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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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 Eight: Methane Emissions from Flooded Rice Fields
- 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

The modeling and forecasting section of the project will be provided as a separate report accompanied by a spreadsheet file.

Results

Results of the inventory are summarized in the following tables. The first table shows greenhouse gas emissions by type, amount, and CO_2 equivalence. Eleven of the twelve sources are net producers while one, forest management and land use changes, is a major "sink," reducing the estimate of the state's total emissions by about 10 percent.

Table I Summary of the Inventory Estimates by Source

Source	Greenhouse Gas	Emissions (thousand metric tons)	Global Warming Potential	CO_2 Equivalent Emissions (thousand metric tons)	MMTCE*	Percent of Total Emissions
1. Fossil Fuel Combustion	CO_2	214,270.5	1	214,270.5	58.437	98.61
2. Production and Consumption Processes	CO_2	1,447.4	1	1,447.4	0.395	0.67
	N_2O	5.4	310	1,662.8	0.453	0.77
	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			8,515.0	2.322	3.92
3. Natural Gas and Oil Systems	CH_4	384.6	21	8,077.5	2.203	3.72
4. Coal Mining	CH_4	0.5	21	10.4	0.003	0.00
5. Municipal Waste Management	CH_4	199.2	21	4,183.7	1.141	1.93
6. Domesticated Animals	CH_4	68.4	21	1,435.6	0.392	0.66
7. Manure Management	CH_4	7.3	21	153.3	0.042	0.07
8. Flooded Rice Fields	CH_4	108.3	21	2,275.0	0.620	1.05
9. Agricultural Soil Management	N_2O	3.4	310	1,058.5	0.289	0.49
	CO_2	22.0	1	22.0	0.006	0.01
	All			1,080.5	0.295	0.50
10. Forest Management and Land Use Change	CO_2	-22,774.9	1	-22,774.9	-6.211	-10.48
11. Burning of Agricultural Crop Waste	CH_4	0.2	21	3.8	0.001	0.00
	N_2O	0.0	310	1.1	0.000	0.00
	All			4.8	0.001	0.00
12. Municipal Wastewater	CH_4	1.3	21	27.0	0.007	0.01

* Million metric tons of Carbon equivalent

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 59.26 million metric tons of carbon equivalent (MMTCE). Almost 99 percent of total emissions are attributed to combustion of fossil fuels. Among different greenhouse gases, carbon dioxide is the most important; it accounts for 89 percent of all emissions in Louisiana.

Table III compares Louisiana's greenhouse gas emissions with national totals. It shows amounts and a percentage distribution for each major sector for the state and the nation.

Table III Comparison of the total U.S. and Louisiana Greenhouse Gas Emissions

Sectors	Louisiana		U.S. Total		Louisiana Emissions as a Share of U.S. Emissions
	Emissions (MMTCE)	Sectoral Distribution	Emissions (MMTCE)	Sectoral Distribution	
Fossil Fuel Combustion	58.437	98.612%	1,450.300	93.792%	4.03%
Production and Consumption Processes	2.322	3.919%	61.500	3.977%	3.78%
Natural Gas and Oil Systems	2.203	3.717%	35.600	2.302%	6.19%
Coal Mining	0.003	0.005%	18.900	1.222%	0.01%
Municipal Waste Management	1.141	1.925%	65.200	4.217%	1.75%
Domesticated Animals	0.392	0.661%	34.500	2.231%	1.13%
Manure Management	0.042	0.071%	16.600	1.074%	0.25%
Flooded Rice Fields	0.620	1.047%	2.500	0.162%	24.82%
Agricultural Soil Management	0.295	0.497%	68.600	4.436%	0.43%
Forest Management and Land Use Change	-6.211	-10.482%	-208.600	-13.490%	2.98%
Burning of Agricultural Crop Waste	0.001	0.002%	0.300	0.019%	0.44%
Municipal Wastewater	0.007	0.012%	0.900	0.058%	0.82%
Total	59	100.000%	1,546.300	100.000%	3.83%

Overall, relative contributions of different sources of emissions in Louisiana resemble those in the national picture. In most cases, deviations from national benchmarks are easily explained by the particulars of the industry mix in Louisiana. For example, fossil fuel combustion, natural gas and oil systems, and flooded rice fields contribute to emissions relatively more in Louisiana than in the nation; however, given the fact that Louisiana is prominent nationally in the chemical industry, oil and gas production, and rice cultivation, these results are neither surprising nor alarming. Another way of comparing Louisiana emissions to the U.S. emissions is through looking at the share of Louisiana emissions in the total U.S. greenhouse gas emissions. Louisiana accounts for 3.8 percent of the national emissions; this is somewhat higher that its "share" based on the proportion of population or gross domestic product attributable to Louisiana which are measured respectively at 1.7 and 1.5 percent of the U.S. total. Again, this result is a function of the state's industry mix, but Louisiana's share of the nation's greenhouse gas emissions is well more than twice its share of the nation's population and output.

Table IV lists shares for greenhouse gas emissions, population, and Gross State Product for states with completed greenhouse gas inventories. In order to compare emissions "performance" by different states, we constructed ratios of the state's share of emissions to the state's share of Gross Domestic Product and the state's share of emissions to the state's share of the U.S. population. Results are presented in Figure I. A low (below 1) value of the ratio indicates that a state's greenhouse gas emissions are smaller than one might expect, based on the state's contribution to the U.S. Gross Domestic Product or its share in population. A high (above 1) value of the ratio indicates that a state's emissions are greater than expected. According to Figure I, Louisiana, New Mexico, Mississippi, Alabama, Utah, and Kansas form a group of states with emission shares well above the expected range. This analysis rests upon the assumption that greenhouse gas emissions depend on the levels of GDP and population; however, further research is required to determine if that assumption is valid and whether these are appropriate standardization variables.

