INVENTORY OF GREENHOUSE GASES IN LOUISIANA

PREPARED FOR

The Louisiana Department of Natural Resources

PREPARED BY

The Center for Energy Studies
Louisiana State University

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Report Summary

Purpose

The purposes of this project were to accomplish the following:

- Develop a quantitative inventory of emissions and sinks of greenhouse gases in the State of Louisiana,
- Forecast emissions in the near future, and
- Analyze how emissions might change under alternative assumptions about the growth and composition of the State's economy.

When greenhouse gases of which the most important are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and some man-made chemicals such as hydrofluorocarbons (HFCs) are released into the atmosphere, they absorb the low-energy terrestrial radiation (i.e., radiation reflected by the earth's surface) thereby heating up the atmosphere and contributing to a global warming, which could have serious global human and economic effects. Only a share of greenhouse gas emissions comes from anthropogenic (man-made) sources such as combustion of fossil fuels and various industrial and agricultural processes. Therefore, an accurate inventory of emissions and sinks is the necessary first step in the formulation of the climate change policies and actions. The U.S. Environmental Protection Agency has completed an inventory of greenhouse gas emissions and sinks on the national level and actively encourages states to develop state-level inventories. EPA wants inventories that are based as much as possible on original primary information collected by state agencies or obtained directly from emitters. Louisiana Department of Natural Resources has responded to this initiative and provided funding for this study.

Content of Report

This report is divided into twelve chapters; each of the chapters focuses on a different source of greenhouse gas emissions in Louisiana. The chapters are as follows:

- Chapter One: Carbon Dioxide Emissions from Combustion of Fossil Fuels
- Chapter Two: Emissions from Production and Consumption Processes
- Chapter Three: Methane Emissions from Natural Gas and Oil Systems
- Chapter Four: Methane Emissions from Coal Mining
- Chapter Five: Emissions from Municipal Waste Management
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- Chapter Nine: Emissions from Agricultural Soil Management
- Chapter Ten: Emissions from Forest Management and Land-Use Change
- Chapter Eleven: Emissions from Burning of Agricultural Wastes
- Chapter Twelve: Methane Emissions from Municipal Wastewater

Table II Summary of Inventory Estimates by Type of Emission

Source	Greenhouse Gas	Emissions (thousand metric tons)	Global Warming Potential	CO_2 Equivalent Emissions (thousand metric tons)	MMTCE	Percent of Total Emissions
All Sources	CO_2	192,965.0	1	192,965.0	52.627	88.81
	CH_4	769.8	21	16,166.3	4.409	7.44
	N_2O	8.8	310	2,722.4	0.742	1.25
	HFC-23	0.5	11,700	5,307.1	1.447	2.44
	SF_6	0.0	23,900	97.7	0.027	0.04
	All			**217,285.4**	**59.260**	100.00

The total greenhouse gas emissions in Louisiana in 1996 are estimated to be in3 nation; however, given the fact that Louisiana is prominent nationally in the chemical industry, oil and gas production, and

Table IV Greenhouse Gas Emissions, Population, and Gross State Product,
Selected States and U.S. Total

State	**Inventory Year**	**Population (millions)**	**Gross State Product (billion $)**	**EmissionsEmissi 11cted Sta 11cted TD ha-0.of the48.6 TD /F (%2309 T**			

Chapter One: Carbon Dioxide Emissions from Combustion of Fossil Fuels

Overview

The principal anthropogenic source of carbon dioxide is the combustion of fossil fuels. The purpose of this chapter is to quantify greenhouse gas emissions from the combustion of fossil fuels and biomass fuels of different sectors in the state of Louisiana for 1996. Fossil fuel consumption accounts for approximately three-quarters of the total anthropogenic emissions of carbon worldwide (EIA 1998). Carbon dioxide is emitted during the combustion of fossil fuels. The principal fossil fuels include coal, oil, natural gas, and gasoline.

Methodologies

The methodologies used were taken from the *State Workbook* (1998a). Estimation proceeded in the following steps:

1. The amount of fuel consumed by fuel type and end-use sector was taken from *State Energy Data Report 1996* and *Annual Energy Review 1996*.
2. The total carbon content of fuels consumed was taken from *State Workbook (1998a)*. This number was multiplied by the amount of fuel used to find the total carbon content.
3. The amount of carbon stored in products was subtracted from the total carbon content.
4. Adjustments were made for the amount not oxidized during combustion.

