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GREENHOUSE GAS EMISSIONS: METHANE RELEASED IN NORTH CAROLINA, 1990

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Introduction

Earth's atmosphere is heated by the sun, but most of that energy comes to the atmosphere via indirect routes. Being transparent to most forms of direct solar energy, much of the sun's electromagnetic energy passes through the atmosphere and heats the surface of the Earth. Energy is then re-emitted as longwave energy. Compounds in the atmosphere known as "greenhouse gases" readily absorb that longwave radiation. Greenhouse gases include water vapor, carbon dioxide, methane, chlorofluorocarbons (CFCs), and other gases. Energy is temporarily "trapped" resulting in additional warming of the atmosphere. This natural greenhouse effect is what makes Earth habitable; without it, the average temperature of the planet would be 55 F° (30 C°) colder than it is today (U.S. EPA, 1995a).

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Human activities have profoundly influenced the atmosphere of Earth since the beginning of the Industrial Age, leading many prominent scholars to warn of significant global change (Santer, 1995; Schneider, 1990). While skeptics remain in the scientific community, there is an increasingly strong consensus among climatologists that global warming has begun and that it will accelerate over the next century (Michaels, 1990; Kerr, 1995; Schneider, 1994). Global warming is one major category of change that is being critically evaluated by climatologists and other scientists. The concern is that greenhouse gases will continue to accumulate in the troposphere at rates that could lead to significant warming over the next century and beyond. One prominent group of scientists has predicted a warming of approximately 4.5 F° (2.5 C°) over the next century (Bolin, et al., 1995). Impacts from such warming could include rapidly rising sea level, major shifts in crop production, geographic displacement of species and entire ecosystems, and increased costs for climate control in houses and other structures.

Without the natural greenhouse effect the Earth's average temperature would be 55° F cooler

With its barrier island coast and vast areas of estuaries, North Carolina is particularly vulnerable to global warming (Daniels, 1996). Coastal regions are likely to experience more significant and immediate impacts from global warming than interior locations. Agriculture, of great importance to the economy of the state, is also highly susceptible to impact from changes in temperature and precipitation (Easterling, et al., 1992). In addition, urban areas are more vulnerable to summer heat waves and associated human discomfort and mortality than other areas.

While considerable uncertainty surrounds most specific projections of climate change, the probability of change and the consequences of such change are serious enough that international bodies have determined the need for a global assessment of sources of radiatively active gases. The Intergovernmental Panel on Climate Change (IPCC) has been charged with completing inventories of all greenhouses gases for the nations of the world. In the United States, the U.S. Environmental Protection Agency (EPA) is responsible for estimating greenhouse gas emissions. It has completed a national survey (U.S. EPA, 1995a; 1995b) and has recently commissioned more detailed state level surveys.

Human activities have initiated a global warming trend that will accelerate over the next century

At Appalachian State University, the Department of Geography and Planning contracted with the North Carolina Department of Commerce, Energy Division to produce the state inventory (ASU, 1996). Funded jointly by the N.C Energy Division and the U.S. Environmental Protection Agency's Office of Policy, Planning and Evaluation, Climate Change Division, State and Local Outreach Program, this recently completed inventory is one of only three to have been completed at the county level. Only state totals have been provided by the other 22 states which have completed inventories. The North Carolina inventory followed IPCC and EPA protocols for accounting, supplemented by internally developed procedures to produce county level emission estimates (IPCC, 1995; EPA, 1995b; ASU, 1996). A total of 120 linked spreadsheet files with a combined size of approximately 210 megabytes of disk space were required to complete the work. Detailed descriptions of the inventory procedures are contained within the inventory manuals (IPCC, 1995; EPA, 1995b; ASU, 1996).

In order to compare different gases with different atmospheric impacts, all gases were converted to global warming potential (GWP) values, which are expressed in tons of carbon dioxide equivalent. By converting emissions for all gases to GWP values, the impacts of emissions of different gases can be compared directly (U.S. EPA, 1995a). Greenhouse gases inventoried in this study included methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O), ozone depleting compounds (ODCs), carbon monoxide (CO), oxides of nitrogen (NO_x), and nonmethane volatile organic compounds (NMVOCs). This report focuses on releases of methane during 1990, the last year for which a full data set exists. The combined total of all greenhouse gas emissions for the State of North Carolina in 1990 was almost 152,000,000 tons of CO_2 equivalent. That amount equals approximately 23 tons of CO_2 for each person in the state (Table 1).

