA). 1990 & 1999. *Natural Gas Annual*.
3. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VII.*

CH_4 EMISSIONS FROM OIL

Process Description:

Methane is emitted from oil production, transportation, and refining.

Required Data:

- Oil produced in Pennsylvania [(1)].
- Natural gas produced in Pennsylvania [(2)].

Estimation Method:

To convert oil produced from barrels to MMBtu, we multiplied each barrel by 5.8[(3)].

To estimate methane emitted from oil transportation and refining, the data required is the total amount of oil refined and stored at oil facilities[(4)]. We assumed that oil refined is equal to oil stored in the state.

After gathering the basic data, we accessed the emissions factors for each activity given by EPA Guide Book[(3)] to calculate tons of methane emissions for each stage.

*(annual methane emissions from oil in tons = annual oil & natural gas production * emission factor of each stage)*

*To obtain the amount of emissions in metric tons of carbon equivalent (MTCE), the CH_4 emissions calculated above should be multiplied by 0.9072*21*12/44, where 0.9072 is the conversion factor from tons to metric tons and 21 is CH_4 Global Warming Potential in relation to carbon.*

Data Sources:

1. American Petroleum Institute (API). 2000. *Basic Petroleum Data Book*.
2. American Gas Association (AGA). 1991 & 2000. *Gas Facts*.
3. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*
4. American Petroleum Institute (API). 2000. *Basic Petroleum Data Book*.

CH_4 EMISSIONS FROM COAL MINING

Process Description:

Methane is emitted from coal underground mining, surface mining and post-mining activities.

Required Data:

- Ventilation emissions and degasification system of each mine in cubic feet in Pennsylvania [1].
- Annual production of underground and surface coal mined in tons in Pennsylvania [2].

Estimation Method:

To estimate methane emissions from underground mining, the data required are the total methane liberated from ventilation systems and the total methane liberated from degasification systems[1]. To estimate methane emissions from surface mining, the data required is the total amount of coal produced from surface mining in the state [2]. To estimate post-mining activities, the data required is the total amount of coal produced from underground and surface mining. After gathering the basic data, we accessed the emission factors for each type of activity given by the EPA Guide Book[3] to calculate the cubic feet of methane emissions.

(annual CH_4 emissions from coal mining in cubic feet = annual production of mine emission factor + emissions from ventilation and degasification system)*

*To obtain the amount of emissions in metric tons of carbon equivalent (MTCE), the CH_4 emissions calculated above should be multiplied by 0.0000192*21*12/44, where 0.0000192 is the conversion factor from cubic feet to metric tons and 21 is CH_4 Global Warming Potential in relation to carbon.*

Data Sources:

1. Mine Safety Health Administration (MSHA).
2. Energy Information Administration (EIA). 1999. *State Energy Report*.
3. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

GHG EMISSIONS FROM MUNICIPAL WASTE MANAGEMENT

Process Description:

CH_4 emitted from landfills, CO_2 sequestered in landfills, and CO_2 and N_2O from combustion of MSW.

Required Data:

- Annual Amount of MSW landfilled and combusted in Pennsylvania [1,2,3].
- Total Waste in Place, by landfill type in Pennsylvania [3].
- Methane recovery in Pennsylvania [4].

Estimation Method:

Annual municipal solid waste combusted and landfilled was estimated using data on total solid waste combusted and landfilled [1,2] and proportion of that waste that was MSW [3]. Total Waste in place was estimated using regional averages provided by the EPA Methodology [3]. The appropriate conversion factors [3] were applied to each type of waste and process to determine the total amount of each gas emitted, which were then converted into MTCE.

Data Sources:

1. Glenn, Jim 1992. *The State of Garbage*. BioCycle. April 1992, pp 46-55
2. Glenn, Jim 1999. *The State of Garbage*. BioCycle. April 1999, pp 60-71
3. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*
4. EPA Landfill Methane Outreach Program (www.epa.gov).

CH_4 EMISSIONS FROM DOMESTIC ANIMALS

Process Description:

CH_4 emitted by domesticated animals.

Required Data:

- Number of Animals, by type and size in Pennsylvania [1,2,3].

Estimation Method:

The number of animals for each classification was multiplied by animal-specific conversion factors provided [4], to determine the volume of methane emitted. This was then converted into MTCE and summed.

Data Sources:

1. Mark Linstedt, Agricultural Statistician, Pennsylvania Agricultural Statistics Service
2. USDA Website (www.usda.gov)
3. Census of Agriculture, 1987, 1992, 1997
4. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

GHG EMISSIONS FROM MANURE MANAGEMENT

Process Description:

CH_4 and N_2O emitted from management of the manure of domesticated animals.

Required Data:

- Number of Animals, by type and size in Pennsylvania [1,2,3].
- Percentage of each type of manure processed by each manure management practice[4].

Estimation Method:

The number of animals for each classification was multiplied by animal-specific conversion factors provided [4], to determine the volume of volatile solids produced, which was then converted into total maximum potential methane and nitrogen emissions. For each animal type, regional averages of the proportion of each manure-management practice used [4] were applied, along with their corresponding conversion factors [4], to determine the volume of gas emitted, by animal type and manure-management practice. These values were then summed and converted to MTCE.

Data Sources:

1. Mark Linstedt, Agricultural Statistician, Pennsylvania Agricultural Statistics Service
2. USDA Website (www.usda.gov)
3. Census of Agriculture, 1987, 1992, 1997
4. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

GHG EMISSIONS FROM COMBUSTION OF AGRICULTURAL WASTE

Process Description:

CH_4 and N_2O emitted from the burning of crop residues from rice, wheat, and sugarcane.

Required Data:

- Crop Production in Pennsylvania [1].

Estimation Method:

The volume of crop produced is converted using standard conversion factors [2] into crop residue, which is then converted using average percentage burned, proportion of dry matter, burning efficiency, carbon content, nitrogen content, and other appropriate conversion factors [2] into total gasses emitted by each crop. These values are summed and then converted into MTCE.

Data Sources:

1. USDA Website (www.usda.gov)
2. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

GHG EMISSIONS FROM MUNICIPAL WASTE WATER MANAGEMENT

Process Description:

CH_4 and N_2O emitted from the management of municipal waste water

Required Data:

- Volume of waste water generated, by treatment method [1].

Estimation Method:

The volume of waste water generated is estimated by population, using regional averages. Conversion factors and proportion of waste water treated using each process are provided by the EPA Methodology and applied to the estimates of waste-water generation to estimate total gasses emitted, and these values are summed and converted to MTCE.

Data Sources:

1. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

GHG EMISSIONS FROM MOBILE FOSSIL FUEL COMBUSTION

Process Description:

CH_4 and N_2O emitted from highway and non-highway vehicles burning fossil fuels.

Required Data:

- Vehicle miles traveled, by highway vehicle type in Pennsylvania [1,2].
- Fuel combusted by non-highway vehicles in Pennsylvania [3].

Estimation Method:

For highway vehicles, vehicle-miles traveled, by vehicle type are converted using national time-dependent averages for vehicle classification, emission controls in place and methane and nitrous oxide emissions coefficients [4] to estimate the volume of each gas emitted by each vehicle type. These values are then converted to MTCE.

For non-highway vehicles, fuel purchased in the state is assumed to be combusted in the state, and these values are multiplied by simple conversion factors [4] to estimate the volume of methane and nitrous oxide emitted. These values are then summed and converted to MTCE.

Data Sources:

1. OHIM, 1994. *Highway Statistics 1994.* Washington, DC: Office of Highway Information Management, Department of Transportation. http://www.fhwa.dot.gov/ohim/ohimstat.htm
2. OHIM, 1999. *Highway Statistics 1999.* Washington, DC: Office of Highway Information Management, Department of Transportation. http://www.fhwa.dot.gov/ohim/ohimstat.htm
3. Energy Information Administration (EIA). 1999. *State Energy Report*.
4. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

N_2O EMISSIONS FROM STATIONARY COMBUSTION

Process Description:

N_2O emissions from stationary sectors (residential, commercial, industrial, and electric utilities) combustion of fossil fuels (natural gas, coal, gasoline, etc.).

Required Data:

- Annual amount of coal, oil and natural gas in MMBtu consumed by each stationary sector[(1)].

Estimation Method:

We obtained all fossil fuels consumed by energy type and by sector in MMBtu[(1)]. Since the data are in higher heating values, we transferred them to lower heating values in order to eliminate the effect of moisture in the fuel during combustion. We multiplied the higher heating value of petroleum and coal by 0.95 and natural gas by 0.9 to get the lower heating value.

We accessed the emission factors[(2)] for each activity to calculate pounds of N_2O emissions.

*(annual N_2O emissions from stationary combustion in pounds = consumption of each fuel by sectors*emission factor)*

*To obtain the amount of emissions in metric tons of carbon equivalent (MTCE), the N_2O emissions calculated above should be multiplied by 1/2205 and 310*12/44, where1/2205 is the conversion factor from pounds to metric tons and 310 is N_2O Global Warming Potential in relation to carbon.*

Data Sources:

1. Energy Information Administration (EIA). 1999. *State Energy Report*.

2. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

CH4 EMISSIONS FROM STATIONARY COMBUSTION

Process Description:

CH_4 emissions from stationary sectors (residential, commercial, industrial, and electric utilities) combustion of natural gas, coal, gasoline and wood.

Required Data:

- Annual amount of Wood, Coal, Oil and Natural Gas in TBtu consumed by each stationary sector in Pennsylvania [(1)].

Estimation Method:

We obtain all fossil fuels consumed by energy type and by sector in MMBtu[(1)]. Since the data in MMBtu are in higher heating values, we have to transfer the data to lower heating values in MMBtu in order to get rid of the effect of moisture in the fuel when combustion happened. We multiply the higher heating value of the amount of petroleum, coal and wood by 0.95 and natural gas by 0.9 to get lower heating value. Then we convert MMBtu of each energy type to terajoules of each energy type by multiplying 1/947.8.

Referring to EPA Guide Book[(2)], the performance of pollution control can be ignored for CH_4. We accessed the emission factors[(2)] for each sector category and technology subcategory given by the EPA Guide Book to calculate the estimated emissions factors by weighting average. Then we use estimating emission factors and terajoules of each type of fossil fuel consumed to calculate CH_4 emissions in metric tons.

a. *(emissions from coal = consumption of coal *0.95* emission factor)*
b. *(emissions from oil = consumption of oil* 0.95*emission factor)*
c. *(emissions from gas = consumption of gas*0.9* emission factor)*
d. *(emissions from wood = consumption of gas*0.95* emission factor)*

(annual CH_4 emissions from stationary combustion = a + b + c + d)

*To obtain the amount of emissions in metric tons of carbon equivalent (MTCE), the CH_4 emissions calculated above should be multiplied by 21*12/44, where 21 is CH_4 Global Warming Potential in relation to carbon.*

Data Sources:

1. *Energy Information Administration (EIA). 1999. State Energy Report.*

2. Emission Inventory Improvement Program (EIIP), 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX B. SPREADSHEET CALCULATIONS

Note: Table numbers in this appendix correspond to chapters in Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX B-1

Calculation of Carbon Dioxide Emissions from Fossil Fuel Combustion

Table B.1-1: 1990 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuel in Pennsylvania - Residential

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
	(A) Consumption[a] (10^6 BTU)	(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)	(C) Total Carbon (tons C)	(D) Stored Carbon (tons C)	(E) International Bunkers (tons C)	Fraction Oxidized[b]	(F) Net Carbon Emissions (MTCE)
RESIDENTIAL							
Asphalt and Road Oil		45.5					
Aviation Gasoline		41.6				0.990	
Distillate Fuel Oil	99,100,000	44.0	2,180,200			0.990	1,958,099
Jet Fuel: Kerosene Type		43.5				0.990	
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene	7,800,000	43.5	169,650			0.990	152,367
Liquified Petroleum Gas	9,200,000	37.8	173,880			0.990	156,166
Lubricants		44.6					
Misc. Petroleum Products		44.7					
Motor Gasoline		42.8				0.990	
Naptha		40.0					
Other Oil		44.0					
Pentane Plus		40.2					
Petroleum Coke		61.4					
Residual Fuel Oil		47.4				0.990	
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal	17,700,000	56.2	497,370			0.990	446,702
Coke							
Natural Gas	248,900,000	31.9	3,969,955			0.995	3,583,535
RESIDENTIAL TOTAL	382,700,000		6,991,055.0				6,296,870

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-2: 1990 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuel in Pennsylvania - Commercial

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	**(A) Consumption[a] (10^6 BTU)**	**(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)**	**(C) Total Carbon (tons C)**	**(D) Stored Carbon (tons C)**	**(E) Internat'l Bunkers (tons C)**	**Fraction Oxidized[b]**	**(F) Net Carbon Emissions (MTCE)**
COMMERCIAL							
Asphalt and Road Oil		45.5					
Aviation Gasoline		41.6				0.990	
Distillate Fuel Oil	32,600,000	44.0	717,200			0.990	644,137
Jet Fuel: Kerosene Type		43.5				0.990	
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene	900,000	43.5	19,575			0.990	17,581
Liquified Petroleum Gas	1,600,000	37.8	30,240			0.990	27,159
Lubricants		44.6					
Misc. Petroleum Products		44.7					
Motor Gasoline	3,700,000	42.8	79,180			0.990	71,114
Naptha		40.0					
Other Oil		44.0					
Pentane Plus		40.2					
Petroleum Coke		61.4					
Residual Fuel Oil	5,100,000	47.4	120,870			0.990	108,557
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal	15,200,000	56.2	427,120			0.990	383,608
Coke							
Natural Gas	130,300,000	31.9	2,078,285			0.995	1,875,993
COMMERCIAL TOTAL	189,400,000		3,472,470				3,128,150

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-3: 1990 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuel in Pennsylvania - Industrial