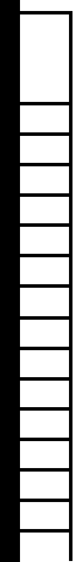
Data Source

The information for this chapter was obtained from the Department of Energy and the Energy Information Administration's *State Energy Data Report 1996* and *Annual Energy Review 1996*.

Results

Results of the estimation are presented in Table 1.1 and Figure 1.1. According to Figure 1.1, the industrial sector accounts for 55 percent of all CO_2 emissions from combustion of fossil fuels. The next two largest sources of carbon dioxide were the transportation sector (27 percent) and electric

[redacted]



[redacted])lb perMil

Chapter Two: Emissions from Production and Consumption Processes

Overview

Emissions are produced as a by-product of various non-energy related production and consumption activities. Unlike the CO_2 emissions from combustion of fuels (Chapter 1), these emissions are produced directly from the production or consumption process itself. In some industrial processes, raw materials are chemically transformed from one state to another. This transformation can result in the release of greenhouse gases such as carbon dioxide, nitrous oxide, hydrofluorocarbons, perfluorinated carbons, and sulfur hexafluoride. The production processes addressed in this section include the following:

- Nitric acid production
- Lime production
- Limestone use
- Soda ash consumption
- CO_2prw 3.6 0 184.0t5 (36 TH CFC-22-30 -13.8 5 1098 Tc 0.1 05 — 7 Tc 0.195) Tj 36 0 TD -0.2 de, (36 imTD 0 Tc3) Tj 4.8 0 TD hexaflu115 0 TD

19 c (carbon) 07 Tj 9 0.592id prods .8 0 TD 160.2Tj 1discutio

Data Source

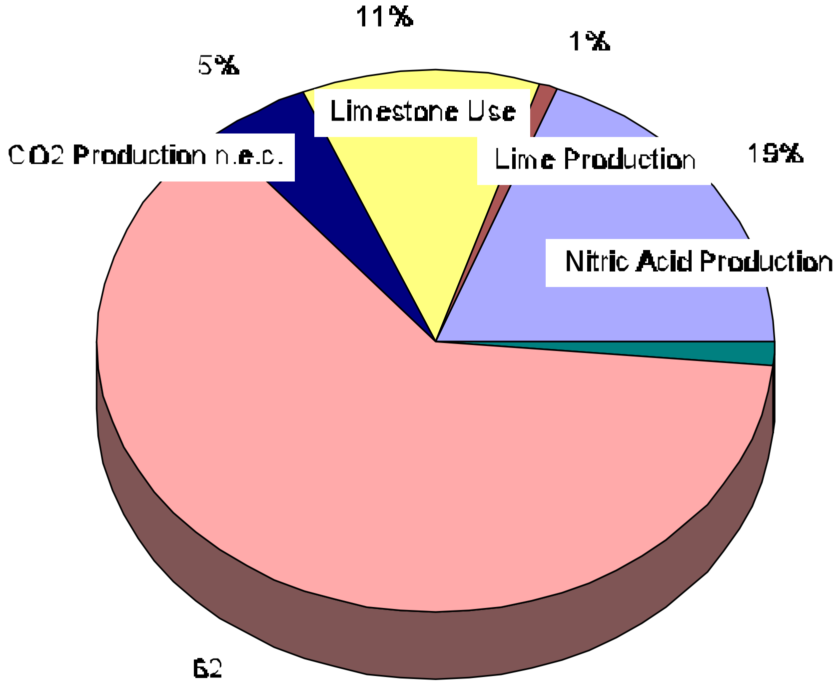
The data for these estimates were obtained from Louisiana Department of Economic Development's *Louisiana Chemical and Petroleum Products Directory*, *Chemical Economics Handbook*, *Minerals Yearbook*, and surveys of private companies. The information is for 1997.

Results

Results of the estimation are reported in Table 2.1 and Figure 2.1. Total amount of emissions from production and consumption processes is approximately 8.5 million metric tons of CO_2 equivalent or 2.23 MMTCE. According to Figure 2.1, production of HCFC-22 accounts for almost two-thirds of all greenhouse gas emissions from industrial production and consumption processes. The second most important source is limestone use, which accounts for 19 percent.