This study is near unique among a multitude of global warming research in its emphasis on the county level of data evaluation

	Actual Emissions and Global Warming Potential (tons/yr)					
Emission Source Category	CH_4	CH_4 as CO_2 equiv.	CO_2	N_2O as CO_2 equiv.	% of CO_2 equiv.	Total CO_2 equiv.
Fossil Fuel Consumption	**9,266**	**203,841**	**120,847,628**	**992,883**	**80.46%**	**122,044,351**
Commercial/Institutional	7	145	3,731,586	1,324	2.46%	3,733,054
Industrial/Manufacturing	33	718	23,372,681	67,304	15.45%	23,440,702
Residential	42	927	5,591,119	95,113	3.75%	5,687,159
Utilities	269	5,928	46,231,048	106,391	30.55%	46,343,367
Transportation	8,915	196,123	41,921,195	722,751	28.24%	42,840,070
Biomass Fuel Consumption	**26,596**	**585,110**	**16,578,428**	**198,491**	**11.45%**	**17,362,029**
Production Processes	**0**	**0**	**426,097**	**366,849**	**0.52%**	**792,946**
Agriculture and Livestock Production	**377,606**	**8,307,332**	**340,548**	**1,007,854**	**6.37%**	**9,655,734**
Domestic Animals	37,912	834,064	0	0	0.55%	834,064
Animal Manure Management	339,694	7,473,268	0	0	4.93%	7,473,268
Fertilizer Use/Agricultural Liming	0	0	340,548	1,007,854	0.89%	1,348,402
Waste Disposal, Treatment, & Recovery	**266,825**	**5,870,151**	**506,614**	**18,851**	**4.22%**	**6,395,615**
Landfills	260,355	5,727,817	0	0	3.78%	5,727,817
Waste Incineration	1,056	23,241	506,614	18,851	0.36%	548,706
Sewage Treatment	5,413	119,092	0	0	0.08%	119,092
ODC					**2.54%**	**3,859,270**
Human Emissions	**49,183**	**1,082,015**	**57,965**	**0**	**0.75%**	**1,139,980**
Land Use Changes	**-108**	**-2,372**	**-9,611,812**	**53,955**	**-6.30%**	**-9,560,229**
Total Emissions	**729,367**	**16,046,077**	**129,145,468**	**2,638,883**	**100%**	**151,689,698**
%Global Warming Potential		11%	84%	2%		100%

Table 1: Summary of North Carolina 1990 Greenhouse Gas Emissions: Primary Gases (tons/year)
Source: ASU, 1996.

Methane Emissions in North Carolina

One of the most significant greenhouse gases produced by human activity is methane (Smith, 1995). Methane is a greenhouse gas of special concern because every ton of methane released to the atmosphere produces 24.5 times as much warming as a ton of CO_2. Roughly 17,000,000 tons (11%) of the total CO_2 equivalent for the state in 1990 resulted from methane emissions. Methane is emitted from a wide variety of sources, both "natural" and from human activities. The methane is generated by direct emissions such as cattle flatulence and from secondary processes such as the decomposition of hog manure in anaerobic waste lagoons. Emissions associated with human activity are increasing significantly through time in North Carolina

Agriculture is the most important source of methane emissions in North Carolina, with almost half the state total (Figure 1). Animal manure management accounted for 44% of N.C. methane emissions and domesticated animals produced 5% of the total. Following agriculture are landfills (36%), human emissions (7%), biomass fuels (4%), and fossil fuel combustion (1%).