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 $)	Emissions (MMTCE)	Share of the U.S. Total (%)		
					Emissions	Population	GSP
California	1990	29.8	794.4	114.5	8.67	13.16	14.03
Pennsylvania	1990	11.9	245.4	76	5.75	5.25	4.33
New York	1990	18	497.5	73.7	5.58	7.95	8.79
Illinois	1992	11.4	273.4	66.1	5.00	5.03	4.83
Louisiana	1996	4.4	117.6	59.3	3.83	1.67	1.54
Georgia	1990	6.5	140.1	40.3	3.05	2.87	2.47
New Jersey	1990	7.7	214.8	35.1	2.66	3.40	3.79
Alabama	1990	4	71.1	33.3	2.52	1.77	1.26
North Carolina	1990	6.6	143.5	31.3	2.37	2.91	2.53
Missouri	1990	5.1	104.1	29.9	2.26	2.25	1.84
Virginia	1990	6.2	148	29.2	2.21	2.74	2.61
Tennessee	1990	4.9	94.2	29.1	2.20	2.16	1.66
Wisconsin	1990	4.9	99.3	26.7	2.02	2.16	1.75
Mississippi	1992	2.6	38	25.1	1.90	1.15	0.67
Minnesota	1990	4.4	99.6	22.1	1.67	1.94	1.76
Kansas	1990	2.5	51.2	20.8	1.57	1.10	0.90
Kentucky	1990	3.7	67.4	20.8	1.57	1.63	1.19
Maryland	1990	4.8	113.9	20.5	1.55	2.12	2.01
Iowa	1990	2.8	54.9	17	1.29	1.24	0.97
Utah	1990	1.7	31.1	16.9	1.28	0.75	0.55
Washington	1990	4.9	114.2	16.7	1.26	2.16	2.02
New Mexico	1990	1.5	26.6	16.2	1.23	0.66	0.47
Oregon	1990	2.8	57	15.1	1.14	1.24	1.01
Maine	1990	1.2	23.2	4.6	0.35	0.53	0.41
Delaware	1990	0.7	20.9	4.3	0.33	0.31	0.37
Montana	1990	0.8	13.3	4.1	0.31	0.35	0.23
Hawaii	1990	1.1	32.5	3.8	0.29	0.49	0.57
Colorado	1990	3.3	74.3	3.5	0.26	1.46	1.31
New Hampshire	1990	1.1	23.8	3.1	0.23	0.49	0.42
Vermont	1990	0.6	11.5	2.1	0.16	0.26	0.20
USA	1990	226.5	5,662	1,321.2			

Source: CES Inventory and EPA (http://yosemite.epa.gov/globalwarming)

