Modeling Greenhouse Gas Emission in Louisiana

PREPARED FOR

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PREPARED BY

The Center for Energy Studies
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Introduction

As carbon dioxide (CO_2) and other "greenhouse gases" accumulate in the atmosphere they act like a blanket to insulate and warm the planet. Monitoring has established a build up of six core greenhouse gases – carbon dioxide, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexaflouride (SF_6)–which is expected to increase the degree of global warming. The consequences of the build up are controversial as are policy alternatives to deal with it. The focus of this report is to model Louisiana's contribution to the greenhouse gas build up over the next fifteen years. Four different scenarios are used to model the magnitude and pattern of emissions and emission-producing activities. The forecasts are heuristic and illustrative. The model results presented are not forecasts in the usual sense of the term since more data and analysis are required to select one forecast over another.

The four scenarios analyzed are based on different assumptions about the rate and pattern of future growth. The first uses the growth rates of greenhouse gases from fossil fuel consumption in Louisiana observed over the 1990 to 1996 period. The assumption is made that these growth rates will be maintained over the entire 2000 to 2015 period. The other three scenarios are based on emission and production forecasts from the U.S. Department of Energy, Energy Information Administration's *Annual Energy Outlook* (EIA 2000). The first gives emission levels for the emi5n the percentage share of total emissions.

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

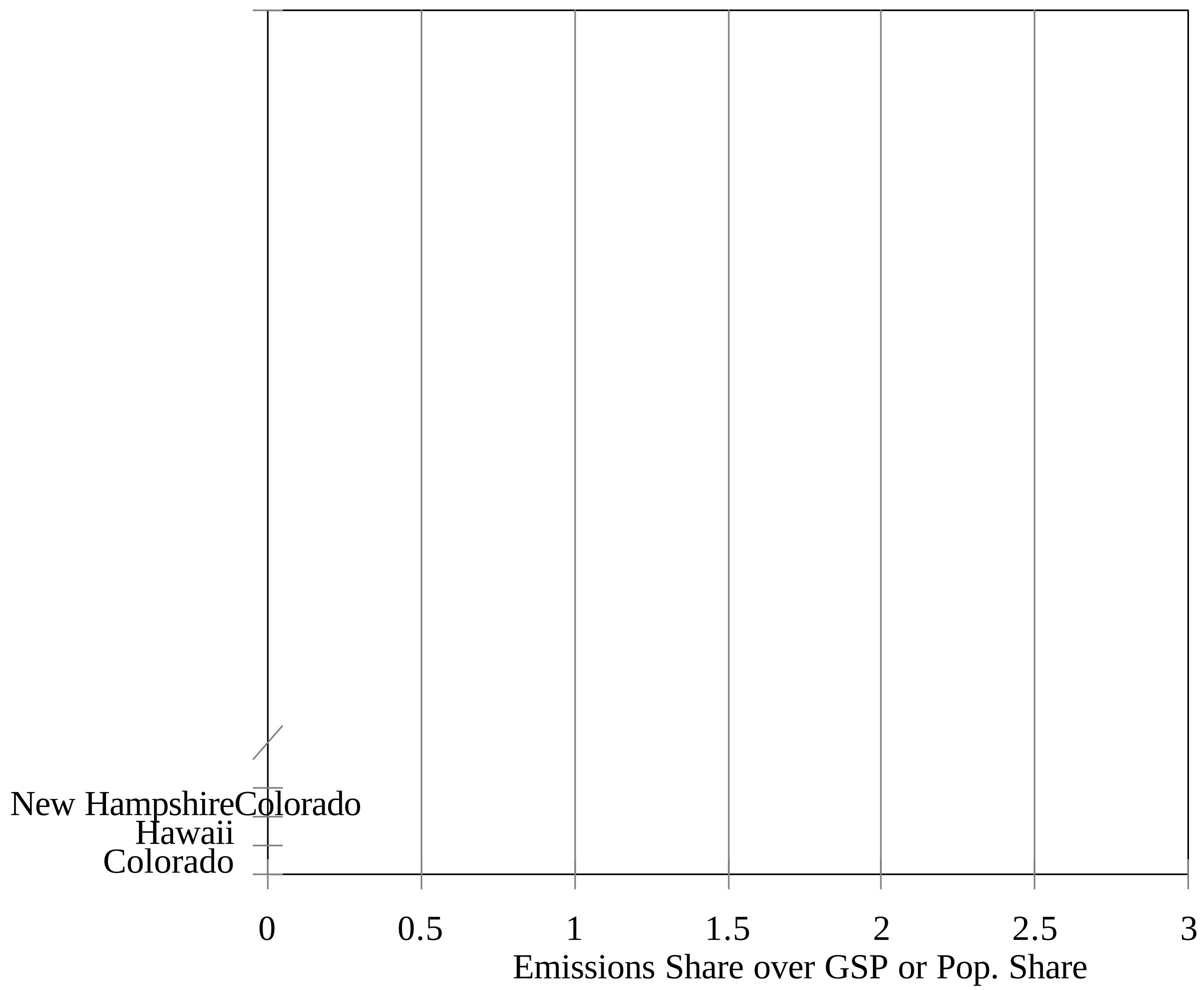
* Million metric tons of Carbon equivalent