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	(A) Consumption[a] (10^6 BTU)	(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)	(C) Total Carbon (tons C)	(D) Stored Carbon (tons C)	(E) International Bunkers (tons C)	Fraction Oxidized[b]	(F) Net Carbon Emissions (MTCE)
INDUSTRIAL							
Asphalt and Road Oil	49,500,000	45.5	1,126,125			0.990	1,011,404
Aviation Gasoline		41.6				0.990	
Distillate Fuel Oil	36,700,000	44.0	807,400			0.990	725,149
Jet Fuel: Kerosene Type		43.5				0.990	
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene	700,000	43.5	15,225			0.990	13,674
Liquified Petroleum Gas	11,500,000	37.8	217,350			0.990	195,208
Lubricants	17,100,000	44.6	381,330			0.990	342,483
Misc. Petroleum Products		44.7					
Motor Gasoline	6,200,000	42.8	132,680			0.990	119,164
Naptha		40.0					
Other Oil	113,900,000	44.0	2,505,800			0.990	2,250,529
Pentane Plus		40.2					
Petroleum Coke		61.4					
Residual Fuel Oil	36,600,000	47.4	867,420			0.990	779,054
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal	107,400,000	56.2	3,017,940			0.990	2,710,496
Coke	274,700,000	56.3	7,732,805			0.990	6,945,049
Natural Gas	250,300,000	31.9	3,992,285			0.995	3,603,692
INDUSTRIAL TOTAL	904,600,000		20,796,360				18,695,902

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-4: 1990 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuel in Pennsylvania - Transportation

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	**(A) Consumption[a] (10^6 BTU)**	**(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)**	**(C) Total Carbon (tons C)**	**(D) Stored Carbon (tons C)**	**(E) International Bunkers (tons C)**	**Fraction Oxidized[b]**	**(F) Net Carbon Emissions (MTCE)**
TRANSPORTATION							
Asphalt and Road Oil		45.5					
Aviation Gasoline	700,000	41.6	14,560			0.990	13,077
Distillate Fuel Oil	138,800,000	44.0	3,053,600			0.990	2,742,524
Jet Fuel: Kerosene Type	68,200,000	43.5	1,483,350			0.990	1,332,238
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene		43.5				0.990	
Liquified Petroleum Gas	600,000	37.8	11,340			0.990	10,185
Lubricants	8,100,000	44.6	180,630				
Misc. Petroleum Products		44.7					
Motor Gasoline	554,600,000	42.8	11,868,440			0.990	10,659,378
Naptha		40.0					
Other Oil		44.0					
Pentane Plus		40.2					
Petroleum Coke		61.4					
Residual Fuel Oil	35,600,000	47.4	843,720			0.990	757,769
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal		56.2				0.990	
Coke							
Natural Gas	35,700,000	31.9	569,415			0.995	513,990
TRANSPORTATION TOTAL	842,300,000		18,025,055				16,029,161

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-5: 1990 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuel in Pennsylvania - Electricity Generation

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	**(A) Consumption[a] (10^6 BTU)**	**(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)**	**(C) Total Carbon (tons C)**	**(D) Stored Carbon (tons C)**	**(E) International Bunkers (tons C)**	**Fraction Oxidized[b]**	**(F) Net Carbon Emissions (MTCE)**
Asphalt and Road Oil		45.5					
Aviation Gasoline		41.6				0.990	
Distillate Fuel Oil	6,900,000	44.0	151,800			0.990	136,336
Jet Fuel: Kerosene Type		43.5				0.990	
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene		43.5				0.990	
Liquified Petroleum Gas		37.8				0.990	
Lubricants		44.6					
Misc. Petroleum Products		44.7					
Motor Gasoline		42.8				0.990	
Naptha		40.0					
Other Oil		44.0					
Pentane Plus		40.2					
Petroleum Coke	6,100,000	61.4	187,270			0.990	168,192
Residual Fuel Oil	34,000,000	47.4	805,800			0.990	723,712
Still Gas		43.8					
Waxes		43.7					
Antrhacite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal	1,044,848,000	56.2	29,360,229			0.990	26,369,244
Coke							
Natural Gas	2,400,000	31.9	38,280			0.995	34,554
ELECTRICITY GENERATION TOTAL	1,094,248,000	N/A	30,543,379				27,432,037

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-6: 1999 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuels in Pennsylvania - Residential

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	**(A) Consumption[a] (10^6 BTU)**	**(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)**	**(C) Total Carbon (tons C)**	**(D) Stored Carbon (tons C)**	**(E) International Bunkers (tons C)**	**Fraction Oxidized[b]**	**(F) Net Carbon Emissions (MTCE)**
Asphalt and Road Oil		45.5					
Aviation Gasoline		41.6				0.990	
Distillate Fuel Oil	112,300,000	44.0	2,470,600			0.990	2,218,915
Jet Fuel: Kerosene Type		43.5				0.990	
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene	14,300,000	43.5	311,025			0.990	279,340
Liquified Petroleum Gas	13,500,000	37.8	255,150			0.990	229,157
Lubricants		44.6					
Misc. Petroleum Products		44.7					
Motor Gasoline		42.8				0.990	
Naptha		40.0					
Other Oil		44.0					
Pentane Plus		40.2					
Petroleum Coke		61.4					
Residual Fuel Oil		47.4				0.990	
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal	9,000,000	55.1	247,950			0.990	222,691
Coke							
Natural Gas	250,200,000	31.9	3,990,690			0.995	3,602,252
RESIDENTIAL TOTAL	399,300,000		7,275,415				6,552,356

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-7: 1999 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuels in Pennsylvania - Commercial

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	**(A) Consumption[a] (10^6 BTU)**	**(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)**	**(C) Total Carbon (tons C)**	**(D) Stored Carbon (tons C)**	**(E) International Bunkers[c] (tons C)**	**Fraction Oxidized[b]**	**(F) Net Carbon Emissions (MTCE)**
Asphalt and Road Oil		45.5					
Aviation Gasoline		41.6				0.990	
Distillate Fuel Oil	27,800,000	44.0	611,600			0.990	549,295
Jet Fuel: Kerosene Type		43.5				0.990	
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene	2,000,000	43.5	43,500			0.990	39,069
Liquified Petroleum Gas	2,400,000	37.8	45,360			0.990	40,739
Lubricants		44.6					
Misc. Petroleum Products		44.7					
Motor Gasoline	1,000,000	42.8	21,400			0.990	19,220
Naptha		40.0					
Other Oil		44.0					
Pentane Plus		40.2					
Petroleum Coke		61.4					
Residual Fuel Oil	4,100,000	47.4	97,170			0.990	87,271
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal	8,100,000	55.1	223,155			0.990	200,422
Coke							
Natural Gas	148,400,000	31.9	2,366,980			0.995	2,136,588
COMMERCIAL TOTAL	193,800,000		3,409,165				3,072,603

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-8: 1999 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuels in Pennsylvania - Industrial

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	**(A) Consumption[a] (10^6 BTU)**	**(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)**	**(C) Total Carbon (tons C)**	**(D) Stored Carbon (tons C)**	**(E) International Bunkers (tons C)**	**Fraction Oxidized[b]**	**(F) Net Carbon Emissions (MTCE)**
Asphalt and Road Oil	33,200,000	45.5	755,300			0.990	678,356
Aviation Gasoline		41.6				0.990	
Distillate Fuel Oil	29,500,000	44.0	649,000			0.990	582,885
Jet Fuel: Kerosene Type		43.5				0.990	
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene	1,100,000	43.5	23,925			0.990	21,488
Liquified Petroleum Gas	4,300,000	37.8	81,270			0.990	72,991
Lubricants	17,700,000	44.6	394,710			0.990	354,500
Misc. Petroleum Products		44.7					
Motor Gasoline	3,900,000	42.8	83,460			0.990	74,958
Naptha		40.0					
Other Oil	122,300,000	44.0	2,690,600			0.990	2,416,503
Pentane Plus		40.2					
Petroleum Coke		61.4					
Residual Fuel Oil	14,400,000	47.4	341,280			0.990	306,513
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal	94,100,000	55.1	2,592,455			0.990	2,328,356
Coke	169,900,000	56.3	4,782,685			0.990	4,295,463
Natural Gas	249,600,000	31.9	3,981,120			0.995	3,593,614
INDUSTRIAL TOTAL	740,000,000		16,375,805				14,725,627

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-9: 1999 Worksheet to Calculate CO_2 Emissions in MTCE from Fossil Fuels in Pennsylvania - Transportation

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	**(A) Consumption[a] (10^6 BTU)**	**(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)**	**(C) Total Carbon (tons C)**	**(D) Stored Carbon (tons C)**	**(E) International Bunkers (tons C)**	**Fraction Oxidized[b]**	**(F) Net Carbon Emissions (MTCE)**
Asphalt and Road Oil		45.5					
Aviation Gasoline	1,000,000	41.6	20,800			0.990	18,681
Distillate Fuel Oil	197,600,000	44.0	4,347,200			0.990	3,904,342
Jet Fuel: Kerosene Type	90,400,000	43.5	1,966,200			0.990	1,765,899
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene		43.5				0.990	
Liquified Petroleum Gas	300,000	37.8	5,670			0.990	5,092
Lubricants	8,400,000	44.6	187,320				
Misc. Petroleum Products		44.7					
Motor Gasoline	607,000,000	42.8	12,989,800			0.990	11,666,503
Naptha		40.0					
Other Oil		44.0					
Pentane Plus		40.2					
Petroleum Coke		61.4					
Residual Fuel Oil	37,800,000	47.4	895,860			0.990	804,597
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal and Lignite[d]		55.1				0.990	
Coke							
Natural Gas	37,300,000	31.9	594,935			0.995	537,026
TRANSPORTATION TOTAL	979,800,000		21,007,785				18,702,141

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.1-10: 1999 Worksheet to Calculate CO2 Emissions in MTCE from Fossil Fuels in Pennsylvania - Electricity Generation

	Input	Input	(A) x (B) / 2000	Input	Input	Input	[(C) - (D) -(E)]* Fraction Oxidized*.9072 Metric Tons/Ton
Sector/Fuel	**(A) Consumption[a] (10^6 BTU)**	**(B) Carbon Content Coefficient[b] (lbs C/10^6 BTU)**	**(C) Total Carbon (tons C)**	**(D) Stored Carbon (tons C)**	**(E) International Bunkers (tons C)**	**Fraction Oxidized[b]**	**(F) Net Carbon Emissions (MTCE)**
Asphalt and Road Oil		45.5					
Aviation Gasoline		41.6				0.990	
Distillate Fuel Oil	6,800,000	44.0	149,600			0.990	134,360
Jet Fuel: Kerosene Type		43.5				0.990	
Jet Fuel: Naptha Type		43.5				0.990	
Kerosene		43.5				0.990	
Liquified Petroleum Gas		37.8				0.990	
Lubricants		44.6					
Misc. Petroleum Products		44.7					
Motor Gasoline		42.8				0.990	
Naptha		40.0					
Other Oil		44.0					
Pentane Plus		40.2					
Petroleum Coke	4,300,000	61.4	132,010			0.990	118,562
Residual Fuel Oil	27,800,000	47.4	658,860			0.990	591,741
Still Gas		43.8					
Waxes		43.7					
Anthracite Coal		62.1				0.990	
Sub-bituminous Coal		57.9				0.990	
Lignite Coal		58.7				0.990	
Bituminous Coal	1,128,566,000	55.1	31,091,993			0.990	27,924,590
Coke							
Natural Gas	10,736,000	31.9	171,239			0.995	154,571
ELECTRICITY GENERATION TOTAL	1,178,202,000		32,203,703				28,923,824

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX B-2

Calculation of Greenhouse Gas Emissions from Industrial Processes

Table B.2-1: 1990 Worksheet To Calculate CO_2 Emissions from Soda Ash

Activity	Input (metric tons) [a]	Emission Factor (tons CO_2/ton soda ash)[b]	Annual CO_2 Emissions(tons)	Net CO_2 Emission(MTCE)
SODA ASH MANUFACTURE				
Trona Produced[c]	0	0.0974	0	0
SODA ASH CONSUMPTION				
Soda Ash Consumption[d]	326,162	0.415	135,357	36,916
Total	326,162		135,357	36,916

a.Soda ash consumption data is taken from U.S. Geological Survey, 2000. Minerals Information
http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/
b.Emission factors: EPA Emission Inventory Improvement Program (EIIP), 1999.
Estimating Greenhouse Gas Emissions, Volume VIII.
c.Trona is the raw mineral used to produce Soda Ash. Only Wyoming and California produce soda ash.
d.Soda ash consumption in Pennsylvania is estimated by:
total consumption in U.S. * population in Pennsylvania/ population in U.S.

Table B.2-2: 1999 Worksheet To Calculate CO_2 Emissions from Soda Ash

Activity	Input (metric tons) [a]	Emission Factor (tons CO_2/ton soda ash)[b]	Annual CO_2 Emissions(tons)	Net CO_2 Emission(MTCE)
SODA ASH MANUFACTURE				
Trona Produced[c]	0	0.0974	0	0
SODA ASH CONSUMPTION				
Soda Ash Consumption[d]	282,816	0.415	117,369	32,010
Total	282,816		117,369	32,010

a.Soda ash consumption data is taken from U.S. Geological Survey, 2000. Minerals Information
http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/
b.Emission factors: EPA Emission Inventory Improvement Program (EIIP), 1999.
Estimating Greenhouse Gas Emissions, Volume VIII.
c.Trona is the raw mineral used to produce Soda Ash. Only Wyoming and California produce soda ash.
d.Soda ash consumption in Pennsylvania is estimated by:
total consumption in U.S. * population in Pennsylvania/ population in U.S.

Table B.2-3: 1990 Worksheet to Calculate CO_2 Emissions from Cement Production

Activity	Input (tons)	Emission Factor	Annual CO_2 Emissions (tons)	Net CO_2 Emission (MTCE)
Clinker Production (CP) in short tons	5,668,000	0.507	2,873,676	711,000
Masonry Cement Production (MCP) in short tons	303,000	0.0224	6,787	1,679
Total	5,971,000		2,880,463	712,522

Table B.2-4: 1999 Worksheet to Calculate CO_2 Emissions from Cement Production

Activity	Input (tons)	Emission Factor	Annual CO_2 Emissions (tons)	Net CO_2 Emission (MTCE)
Clinker Production (CP) in short tons	7,715,200	0.507	3,911,606	967,803
Masonry Cement Production (MCP) in short tons	327,000	0.0224	7,325	1,812
Total	8,042,200		3,918,931	969,401

Computations:

CP in 1999

Computed as (CP in 1990 / National Production of Clinker in 1990) * (National Production of Clinker in 1999).