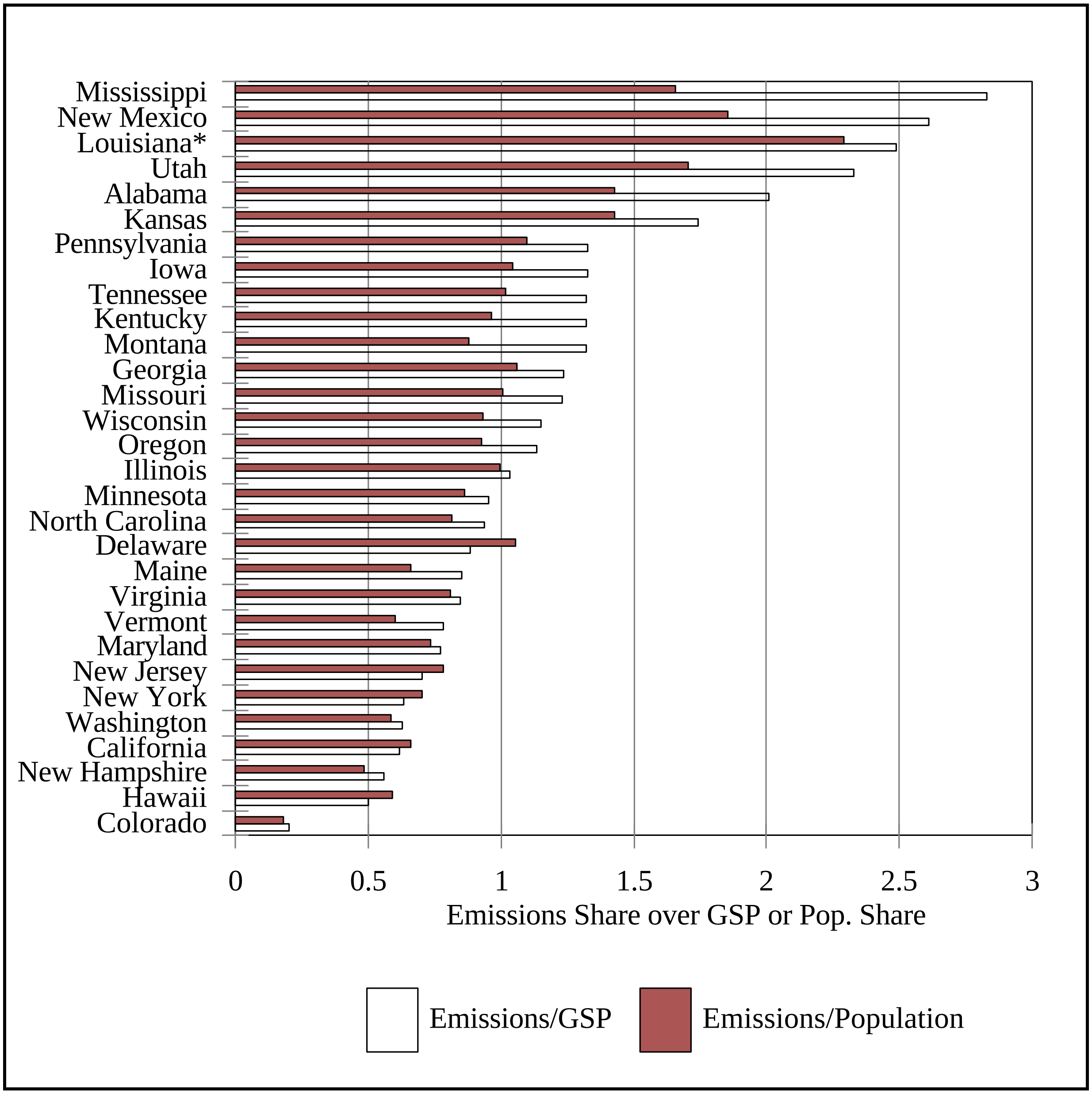

Figure I Share of Greenhouse Gas Emissions Standardized by Shares of Gross Domestic Product and Population

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 utilities (15 percent). The combined share of residential and commercial sectors is fairly small–approximately 3 percent.

Table 1.1 Emissions of Greenhouse Gases from Combustion of Fossil Fuels in Louisiana

Sector/Fuel	Consumption (Million Btu)	Carbon Content (lb per Million BTU)	CO_2 Emissions (metric tons)	MMTCE
Residential				
Kerosene	100,000	43.5	7,163	0.002
LPG	2,900,000	37.8	180,496	0.049
Natural Gas	59,100,000	31.9	3,119,916	0.851
Total Residential	**62,100,000**		**3,307,574**	**0.902**
Commercial				
Distillate Fuel Oil	700,000	44.0	50,714	0.014
LPG	500,000	37.8	31,120	0.008
Motor Gasoline	200,000	42.8	14,095	0.004
Bituminous Coal	100,000	56.0	9,221	0.003
Natural Gas	26,900,000	31.9	1,420,063	0.387
Total Commercial	**28,400,000**		**1,525,212**	**0.416**
Industrial				
Distillate Fuel Oil	64,000,000	44.0	4,636,705	1.265
Kerosene	200,000	43.5	14,325	0.004
LPG	243,500,000	37.8	7,362,369	2.008
Lubricants	7,400,000	44.6	271,715	0.074
Motor Gasoline	4,100,000	42.8	288,938	0.079
Other Petroleum	511,100,000	44.0	37,028,437	10.099
Residual Fuel	4,800,000	47.4	374,625	0.102
Coal	2,100,000	56.0	193,635	0.053
Natural Gas	1,317,900,000	31.9	67,386,669	18.378
Total Industrial	**2,166,500,000**		**117,557,418**	**32.061**
Transportation				
Aviation Gasoline	400,000	41.6	27,399	0.007
Distillate Fuel	163,000,000	44.0	11,809,108	3.221
Jet Fuel: Kerosene	164,600,000	43.5	11,789,514	3.215
LPG	200,000	37.8	12,448	0.003
Lubricants	4,100,000	44.6	301,089	0.082
Motor Gasoline	263,000,000	42.8	18,534,306	5.055
Residual Fuel	163,000,000	47.4	12,721,630	3.470
Bituminous Coal	770,000	56.0	71,000	0.019
Natural Gas	70,800,000	31.9	3,737,564	1.019
Total Transportation	**829,870,000**		**59,004,059**	**16.092**
Electric Utilities				
Crude Oil	3,100,000	44.7	228,163	0.062
Bituminous Coal	203,500,000	56	18,764,166	5.117
Natural Gas	263,000,000	31.9	13,883,889	3.787
Total Electric Utilities	**469,600,000**		**32,876,218**	**8.966**
All Sectors	**3,556,470,000**		**214,270,481**	**58.437**