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

Table II shows the distribution of greenhouse gases by type. CO_2 is by far the largest contributor, accounting for almost 89 percent on a CO_2 equivalent basis.

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. The major difference is that fossil fuel combustion contributes a larger share in Louisiana than is true nationally.


New HampshireColorado
Hawaii
Colorado
0
0.5
1
1.5
2
2.5
3
Emissions Share over GSP or Pop. Share

Historical Inventory Data

The models developed here are constrained by a single observation for each of the inventoried emissions in the year 1996. To provide some historical context, we also gathered data for the fossil fuels section of the inventory for the year 1990 and calculated annual growth rates for the 1990 to 1996 period.

One of the projections discussed below was made by assuming that the 1990 to 1996 growth rate was maintained over the 2000 to 2015 period. Three other projections were also made. The first assumes that the rate of growth in Louisiana over the 2000 to 2015 period in each of the principal modeling categories was identical to the rate for the nation as a whole. The second scenario is based on0458 Tc Te7 TD

6. **HFCs –** includes all hydrofluorocarbon related emissions activities having been inventoried and forecasted.

7. **PFCs –** includes all perfluorocarbons related emissions activities having been inventoried and forecasted.

8. **SF_6** – includes all sulfur hexaflouride related emissions activities having been inventoried and forecasted.

User Specified Input Parameters for Emissions Forecasting

The top portion of the **MODEL** spreadsheet contains all required input parameters. These parameters include growth (*g*), consumption (*c*), and technology improvement (*t*) rates. Relevant growth and consumption rates are applied to each industrial or agricultural emitter category to forecast their emissions. Once totals from each contributor for each greenhouse gas are compiled, a technology improvement rate is applied to forecast total greenhouse gas emissions for the years 2000, 2005, 2010, and 2015. Descriptions of the various growth, consumption, and technology improvement rates can be found in the following subsections.

Growth Rates and Consumption Rates

As manufacturing and agricultural industries and state and animal populations grow, the greenhouse gas emissions they create will also continue to grow. The model forecasts future greenhouse gas (GHG) emissions using hypothetical or judgmental compounding factors for growth curve implementation. Such growth rates include the following:

1. *Natural Gas Production Growth Rate* – the rate of increase in the production of natural gas per year.
2. *Oil Production Growth Rate* – the rate of increase in the production of oil per year.
3. *Coal Production Growth Rate* – the rate of increase in the production of coal per year.
4. *Manufacturing/Production Growth Rate* – the growth rate per year for commodities manufactured or produced that emit greenhouse gases.
5. *Human Population Growth Rate* – the rate of increase in Louisiana's population per year.
6. *Animal Population Growth Rate* – the rate of increase in the population of domesticated farm animals per year.
7. *Farming Growth Rate* – the rate of increase in farm acreage per year.
8. *Tree Farming Growth Rate* – the rate of increase in the number of trees planted per year.