CO_2 Emissions from Cement Production (ECP)

Computed as CP*0.507+MCP*0.0224 (0.507 and 0.0224 are Emissions Factors).

Data Sources:

CP and MCP in 1990: U.S. Bureau of Mines. 1990. *"Minerals Yearbook."*
MCP in 1999: U.S. Geological Survey. 1999. *"Minerals Yearbook."*
Emission Factors: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.2-5: 1990 Worksheet to Calculate CO_2 Emissions from Lime

Activity	Input (Tons)	Emission Factor	CO2 recovered in tons per ton of lime produced.	Annual CO_2 Emissions (tons)	Net CO_2 Emission (MTCE)
Lime Production	1,626,000	0.785	0.03277	1,223,126	302,557

Table B.2-6: 1999 Worksheet to Calculate CO_2 Emissions from Lime

Activity	Input (tons)	Emission Factor	CO2 recovered in tons per ton of lime produced.	Annual CO_2 Emissions (tons)	Net CO_2 Emission (MTCE)
Lime Production	1,350,000	0.785	0.03277	1,015,511	251,200

Computations:

CO_2 Emissions from Lime Production (ELP)

Computed as LP*0.785-LP*0.03277 where: 0.785 is the emission factor,

0.03277 is the amount of CO2 recovered in tons per ton of lime produced.

0.03277 is computed as (CO_2 recovered in 1990)/(lime production in 1990).

Data Sources:

LP in 1990: U.S. Bureau of Mines. 1990. "Minerals Yearbook."

LP in 1999: U.S. Geological Survey. 1999. "Minerals Yearbook."

Emission Factors: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

CO2 Recovered: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.2-7: 1990 Worksheet to Calculate CO_2 Emissions from Limestone Use

Activity	Input (tons)	Emission Factor	Annual CO_2 Emissions (tons)	Net CO_2 Emission (MTCE)
Limestone Use (LU)	281,290	0.12	33,755	8,352
Dolomite Use (DU)	14,623	0.13	1,901	470
Total	295,913		35,656	8,822

Table B.2-8: 1999 Worksheet to Calculate CO_2 Emissions from Limestone Use

Activity	Input (tons)	Emission Factor	Annual CO_2 Emissions (tons)	Net CO_2 Emission (MTCE)
Limestone Use (LU)	439,537	0.12	52,744	13,047
Dolomite Use (DU)	32,411	0.13	4,213	1,042
Total	471,948		56,958	14,089

Computations:

CO_2 Emissions from Limestone Use (ELU)

Computed as LU*0.12+DU*0.13 where: 0.12 is the emissions factor for limestone,
0.13 the emissions factor for dolomite use.

Data Sources:

LU in 1990: U.S. EPA. 2000. *"U.S. Inventory of Greenhouse Gas and Sinks: 1990-1999."*
LU in 1999: U.S. EPA. 2000. *"U.S. Inventory of Greenhouse Gas and Sinks: 1990-1999."*
DU in 1990: U.S. EPA. 2000. *"U.S. Inventory of Greenhouse Gas and Sinks: 1990-1999."*
DU in 1999: U.S. EPA. 2000. *"U.S. Inventory of Greenhouse Gas and Sinks: 1990-1999."*
Emission Factors: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.2-9: 1990 Worksheet to Calculate SF_6 Emissions from Magnesium

Activity	National Production of cast magnesium (NPC) in metric tons	Ratio of casting activity in Pennsylvania to National casting activity	State Production of cast magnesium (SPC) in metric tons	Emission Factor	Annual SF6 Emissions (tons)	Net CO2 Emission (MTCE)
Magnesium Production and Processing	19,650	0.06	1,179	0.0041	5	31,508

Table B.2-10: 1999 Worksheet to Calculate SF_6 Emissions from Magnesium

Activity	National Production of cast magnesium (NPC) in metric tons	Ratio of casting activity in Pennsylvania to National casting activity	State Production of cast magnesium (SPC) in metric tons	Emission Factor	Annual SF6 Emissions (tons)	Net CO2 Emission (MTCE)
Magnesium Production and Processing	49,181	0.06	2,951	0.0041	12	78,860

Computations

State Production of Cast Magnesiun (SPC)
Computed as 0.06*NPC

0.06 is the ratio of casting activity in Pennsylvania to national casting activity.

SF_6 Emissions from Magnesiun Production (SEM)
Computed as SPC*0.0041 (0.0041 is the emissions factor).

Data Sources:

NPC in 1990: U.S. Geological Survey. 1990. "Minerals Yearbook."
NPC in 1999: U.S. Geological Survey. 1999. "Minerals Yearbook."
Emission Factors: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.2-11: 1990 Worksheet to Calculate N_2O from Nitric Acid

U.S. Emissions (MTCE)	U.S. Production Capacity	PA Production Capacity	Capacities Ratio	PA Emissions (MTCE)
4,900,000	8,635,000	190,000	0.0220	107,817

Table B.2-12: 1999 Worksheet to Calculate N_2O from Nitric Acid

U.S. Emissions (MTCE)	U.S. Production Capacity	PA Production Capacity	Capacities Ratio	PA Emissions (MTCE)
5,568,000	10,445,000	190,000	0.0182	101,285

Data Sources:

NEM for 1990: U.S. EPA. 2000. *"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998."*
NEM for 1999: U.S. DOE. 2000. *"U.S. Nitrous Oxide Emissions from Industrial Processes, 1990-1999."*
NPC for 1990 and 1999: Directory of Chemical Producers.

Table B.2-13: 1990 Worksheet to Calculate HFCs and PFCs from Consumption of Substitutes of Depleting Substances

U.S. Emissions (MTCE)	U.S. Population (NP)	PA Population (PP)	Per Capita Emissions (PCE)	PA Emissions (MTCE)
300,000	249,464,400	11,895,600	0.0012	14,305

Table B.2-14: 1999 Worksheet to Calculate HFCs and PFCs from Consumption of Substitutes of Depleting Substances

U.S. Emissions (MTCE)	U.S. Population (NP)	PA Population (PP)	Per Capita Emissions (PCE)	PA Emissions (MTCE)
18,526,100	272,690,800	11,994,000	0.07	814,850

Computations:

National Emissions (NEM)
NEM in 1999: Computed using the average annual growth rate for for the period 1996-1998.

Per Capita Emissions
Computed as (NEM/NP)

Pennsylvania Emissions
Computed as (PCE*PP)

Data Sources:

NEM in 1990: U.S. EPA. 2000. *"U.S. Inventory of Greenhouse Gas and Sinks: 1990-1998."*
NP : U.S. Bureau of the Census. 2000. *"Historical National Population Estimates: July 1, 1900 to July 1, 1999."* Population Estimates Program, Population Division.
PP : U.S. Bureau of The Census. 2000. *"State Population Estimates and Demographic Components of Population Change: April 1, 1990 to July 1, 1999."* Population Estimates Program, Population Division, Washington, DC 20233.

Table B.2-15: 1990 Worksheet to Calculate SF6 from Electric Utilities

U.S. Emissions (MTCE)	U.S. Electricity Consumption	PA Electricity Consumption	Consumption Ratio	PA Emissions (MTCE)
5,600,000	2,817,000	110,882	0.04	220,426

Table B.2-16: 1999 Worksheet to Calculate SF6 from Electric Utilities

U.S. Emissions (MTCE)	U.S. Electricity Consumption	PA Electricity Consumption	Consumption Ratio	PA Emissions (MTCE)
7,000,000	3,501,000	128,491	0.04	256,909

Computations:

National SF_6 Emissions
NE for 1999: Extrapolation of EPA estimates for 1996-98 to the year 1999.
Row PEC/NEC
Computed as (row PEC/ row NEC).
Pennsylvania SF_6 Emissions
Computed as (row NEM times row (PEC/NEC)).

DATA SOURCES:

PEC: U.S. DOE, 2000. *"Table 246.Residential Energy Consumption Estimates, Selected years 1960-1999, Pennsylvania." State Energy Data Report 1999.*
: U.S. DOE, 2000. *"Table 247.Commercial Energy Consumption Estimates, Selected years 1960-1999, Pennsylvania." State Energy Data Report 1999.*
: U.S. DOE. 2000. "Table 248.Industrial Energy Consumption Estimates, Selected years 1960-1999, *Pennsylvania." State Energy Data Report 1999*
NEC: U.S. DOE. 2001. *"Table 8.1 Electricity Overview,1949-2000."*
NEM for 1990: U.S. EPA. 2000. *"Inventory of US Greenhouse Gas Emissions and Sinks: 1990-1998."*

Table B.2-17: 1990 Worksheet to Calculate CO_2 Emissions from Manufacture

The U.S. Emissions (tons)[a]	The U.S. Population[b]	PA Population[c]	Population Ratio	PA Emissions (tons)	PA Emissions (MTCE)
800,000	249,464,400	11,895,600	0.05	38,148	10,404

a. Data are taken from http://www.epa.gov/globalwarming/emissions/national/co2.html

b. National Population data are taken from U.S. Bureau of Census, 2000.

c. Population in Pennsylvania data are taken from U.S. Bureau of Census, 2000.

Table B.2-18: 1999 Worksheet to Calculate CO_2 Emissions from Manufacture

U.S. Emissions (tons)[a]	U.S. Population[b]	PA Population[c]	Population Ratio	PA Emissions (tons)	PA Emissions (MTCE)
1,600,000	272,690,800	11,994,000	0.04	70,374	19,193

a. Data are taken from http://www.epa.gov/globalwarming/emissions/national/co2.html

b. National Population data are taken from U.S. Bureau of Census, 2000.

c. Population in Pennsylvania data are taken from U.S. Bureau of Census, 2000.

APPENDIX B-3

Calculation of Greenhouse Gas Emissions from Oil and Natural Gas

Table B.3-1: 1990 Worksheet to Calculate CH_4 Emissions from Natural Gas

Sector	Input	Emission Factor[a]	Annual Methane Emissions (metric tons)	Metric Tons of Carbon Equivalent (MTCE)
PRODUCTION EMISSIONS				
Total number of wells	30,300.0	2.5	75,750.0	433,840.9
Miles of gathering pipeline	6,110.0	0.37	2,260.7	12,947.6
GAS PROCESSING EMISSIONS				
Number of gas processing plants	2	948	1,896.0	10,858.9
GAS TRANSMISSION EMISSIONS				
Number of gas transmission stations	77.6	891	69,145.2	396,013.2
Number of gas storage stations	18.1	914	16,550.3	94,788.3
Miles of transmission pipeline	12,934.00	0.68	8,795.1	50,372.1
GAS DISTRIBUTION EMISSIONS				
Miles of distribution pipeline	37,036.0	0.7000	25,925.2	148,480.7
Total number of services	2,498,400.0	0.0140	34,977.6	200,326.3
Number of unprotected steel services	299,808.0	0.0300	8,994.2	51,512.5
Number of protected steel services	1,174,248.0	0.0035	4,109.9	23,538.3
Total				1,422,678.8

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.3-2: 1998 Worksheet to Calculate CH_4 Emissions from Natural Gas[a]

Sector	Input	Emission Factor[a]	Annual Methane Emissions (metric tons)	Metric Tons of Carbon Equivalent (MTCE)
PRODUCTION EMISSIONS				
Total number of wells	32,700.0	2.5	81,750.0	468,204.5
Miles of gathering pipeline	3,972.0	0.37	1,469.6	8,417.0
GAS PROCESSING EMISSIONS				
Number of gas processing plants	3	948	2,844.0	16,288.4
GAS TRANSMISSION EMISSIONS				
Number of gas transmission stations	77.6	891	69,166.5	396,135.7
Number of gas storage stations	18.1	914	16,555.5	94,817.7
Miles of transmission pipeline	12,938.00	0.68	8,797.8	50,387.6
GAS DISTRIBUTION EMISSIONS				
Miles of distribution pipeline	39,475.0	0.7000	27,632.5	158,258.9
Total number of services	2,466,700.0	0.0140	34,533.8	197,784.5
Number of unprotected steel services	296,004.0	0.0300	8,880.1	50,858.9
Number of protected steel services	1,159,349.0	0.0035	4,057.7	23,239.7
Total				1,464,392.8

a. 1999 data not available. Phase II Report will have updated data.