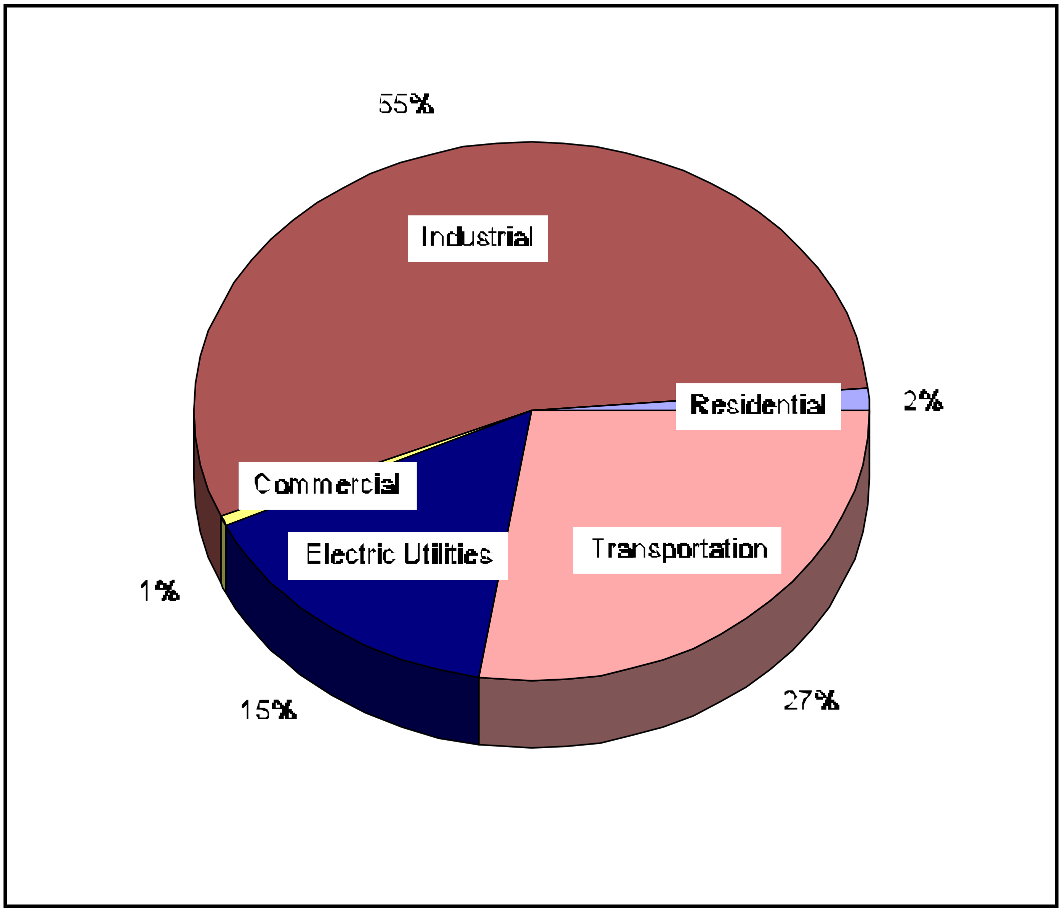

Figure 1.1 Sectoral Composition of CO2 Emissions from Fuel Combustion

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_2 production not elsewhere classified
- HCFC-22 production
- Sulfur hexafluoride use in electrical power systems

Other production processes also release greenhouse gas emissions and are discussed in the *State Workbook* (1998a). We did not estimate emissions from these processes because either data was not available or these processes are not performed in Louisiana. These processes include the following:

- Clinker production
- Masonry cement production
- Adipic acid production
- Trona production
- Aluminum production

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) have extremely long life times. They will continue to accumulate in the atmosphere as long as emissions continue. Sulfur hexafluoride is the most potent greenhouse gas the Intergovernmental Panel on Climate Change (IPCC) has ever evaluated. The use of these substances is growing rapidly in part because they are the main substitute for ozone-depleting substances (EPA 1998b).

Methodologies

The methodologies used were taken from the *State Workbook* (1998a). The methodology for each production process followed the general procedure of determining the "activity level" (i.e., production or consumption data) and the "emission factor" for the activity (i.e., emissions per unit production or consumption). The activity level was then multiplied by emissions factors to determine total emissions.

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**

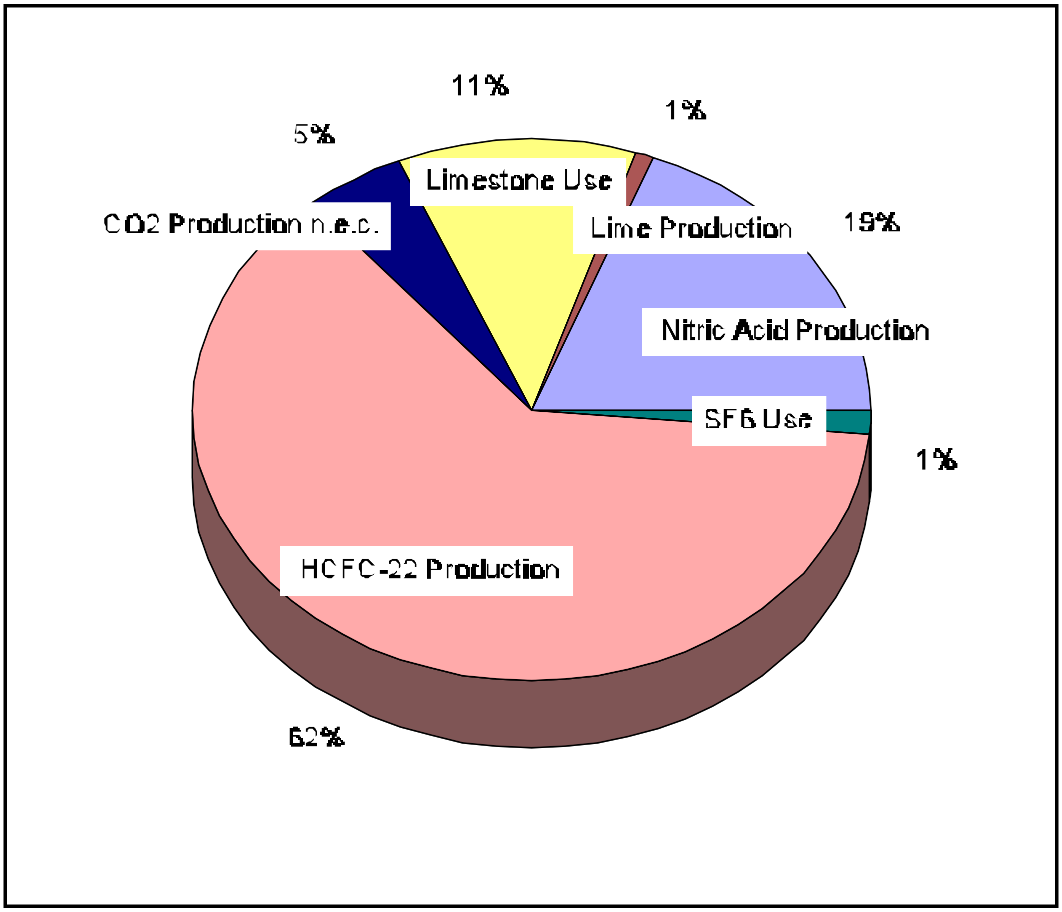

Figure 2.1 Sectoral Composition of Greenhouse Gas Emissions from Industrial Processes