Table 2.1 Emissions of Greenhouse Gases from Industrial Processes in Louisiana

Industrial Process	**Amount (short tons)**	**GHG**	**Emission Factor**	**CO_2 Equivalent Emissions (metric tons)**	**MMTCE**
Nitric Acid Production	1,075,000	N_20	0.0055	1,662,773	0.453
Lime Production	94,449	CO_2	0.7850	67,262	0.018
Limestone Use	8,931,618	CO_2	0.1200	972,325	0.265
Soda Ash Consumption	1,500	CO_2	0.4150	565	0.000
CO_2 Production n.e.c.	448,950	CO_2	1.0000	407,285	0.111
HCFC-22 Production	25,000	HFC-23	0.0200	5,307,085	1.447
SF_6 Use	5	SF_6	1.0000	97,677	0.027
Total				**8,514,972**	**2.232**


11%
1%
5%
Limestone Use
CO2 Production n.e.c.
Lime Production
19%
Nitric Acid Production
62

Chapter Three: Methane Emissions from Natural Gas and Petroleum Systems

Overview

Production and processing of natural gas and petroleum result in emissions of methane. Natural gas systems can be divided into four stages, with each stage having different emissions factors: field production, processing, transmission and storage, and distribution. Petroleum systems can be divided into five stages: field operations, crude oil storage, refining, tanker operations, and venting and flaring. In natural gas and petroleum systems, methane emissions occur as a result of (a) normal operations (e.g., emissions from turbine exhaust, bleed from pneumatic devices, waste gas streams, venting and flaring, and fugitive emissions; (b) routine maintenance; and (c) accidents (e.g., pressure relief systems)

Methodologies

For this workbook the methodologies deviated from the third [illegible]

Annual, *Louisiana Crude Oil Refinery Survey Report,* and *Strategic Petroleum*

Chapter 4: Methane Emissions from Coal Mining

Overview

The process of coal formation, normally referred to as coalification, produces not just coal but also methane and other byproducts. The process, which involves the conversion of vegetation into coal, is complex and occurs over m

Chapter Five: Emissions from Municipal Waste Management

Overview

Landfills are the largest anthropogenic source of methane emissions in the United States (*EPA 1998b*). Landfill gas, primarily methane (CH_4) and carbon dioxide (CO_2), is produced as a result of the decomposition of organic waste in an anaerobic (without oxygen) environment. Most landfill gas is emitted directly to the atmosphere. However, at some landfills the gas is recovered and either flared or used as an energy source.

The major factors influencing the amount of CH_4 that is emitted from landfills are as follows (*EPA 1995*):

- composition of the waste
- moisture content of the waste
- pH of landfill leachate
- available nutrients in the waste
- the temperature of the waste
- the density and particle size of the waste

These factors affect either the presence of the required anaerobic environment or the ability of facultative bacteria to survive and multiply. Landfills with shredded waste that is moist, nutrient rich, tightly packed, to ½non-haz

4. The amount of methane generated from large landfills was estimated.
Methane Emissions from Large Landfills (ft^3) = Number of Large Landfills* (417,957 + 0.26 * Waste in Place) ± 15%

5. The result was converted to tons of CH_4 per year.
Methane Emissions (tons) = Methane Emissions (ft^3) * 0.0077

6. The amount of methane emitted from small and large landfills was found.
Total Methane from Municipal Solid Waste Landfills = Methane Emissions from Small Landfills + Methane Emissions from Large Landfills

7. The amount of methane emissions from industrial landfills was calculated.
Methane Emissions from Industrial Landfills = 7% * Total Methane Emissions from Municipal Solid Waste Landfills

8. The total amount of methane generated by municipal solid waste and industrial landfills was found.
Total Methane Emissions = Total Methane Emissions from Municipal Landfills + Total Methane Emissions from Industrial Landfills

9. Any methane flared or recovered was subtracted from the methane generated to give the preliminary net methane Emissions.
Preliminary Net Methane Emissions = Total Methane Generated – Methane Flared or Recovered

10. The result was adjusted for oxidation.
Net Methane Emissions from Landfills = Preliminary Net Methane Emissions * 90%

Data Source

The data for this chapter were gathered from the Louisiana Department of Environmental Quality Solid Waste Division. Amount of methane flared or recovered came from interviewing individuals at each landfill in the state.

Results

Results of the estimation and model assumptions are presented in Table 5.1. In 1996 the total amount of emitted methane was 4,183,722 metric tons of CO_2 equivalent or 1.14 MMTCE.