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.3-3: 1990 Worksheet to Calculate CH_4 Emission from Oil[a]

Sector	Input (MMBtu)	Emission Factor (lbs CH4/MMBtu)[b]	Annual Methane Emissions (tons)	Net Methane Emission (MTCE)
OIL PRODUCTION				
Oil	15,329,400	0.0062	47.5	246.9
Oil & Gas : Venting and Flaring[c]	15,507,009	0.0099	76.8	398.8
CRUDE OIL TRANSPORTATION AND REFINING				
Refining	1,565,129,855	0.0017	1,330.4	6,912.3
Storage Tanks[d]	1,565,129,855	0.0003	234.8	1,219.8
Total	3,161,096,119.0	0.00107[e]	1,689.4	8,777.8

a. Data are taken form API, *Basic Petroleum Data Book, 2000.*
b. Emission factors are taken from *EPA Emission Inventory Improvement Program (EIIP). 1999. Estimating Greenhouse Gas Emissions, Volume VIII.*
c. Emission are based on total production of oil and gas.
d. Assume oil stored is equivalent to oil refined
e. Weighted average

Table B.3-4: 1999 Worksheet to Calculate CH_4 Emission from Oil[a]

Sector	Input (MMBtu)	Emission Factor (lbs CH4/MMBtu)[b]	Annual Methane Emissions (tons)	Net Methane Emission (MTCE)
OIL PRODUCTION				
Oil	8,526,000	0.0062	26.4	137.3
Oil & Gas : Venting and Flaring[c]	8,703,609	0.0099	43.1	223.8
CRUDE OIL TRANSPORTATION AND REFINING				
Refining[d]	1,625,432,600	0.0017	1,381.6	7,178.6
Storage Tanks[d]	1,625,432,600	0.0003	243.8	1,266.8
Total	3,268,094,809.0	0.00104[e]	1,694.9	8,806.6

a. Data are taken form API, *Basic Petroleum Data Book, 2000.*
b. Emission factors are taken from *EPA Emission Inventory Improvement Program (EIIP). 1999. Estimating Greenhouse Gas Emissions, Volume VIII.*
c. Emission are based on total production of oil and gas.
d. Assume oil stored is equivalent to oil refined
e. Weighted average

APPENDIX B-4

Calculation of Greenhouse Gas Emissions from Coal Mining

Table B.4-1: 1990 Worksheet to Calculate CH_4 Emissions from Coal Mining

Activities	Input (short tons)[a]	Emission Factor (cubic feet methane/ton of coal mined)[b]	Annual Methane Emissions (cubic feet of methane)	Net Methane Emission (MTCE)
UNDERGROUND MINING				
Ventilation	-	-	15,401,547,300	1,693,610
Degasification	-	-	2,287,487,120	251,540
SURFACE MINING				
Coal produce	17,188,000	98.6	1,694,736,800	186,359
POST-MINING				
Underground	59,211,000	55.8	3,303,973,800	363,317
Surface	17,188,000	16	275,008,000	30,241
Total	-	-	**20,675,265,900**	**2,273,527**

a. Data are taken from www.eia.doe.gov/cneaf/coal/cia and www.eia.doe.gov/cneaf/coal/cia/html/a11p01p1.html.
b. Emission factors: *EPA Emission Inventory Improvement Program (EIIP). 1999. Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.4-2: 1999 Worksheet to Calculate CH_4 Emissions from Coal Mining

Activities	Input (short tons)[a]	Emission Factor (cubic feet methane/ton of coal mined)[b]	Annual Methane Emissions (cubic feet of methane)	Net Methane Emission (MTCE)
UNDERGROUND MINING				
Ventilation	-	-	12,301,000,000	1,352,663
Degasification	-	-	-	-
SURFACE MINING				
Coal produce	29,984,000	98.6	2,956,422,400	325,099
POST-MINING				
Underground	40,530,000	55.8	2,261,574,000	248,691
Surface	29,984,000	16	479,744,000	52,754
Total	-	-	**17,998,740,400**	**1,979,207**

a. Data are taken from www.eia.doe.gov/cneaf/coal/cia and www.eia.doe.gov/cneaf/coal/cia/html/a11p01p1.html.
b. Emission factors: *EPA Emission Inventory Improvement Program (EIIP). 1999. Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX B-5

Calculation of GHG Emissions from Waste Management

Table B.5-1: Worksheet Showing Calculations for Methane Emissions from Landfills

	A	B	C	D	E	F
	INPUT[a]	INPUT[b]	INPUT[b]	AxBxC	INPUT[b]	(DxE)
	State Population	Current Per Capita Waste Landfilling Rate (lbs/capita/year)	30-year Multiplier	Waste In Place (tons)	Fraction of Waste in Place Large Landfills	Waste in large landfills (tons)
1990	11,895,600.00	1,055.00	23.10	144,950,859.90	0.89	129,006,265.31
1999	11,994,000.00	902.00	23.80	128,741,197.20	0.89	114,579,665.51

	G	H	I	J	K	L
	(Dx(1-E))	(Gx.35x.0077)	(Fx.35x.0077)	H+I	Jx.07	J+K
	Waste in small landfills (tons)	Methane emitted from small landfills (tons CH4/year)	Methane emitted from large landfills (tons CH4/year)	Total Methane emitted from MSW (tons CH4/year)	Total Methane emitted from Industrial Landfills (tons CH4/year)	Total CH4/year
1990	15,944,594.59	42,970.68	338,727.27	381,697.95	26,718.86	408,416.80
1999	14,161,531.69	38,165.33	309,845.21	348,010.54	24,360.74	372,371.28

	M	N	O	P
	INPUT[c]	L-M	Nx0.9	Ox(.907x(12/44))x21
	Minus Recovery	Net CH4/year	Grand total CH4/year (tons)	MTCE
1990	83,641.00	324,775.80	292,298.22	1,518,382.98
1999	83,641.00	288,730.28	259,857.25	1,349,863.92

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*
c. EPA Landfill Methane Outreach Program (EPA) (http://www.epa.gov/lmop/)

Table B.5-2: Worksheet Showing Calculation of CO_2 Sequestered by Landfills

	A	B	C
	INPUT[a]	Ax0.18	Bx.907
	MSW Landfilled	Carbon Sequestration (tons)	MTCE Sequestered
1990	3,443,750.00	619,875.00	562,226.63
1999	2,668,000.00	480,240.00	435,577.68

a. Estimated Following Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.5-3: Carbon Dioxide Emitted from Combustion of MSW

	A	B	C
	INPUT[a]	Ax0.18	Bx.907x(12/44)
	MSW Combusted	Carbon Dioxide Emitted (tons)	MTCE
1990	2,758,064.52	1,103,225.81	272,897.95
1999	2,350,451.61	940,180.65	232,566.50

a. Estimated Following Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.5-4: N_2O Emitted from Combustion of MSW

	A	B	C
	INPUT[a]	Ax0.18	Bx(12/44)x.907x310
	MSW Combusted	N_2O Emitted (tons)	MTCE
1990	2,758,064.52	275.81	21,149.59
1999	2,350,451.61	235.05	18,023.90

a. Estimated Following Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX B-6

Calculation of Methane Emissions from Domestic Animals

Table B.6-1: Worksheet Showing Calculation of 1990 Methane Emissions from Domestic Animals

		INPUT[a,b]	INPUT[c]	(A*B)	(C)/2000	(D)*.9072* 21* (12/44)
		(A)	(B)	(C)	(D)	(E)
Classification	Subcategory	Number	Regional Emissions Factor (lbs CH_4/head/year)	Pounds CH_4/year	Tons CH_4/year	MTCE
Dairy Cattle						
	Replacements 0-12 months[d]	285,000.0	42.9	12,226,500.0	6,113.3	3,403.2
	Replacements 12-24 months[d]	285,000.0	128.5	36,622,500.0	18,311.3	10,193.7
	Mature Cows	694,000.0	277.4	192,515,600.0	96,257.8	53,585.8
Beef Cattle						
	Replacements 0-12 months[d]	39,000.0	42.2	1,645,800.0	822.9	458.1
	Replacements 12-24 months[d]	39,000.0	140.4	5,475,600.0	2,737.8	1,524.1
	Mature Cows	166,000.0	135.3	22,459,800.0	11,229.9	6,251.6
	Weanling System Steers/Heifers[e]		N/A	0.0	0.0	0.0
	Yearling System Steers/Heifers[e]		N/A	0.0	0.0	0.0
	Bulls	29,000.0	220.0	6,380,000.0	3,190.0	1,775.8
Sheep		134,000.0	17.6	2,358,400.0	1,179.2	656.4
Goats		9,753.5	11.0	107,288.5	53.6	29.9
Swine		975,000.0	3.3	3,217,500.0	1,608.8	895.6
Horses		61,613.5	39.6	2,439,894.6	1,219.9	679.1
Mules/Asses		3,517.5	48.5	170,598.8	85.3	47.5
Total				285,619,481.9	142,809.7	79,500.9

a. Data for all cattle from USDA (http://www.nass.usda.gov/pa/) for 1990. Swine and sheep from State of Pennsylvania Dept. of Agriculture (Mark Linstedt, personal communication) for 1990.
b. Data for Goats, Horses and Mules/Asses from Census of Agriculture, and are averages of 1987 and 1992 values.
c. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*
d. The USDA's reported heifer count is the number of replacements 12-24 months old. It is assumed that there will be an equal number of replacements 0-12 months old.
e. These cattle types are not typically found in the region.

Table B.6-2: Worksheet Showing Calculation of 1999 Methane Emissions from Domestic Animals

		INPUT[a,b]	INPUT[c]	(A*B)	(C)/2000	(D)*.9072* 21* (12/44)
		(A)	(B)	(C)	(D)	(E)
Classification	**Subcategory**	**Number**	**Regional Emissions Factor ($lbs CH_4$/head/year)**	**Pounds CH_4/year**	**Tons CH_4/year**	**MTCE**
Dairy Cattle						
	Replacements 0-12 months[d]	280,000.00	42.90	12,012,000.00	6,006.00	3,343.49
	Replacements 12-24 months[d]	280,000.00	128.50	35,980,000.00	17,990.00	10,014.87
	Mature Cows	619,000.00	277.40	171,710,600.00	85,855.30	47,794.87
Beef Cattle						
	Replacements 0-12 months[d]	42,000.00	42.20	1,772,400.00	886.20	493.34
	Replacements 12-24 months[d]	42,000.00	140.40	5,896,800.00	2,948.40	1,641.35
	Mature Cows	151,000.00	135.30	20,430,300.00	10,215.15	5,686.68
	Weanling System Steers/Heifers[e]		N/A	0.00	0.00	0.00
	Yearling System Steers/Heifers[e]		N/A	0.00	0.00	0.00
	Bulls	25,000.00	220.00	5,500,000.00	2,750.00	1,530.90
Sheep		81,000.00	17.60	1,425,600.00	712.80	396.81
Goats		20,403.00	11.00	224,433.00	112.22	62.47
Swine		1,030,000.00	3.30	3,399,000.00	1,699.50	946.10
Horses		65,072.00	39.60	2,576,851.20	1,288.43	717.25
Mules/Asses		5,001.00	48.50	242,548.50	121.27	67.51
Total				261,170,532.70	130,585.27	72,695.63

a. Data for all cattle from USDA (http://www.nass.usda.gov/pa/) for 1990. Swine and sheep from State of Pennsylvania Dept. of Agriculture (Mark Linstedt, personal communication) for 1990.
b. Data for Goats, Horses and Mules/Asses from Census of Agriculture, and are averages of 1987 and 1992 values.
c. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*
d. The USDA's reported heifer count is the number of replacements 12-24 months old. It is assumed that there will be an equal number of replacements 0-12 months old.
e. These cattle types are not typically found in the region.

APPENDIX B-7

Calculation of GHG Emissions from Manure Management

Table B.7-1: 1990 Maximum Potential Methane Emissions by Animal Type

		Input[a]	Input[b]	Input[b]	(A)X(B)X (C)	Input[b]	(D)X(E)
		(A)	(B)	(C)	(D)	(E)	(F)
		Number	Typical Animal Mass (lbs.)	Volatile Solids (lbs. VS/ lb. Animal mass/ yr)	Volitale Solids Produced	Maximum Potential Emissions (Bo) (cf CH_4/lb-VS)	Maximum Potential Methane Emissions (cubic ft.)
Feedlot Beef Cattle	Steers/Heifers	80,000	915.00	2.60	2,176,785.00	5.29	11,515,192.65
Other Beef Cattle	Calves	363,000	397.00	2.60	409,783.40	2.72	1,114,610.85
	Steers/Heifers	203,000	794.00	2.60	1,639,133.60	2.72	4,458,443.39
	Cows	166,000	1,102.00	2.60	3,157,450.40	2.72	8,588,265.09
	Bulls	29,000	1,587.00	2.60	6,548,279.40	2.72	17,811,319.97
Dairy Cattle	Heifers	285,000	903.00	3.65	2,976,242.85	3.84	11,428,772.54
	Cows	694,000	1,411.00	3.65	7,266,861.65	3.84	27,904,748.74
Swine	Market	820,000	101.00	3.10	31,623.10	7.53	238,121.94
	Breeding	100,000	399.00	3.10	493,523.10	5.77	2,847,628.29
Poultry	Layers	18,578,000	3.50	4.40	53.90	5.45	293.76
	Broilers	115,600,000	1.50	6.20	13.95	4.81	67.10
	Ducks	N/A	3.10	6.75	64.87	5.13	332.77
	Turkeys	8,430,000	7.50	3.32	186.75	4.81	898.27
Other	Sheep	N/A	154.00	3.36	79,685.76	5.77	459,786.84
	Goats	9,098	141.00	3.48	69,185.88	2.72	188,185.59
	Donkeys	3,418	661.00	3.65	1,594,761.65	5.29	8,436,289.13
	Horses/Mules	65,203	992.00	3.65	3,591,833.60	5.29	19,000,799.74

a. Data for all cattle from USDA. Swine and sheep from State of Pennsylvania Dept. of Agriculture.
Data for Poultry, Goats, Horses and Mules/Asses from Census of Agriculture, and are 1997 values.

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-2: 1990 Methane Emissions by Animal Type

All Beef Cattle

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%	94%	248,102.3	10,246.6
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%	6%	17,595.9	726.7
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0

Total Methane Emissions: (tons/yr)	5.5

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-2: 1990 Methane Emissions by Animal Type (cont.)

All Dairy

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%		0.0	0.0
Daily Spread	0.20%	0.95	74,733.7	3,086.5
Solid Storage	0.90%	0.03	10,620.1	438.6
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%	0.02	147,107.4	6,075.5
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0

Total Methane Emissions: (tons/yr)	4.8

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-2: 1990 Methane Emissions by Animal Type (cont.)

All Swine

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%		0.0	0.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%	39%	12,034.4	497.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%	0.01	2,885.2	119.2
Pit Storage > 1 mo.	19%	0.6	346,221.2	14,298.9

Total Methane Emissions: (tons/yr)	7.5

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-2: 1990 Methane Emissions by Animal Type (cont.)

Layers

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%		0.0	0.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%	0.65	19.1	0.8
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%	0.05	2.7	0.1
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2	0.3	17.6253	0.72792489

Total Methane Emissions: (tons/yr)	0.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-2: 1990 Methane Emissions by Animal Type (cont.)

Broilers

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%		0.0	0.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%	1	6.7	0.3
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2		0	0

Total Methane Emissions: (tons/yr)	0.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-2: 1990 Methane Emissions by Animal Type (cont.)

Turkeys

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%	10%	0.8	0.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%	0.9	80.8	3.3
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2		0	0

Total Methane Emissions: (tons/yr)	0.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-2: 1990 Methane Emissions by Animal Type (cont.)

Goats

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%	50%	846.8	35.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2	0.5	18818.55936	777.2065016

Total Methane Emissions: (tons/yr)	0.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-2: 1990 Methane Emissions by Animal Type (cont.)