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 edition of the *State Workbook* (1998a). The methodologies used were taken from a draft form of a later edition of the *State Workbook (1998a)*. The following data were needed for emissions from natural gas systems:

- number of wells, broken down into associated and non-associated wells,
- number of offshore platforms in the Gulf of Mexico,
- number of miles of gathering pipeline,
- number of gas processing plants,
- number of miles of transmission pipelines,
- number of transmission and storage stations,
- number of miles of cast iron main pipeline,
- number of miles of unprotected steel main pipeline,
- number of miles of protected steel main pipeline,
- number of miles of plastic main pipeline,
- total number of services,
- number of unprotected steel services,
- number of protected steel services.

For some of these numbers, default numbers were used as outlined in the workbook. Numbers were multiplied by an emissions factor to produce the annual methane emissions. The annual methane emissions were then multiplied by 21 (the global warming potential of methane) and then by 12/44 (the ratio of the atomic weight of carbon to the molecular weight of CO_2) to obtain the amount of methane in units of MTCE. For the oil section the information needed was the amount of oil produced, refined, transported, and stored at oil facilities.

Data Source

The data needed for this chapter were obtained from the following sources: *Basic Petroleum Data Book*, MMS web site, *Gas Fact*, *Oil & Gas Journal*, *Natural Gas Annual*, *Louisiana Energy Facts*

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

Results

Results of the estimation are presented in Table 3.1. Total greenhouse gas emissions in Louisiana from natural gas and petroleum systems was 8,077,544 metric tons of CO_2 equivalent or 2.20 MMTCE.

Table 3.1 Emissions of Greenhouse Gases from Natural Gas and Petroleum Systems In Louisiana

Operations	Amount or Number	Emission Factor	Methane Emissions (metric tons)	CO_2 Equivalent Emissions (metric tons)	MMTCE
Oil Operations					
Oil production, barrels	468,172,092	0.0062	7,637	160,367	0.044
Tankered oil, barrels	120,000,000	0.0017	537	11,271	0.003
Oil refining, barrels	848,588,077	0.0017	3,795	79,701	0.022
Oil storage, barrels	262,900,000	0.0003	207	4,357	0.001
Gas Production Emissions					
Non-associated wells	15,295	2.5400	35,244	740,121	0.202
Associated wells	24,402	0.0200	443	9,298	0.003
Offshore platforms	3,849	20.4000	71,233	1,495,883	0.408
Gas gathering pipeline, miles	2,536	0.3700	938	17,876	0.005
Gas Processing Emissions					
Processing plants	72	948.0000	61,921	1,300,350	0.355
Gas Transmission Emissions					
Transmission pipelines, miles	25,709	0.6800	15,860	333,053	0.091
Transmission stations	154	891.0000	124,166	2,607,476	0.711
Storage stations	35	914.0000	28,928	607,478	0.166
Gas Distribution Emissions					
Distribution pipelines, miles	21,820	0.7000	13,856	290,986	0.079
Cast iron main pipelines, miles	1,440	4.6300	6,049	127,028	0.035
Unprotected steel main pipelines, miles	2,138	2.1600	4,190	87,994	0.024
Protected steel main pipelines, miles	11,565	0.1100	1,154	24,235	0.007
Plastic main pipelines, miles	6,546	0.4200	2,494	52,378	0.014
Services	1,026,486	0.0140	13,037	273,779	0.075
Unprotected steel services	123,178	0.0330	3,688	77,440	0.021
Protected steel services	482,448	0.0035	1,532	32,169	0.009
Total			**384,645**	**8,077,544**	**2.203**