Table 5.1 Emissions of Greenhouse Gases from Municipal Waste Management in Louisiana

Current population	4,351,000
Average annual population growth rate over last 30 years	1%
Per-capita waste generation rate per year(lb/capita/yr)	1642.5
Portion of waste generated that is landfilled	85%
Estimated waste in place (tons)	85,954,739
Portion of waste generated that is landfilled	85%
Number of large landfills (>1.1 mil tons)	16
Fraction of waste in place in large (>1.1 mil tons) landfills	73%
Waste in place at small landfills (tons)	23,207,780
tons)	

Chapter 6: Methane Emissions from Domesticated Animals

Overview

Animals emit methane through the digestion in a process called enteric fermentation. It involves the breaking up of food consumed by the animals by microbes resident in the particular animal. Ruminants, for example, cattle, sheep, and goats produce high amounts of methane because they have a large "fore-stomach" (rumen) where the methane is produced. Non- ruminants (animals without rumen) such as pigs and horses, on the other hand, produce less methane. Methane emissions from animals also depend on the quantity and type of the animal feed. Wild animals also emit methane, but it is not considered here.

Methodologies

Calculating methane emissions from domestic animals in Louisiana involved collecting data on the population of the various types of domestic animals reared in the state. The animal population was multiplied by the regional emissions factor and methane emissions were thus obtained. The results were divided by 2,000 (lbs/ton) to convert into tons of methane. These were then converted to carbon and carbon dioxide equivalents.

Data Sources

Cattle population data were obtained from the USDA. Data on goats, sheep, horses, and swine were obtained from the Agricultural Center at Louisiana State University.

Results

The results of the estimation of methane emissions from domesticated animals in Louisiana are presented in Table 6.1 and Figure 6.1.Figure

Chapter 7: Methane Emissions from Manure Management

Overview

When the organic material in animal manure decomposes in an anaerobic environment, methane is produced. The quantity of methane produced depends on the way the manure is stored and treated. Liquid systems, e.g., lagoons, ponds, tanks, or pits, produce more methane than solid manure deposited on pastures and rangelands. Higher temperatures and moist conditions also enhance the production of methane.

Methodologies

The methodology used to estimate methane emissions from manure management for Louisiana involves the following steps:

(1) determining the total number of animals by type within the state;
(2) determining the total manure produced from the animals;
(3) applying an emissions factor for each animal category based the manure management system used. The formula used is as follows:

$$CH_4 = A_i * TAM_i * VS_i * Bo_i * MCF_j * WS_{i\,j}$$

where,

CH_4	is the annual methane released (lbs/yr)
A_i	is the animal population of type *i*
TAM_i	is the typical animal mass (lbs/head) for type *i*
VSi_i	is the average annual volatile solids production per unit of animal mass for type *i*
Bo_i	is the maximum methane producing capacity per pound of VS for animal type *i*
MCF_j	is the methane conversion factor for manure management system *j* (%)
$WS\%_{i\,j}$	is percent of animal type *i* manure managed in manure system *j* (%).

Table 7.1 shows the types of animals and the manure management system used.

Table 7.1 Animal Types and Manure Management Systems Used in Louisiana

Type of Animal	Manure Management System
Dairy Cattle	Daily spread, anaerobic lagoon
Non Dairy Cattle -steers, heifers	Pasture, range, dry lot
Swine - Breeding	Anaerobic lagoon, dry lot
Swine- Market	Anaerobic lagoon, dry lot
Poultry- Layers	Anaerobic lagoon
Sheep	Pasture, range
Goats	Pasture, range
Horses/Mules	Pasture, range, paddock

Data Sources

Data were obtained from *Agricultural Statistics and Prices for Louisiana*, the Louisiana State University Agricultural Center, and the U.S. Department of Agriculture at the following web sites: www.nass.usda.gov/la/annbul2.htm and www.usda.gov/nass/pubs/agr97/acro97.htm

Results

Results of the estimation are presented in Tables 7.2 and 7.3. Manure management systems in Louisiana emitted in 1997 7,300 metric tons of methane or 0.042 MMTCE.