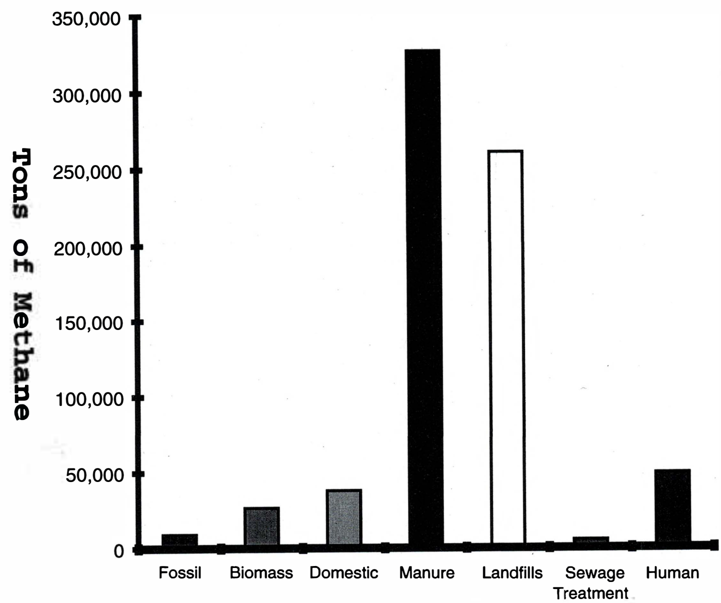

Figure 1: State Methane Emissions (tons/yr.).

Agricultural activity produces large amounts of methane from a variety of sources. For the entire Earth, agriculture contributes 65% of all anthropogenic methane emissions (Duxbury, 1994). Domesticated animals are one important source. Cows and other ruminants chew their cud and regurgitate the food between multiple stomachs. During that activity, anaerobic bacteria convert some of the food into methane in the digestive tract of the animal. The result is the emission of methane through belching and flatulence. An 800 lb. steer fed on grains will emit approximately 150 pounds of methane per year. Other feed types result in lesser amounts of methane released to the atmosphere (U.S. EPA, 1995b). Statewide, about 38,000 tons of methane are released to the atmosphere each year from domesticated animals, which is the equivalent of over 830,000 tons of CO_2 (Table 1). On the other hand, the 6.6 million persons living in North Carolina in 1990 directly emitted over 49,000 tons of methane as a result of digestion and respiration. Finally, game animals released another 13,000 tons of methane that year.

By far the most important source of agricultural methane is the anaerobic digestion of animal waste products by bacteria. So when hog wastes are collected and decomposed in waste lagoons, enormous amounts of methane are generated. Thus, hog operations contribute more methane to the atmosphere than any other activity in North Carolina. Animal manure management, comprised of hogs, cattle, and chickens, systems in North Carolina released approximately 7,200,000 tons of CO_2 equivalent in methane in 1990, or nearly nine times the direct emissions of domesticated animals in the state.

Waste products from homes, industry, and commerce are primarily disposed of in sanitary landfills. These are largely anaerobic environments, so significant amounts of methane are generated as the organic components of the waste stream are broken down by microbes (U.S. EPA, 1995a). Approximately 260,000 tons of methane were generated in landfills in 1990, equivalent to over 5.8 million tons of carbon dioxide.

Agriculture, especially animal manure management practices, is the most important source of methane emission

Combustion of biomass fuels such as firewood contributed over 26,000 tons of methane in 1990, with a GWP of 585,000 tons of carbon dioxide. Almost all of that biomass related methane came from residences. Although the relative contribution of domestic wood burning to methane production in North Carolina is small, it is accompanied by significant releases of carbon dioxide, air pollutants, and reduced carbon stores in forests.

When we account for the greenhouse gas emissions associated with the out of state production of fuels that are ultimately used in North Carolina, the total methane emissions increases significantly. Here coal mining figures prominently. Large amounts of methane contained within the coal are released to the atmosphere when coal is mined. Following a protocol established by the State of Wisconsin, we have estimated that fuel production for North Carolina released 1.8 million tons of CO_2 equivalent and that transportation and distribution of fuels released another 15.1 million tons of CO_2 in 1990 (WDNR, 1993).

Geographic Patterns Within North Carolina

While the state totals of methane production are substantial, it is necessary to examine emissions of greenhouse gases at the local level in order to understand the driving forces which lead to those releases. Once those driving forces are understood, remediation and mitigation may be effectively addressed (Dietz and Rosa, 1997). For the North Carolina Greenhouse Gas Inventory, we used the county as our smallest level of spatial analysis a level of precision not before attempted. Estimating greenhouse gas emissions at the county level is especially challenging because data on rates of fuel consumption and other critical activities are often compiled at the state level. For each sector of activity, the research team had to find ways to estimate greenhouse gas production using available data. For example, in order to calculate CO_2 emissions from automobiles, it was necessary to use vehicle miles traveled in each county, enter that into a sophisticated carbon monoxide emissions model, then estimate the emissions of CO_2 based upon fuel consumption rates and established ratios between CO and CO_2 emissions.