Horses

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%	50%	85,503.6	3,531.3
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%	0.5	85,503.6	3,531.3
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2		0	0

Total Methane Emissions: (tons/yr)	3.5

Total Methane Emissions (All Animals, tons/yr):	21.3
Total Methane Emissions (All Animals, MTCE/yr):	110.6

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-3: 1999 Maximum Potential Methane Emissions by Animal Type

		Input[a]	Input[b]	Input[b]	(A)X(B)X (C)	Input[b]	(D)X(E)
		(A)	(B)	(C)	(D)	(E)	(F)
		Number	Typical Animal Mass (lbs.)	Volatile Solids (lbs. VS/ lb. Animal mass/ yr)	Volitale Solids Produced	Maximum Potential Emissions (Bo) (cf CH_4/lb-VS)	Maximum Potential Methane Emissions (cubic ft.)
Feedlot Beef Cattle	Steers/Heifers	75,000	915.00	2.60	2,176,785.00	5.29	11,515,192.65
Other Beef Cattle	Calves	335,000	397.00	2.60	409,783.40	2.72	1,114,610.85
	Steers/Heifers	165,000	794.00	2.60	1,639,133.60	2.72	4,458,443.39
	Cows	150,000	1,102.00	2.60	3,157,450.40	2.72	8,588,265.09
	Bulls	25,000	1,587.00	2.60	6,548,279.40	2.72	17,811,319.97
Dairy Cattle	Heifers	280,000	903.00	3.65	2,976,242.85	3.84	11,428,772.54
	Cows	610,000	1,411.00	3.65	7,266,861.65	3.84	27,904,748.74
Swine	Market	910,000	101.00	3.10	31,623.10	7.53	238,121.94
	Breeding	120,000	399.00	3.10	493,523.10	5.77	2,847,628.29
Poultry	Layers	41,877,000	3.50	4.40	53.90	5.45	293.76
	Broilers	133,300,000	1.50	6.20	13.95	4.81	67.10
	Ducks	N/A	3.10	6.75	64.87	5.13	332.77
	Turkeys	9,300,000	7.50	3.32	186.75	4.81	898.27
Other	Sheep	N/A	154.00	3.36	79,685.76	5.77	459,786.84
	Goats	20,403	141.00	3.48	69,185.88	2.72	188,185.59
	Donkeys	5,001	661.00	3.65	1,594,761.65	5.29	8,436,289.13
	Horses/Mules	65,072	992.00	3.65	3,591,833.60	5.29	19,000,799.74

a. Data for all cattle from USDA. Swine and sheep from State of Pennsylvania Dept. of Agriculture.
Data for Poultry, Goats, Horses and Mules/Asses from Census of Agriculture, and are 1997 values.
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-4: 1999 Methane Emissions by Animal Type

All Beef Cattle

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%	94%	367,907.1	15,194.6
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%	6%	26,092.7	1,077.6
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0

Total Methane Emissions: (tons/yr)	8.1

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-4: 1999 Methane Emissions by Animal Type (cont.)

All Dairy

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%		0.0	0.0
Daily Spread	0.20%	0.95	74,733.7	3,086.5
Solid Storage	0.90%	0.03	10,620.1	438.6
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%	0.02	147,107.4	6,075.5
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0

Total Methane Emissions: (tons/yr)	4.8

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-4: 1999 Methane Emissions by Animal Type (cont.)

All Swine

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%		0.0	0.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%	39%	12,034.4	497.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%	0.01	2,885.2	119.2
Pit Storage > 1 mo.	19%	0.6	346,221.2	14,298.9

Total Methane Emissions: (tons/yr)	7.5

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-4: 1999 Methane Emissions by Animal Type (cont.)

Layers

	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%		0.0	0.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%	0.65	19.1	0.8
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%	0.05	2.7	0.1
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2	0.3	17.6253	0.73

Total Methane Emissions: (tons/yr)	0.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-4: 1999 Methane Emissions by Animal Type (cont.)

Broilers

Manure System	(G) Methane Conversion Factor (MCF) (%)	(H) Waste System Usage (WS%) (%)	(I) Methane Emissions (cubic ft.)	(J) Methane Emissions (lbs.)
Pasture/Range	0.90%		0.0	0.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%	1	6.7	0.3
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2		0	0

Total Methane Emissions: (tons/yr)	0.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-4: 1999 Methane Emissions by Animal Type (cont.)

Turkeys

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	Methane Conversion Factor (MCF) (%)	Waste System Usage (WS%) (%)	Methane Emissions (cubic ft.)	Methane Emissions (lbs.)
Pasture/Range	0.90%	10%	0.8	0.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%	0.9	80.8	3.3
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2		0	0

Total Methane Emissions: (tons/yr)	0.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-4: 1999 Methane Emissions by Animal Type (cont.)

Goats

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%	50%	846.8	35.0
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%		0.0	0.0
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2	0.5	18818.55936	777.21

Total Methane Emissions: (tons/yr)	0.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-4: 1999 Methane Emissions by Animal Type (cont.)

Horses

	Input[a]	Input[a]	(F)X(G)X(H)	(I) X .0413
	(G)	(H)	(I)	(J)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**Methane Emissions (cubic ft.)**	**Methane Emissions (lbs.)**
Pasture/Range	0.90%	50%	85,503.6	3,531.3
Daily Spread	0.20%		0.0	0.0
Solid Storage	0.90%		0.0	0.0
Drylot	1.00%		0.0	0.0
Deep Pit Stacks	10%		0.0	0.0
Litter	10%		0.0	0.0
Paddock	0.90%	0.5	85,503.6	3,531.3
Liquid/Slurry	18.70%		0.0	0.0
Anaerobic Lagoon	90%		0.0	0.0
Pit Storage < 1 mo.	9%		0.0	0.0
Pit Storage > 1 mo.	19%		0.0	0.0
Other	0.2		0	0

Total Methane Emissions: (tons/yr)	3.5

Total Methane Emissions (All Animals, tons/yr):	23.9
Emissions (All Animals, MTCE/yr):	124.4

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-5: 1990 Maximum Potential Nitrogen by Animal Type

		Input[a]	Input[b]	Input[b]	(((A)X(B)X (C) X 365)/1000)* .8
		(A)	(B)	(C)	(((A)X(B)X(C)X365)/1000)*.8
		Number	Typical Animal Mass (lbs.)	Kjeldahl N Per day per 1000 lbs animal mass (kg per day)	Maximum N (kg)/Year
Feedlot Beef Cattle	Steers/Heifers	80,000	915.00	0.34	7,267,296.00
Other Beef Cattle	Calves	363,000	397.00	0.34	14,307,340.08
	Steers/Heifers	203,000	794.00	0.34	16,002,148.96
	Cows	166,000	1,102.00	0.34	18,161,488.96
	Bulls	29,000	1,587.00	0.34	4,569,163.44
Dairy Cattle	Heifers	285,000	903.00	0.45	33,816,447.00
	Cows	694,000	1,411.00	0.45	128,671,347.60
Swine	Market	820,000	101.00	0.52	12,575,388.80
	Breeding	100,000	399.00	0.52	6,058,416.00
Poultry	Layers	18,578,000	3.50	0.84	15,948,841.44
	Broilers	115,600,000	1.50	1.10	55,696,080.00
	Ducks	N/A	3.10	0.62	
	Turkeys	8,430,000	7.50	0.62	11,446,254.00
Other	Sheep	N/A	154.00	0.42	
	Goats	9,098	141.00	0.42	157,324.80
	Donkeys	3,418	661.00	0.30	197,914.50
	Horses/Mules	65,203	992.00	0.30	5,666,088.54

a. Data for all cattle from USDA. Swine and sheep from State of Pennsylvania Dept. of Agriculture.
Data for Poultry, Goats, Horses and Mules/Asses from Census of Agriculture, and are 1997 values.

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-6: 1990 N_2O Emissions by Animal Type

All Beef Cattle

	Input[a]	Input[a]	(F)X(G)X(H)
	(G)	(H)	(I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020	94%	1,133,779.8
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020	6%	72,368.9
Deep Pit Stacks	0.020		0.0
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001		0.0
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0

Total N_2O/N Emissions: (tons/yr)	1,206.1

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-6: 1990 N_2O Emissions by Animal Type (cont.)

All Dairy

	Input[a]	Input[a]	(F)X(G)X(H)
	(G)	(H)	(I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020		0.0
Daily Spread	0.020	0.95	3,087,268.1
Solid Storage	0.020	0.03	97,492.7
Drylot	0.020		0.0
Deep Pit Stacks	0.020		0.0
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001	0.02	3,249.8
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0

Total N_2O/N Emissions: (tons/yr)	3,188.0

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-6: 1990 N_2O Emissions by Animal Type (cont.)

All Swine

Manure System	Input[a] (G) Methane Conversion Factor (MCF) (%)	Input[a] (H) Waste System Usage (WS%) (%)	(F)X(G)X(H) (I) N_2O/N Emissions (kg/year)
Pasture/Range	0.020		0.0
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020	39%	145,343.7
Deep Pit Stacks	0.020		0.0
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001		0.0
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020	0.01	3,726.8
Pit Storage > 1 mo.	0.020	0.6	223,605.7
		Total N_2O/N Emissions: (tons/yr)	372.7

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-6: 1990 N_2O Emissions by Animal Type (cont.)

Layers

Manure System	Input[a] (G) Methane Conversion Factor (MCF) (%)	Input[a] (H) Waste System Usage (WS%) (%)	(F)X(G)X(H) (I) N_2O/N Emissions (kg/year)
Pasture/Range	0.020		0.0
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020		0.0
Deep Pit Stacks	0.020	0.65	207,334.9
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001	0.05	797.4
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0
Other	0.02	0.3	95,693.05
		Total N_2O/N Emissions: (tons/yr)	303.8

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-8: 1999 N_2O Emissions by Animal Type

All Beef Cattle

	Input[a]	Input[a]	(F)X(G)X(H)
	(G)	(H)	(I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020	94%	1,003,420.4
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020	6%	64,048.1
Deep Pit Stacks	0.020		0.0
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001		0.0
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0

Total N_2O/N Emissions: (tons/yr)	1,067.5

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-8: 1999 N_2O Emissions by Animal Type (cont.)

All Dairy

	Input[a]	Input[a]	(F)X(G)X(H)
	(G)	(H)	(I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020		0.0
Daily Spread	0.020	0.95	2,780,088.9
Solid Storage	0.020	0.03	87,792.3
Drylot	0.020		0.0
Deep Pit Stacks	0.020		0.0
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001	0.02	2,926.4
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0

Total N_2O/N Emissions: (tons/yr)	2,870.8

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-8: 1999 N_2O Emissions by Animal Type (cont.)

All Swine

	Input[a]	Input[a]	(F)X(G)X(H)
	(G)	(H)	(I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020		0.0
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020	39%	165,560.6
Deep Pit Stacks	0.020		0.0
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001		0.0
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020	0.01	4,245.1
Pit Storage > 1 mo.	0.020	0.6	254,708.56

Total N_2O/N Emissions: (tons/yr)	424.5

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-8: 1999 N_2O Emissions by Animal Type (cont.)

Layers

	Input[a]	Input[a]	(F)X(G)X(H)
	(G)	(H)	(I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020		0.0
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020		0.0
Deep Pit Stacks	0.020	0.65	467,357.4
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001	0.05	1,797.5
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0
Other	0.02	0.3	215,703.40

Total N_2O/N Emissions: (tons/yr)	684.9

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-8: 1999 N_2O Emissions by Animal Type (cont.)

Broilers

	Input[a]	Input[a]	(F)X(G)X(H)
	(G)	(H)	(I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020		0.0
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020		0.0
Deep Pit Stacks	0.020		0.0
Litter	0.020	1	1,284,478.8
Paddock	0.020		0.0
Liquid/Slurry	0.001		0.0
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0
Other	0.02		0

Total N_2O/N Emissions: (tons/yr)	1,284.5

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-8: 1999 N_2O Emissions by Animal Type (cont.)

Turkeys

	Input[a]	Input[a]	(F)X(G)X(H)
	(G)	(H)	(I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020	10%	25,255.1
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020		0.0
Deep Pit Stacks	0.020		0.0
Litter	0.020	0.9	227,295.7
Paddock	0.020		0.0
Liquid/Slurry	0.001		0.0
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0
Other	0.02		0

Total N_2O/N Emissions: (tons/yr)	252.6

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-8: 1999 N_2O Emissions by Animal Type (cont.)

Goats

	Input[a] (G)	Input[a] (H)	(F)X(G)X(H) (I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020	50%	3,528.1
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020		0.0
Deep Pit Stacks	0.020		0.0
Litter	0.020		0.0
Paddock	0.020		0.0
Liquid/Slurry	0.001		0.0
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0
Other	0.02	0.5	3528.135727

Total N_2O/N Emissions: (tons/yr)	3.5

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.7-8: 1999 N_2O Emissions by Animal Type (cont.)

Horses

	Input[a] (G)	Input[a] (H)	(F)X(G)X(H) (I)
Manure System	**Methane Conversion Factor (MCF) (%)**	**Waste System Usage (WS%) (%)**	**N_2O/N Emissions (kg/year)**
Pasture/Range	0.020	50%	56,547.0
Daily Spread	0.020		0.0
Solid Storage	0.020		0.0
Drylot	0.020		0.0
Deep Pit Stacks	0.020		0.0
Litter	0.020		0.0
Paddock	0.020	0.5	56,547.0
Liquid/Slurry	0.001		0.0
Anaerobic Lagoon	0.001		0.0
Pit Storage < 1 mo.	0.020		0.0
Pit Storage > 1 mo.	0.020		0.0
Other	0.02		0

Total N_2O/N Emissions: (tons/yr)	113.1

Total N_2O/N Emissions (All Animals, metric tons/yr):	6,701.3
Total N_2O Emissions (All Animals, MTCE/yr):	807,694.3

a. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX B-8

Calculation of Greenhouse Gas Emissions from Rice

Note: Greenhouse gas emissions from rice cultivation is not relevant in Pennsylvania, which has no rice production of any significance.

APPENDIX B-9

Calculation of GHG Emissions from Agriculture Soils

Note: Data on specific types of fertilizers were unavailable from state and federal sources; emissions are assumed to be minimal, based on other agricultural emissions sources.