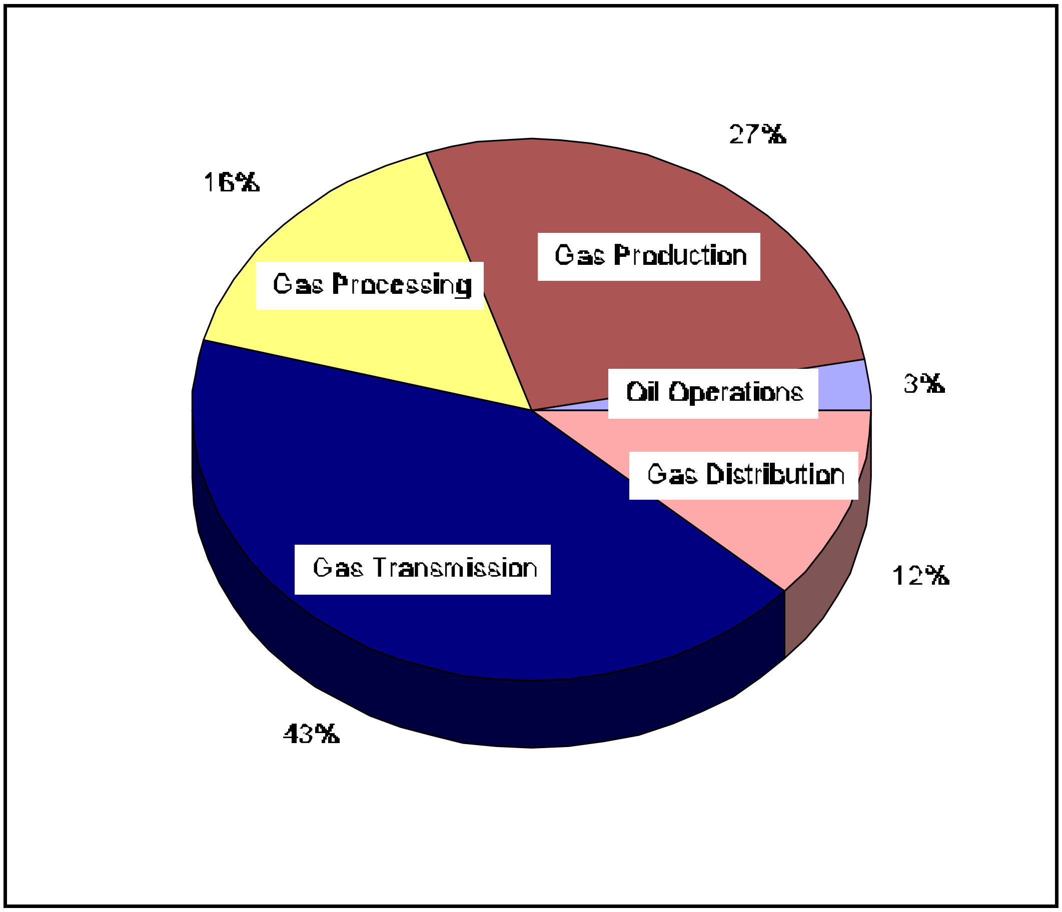

Figure 3.1 Sectoral Composition of CO2 Emissions from Natural Gas and Petroleum Systems

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 millions of years. The amount of methane generated depends on the depth and rank of the coal (high coal ranks, such as bituminous, contain more methane than low coal ranks, such as lignite). The greater the depth of the coal, the higher the pressure, and thus the higher the amount of methane produced. Once generated, the methane is stored in the coal until the pressure on the coal is reduced through natural erosion, faulting, or mining.

Methodologies

The methodologies used were taken from the *State Workbook (1998a).* Louisiana has only several surface coal mines. The data required were annual coal production from surface mines and methane recovered. First the annual production of coal was multiplied by a high and a low emission coefficient to produce the amount of methane emitted into the atmosphere. The range of emission coefficients is due to the uncertainty associated with measuring methane emissions from surface mines. The amount of coal produced was multiplied by the emission coefficients to find post-mining emissions. The emissions from the surface mining and the post-mining were added to determine total methane emissions. The estimate of the total emissions was obtained by averaging the high and low totals. The total emissions estimate was then converted from million cubic feet to tons by multiplying by 20.66 tons per million cubic feet. The approach used to estimate the emissions assumes there was no methane recovery during mining and post-mining activities.

Data Sources

Data on the lignite surface mining came from Louisiana's Mineral Resource Office. Methane Emission Coefficients for Coal produced from Surface mines and from Post-mining were obtained from the EPA State Workbook: Methodologies for Estimating Greenhouse Gas Emissions.

Results

Production of coal in Louisiana is fairly small, it amounted in 1997 to only 3.5 million short tons. This level of production corresponds to 10,386 metric tons of CO_2 equivalent or 0.003 million metric tons of carbon equivalent (MMTCE).

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, and warm have a neutral pH and provide ideal conditions to create landfill gas.

Municipal solid waste (MSW) landfills are estimated to account for over 90 percent of all methane emissions from landfills in the U.S. (*EPA 1993*). Industrial landfills, which receive non-hazardous waste from factories, processing plants, and other manufacturing activities, account for the remainder of the landfill methane emissions.

Methodologies

The methodologies used were taken from the *State Workbook* (1998a).
1. The amount of waste in place at municipal solid waste landfills was found.
Waste in Place (tons) = Current State Population * Current Per Capita Waste generation rate per year (lbs/capita/yr) * Portion of waste that is landfilled * "30-year Multiplier for Waste in Place"/ 2,000 lbs/ton.

2. The fraction of waste in large landfills versus small landfills was found.
Average Waste in Large Landfills = Waste in Place at Large Landfills/Number of Large Landfills

3. The amount of methane generated from small landfills was estimated.
Methane Emissions from Small Landfills (ft^3) = 0.35 * Waste in Place ± 20%

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
Waste in place at large landfills (tons)	62,746,960
Average amount of waste at large landfill (tons)	3,921,685
Average annual rainfall (inches)	64
Quantity of landfill gas that is flared or recovered for energy purposes (tons)	12,564
Estimated methane generated from waste in place at small landfills (tons CH_4/year +/- 20%)	62,545
Estimated methane generated from waste in place at large landfills (tons CH_4/year +/- 15%)	177,240
Sum of methane from municipal landfills (tons)	239,785
Estimated methane generated from industrial landfills (tons)	16,785
Adjustment for Oxidation (10%)	90.00%
Total Methane Emissions (tons)	**219,606**
Total Methane Emissions (metric tons)	**199,225**
CO_2 equivalent Emissions (metric tons)	**4,183,722**
MMTCE	**1.141**

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. Total emissions from domesticated animals reach 0.39 MMTCE, with beef contributing approximately 80 percent.