Total methane emissions in North Carolina in 1990 are shown in Figure 2. Counties range from a low of less than 1000 tons of GWP in most of the mountain counties to over 100,000 tons in Duplin and Sampson Counties; those two counties alone generate one-fifth of the state total. Both the Piedmont and Coastal Plain regions showed significant levels of methane emissions, but the activities responsible for those emissions are quite different for the two regions.

Coastal Plain counties which produce large amounts of methane are concentrated in the inner part of that region, with highest totals coming from Duplin, Sampson, Greene, and Wayne Counties. Most of that methane is associated with domesticated animals with the majority coming from hog waste management. While environmental problems such as waste spills, nitrification of groundwater, and odor problems associated with swine operations have been in the news frequently, little mention has been made of the contribution of those operations to greenhouse warming. Figure 3 illustrates the growth of the swine population in the state from 1978 to 1992 and the methane generated by their waste. The great concentration of swine populations in Duplin and Sampson Counties is especially notable.

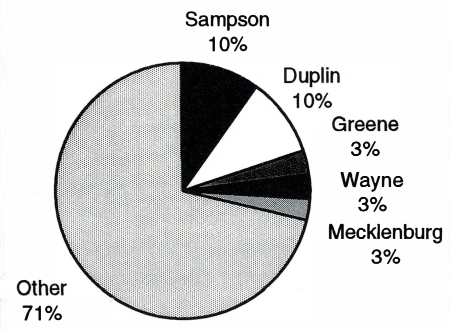

Figure 2: Total State Methane (tons/yr.).

North Carolinians generate large amounts of garbage in their everyday work and home environments. That waste is disposed of in a variety of ways, but by far the most common method of disposal is the sanitary landfill. Emissions of methane in the Piedmont are directly tied to decomposition of waste in landfills. Piedmont counties which produce high concentrations of methane include Mecklenburg, Guilford, Wake, and Forsyth, revealing a clear pattern of emissions rates being tied directly to population concentrations (Figure 4). Because of persistent problems with groundwater contamination from landfill leachate, the EPA has recently imposed stringent regulations on the construction and operation of landfills. As small landfills are decommissioned and more waste is shipped to large landfills, the spatial patterns of methane releases from landfills will change significantly. For example, the Watauga County landfill was closed in 1995 and waste is now trucked 100 miles to a private landfill in Forsyth County (Payne, 1997).

Methane generated by swine producers contributes significantly to greenhouse warming

Opportunities to Reduce Methane Emissions

While it is clear that human actions have substantially altered Earth's atmospheric chemistry, there are a number of steps that can be taken to reduce the volume of greenhouse gases added to the atmosphere each year (Thompson, et al., 1992). Greenhouse gases mix readily in the atmosphere, so all such emissions have impacts on the global atmosphere and climates worldwide will be affected by emissions regardless of their source. Nonetheless, actions to stabilize or reduce emissions must take place at the local level.