APPENDIX B-10

Calculation of GHG Emissions from Forests and Land Use Change

Note: For Pennsylvania Data, see Richard A. Birdsey and George M. Lewis. 2002. *Carbon in United States Forests and Wood Products, 1987-1997: State-by-State Estimates*, General Technical Report, Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station, in press.

APPENDIX B-11

Calculations of Greenhouse Gas Emissions from Burning of Agricultural Waste

Table B.11-1: Worksheet to Calculate CH_4 and N_2O Emissions for 1990

	A	B	C	D	E	F	G
	INPUT[a]	INPUT[b]	INPUT[b]	INPUT[b]	INPUT[b]	INPUT[b]	AxBxCxDxExF
Crop Type	Crop Production (lbs)	Residue /Crop Ratio	Proportion of Residue Burned	Proportion of Dry Matter	Burning Efficiency	Combustion Efficency	Dry Matter Combusted
Rice	0	1.4	0.03	0.85	0.93	0.88	0
Sugarcane	0	0.8	0.03	0.62	0.93	0.88	0
Wheat	630000	1.3	0.03	0.85	0.93	0.88	17091.8748
Total							

	H	I	J	K	L	M	N	O
	INPUT[b]	GxH	INPUT[b]	GxJ	INPUT[b]	(IxL)x(16/12)/2205x(12/44)x21	INPUT[b]	(IxN)x(44/28)/2205x(12/44)x310
Crop Type	Carbon Contenet	Total C Released	Nitrogen Content	Total Nitrogen Released	CH4-C Emissions Ratio	CH4 Emitted (MTCE)	N_2O/N Emissions Ratio	N_2O Emitted (MTCE)
Rice	0.4144	0	0.0067	0	0.005	0	0.007	0
Sugarcane	0.42	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Wheat	0.49	8,294.69	0.00	47.86	0.01	0.14	0.01	0.02
Total						0.14		0.02

a. USDA NASS Database (http://www.nass.usda.gov/pa/).
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.11-2: Worksheet to Calculate CH_4 and N_2O Emissions for 1999

	A	B	C	D	E	F	G
	INPUT[a]	INPUT[b]	INPUT[b]	INPUT[b]	INPUT[b]	INPUT[b]	AxBxCxDxExF
Crop Type	Crop Production (lbs)	Residue /Crop Ratio	Proportion of Residue Burned	Proportion of Dry Matter	Burning Efficiency	Combustion Efficency	Dry Matter Combusted
Rice	0.00	1.40	0.03	0.85	0.93	0.88	0.00
Sugarcane	0.00	0.80	0.03	0.62	0.93	0.88	0.00
Wheat	615,600.00	1.30	0.03	0.85	0.93	0.88	16,701.20
Total							

	H	I	J	K	L	M	N	O
	INPUT[b]	GxH	INPUT[b]	GxJ	INPUT[b]	(IxL)X(16/12)/2205x(12/44)x21	INPUT[b]	(IxN)X(44/28)/2205x(12/44)x310
Crop Type	Carbon Contenet	Total C Released	Nitrogen Content	Total Nitrogen Released	CH4-C Emissions Ratio	CH4 Emitted (MTCE)	N_2O/N Emissions Ratio	N_2O Emitted (MTCE)
Rice	0.41	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Sugarcane	0.42	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Wheat	0.49	8,105.09	0.00	46.76	0.01	0.14	0.01	0.02
Total						0.14		0.02

a. USDA NASS Database (http://www.nass.usda.gov/pa/).
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX B-12

Calculations of Greenhouse Gas Emissions from Municipal Waste Water Management

Table B.12-1: Methane Emissions from Municipal Wastewater Management

Year	A	B	C	D	E	F
	INPUT[a]	INPUT[b]	(A)x(B)	INPUT[b]	INPUT[b]	[Cx(1-D)xEx365]
	Population (persons)	Wastewater BOD Generation rate (lbs BOD/capita /day)	BOD Generated (lbs BOD/day)	Fraction of BOD removed as sludge	Fraction of Wastewater BOD Treated An-aerobically	Quantity of BOD Treated Anaerobically (lbs BOD/yr)
1990	11,895,600.00	0.11	1,308,516.00	0.90	0.15	7,164,125.10
1999	11,994,000.00	0.11	1,319,340.00	0.90	0.15	7,223,386.50

Year	G	H	I	J
	INPUT[b]	FxG	INPUT[b]	[(H-I)/2205X (12/44)X21]
	Methane Emissions Factor (lbs CH4/lb BOD)	CH4 Emissions (lbs CH4)	Methane Recovered (lbs CH4)	Net CH4 Emissions (MTCE CH4)
1990	0.25	1,791,031.28	0.00	4,652.03
1999	0.25	1,805,846.63	0.00	4,690.51

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.12-2: Methane Emissions from Sludge

Year	A	B	C	D	E	F
	Table 1, C	INPUT[b]	INPUT[b]	AxBxCx365	INPUT[b]	DxE
	BOD Generated (lbs BOD/day)	Fraction of BOD removed as sludge	Fraction of Sludge BOD Treated Anaerobically	Quantity of BOD Treated Anaerobically (lbs BOD/yr)	Methane Emissions Factor (lbs CH4/lb BOD)	CH4 Emissions (lbs CH4)
1990	1,308,516.00	0.90	0.15	64,477,125.90	0.25	16,119,281.48
1999	1,319,340.00	0.90	0.15	65,010,478.50	0.25	16,252,619.63

Year	G	H	SUM
	INPUT[b]	[(F-G)/2205]x(12/44)x21	H+1.J
	Methane Recovered (lbs CH4)	Net CH4 Emissions (MTCE CH4)	Net CH4 Emissions (MTCE CH4)
1990	0	41,868	46,520
1999	0	42,215	46,905

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.12-3: N_2O Emissions from Municipal Wastewater Management

Year	A	B	C	D	E	F
	INPUT[a]	INPUT[b]	AxB	INPUT[b]	CxD	Ex(44/28)x(12/44)x310
	Population (persons)	Nitrogen Consumed Per Capita (kg)	Nitrogen Consumed (kg)	Emissions Factor	N_2O/N Emitted	MTCE
1990	11,895,600.00	6.37	75,774,972.00	0.01	757,749.72	100,672.46
1999	11,994,000.00	6.37	76,401,780.00	0.01	764,017.80	101,505.22

a. Energy Information Administration (EIA). 1999. *State Energy Data Report.*
b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX B-13

Calculation of Non-CO_2 GHG Emissions from Mobile Combustion

Table B.13-1: Vehicle Miles Traveled, by Vehicle Classification, 1990

	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC	Total
PA TOTAL	54,836	13,683	6,883	3,122	664	168	5,335	664	85,353

Source: Pennsylvania Department of Transportation.

Table B.13-2: Percentage of Emissions Control Technologies Used by Each Vehicle Classification, 1990

	AI	AJ	AK	AL	AM	AN	AO
	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)
LDGV	0.00	0.00	0.00	0.96	0.04	0.00	0.00
LDGT	0.00	0.00	0.15	0.82	0.04	0.00	0.00
HDGV	0.00	0.61	0.23	0.17	0.00	0.00	0.00
LDDV	0.00	0.00	0.00	0.00	0.00	0.60	0.40
LDDT	0.00	0.00	0.00	0.00	0.00	0.60	0.40
HDDV	0.00	0.00	0.00	0.00	0.00	0.60	0.40
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emisions, Volume VIII.*

Table B.13-3: Vehicle Miles Traveled, by Pollution Control Technology and Vehicle Classification, 1990

	AP	AQ	AR	AS	AT	AV	AW
	AIxTable B.13-1	AJxTable B.13-1	AKxTable B.13-1	ALxTable B.13-1	AMxTable B.13-1	ANxTable B.13-1	AOxTable B.13-1
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)
LDGV	0.00	0.00	0.00	52,642.09	2,193.42	0.00	0.00
LDGT	0.00	0.00	2,981.98	16,760.76	822.61	0.00	0.00
HDGV	0.00	1,888.87	702.47	530.76	0.00	0.00	0.00
LDDV	0.00	0.00	0.00	0.00	0.00	398.23	265.49
LDDT	0.00	0.00	0.00	0.00	0.00	100.72	67.15
HDDV	0.00	0.00	0.00	0.00	0.00	3,200.99	2,134.00
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Pennsylvania Department of Transportation.

Table B.13-4: 1990 Methane Emissions Coefficients, by Pollution Control Technology and Vehicle Classification

	AX	AY	AZ	BA	BB	BC	BD
	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)
LDGV	0.14	0.12	0.07	0.04	0.03	0.00	0.00
LDGT	0.14	0.14	0.09	0.07	0.04	0.00	0.00
HDGV	0.27	0.13	0.09	0.08	0.00	0.00	0.00
LDDV	0.01	0.00	0.00	0.00	0.00	0.01	0.01
LDDT	0.01	0.00	0.00	0.00	0.00	0.01	0.01
HDDV	0.06	0.00	0.00	0.00	0.00	0.05	0.04
MC	0.26	0.13	0.00	0.00	0.00	0.00	0.00

Source: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Grenhouse Gas Emisions, Volume VIII.*

Table B.13-5: 1990 Methane Emissions by Pollution Control Technology and Vehicle Classification

	BE	BF	BG	BH	BI	BJ	BK	BL	BM
	APxAX	AQxAY	ARxAZ	ASxBA	ATxBB	AVxBC	AWxBD	SUM(BE-BK)	BLx(12/44)x21
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)	Total	MTCE
LDGV	0.00	0.00	0.00	2,105.68	65.80	0.00	0.00	2,171.49	12,436.69
LDGT	0.00	0.00	268.38	1,173.25	28.79	0.00	0.00	1,470.42	8,421.51
HDGV	0.00	236.11	63.22	39.81	0.00	0.00	0.00	339.14	1,942.34
LDDV	0.00	0.00	0.00	0.00	0.00	3.98	2.65	6.64	38.01
LDDT	0.00	0.00	0.00	0.00	0.00	1.01	0.67	1.68	9.61
HDDV	0.00	0.00	0.00	0.00	0.00	160.05	85.36	245.41	1,405.53
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
								4,234.77	24,253.70

Table B.13-6: N_2O Emissions Coefficients, by Pollution Control Technology and Vehicle Type, 1990

	AX	AY	AZ	BA	BB	BC	BD
	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT
Vehicle Type	**Uncontrolled**	**Non-Catalyst Control**	**Oxidation Catalyst**	**Tier 0 Three-way Catalyst**	**Tier 1 Three-way Catalyst**	**Moderate (Diesel)**	**Advanced (Diesel)**
LDGV	0.01	0.01	0.03	0.05	0.03	0.00	0.00
LDGT	0.01	0.01	0.04	0.09	0.04	0.00	0.00
HDGV	0.03	0.03	0.09	0.17	0.00	0.00	0.00
LDDV	0.01	0.00	0.00	0.00	0.00	0.01	0.01
LDDT	0.02	0.00	0.00	0.00	0.00	0.02	0.02
HDDV	0.03	0.00	0.00	0.00	0.00	0.03	0.03
MC	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Source: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Grenhouse Gas Emisions, Volume VIII.*

Table B.13-7: N_2O Emissions, by Pollution Control Technology and Vehicle Type, 1990

	BE	BF	BG	BH	BI	BJ	BK	BL	BM
	APxAX	AQxAY	ARxAZ	ASxBA	ATxBB	AVxBC	AWxBD	SUM(BE-BK)	BLx(12/44)x310
Vehicle Type	**Uncontrolled**	**Non-Catalyst Control**	**Oxidation Catalyst**	**Tier 0 Three-way Catalyst**	**Tier 1 Three-way Catalyst**	**Moderate (Diesel)**	**Advanced (Diesel)**	**Total**	**MTCE**
LDGV	0.00	0.00	0.00	2,684.75	63.61	0.00	0.00	2,748.36	232,360.98
LDGT	0.00	0.00	125.24	1,424.66	32.90	0.00	0.00	1,582.81	133,819.59
HDGV	0.00	49.11	61.12	91.82	0.00	0.00	0.00	202.05	17,082.14
LDDV	0.00	0.00	0.00	0.00	0.00	3.98	2.65	6.64	561.14
LDDT	0.00	0.00	0.00	0.00	0.00	2.01	1.34	3.36	283.85
HDDV	0.00	0.00	0.00	0.00	0.00	96.03	64.02	160.05	13,531.47
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total								4,703.26	397,639.18

Table B.13-8: Vehicle Miles Traveled, by Vehicle Classification, 1999

	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC	Total
PA TOTAL	63,166	18,988	8,733	3,368	202	102	7,062	700	102,320

Source: Pennsylvania Department of Transportation.

Table B.13-9: Percentage of Emissions Control Technologies Used by Each Vehicle Classification, 1999

	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)
LDGV	0.00	0.00	0.00	0.58	0.42	0.00	0.00
LDGT	0.00	0.00	0.03	0.56	0.42	0.00	0.00
HDGV	0.00	0.45	0.30	0.25	0.00	0.00	0.00
LDDV	0.00	0.00	0.00	0.00	0.00	0.20	0.80
LDDT	0.00	0.00	0.00	0.00	0.00	0.20	0.80
HDDV	0.00	0.00	0.00	0.00	0.00	0.20	0.80
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Grenhouse Gas Emisions, Volume VIII.*

Table B.13-10: Vehicle Miles Traveled, by Pollution Control Technology and Vehicle Classification, 1999

	AP	AQ	AR	AS	AT	AV	AW
	AIxTable B.13-8	AJxTTable B.13-8	AKxTable B.13-8	ALxTable B.13-8	AMxTable B.13-8	ANxTable B.13-8	AOxTable B.13-8
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)
LDGV	0.00	0.00	0.00	36,636.51	26,529.89	0.00	0.00
LDGT	0.00	0.00	693.01	15,384.79	11,642.54	0.00	0.00
HDGV	0.00	1,515.50	1,010.34	841.95	0.00	0.00	0.00
LDDV	0.00	0.00	0.00	0.00	0.00	40.32	161.27
LDDT	0.00	0.00	0.00	0.00	0.00	20.35	81.41
HDDV	0.00	0.00	0.00	0.00	0.00	1,412.44	5,649.77
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Pennsylvania Department of Transportation.