Table 6.1 Emissions of Greenhouse Gases from Domesticated Animals in Louisiana

Types of Cattle	Annual Average Animal Population	Emission Factor	CO_2 Equivalent Emissions (metric tons)	MMTCE
Dairy Cattle				
Replacements 12-24 months	17,000	135.70	21,974	0.006
Mature Cows	78,000	257.70	191,469	0.052
Total Dairy Cattle	95,000		213,443	0.058
Beef Cattle				
Replacements 0-12 months	198,000	51.90	97,886	0.027
Replacements 12-24 months	97,000	148.90	137,580	0.038
Mature Cows	547,000	155.90	812,312	0.222
Weanling System Steers/Heifers	27,000	52.80	13,580	0.004
Bulls	34,000	220.00	71,251	0.019
Total Beef Cattle	903,000		1,132,609	0.309
Other Cattle				
sheep	16,000	17.60	2,682	0.001
goats	7,000	11.00	726	0.000
swine	40,000	3.30	1,257	0.000
horses	225,000	39.60	84,873	0.023
Total Other Cattle	288,000		89,538	0.024
All Cattle	1,286,000		**1,435,591**	**0.392**

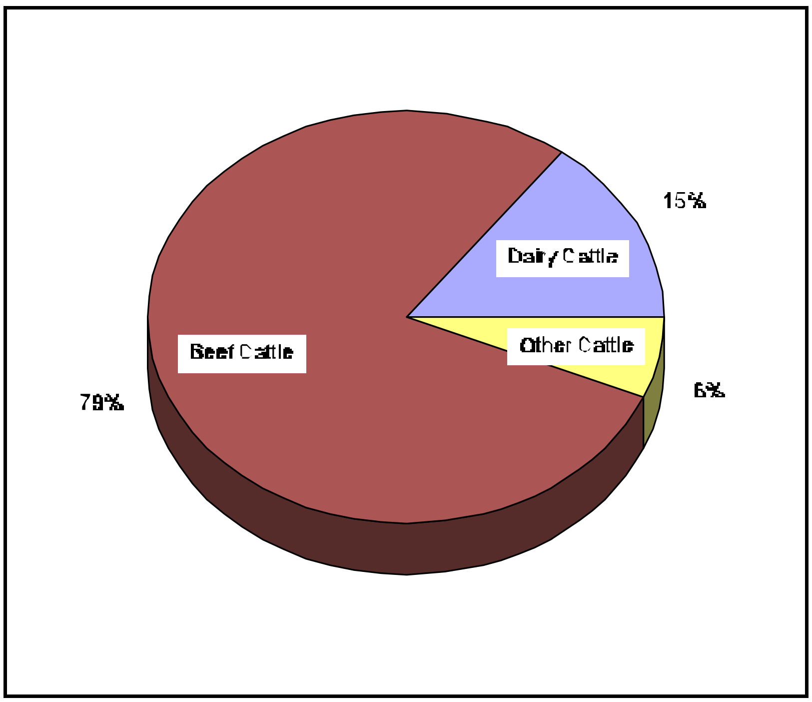

Figure 6.1 Sectoral Composition of Methane Emissions from Domesticated Animals

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:

$$CH_4 = A_i * TAM_i * VS_i * Bo_i * MCF_j * WS_{ij}$$

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* (%)
$WS\%_{ij}$	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_2 Equivalent Emissions (metric tons)**	**MMTCE**
Pasture/Range	867	18,198	0.005
Daily Spread	6	116	0.000
Dry Lot	3	56	0.000
Paddock	283	5,934	0.002
Anaerobic Lagoon	6,143	129,007	0.035
All Systems	**7,300**	**153,310**	**0.042**

Chapter Eight: Methane Emissions from Flooded Rice Fields

Overview

All of the rice in the United States is grown in flooded fields. When fields are flooded, anaerobic conditions develop in the soil, and methane is produced through anaerobic decomposition of soil organic matter. Methane is released primarily through the rice plants, which act as conduits from the soil to the atmosphere. However, not all of the methane that is produced is released into the atmosphere. As much as 60 to 80 percent of the methane produced is oxidized by aerobic methanotrophic bacteria in the soil (*Holzapfel-Pschorn et al. 1985, Sass et al., 1990*). Some of the methane is also leached to ground water as dissolved methane. Some of the methane also escapes from the soil via diffusion and bubbling through the flood waters.

Methodologies

The methodologies used were taken from the *State Workbook* (1998a).

(1) The area harvested during the study year was determined. Included here was the area used for ratoon crop (second crop).

Acres Harvested for Ratoon Crop = Acres of Primary Crop Harvested * 30%
Total Acres Harvested = Ratoon Crop Acres + Primary Crop Acres

(2) The number of acre-days that the rice was grown was obtained for the high and low estimate.

Acre-days (low estimate) = Area Harvested (acres) * Length of Growing Season (days/yr, low estimate)

Acre-days (high estimate) = Area Harvested (acres) * Length of Growing Season (days/yr, high estimate)

(3) The range of methane emissions from flooded rice fields was obtained.
CH_4 Emissions (low, lbs CH_4/yr) = Number of Acre-Days/yr (low) * 0.9504
CH_4 Emissions (high, lbs CH_4/yr) = Number of Acre-Days/ yr (high) * 5.032

(4) The result was converted to methane emissions in tons by dividing by 2000.
CH_4 Emissions low (tons) = CH_4 Emissions (low, lbs CH_4/yr)/2000
CH_4 Emissions high (tons) = CH_4 Emissions (high, lbs CH_4/yr)/2000

(5) The average of the high and low emissions was calculated.

Data Source:

The Louisiana Agricultural Statistics Service supplied the data for this chapter.

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 Nine: Emissions from Agricultural Soil Management

Overview

Agricultural soil management, here interpreted narrowly as use of fertilizers, results in emissions of nitrous oxide and carbon dioxide. Application of nitrogen fertilizers increases the amount of nitrogen available for the production of nitrous oxide, which is generated by microbial processes of nitrification and denitrification. Acid soil conditions are often ameliorated by the application of crushed lime and dolomite to agricultural soils. Carbon, which is contained in both compounds, reacts with acid soils, thereby generating CO_2.