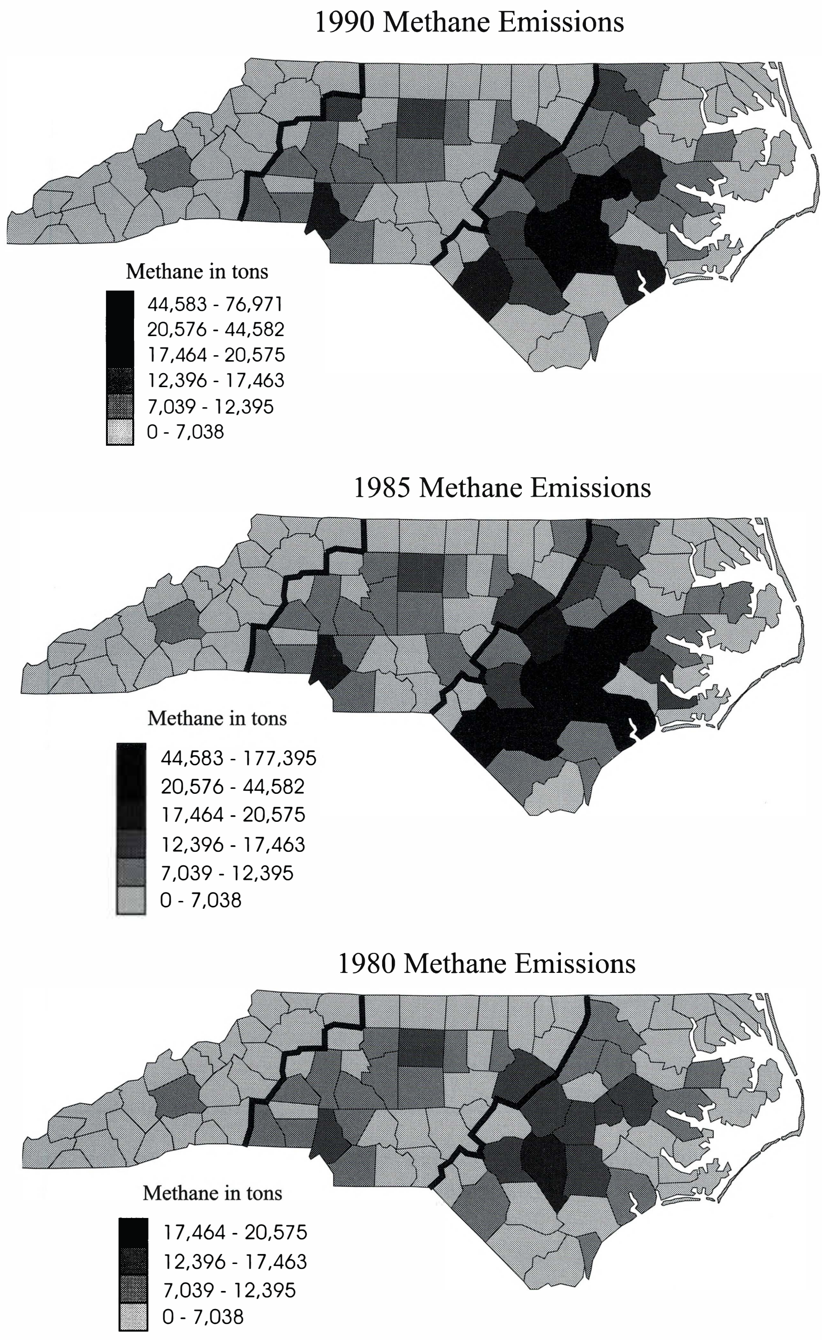

Figure 3: Methane Emissions for North Carolina 1980-1990.