Table B.13-11: 1999 Methane Emissions Coefficients, by Pollution Control Technology and Vehicle Classification

	AX	AY	AZ	BA	BB	BC	BD
	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)
LDGV	0.14	0.12	0.07	0.04	0.03	0.00	0.00
LDGT	0.14	0.14	0.09	0.07	0.04	0.00	0.00
HDGV	0.27	0.13	0.09	0.08	0.00	0.00	0.00
LDDV	0.01	0.00	0.00	0.00	0.00	0.01	0.01
LDDT	0.01	0.00	0.00	0.00	0.00	0.01	0.01
HDDV	0.06	0.00	0.00	0.00	0.00	0.05	0.04
MC	0.26	0.13	0.00	0.00	0.00	0.00	0.00

Source: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Grenhouse Gas Emisions, Volume VIII.*

Table B.13-12: 1999 Methane Emissions By Pollution Control Technology and Vehicle Classification

	BE	BF	BG	BH	BI	BJ	BK	BL	BM
	APxAX	AQxAY	ARxAZ	ASxBA	ATxBB	AVxBC	AWxBD	SUM(BE-BK)	BLx(12/44)x21
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)	Total	MTCE
LDGV	0.00	0.00	0.00	1,465.46	795.90	0.00	0.00	2,261.36	12,951.41
LDGT	0.00	0.00	62.37	1,076.94	407.49	0.00	0.00	1,546.79	8,858.92
HDGV	0.00	189.44	90.93	63.15	0.00	0.00	0.00	343.51	1,967.40
LDDV	0.00	0.00	0.00	0.00	0.00	0.40	1.61	2.02	11.55
LDDT	0.00	0.00	0.00	0.00	0.00	0.20	0.81	1.02	5.83
HDDV	0.00	0.00	0.00	0.00	0.00	70.62	225.99	296.61	1,698.78
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
								4,451.31	25,493.88

Table B.13-13: N_2O Emission Coefficients, 1999

	AX	AY	AZ	BA	BB	BC	BD
	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT	INPUT
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)
LDGV	0.01	0.01	0.03	0.05	0.03	0.00	0.00
LDGT	0.01	0.01	0.04	0.09	0.04	0.00	0.00
HDGV	0.03	0.03	0.09	0.17	0.00	0.00	0.00
LDDV	0.01	0.00	0.00	0.00	0.00	0.01	0.01
LDDT	0.02	0.00	0.00	0.00	0.00	0.02	0.02
HDDV	0.03	0.00	0.00	0.00	0.00	0.03	0.03
MC	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Source: Emission Inventory Improvement Program (EIIP). 1999. *Estimating Grenhouse Gas Emisions, Volume VIII.*

Table B.13-14: N_2O Emissions, 1999

	BE	BF	BG	BH	BI	BJ	BK	BL	BM
	APxAX	AQxAY	ARxAZ	ASxBA	ATxBB	AVxBC	AWxBD	SUM(BE-BK)	BLx(12/44)x 310
Vehicle Type	Uncontrolled	Non-Catalyst Control	Oxidation Catalyst	Tier 0 Three-way Catalyst	Tier 1 Three-way Catalyst	Moderate (Diesel)	Advanced (Diesel)	Total	MTCE
LDGV	0.00	0.00	0.00	1,868.46	769.37	0.00	0.00	2,637.83	223,016.44
LDGT	0.00	0.00	29.11	1,307.71	465.70	0.00	0.00	1,802.52	152,394.46
HDGV	0.00	39.40	87.90	145.66	0.00	0.00	0.00	272.96	23,077.47
LDDV	0.00	0.00	0.00	0.00	0.00	0.40	1.61	2.02	170.44
LDDT	0.00	0.00	0.00	0.00	0.00	0.41	1.63	2.04	172.08
HDDV	0.00	0.00	0.00	0.00	0.00	42.37	169.49	211.87	17,912.34
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total								4,929.22	416,743.22

APPENDIX B-14

Calculations for Non-CO_2 Greenhouse Gas Emissions from Stationary Combustion

Table B.14-1: 1990 Worksheet to Calculate CH_4 Emissions from Stationary Combustion - Residential

Activities	Input [a] (MMBtu)	Input (terajoules)	Emission Factors[b] (Kg/TJ)	Adjusted Emission Factors[b] (Kg/TJ)	CH_4 Emissions (Kg)	CH_4 Emissions (tons)	CH_4 Emissions (MTCE)
Coal	5,913,000	6,239	150	142.50	889,009	889	5,092
Gas	248,900,000	262,608	1	0.90	236,347	236	1,354
Oil	116,100,000	122,494	0.7	0.67	81,459	81	467
Wood	20,800,000	21,946	200	190.00	4,169,656	4,170	23,881
Total	391,713,000	413,287			5,376,471	5,376	30,793

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

c. Tables B.14-1 to B.14-8 effectively use the low heat values for energy inputs to calculate methane emissions in order to adjust for water vapor in the combustion process. This adjustment however, is not applied to the input column (Since we want to maintain comparability with input columns of other tables (see, e.g., Tables B.1-1 to B.1-10), but rather to the Emission Factors.

Table B.14-2: 1990 Worksheet to Calculate CH_4 Emissions from Stationary Combustion - Industrial

Activities	Input [a] (MMBtu)	Input (terajoules)	Emission Factors[b] (Kg/TJ)	Adjusted Emission Factors[b] (Kg/TJ)	CH_4 Emissions (Kg)	CH_4 Emissions (tons)	CH_4 Emissions (MTCE)
Coal	382,150,000	403,197	1	0.95	383,037	383	2,194
Gas	250,300,000	264,085	1.4	1.26	332,747	333	1,906
Oil	226,300,000	238,763	0.57	0.54	129,290	129	740
Wood	41,600,000	43,891	15	14.25	625,448	625	3,582
Total	900,350,000	949,937			1,470,523	1,471	8,422

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.14-3: 1990 Worksheet to Calculate CH_4 Emissions from Stationary Combustion - Commercial

Activities	Input [a] (MMBtu)	Input (terajoules)	Emission Factors[b] (Kg/TJ)	Adjusted Emission Factors[b] (Kg/TJ)	CH_4 Emissions (Kg)	CH_4 Emissions (tons)	CH_4 Emissions (MTCE)
Coal	26,936,000	28,419	10	9.50	269,985	270	1,546
Gas	130,300,000	137,476	1.2	1.08	148,474	148	850
Oil	43,800,000	46,212	0.78	0.74	34,243	34	196
Total	201,036,000	212,108			452,703	453	2,593

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.14-4: 1990 Worksheet to Calculate CH_4 Emissions from Stationary Combustion - Electricity Generation

Activities	Input [a] (MMBtu)	Input (terajoules)	Emission Factors[b] (Kg/TJ)	Adjusted Emission Factors[b] (Kg/TJ)	CH_4 Emissions (Kg)	CH_4 Emissions (tons)	CH_4 Emissions (MTCE)
Coal	1,044,848,000	1,102,393	0.7	0.67	733,091	733	4,199
Gas	2,400,000	2,532	240.0	216.00	546,951	547	3,133
Oil	46,900,000	49,483	0.9	0.86	42,308	42	242
Total	1,094,148,000	1,154,408			1,322,350	1,322	7,573

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.14-5: 1999 Worksheet to Calculate CH_4 Emissions from Stationary Combustion - Residential

Activities	Input [a] (MMBtu)	Input (terajoules)	Emission Factors[b] (Kg/TJ)	Adjusted Emission Factors[b] (Kg/TJ)	CH_4 Emissions (Kg)	CH_4 Emissions (tons)	CH_4 Emissions (MTCE)
Coal	2,107,000	2,223	150	143	316,784	317	1,814
Gas	241,468,000	254,767	1	1	229,290	229	1,313
Oil	140,100,000	147,816	0.7	0.7	98,298	98	563
Wood	13,100,000	13,821	200	190	2,626,081	2,626	15,040
Total	396,775,000	418,627			3,270,453	3,270	18,731

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.14-6: 1999 Worksheet to Calculate CH_4 Emissions from Stationary Combustion - Industrial

Activities	Input [a] (MMBtu)	Input (terajoules)	Emission Factors[b] (Kg/TJ)	Adjusted Emission Factors[b] (Kg/TJ)	CH_4 Emissions (Kg)	CH_4 Emissions (tons)	CH_4 Emissions (MTCE)
Coal	271,585,000	286,543	1	0.95	272,215	272	1,559
Gas	253,388,000	267,343	1.4	1.26	336,853	337	1,929
Oil	226,300,000	238,763	0.38	0.36	86,194	86	494
Wood	79,600,000	83,984	15	13.50	1,133,783	1,134	6,493
Total	830,873,000	876,633			1,829,045	1,829	10,475

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.14-7- 1999 Worksheet to Calculate CH_4 Emissions from Stationary Combustion - Commercial

Activities	Input [a] (MMBtu)	Input (terajoules)	Emission Factors[b] (Kg/TJ)	Adjusted Emission Factors[b] (Kg/TJ)	CH_4 Emissions (Kg)	CH_4 Emissions (tons)	CH_4 Emissions (MTCE)
Coal	15,450,000	16,301	10	9.5	154,859	155	887
Gas	148,420,000	156,594	1.2	1.08	169,122	169	969
Oil	37,200,000	39,249	0.78	0.74	29,083	29	167
Total	201,070,000	212,144			353,064	353	2,022

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.14-8: 1999 Worksheet to Calculate CH_4 Emissions from Stationary Combustion - Electricity Generation

Activities	Input [a] (MMBtu)	Input (terajoules)	Emission Factors[b] (Kg/TJ)	Adjusted Emission Factors[b] (Kg/TJ)	CH_4 Emissions (Kg)	CH_4 Emissions (tons)	CH_4 Emissions (MTCE)
Coal	1,128,566,000	1,190,722	0.7	0.7	791,830	792	4,535
Gas	10,736,000	11,327	240	216	2,446,693	2,447	14,013
Oil	39,000,000	41,148	0.9	0.9	35,181	35	201
Total	1,178,302,000	1,243,197			3,273,705	3,274	18,749

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.14-9: 1990 Worksheet to Calculate N_2O Emissions from Stationary Combustion

Activities	Input[a](MMBtu)	Emission Factors[b] (lbs/MMBtu)	Adjusted Emission Factors[b]	N_2O Emissions (pounds)	N_2O Emissions (tons)	N_2O Emissions (MTCE)
Coal	1,459,846,000	0.0032	0.0030	4,437,932	2,013	170,162
Gas	631,900,000	0.0014	0.0013	796,194	361	30,528
Oil	479,000,000	0.0002	0.0002	91,010	41	3,490
Total	2,570,746,000			5,325,136	2,415	204,180

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

Table B.14-10: 1999 Worksheet to Calculate N_2O Emissions from Stationary Combustion

Activities	Input[a](MMBtu)	Emission Factors[b] (lbs/MMBtu)	Adjusted Emission Factors[b] (lbs/MMBtu)	N_2O Emissions (pounds)	N_2O Emissions (tons)	N_2O Emissions (MTCE)
Coal	1,417,708,000	0.0032	0.0030	4,309,832	1,955	165,250
Gas	662,688,000	0.0014	0.0013	834,987	379	32,016
Oil	442,600,000	0.0002	0.0002	84,094	38	3,224
Total	2,522,996,000			5,228,913	2,371	200,490

a. Energy Information Administration (EIA).1999. *State Energy Data Report.*

b. Emission Inventory Improvement Program (EIIP). 1999. *Estimating Greenhouse Gas Emissions, Volume VIII.*

APPENDIX C. ISSUES IN THE EPA METHODOLOGY

The 2002 GHG emissions inventory for the Commonwealth of Pennsylvania followed the EPA methodology for state-level inventories (EIIP, 1999) in order to generate an inventory that would be compatible and comparable to other state inventories. The EPA methodology also serves as a good starting point for GHG inventory work because it is the most widely accepted methodology in the U.S. for generating GHG emissions inventories. However, it is not without problems and can and should be improved. This Appendix outlines some of the most significant improvements that should be incorporated in future inventories to improve the accuracy and precision of emissions estimates. It is important to note that the improvements suggested here are not substitutes for the current EPA methodology, but are suggested as additional calculations. Because one of the primary goals of any state-level GHG inventory is compatibility and comparability with other state inventories, a common methodology must continue to be used. Nonetheless, the EPA methodology itself encourages states to perform additional calculations where improvements in emissions estimates are possible, and these additional calculations, and the methods behind them, should be included as part of future emissions inventories to ensure that the estimates reported are the most accurate possible.

Of course, this discussion would be moot if it were possible to simply take atmospheric measurements at the point of release of all GHG emissions and report those emissions in a disaggregated manner, across various socioeconomic sectors. Unfortunately, this is not possible. In the first place, the financial cost of establishing a scientifically sound GHG monitoring network at every source of GHGs is prohibitive. Other factors also preclude this approach. Most importantly, there are many significant non-point sources of GHG emissions, including agriculture, land-use change and transportation. Because carbon dioxide and other GHGs mix with other atmospheric gasses quickly and evenly, it is impossible to use atmospheric monitoring devices such as the devices used to measure global CO_2 concentrations to perform local assessments. Further, a major justification for performing GHG emissions inventories at scales smaller than the national, or even international scales, is to identify socioeconomic activities that are responsible for GHG emissions in order to later formulate GHG mitigation plans. In the absence of a scientifically sound emissions monitoring network, and in the absence of the possibility of creating such a network, GHG inventories have focused on identifying socioeconomic processes that both are responsible for GHG emissions and are measurable, and then estimating GHG emissions from those processes based on our understanding of the chemistry that ultimately results in emissions.

Overview of GHG Accounting Issues

Issues relating to the accuracy and precision of estimates are primarily accounting issues, and can be sub-classified into three categories: sectoral accounting issues, geographic accounting issues, and process-based accounting issues. Sectoral accounting issues refer to the problem of clearly identifying which economic sector is responsible for any given emissions estimate. Geographic accounting issues refer to the problem of precisely and accurately attributing emissions to a specific geographic entity, in this case the Commonwealth of Pennsylvania.