Methodologies

The methodologies for this chapter were taken from the *State Workbook (1998a)*. The data needed for the analysis were the annual consumption of nitrogen in fertilizer and the amount of limestone used for agricultural purposes in the state. To obtain total N_2O-N emission in tons, the consumption of nitrogen in fertilizer was multiplied by the emissions factor, and the result was converted into appropriate units. A similar procedure was used to estimate emissions from limestone use.

Data Source

The data needed for this chapter were obtained from the agricultural chemistry program of the Louisiana Department of Agriculture and Forestry.

Results

Agricultural soil management in Louisiana results in annual emissions of approximately 1 million metric tons of CO_2 equivalent or 0.3 MMTCE. Almost all emissions (98 percent) are attributed to the use of nitrogen fertilizers.

Table 9.1 Greenhouse Gas Emissions from Agricultural Soil Management in Louisiana

Fertilizer	Amount Used (tons)	Greenhouse Gas	Emission Factor	Emissions (metric tons)	CO_2 Equivalent Emissions (metric tons)	MMTCE
Nitrogen	204,721	N_20	0.0117	3,415	1,058,534	0.289
Limestone	201,932	CO_2	0.1200	21,983	21,983	0.006
Total					**1,080,517**	**0.295**

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 for agriculture, open burning of cleared biomass, afforestation, wetland draining, and allowing a pasture to return to grassland change the balance between the emission and the uptake of the trace gases hence affecting their atmospheric concentration. Since forests act as an atmospheric carbon sink, the larger the area under forests the smaller the net increase of carbon in the atmosphere. On the other hand, if forested land diminishes in size, less carbon will be absorbed, which will lead to increased atmospheric concentration of carbon dioxide. There is a constant exchange of carbon between the forest ecosystem and the atmosphere as a result of biological activities such as growth, mortality, and human activities including harvesting and other removals of vegetation.

Methodologies

Initially, we used estimation methodologies from the *State Workbook (1998a)*. However, the estimates that we obtained using these methods were not reliable for the following reasons: (1) estimation methods are associated with a high degree of uncertainty (error); (2) some of the important data for Louisiana were not available; (3) the information that is available is considerably outdated. Therefore, we decided to use alternative methods of indirect estimation of greenhouse gas emissions from forest management and land-use change. Since the total acreage of forest land in Louisiana has been relatively stable, we inferred that there are no net emissions or uptake from land-use change. So, resulting uptake of carbon dioxide must be associated with increasing biomass of forests. We estimated carbon dioxide uptake using three different and independent methods as follows:

1. using a reported annual forest biomass growth

LA CO_2 uptake = Net biomass increase(mill. cubic feet) * biomass conversion ratio(tons of dry matter per cubic feet) * carbon fraction of biomass

2. using the ratio of U.S. carbon dioxide uptake to total U.S. carbon dioxide emissions

LA CO_2 uptake = LA CO_2 emissions * (U.S. CO_2 uptake / U.S. CO_2 emissions)

3. using the ratio of Louisiana forested land to the U.S. forested land

LA CO_2 uptake = U.S. CO_2 uptake * (area of LA forests/area of U.S. forests)

Data Sources

Data for this workbook were obtained from the USDA's Forest Service publication by the Southern Forest Experiment Station including *Forest Statistics for Louisiana Parishes -1991*, from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996*, and from USDA Forest Service website (www.fs.fed.us).

Results

The results for the estimation of emissions from Forest Management and Land-Use Change are presented in Table 10.1. The uptake of carbon dioxide is estimated to be 6.2 million metric tons of carbon equivalent.

Table 10.1 Greenhouse Gas Uptake From Forest Management and Land-Use Change in Louisiana

Method	**CO_2 Uptake (metric tons)**	**MMCTE**
Method I	22,222,867	6.061
Method II	27,133,331	7.400
Method III	18,968,502	5.173
Average	22,774,900	6.211

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 amounts of organic matter will more rapidly deplete available oxygen during decomposition than wastewater with lower organic matter. The organic content in water is expressed in terms of biochemical oxygen demand (BOD_5). All else being equal, wastewater with a high BOD_5 will produce more methane when it degrades anaerobically than wastewater with a low BOD_5.

Methodologies

The methods used for this workbook were those used in Connecticut's greenhouse gas inventory. In the *State Workbook* (1998a), estimations are divided into anaerobic treatments of wastewater and anaerobic treatments of sludge waste. Unfortunately, no estimation could be derived to separate wastewater BOD_5 from sludge BOD_5. In the Connecticut inventory, the assumption is made that all BOD_5 is removed as sludge; however, in our estimation, after conversations with Louisiana Department of Environmental Quality, we decided to assume that 90 percent of BOD_5 is removed as sludge. Approximately 88 percent of Louisiana's population is served by public water treatment facilities. Two separate sections are included in this workbook, one for municipal wastewater facilities and the other for on-site septic systems. The estimation proceeded in the following steps:

1. The amount of methane emitted for municipal wastewater facilities was determined.

CH_4 emissions = Population served by municipal wastewater facility * BOD_5 generation rate * (1-fraction removed as sludge) * days/yr * lbs CH_4/lb BOD_5 – CH_4 recovered

2. The amount of methane emitted from on-site septic systems was determined.

CH_4 emissions = Population served by on-site septic systems * BOD_5 generation rate * fraction of wastewater treated anaerobically * days/yr * lbs CH_4/lb BOD_5

3. The total methane emissions from wastewater systems was determined by adding methane emissions from municipal wastewater facilities to the methane emissions from on-site septic systems.

Total CH_4 emissions = CH_4 emissions from municipal wastewater facilities + CH_4 emissions from on-site septic systems

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**

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