Greenhouse gases are also produced from the consumption of raw materials such as coal, oil, natural gas, or other intermediate goods. For example, the transportation and electric utility industries consume significant amounts of fuels and produce one of the fastest accumulating greenhouse gases, carbon dioxide. Such consumption rates include the following:

1. *Residential Fuel Consumption Rate* – the rate of increase in fuel consumption for

residential users per year.

2. *Commercial Fuel Consumption Rate* – the rate of increase in fuel consumption for commercial users per year.
3. *Industrial Fuel Consumption Rate* – the rate of increase in fuel consumption for industrial users per year.
4. *Transportation Fuel Consumption Rate* – the rate of increase in fuel consumption for all modes of transportation per year.
5. *Electric Utility Fuel Consumption Rate* – the rate of increase in fuel consumption for the generation of electricity per year.
6. *Manufacturing/Production Consumption Rate* – the consumption rate per year for commodities manufactured or produced which emit greenhouse gases.

To forecast emissions for each greenhouse gas (l), a growth rate *g* and consumption rate *c* are applied for each emissions contributor (m). The rates are then compounded for *n* years. Equation 1 below sums the forecasted emissions from all industrial and agricultural growth and consumption emission contributors to determine the total forecasted inventory for each greenhouse gas.

$$[\sum_{i=1}^{l} \sum_{j=1}^{m} \text{GHG Inventory}_{lm} * (1 + g_{lm} + c_{lm})^{n}] = \text{Total Forecasted Inventory}_{l}, \ \forall l, \ \forall m$$

(Equation 1)

Technology Improvement Rates

Creatively administered restrictions on greenhouse gas emissions could strongly encourage environmental technology to accelerate to a new regime that provides services both at lower costs under “business as usual” conditions and with much less environmental damage than at present. It could be extremely costly to wait for scientific certainty on the impact of greenhouse gases upon the global climate before committing to a vigorous research and development program (Manne and Richels, 1990a). New technologies require many years for market penetration. If it turns out that substantial reductions in greenhouse gas emissions are needed, it will be important to have the means available for achieving such reductions in a timely manner. This can only be accomplished through a sustained commitment to research and development.

To account for such an impact from technological improvements, the emissions-cost tradeoff model employs a technology improvement rate to project the effects of technology changes. Good judgment plays a pivotal role in forecasting greenhouse gas emissions into the uncertain distant future, and a technological forecasting rate is used to counter the growth of greenhouse gas emissions. Such rates include the following:

1. *CO_2 Emission Technology Improvement Rate* – the yearly rate of improvement in technology designed for carbon dioxide emission reduction.
2. *CH_4 Emission Technology Improvement Rate* – the yearly rate of improvement in

Greenhouse Gas Emissions Forecast

Figure II summarizes the emissions inventory of the five greenhouse gases that are important in Louisiana and compares them to four forecasts based on different assumptions about the rate and pattern of future growth over the 2000 to 2015 period. The figure emphasizes Louisiana's challenge in dealing with greenhouse gases in the future since most greenhouse gas proposals involve maintaining 1990 emission levels or reducing emissions below 1990 levels. However, in the four cases considered, the increase in emissions ranges from a low of 22 percent to a high of 40 percent. More precisely,

- If growth rates observed over the 1990 to 1996 period were to be maintained, by 2015 greenhouse gas emissions would be about 40 percent above 1996 levels.

- If emissions in Louisiana were to grow at the national average rate, by 2015 they would be 29.3 percent above 1996 levels.

- If Louisiana's emissions were to grow at the average rate of the states in the West South Central Census Division (Arkansas, Louisiana, Oklahoma and Texas), emissions would be 28.6 percent above 1996 levels.

- If technological improvements reflected primarily in more efficient energy use were made during the period, emissions would still be about 25.6 percent above 1996 levels.

[redacted]

Alternative Scenarios

The modeling parameters and resulting forecasts for the four scenarios summarized in Figure II are detailed in Tables IV through X. The growth rates shown for the five-year intervals are the average annual rate of growth ending with the year heading the column. The 1990 to 1996 extrapolation maintains the rate through each of the forecast periods. In the other scenarios growth rates change at five-year intervals for some variables.