Table 7.2 Methane Emissions from Manure Management Systems by Animal Types in Louisiana

Animal Types	Methane Emissions (metric tons)	CO_2 Equivalent Emissions (metric tons)	MMTCE
Mature Dairy Cattle	1,493	31,353	0.009
Feedlot-Fed Steers and Heifer on High Grain	10	209	0.000
Swine: Market	1,248	26,202	0.007
Swine: Breeding	801	16,825	0.005
Goats	2	51	0.000
Horses/Mules	1,130	23,736	0.006
Poultry: Layers	2,609	54,796	0.015
Sheep	7	139	0.000
All types	**7,300**	**153,310**	**0.042**

Table 7.3 Methane Emissions from Manure Management Systems in Louisiana

Manure Management Systems	Methane Emissions (metric tons)	CO	

Chapter Eight: Methane Emissions from Flooded Rice Fields

Overview

Results:

Emission estimation assumptions are presented in Table 8.1. Rice fields, which occupied 533,000 acres in Louisiana in 1996, emitted 108,335 metric tons of methane or 0.62 MMTCE.

Table 8.1 Methane Emissions from Flooded Rice Fields in Louisiana

Acreage Harvested in 1996	533,000
Ratoon Crop	159,900
Total Acreage	692,900
Short Growing Season (days)	90
Long Growing Season (days)	120
Short Acre-days/yr	62,361,000
Long Acre-days/yr	83,148,000
Low Emissions Coefficient	0.950
High Emissions Coefficient	5.032
Low Methane Emissions (tons)	29,634
High Methane Emissions (tons)	209,200
Total Methane Emissions (tons)	**119,417**
Total Methane Emissions (metric tons)	**108,335**
CO_2 equivalent Emissions (metric tons)	**2,275,025**
MMTCE	**0.620**

Chapter 10: Carbon Dioxide Emissions from Forest Management and Land -Use Change

Overview

The biosphere emits and absorbs a variety of trace gases including carbon dioxide, methane, carbon monoxide, nitrous oxide, oxides of nitrogen, and non-methane volatile organic compounds. Vegetation withdraws (i.e., uptakes) carbon dioxide from the atmosphere through the process of photosynthesis. Carbon dioxide is returned to the atmosphere through the respiration of the vegetation and the decay of organic matter in soils and litter. Human activities such as cutting down trees to create land

atmosand

Data Sources

Data for this workbook were obtained from the USDA's Forest Service publication by the Southern Forest Experiment Station including

Chapter Eleven: Emissions from Burning of Agricultural Waste

Overview

In some parts of the U.S., agricultural crop wastes are burned in the field to clear remaining straw and stubble after harvest and to prepare the field for the next cropping cycle. When crop residues are burned, a number of greenhouse gases are released, including carbon dioxide, methane, carbon monoxide, nitrous oxide, and nitrogen oxides. Of these, carbon monoxide and nitrogen oxides are "indirect" greenhouse gases for which global warming potentials have not yet been developed; thus, these gases are not covered in the chapter. In addition, crop residue burning is not a net source of carbon dioxide because the carbon released as carbon dioxide during burning had been taken up from carbon dioxide in the atmosphere during the growing season.

Methodologies

The methodologies used were taken from the *State Workbook* (1998a). For each crop the amount of dry matter (lbs) was calculated by multiplying annual crop residue by residue/crop ratio by proportion of crop produced in fields where residue is burned by dry matter content of the residue by burning efficiency by combustion efficiency. To find total carbon released, dry matter was multiplied by the carbon content (lbs C/lb dm). To find total nitrogen released (lbs N) dry matter (lbs dm) was multiplied by the Nitrogen content (lbs N/lb dm).

Rice

Dry Matter = Crop production (lbs) * 1.4 * 3% * 85% * 93% * 88%
Total Carbon Released = Dry Matter * 0.4144
Total Nitrogen Released = Dry Matter * 0.0067
CH_4 Emitted (tons CH_4-C) = (Total Carbon Released * 0.005 * (16/12))/2000
N_2O Emitted (tons N_2O-N) = Total Nitrogen Released * 0.007

Sugarcane

Dry Matter = Crop production (lbs) * 0.8 * 3% * 62% * 93% * 88%
Total Carbon Released = Dry Matter * 0.4235
Total Nitrogen Released = Dry Matter * 0.0040
CH_4 Emitted (tons CH_4-C) = (Total Carbon Released * 0.005 * (16/12))/2000
N_2O Emitted (tons N_2O-N) = Total Nitrogen Released * 0.007

Wheat

Dry Matter = Crop production (lbs) * 1.3 * 3% * 85% * 93% * 88%
Total Carbon Released = Dry Matter * 0.4853
Total Nitrogen Released = Dry Matter * 0.0028
CH_4 Emitted (tons CH_4-C) = (Total Carbon Released * 0.005 * (16/12))/2000
N_2O Emitted (tons N_2O-N) = Total Nitrogen Released * 0.007

Data Source

The Louisiana Agricultural Statistics Service supplied the data for this chapter. Crop productions were averaged over the three-year period (1995-1997).