Process-based accounting issues are a bit more complicated, but constitute a critical consideration in the development and improvement of emissions inventories. As previously stated, one of the major justifications for local and state-based GHG inventories is to identify place-specific estimates of GHG emissions, by socioeconomic or process, in order to aid researchers, policy makers and stakeholders who will use the inventory to generate action plans aimed at reduction of GHG emissions. Further, note that GHG emission inventories are necessarily based on our understanding of the socioeconomic processes and the resulting chemical processes that ultimately result in GHG emissions. While our calculations of GHG emissions from a given sector may be based on large-scale data (in the case of transportation, gasoline sales), the actual processes resulting in those emissions may be, and often are, smaller in scale. Extending the case of transportation, while gasoline sales may provide a reasonable estimate of GHG emissions at a state level, attributing this as the proximate cause of GHG emissions from transportation can be very misleading to policy makers, because it may suggest that the only way to reduce GHG emissions is to use a top-down approach aimed at reducing gasoline sales, such as tax incentives.

In reality, the decisions that result in GHG emissions from transportation occur at multiple scales. To be sure, a national process that involves gasoline prices and the "invisible hand" is to some degree implicated in the GHG emissions. Various econometric analyses have shown that as gasoline price increases, efficiency also increases, resulting in lower gasoline consumption. However, this is only part of the process involved in GHG emissions from transportation. Other factors, such as the origin and destination of a trip, the transportation network available, the mode of transportation chosen, etc. are decided by individual travelers on a much smaller scale. These processes are entirely ignored by the current EPA methodology, as the focus is simply on estimating the weight of carbon dioxide and other GHGs, and large-scale data is sufficient to achieve this goal. However, if the goal of fully informing policy makers and stakeholders about the sum of processes responsible for GHG emissions is to be met, steps should be taken, where possible, to provide richer and more detailed descriptions of these processes, both at large and small scales.

All three accounting issues are critical to a more balanced, accurate, and informative GHG emission inventory. Without accurate and precise geographic accounting, emissions estimates may not reflect the true emissions of the Commonwealth. Without proper sectoral accounting, policy makers may misallocate resources and energy into emissions reductions plans that do not address the true causes of emissions. Finally, without sufficiently detailed descriptions of the multi-scale processes that are proximate causes of emission patterns, policy makers cannot approach the problem of mitigating GHG emissions with a sufficiently multi-tiered and locally specific plan, which is one of the major justifications for performing emissions inventories in the first place. The following section of this document explores flaws and potential improvements to the GHG inventory methodology in three sectors: transportation, land-use change, and electricity generation. In addition, improvements based on more accurate and precise local data are explored with regard to emissions from land-use change and municipal waste management.

Flaws and Potential Improvements in the Methodology

Accurately attributing emissions to specific geographic entities is the primary goal of and justification for performing state-level GHG inventories. The major failing of the EPA Methodology in this area is due primarily to the oversight of bunker fuels. In the context of GHG emissions inventories, bunker fuels are fuels that are purchased in one state, but actually consumed in another. One example of bunker fuels offered by the EPA (EIIP, 1999)is that of jet fuel. Under the current methodology, jet fuel emissions are calculated based on state fuel sales. However, most jet traffic leaves the state after fueling and takeoff, and therefore the actual physical emission of GHG occurs outside the state boundaries. Similarly, emissions from interstate jet traffic entering Pennsylvania are attributed to the origin state, rather than PA, where the emissions actually occur. The EPA methodology suggests ignoring bunker fuels when performing state-level inventories due to the complexity in calculating them, and in the case of emissions from the combustion of jet fuel, the benefits of accurately characterizing jet fuel and aviation gasoline bunkers may indeed be outweighed by costs of collecting and processing the data, as jet and aviation fuel combustion was responsible for only 3.5 percent of 1990 estimated emissions.

- *Transportation*

However, motor gasoline consumption was responsible for more than 13.8 percent of total estimated emissions for 1990, and this estimate suffers from the same problem of geographic accounting. Emissions estimates for consumption of motor gasoline are based on total gasoline sales in the state of Pennsylvania, even though Pennsylvania has considerable interstate traffic, serving as one of the major interstate corridors to and from the eastern seaboard. Unlike the jet fuel, bunkers for motor gasoline can be calculated with minimal time and monetary resources using readily available estimates of vehicle-miles traveled (VMT) from the Office of Highway Information Management. In fact, emissions estimates of Non-CO_2 GHGs from mobile combustion of fossil fuels use these VMT estimates. Further, the state's Department of Transportation (PennDOT) has estimates of VMT for the state of Pennsylvania. We are currently exploring available data to determine the best source of VMT data, by vehicle type, to more accurately characterize actual CO_2 emissions from motor gasoline and other ground transportation.

While this method may more accurately estimate the GHG emissions resulting from transportation, it does little to improve policy makers' understanding of the socioeconomic processes that generate the traffic being measured. However, using local-scale data available from the US Census, it is possible to explore these processes at a more local and detailed scale. Work by Neff (forthcoming) uses census data describing commuters' origins, destinations, and mode of transportation to generate spatially specific characterizations of GHG emissions resulting from the commute to and from work, which is responsible for roughly a third of national GHG emissions from transportation. Attributing emissions to the local places they are emitted allows a more detailed examination of the smaller-scale processes, such as urban sprawl, accessibility to public transportation, and public transit ridership. However, it is important to note this approach requires very detailed origin-destination data, disaggregated by mode of transportation. While such data are available for commuters in every metropolitan area in the

U.S., they are not available for commercial traffic, nor are they available for personal trips, such as running errands, visiting family and friends, or extended trips from one locality to another.

Nevertheless, locally specific examinations of the processes resulting in GHG emissions are critical to public policy aimed at mitigating these emissions, and should be included as supplementary information, where monetary and temporal constraints on the inventory process permit. While it is not the role of a GHG inventory to suggest mitigation options, supplying policymakers, stakeholders and researchers with the necessary information to formulate such a plan *is* a critical role of all inventories. By providing smaller-scale analyses of the processes implicated in GHG emissions, researchers would provide those involved in formulating action plans valuable information that may suggest locally specific approaches to GHG mitigation that may otherwise not be considered due to insufficient information.

➢ *Land-use Change*

Another area where an understanding of smaller-scale processes is critical to understanding GHG emissions is that of land-use change. As in the case of transportation, the estimation of emissions from land-use change is based on state-level data. In this case, those data are of forest composition and scope, and changes in those forests resulting from activities such as logging, conversion to agricultural land, and encroachment on forested land by the expansion of urban and suburban communities. As in the case of transportation, the description of the actual processes resulting in these changes is lacking from the current methodology, and like transportation, a richer and more detailed exploration of these processes is possible through greater attention to the geography of land-use change.

Current estimates of land-use change emissions are based on state-level data gathered by the US Forest Service at five-year intervals and extrapolated based on temporal trends. Smaller scale, and more current data on land-use patterns are available through the use of remote sensing. Using satellite data on land-use is not entirely straightforward, and requires significant expertise on behalf of researchers using the data, particularly in the problem of classifying visual images so the resulting data accurately reflects the composition of land cover on the ground. Nevertheless, such classification is possible and the resulting spatial data could be used to achieve both more accurate accounting of the spatial extent and content of forested areas, and also more spatially specific accounting of the change, allowing researchers to perform local assessments of the locally specific processes resulting in that change.

➢ *Electricity Generation*

Another major area of concern is electricity generation. Here, the problem is multifaceted, and suffers from issues of both sectoral and geographic accounting. Geographically, while emissions can be easily identified as physically originating in one state or another, the actual use of the electricity generated is difficult to attribute to any specific state. This is critical for two reasons. First, Pennsylvania is a major exporter of electricity. Therefore, while the electricity being produced in Pennsylvania physically emits GHGs in the state, the actual socio-economic processes responsible for a significant portion of those emissions occur outside the state, and outside the control of Pennsylvanian policy makers. Secondly, the practice of wheeling complicates determining the exact fuel mix used to generate electricity consumed within the state. Wheeling is a practice that allows consumers to purchase electricity that is actually generated a great distance from the location it is consumed. For instance, residents of PA have the option to purchase electricity from Green Mountain Electricity, which is generated using renewable energy sources such as wind and hydroelectric dams. Therefore, emissions estimates that assume that consumers use the coal-intensive electricity produced within the state may overestimate emissions.

A second flaw in the current methodology for estimating emissions from electricity generation is one of sectoral accounting. The U.S. Energy Information Administration (EIA) has made some very significant adjustments in data reporting for electricity generation and associated carbon dioxide emissions by non-utility generators (NUGs). The change is an outgrowth of the strong effect of electricity industry deregulation (or restructuring). Many major utilities have sold or spun off to unregulated subsidiaries their generation facilities (power plants), which emit CO_2, and now only operate transmission or distribution systems, which do not emit CO_2. Many of the power plants that have changed hands are now listed under the NUGs category rather than under electric utility generation (EIA, 2001a).

Ordinarily, the restructuring would result in data compilations that initially showed sizeable decreases in electric utility emissions but only modest increases in non-utility generation (2001d), which were grouped into the "industrial" emissions category before 1999 (EIA, 2001). However, the decrease in the former category is simply due to an accounting shift rather than any actual efforts at reducing emissions (e.g., in Pennsylvania, there has been relatively little increase in natural gas displacing coal as a fuel source in recent years, in contrast to the relatively large gas for coal displacement nationwide). More recently, an effort has been made to account for all utilities that were reclassified, resulting in a much larger estimate of non-utility power producer activity in 1999, as presented in Table 12 (see EIA, 2002b).

In addition, EIA has gone to a dual reporting format for electricity-related CO_2 emissions. Rather than only presenting electricity generation and emissions on the production (supply) side, EIA now reports emissions according to the end-user (or demand) side as well. (Though not explicitly stated as a purpose for this change, one implication is to take the onus of CO_2 emission creation off the shoulders of the producers alone, and to suggest that consumers, though their purchases of electricity, are also responsible for these emissions.)

On the supply-side, emissions are divided into five categories: industrial, commercial, transportation, residential and electricity utilities. However, on the demand-side there are only four categories: the utility sector emissions are "shared out" to the four other end-user sectors according to their purchases of electricity.[i]

The shift is a positive step toward evaluating the impetus for greenhouse gas emissions and for developing mitigation strategies, which are, of course, applicable to both the demand and supply sides. Economists often prefer mitigation measures that are most "cost-effective" regardless of on which side they are imposed, while others often include the concept of "responsibility" for emissions in formulating policy, including the use of transfers, such as taxes or subsidies, to make adjustments for this concept.

However, the new dual reporting format falls short of the more comprehensive adjustments that may be applicable. For example, the specification of end-use emissions is now only performed at the national level by EIA, and data must be adjusted by the analyst to downscale to the state level. However, data may only be available to specify use within each state on a "net" basis. That is, a factory may purchase electricity from a generator outside the state, yet the basic data would characterize this as a "within state" emission. Likewise, a generator in the state may sell to users outside the state, but the sale cannot be separated from in-state sales. Effectively, interstate sales (gross flows) are omitted, and only a net balance can be inferred. A significant data analysis (probably on a plant-by-plant basis) for electricity produced within the state and for electricity imported into the state is required for a truly accurate assessment.[ii]

Some of the problems with the new adjustments relate to the comparison of data on greenhouse gas (GHG) emissions for 1990 and 1999:

1. The aforementioned adjustments are not undertaken for the Year 1990; hence:

    a. The non-utility generation sub-sector may not be comparable between 1990 and 1999.[iii] The analysis would therefore best be undertaken at the overall electricity utility sector level.

    b. The end-user (demand-side) adjustment needs to be made by the analyst for 1990. With the data at hand, however, the analyst may have to be satisfied with only the net emission outcome.

2. We find the discussion of adjustments and comparability of data in EIA (2001b) especially obtuse, especially when the concepts of the categories of "Non-utility Power Producers" (NUPPs) and "Other Power Producers" are introduced (see pp. 20-25). For example, it is not clear whether electricity from non-utility generators on the supply-side is also shared out to the customer categories.

- *Municipal Waste Management*

Finally, improvements based on more locally specific data can be applied, and in fact are being applied to estimates of GHG emissions from Municipal Waste Management. As previously mentioned, lack of statewide data describing total waste in place at PA landfills necessitated using national and regional averages and trends to estimate methane emissions from landfills. As the EPA continues to release detailed Excel spreadsheets to aid researchers with state-level inventories, improvements in the methodology that take advantage of more readily available smaller-scale data are being incorporated in those spreadsheets. In the case of MWM, the spreadsheets provide a method for estimating waste in place based on historical data describing the annual amount of waste dumped at landfills. This methodology was not previously described in the official methodology and constitutes a significant improvement in the accuracy of estimates of GHG emissions from landfills. Thus, it is important for researchers to continually update their methodology based on the improvements made by others, particularly EPA, which sets the standards for state-level inventories.

Conclusions

This brief overview of potential and existing improvements to the EPA methodology has demonstrated several methods that are available for improving the accuracy and precision of GHG emissions estimates, as well as improving our understanding of the multi-scale processes that are the proximate causes of GHG emissions. Both considerations are critical to our understanding of GHG emissions, and are critical inputs into the logical extension of GHG inventories – the use of the information generated by policy makers, stakeholders, and researchers in formulating GHG mitigation action plans. The potential improvements described here are by no means trivial, neither in their implications for future inventories nor in their increased complexity. As states across the nation continue to implement and improve their GHG inventory and mitigation programs, they will continue to need to balance the need to accurately describe the physical emissions and their causative processes with the monetary, temporal and intellectual resources required to achieve different levels of accuracy in these areas. Nonetheless, if we are to continue to improve our understanding of the state-scale and local-scale components of this national and global issue, it is clear that three issues must be addressed: accurate geographic accounting of emissions, accurate attribution of these emissions to the correct socioeconomic sectors, and a richer and more detailed understanding of the local-scale processes that contribute to GHG emissions.

References:

EIA (2001). *Emissions of Greenhouse Gases in the United States 2000*. Washington, DC, Energy Information Administration, Department of Energy**:** 172.
EIIP (1999). *Introduction to Estimating Greenhouse Gas Emissions*. Washington, DC, U.S. Environmental Protection Agency.