Comparing Tables IV and V (which show modeling parameters and the corresponding forecast for the scenario, which continues the 1990 to 1996 growth rates throughout the period) with Tables VI and VII (which apply the Energy Information Administration's forecast for the U.S. to the Louisiana inventory) helps to identify the factors responsible for differences observed.

- The growth rates in the upper part of Table VI show that EIA expects healthy growth of 1.6 percent per year in natural gas production but a drop of 0.8 percent per year in oil production.

- The rates of growth observed in the 1990 to 1996 period for Louisiana in Table IV were a smaller (0.04 percent) annual growth for natural gas but increased oil production one percent per year.

- Manufacturing production in the U.S. average forecast exceeds the constant 1990-96 scenario in the first two periods but falls below it the last two periods.

- The state population would grow almost twice as fast as it did during the 1990 to 1996 period.

- The number of acres farmed in Louisiana grew modestly during the 1990 to 1996 period but would be expected to decline at about the same rate in the U.S. average case.

Consumption rates shown in the bottom part of the two tables also show differences.

- Residential fuel consumption grew at a rate of 1.45 percent per year in the 1990-96 period, but the U.S. average forecast declined from one percent per year to 0.58 percent over the period.

- Commercial fuel consumption would grow considerably faster in the U.S. average case during the initial three periods but would fall slightly below the historical rate in the last period.

- Industrial fuel consumption would grow only about half as fast in the U.S. average case as it did during the 1990-96 period.

- Transportation fuel was consumed at annual rate of 2.50 percent during the 1990-96 period, but its growth rate would fall from a rate of 2.13 percent in the initial period to 1.51 percent in the last period. Fuel consumed by electric utilities would grow considerably faster in the U.S. average case than it did during the 1990-96 period.

Table IV - Modeling Parameters for Greenhouse Gas Emissions
Case 1: Using 1990-1996 Louisiana Historical Data

Input Year: Source:	Parameters for 2000	Parameters for 2005	Parameters for 2010	Parameters for 2015
Growth Rates				
Natural Gas Production	0.04%	0.04%	0.04%	0.04%
Oil Production	1.01%	1.01%	1.01%	1.01%
Coal Production	0.49%	0.49%	0.49%	0.49%
Manufacturing/Production	2.22%	2.22%	2.22%	2.22%
State Population	0.43%	0.43%	0.43%	0.43%
Animal Population	0.50%	0.50%	0.50%	0.50%
Farming	0.47%	0.47%	0.47%	0.47%
Tree Farming	0.50%	0.50%	0.50%	0.50%
Consumption Rates				
Residential Fuel	1.45%	1.45%	1.45%	1.45%
Commercial Fuel	0.58%	0.58%	0.58%	0.58%
Industrw (1.45%) 1.78 Tj 8 72 0 TD (1.45%) Tj Elec 72 -4 TD Utility Fuel (0.50%) Tj 72 0 TD (1.45%) (0.50%) Tj 72 0 -4 TD (1.39%) (0.50%) Tj 72 0 TD (				

emissions in the energy producing WSC case in the year 2015 are one half of one percent *lower* than the level forecast for the nation considered as a whole. Comparing the twothe

Comparing the U.S. average case with the technology improvement case shows that most greenhouse gas emission methods work by reducing the consumption of fossil fuels. The technology improvement case applies the most-emission-reducing EIA forecast to each of the sectors in the improvement

[redacted]

Table XI - Emissions Forecast, Case 4: Using U.S. Growth Rates Technology Improvements

Year: **Greenhouse Gas:**	**Forecast for 2000**	**Forecast for 2005**	**Forecast for 2010**	**Forecast for 2015**
CO_2	55.786	59.314	63.027	65.656
CH_4	4.681	4.958	5.256	5.575
N_2O	0.792	0.853	0.911	0.974
HFC	1.623	1.839	2.041	2.264
PFC	0.000	0.000	0.000	0.000
SF_6	0.029	0.033	0.037	0.041
TOTALS	62.913	67.000	71.274	74.512

Conclusions and Implications

Although more accurate and detailed modeling may yield

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