Results

Estimates of greenhouse gas emissions burning of agricultural waste are presented in Table 11.1. The total amount of emitted gases is 4,848 metric tons of CO_2 equivalent or 0.001 MMTCE. The crop with the largest contribution is sugar cane, which accounts for 77 percent of emissions.

Table 11.1 Emissions of Greenhouse Gases from Burning of Agricultural Waste in Louisiana

Crop Type	**Crop Production (lbs)**	**Methane Emissions (metric tons)**	**N_2O Emissions (metric tons)**	**Total CO_2 Equivalent Emissions (metric tons)**	**MMTCE**
Rice	1,805,666,667	30	1	973	0.000
Sugarcane	20,842,000,000	146	2	3,749	0.001
Wheat	254,500,000	5	0	123	0.000
Corn	240,667	0	0	0	0.000
Soya (Soybeans)	2,015,800	0	0	3	0.000
Sorghum	501,080	0	0	2	0.000
All Types	**22,904,924,213**	**181**	**3**	**4,848**	**0.001**

Chapter Twelve: Methane Emissions from Municipal Wastewater

Overview

Wastewater can be treated by using aerobic or anaerobic technologies or, if left untreated, can degrade under aerobic or anaerobic conditions. Methane is produced when organic materials in treated and untreated wastewater degrade anaerobically. The amount of emissions is related to the organic content of the wastewater. Wastewater with high 0nbteated, can

Data Source

The information for this chapter was gathered from EPA's Needs Survey (1998), Louisiana Department of Public Health, and Louisiana Department of Environmental Quality.

Results

Table 12.1 presents the results of the estimation. Wastewater systems in Louisiana emit annually almost 27 thousand metric tons of CO_2 equivalent or 0.007 MMTCE.

Table 12.1 Methane Emissions from Municipal Wastewater in Louisiana

Wastewater Systems	**Methane Emissions (metric tons)**	**CO_2 Equivalent Emissions (metric tons)**	**MMTCE**
Municipal Facilities	575	12,070	0.003
On-Site Septic Systems	709	14,893	0.004
Total	**1,284**	**26,962**	**0.007**

References

Birdsey, Richard A. and V. A. Rudis. *Forest Resources Trends and Current Conditions in the Lower Mississippi Valley* . USDA Forest Service. Southern Forest Experiment Station: Resource Bulletin SO- 116 December 1986. New Orleans, LA. 1986.

Chemical Economics Handbook (database). SRI International: Menlo Park, CA. Dialog Corporation/ File 359 (October 12, 1998).

Department of Agricultural Economics and Agribusiness, Louisiana State University and Agricultural and Mechanical College. *Agricultural Statistics and Prices for Louisiana*. Baton Rouge, LA. 1997.

Earles, Jacqueline M. *Forest Statistics for Louisiana Parishes - 1974*: Southern Forest Experiment Station, US Department of Agriculture. New Orleans, LA. 1975.

Energy Information Administration (EIA). *Annual Energy Review 1995*. DOE/EIA-0384(95). US Department of Energy, Washington, DC. 1996.

Energy Information Administration (EIA). *Emissions of Greenhouse Gases in the United States 1997*. DOE/EIA-0573(97). US Department of Energy, Washington, DC. 1998.

Energy Information Administration (EIA), *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*. U.S. Department of Energy Publication SR/OIAF/98-03. Washington D.C. October 1998.

Energy Information Administration (EIA). *State Energy Data Report 1995*. DOE/EIA-0214(95). US Department of Energy, Washington, DC. 1997.

Forest Inventory and Analysis: Timber Product Output (TPO) Database Retrieval System at http://www.srsfia.usfs.msstate.edu/rpa/tpo/rpatpo.htm

Holzapfel-Pschorn, A., R. Conrad, and W. Seiler. *Production, oxidation, and emission of methane in rice paddies*. FEMS Microbiology Ecology DOE/EIA-0573(97) Energy, Washc -0of

Sass, R.L., F.M. Fisher, P.A. Harcombe, and F.T. Turner. *Methane production*