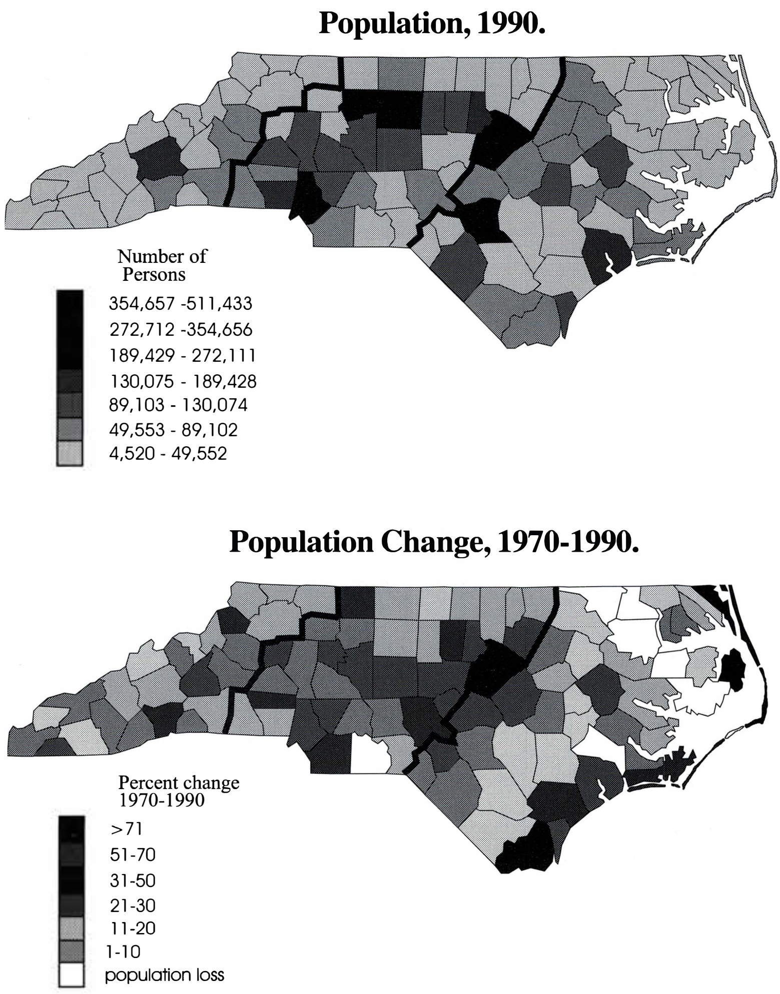

Figure 4: North Carolina Population.
Source: U. S. Bureau of the Census.

The steps that can be taken at the household level can be quite significant, as households account for approximately 36% of the greenhouse gases emitted in North Carolina. Any action that results in a reduction in fossil fuel use will reduce greenhouse gas emissions and generally save the household money at the same time. Simple, cost effective steps include driving fewer miles, using public transportation, driving a more fuel efficient automobile, and adding insulation to the home (Swisher, 1996). Corporate reductions in carbon dioxide emissions must focus on reducing coal consumption at power plants through more efficient com bustion, co-generation, or by switching to natural gas, which releases less carbon dioxide per BTU of energy generated than coal.

Efforts are underway to stabilize and eventually reduce greenhouse gas emissions. The United States recently committed to participating in an international effort to reduce emissions in order to delay and minimize global warming. Some of the approaches recommended for achieving those goals are top-down in nature, meaning that they will be mandated by federal action and involve mandatory compliance. More recently, bottom-up approaches to greenhouse gas reductions have been recommended. A bottom-up approach means that decisions concerning greenhouse gas emissions and actions to mitigate production of those gases are made at the local level. The North Carolina Greenhouse Gas Inventory can contribute significantly to such a bottom-up approach because it identifies the geographic pattern of emissions within the state.

Methane production in North Carolina can be reduced in a variety of ways. In examining Figure 1, it is clear that the largest emissions of methane are associated with manure management from domesticated animals. The largest potential mitigation comes from that source category as well. By changing the manner in which swine, cattle, and poultry waste are collected and disposed of, methane emissions could be significantly reduced while also reducing offensive odors. One way to achieve this reduction in methane emissions is to capture the gas as it rises from waste ponds and to burn the methane for process heat on site. This heat can then be converted to steam to provide for the co-generation of electricity. The N.C. Division of Energy is currently experimenting with such systems (Soderberg, 1996).

Existing technology can aid in converting harmful methane gasses from landfills and animal waste management to usable forms of energy

Landfills are a significant source of methane. As new landfills are completed, it will become easier to capture fugitive methane than in the past, as most of the newer systems collect and burn or compress methane gases. Even if the gases are simply flared on site, a significant reduction in GWP is achieved as the methane is converted to CO_2 because CO_2 has a much lower GWP value than that of methane. If the gases are captured, compressed, and used as an energy source, even greater savings are achieved by having the energy content of the waste stream displace fossil fuel energy otherwise used. Either option will have the added benefit of reducing odors.

Remaining source categories account for only one fifth of the total emissions of methane in North Carolina, so savings potentials are much lower in the remaining categories. As with the previous source categories, however, additional benefits can also be gained at the same time that greenhouse emissions are reduced. Some categories, such as human emissions, are nearly impossible to reduce, while biomass fuel use and sewage treatment plants offer opportunities for substantial reductions.

Conclusions

Methane generated by residential, commercial, and industrial activities in North Carolina represent a significant proportion of the bundle of greenhouse gases emitted within the State each year. Geographic patterns of those emissions are directly related to the population patterns of people and domesticated animals. Counties such as Mecklenburg and Wake with large human populations emit large amounts of methane from solid waste disposal in landfills. But the largest methane emissions in North Carolina are in counties with large swine populations, with most of the emissions coming from waste lagoons.

The climate research community has succeeded in convincing governments and intergovernmental units that global warming is a very real concern. While predicted amounts and patterns of warming vary significantly, the impacts of even the least severe of those predictions will require extensive adaptation by most people on Earth (Henderson-Sellers, 1996). Impacts of warming will be unevenly distributed geographically and socially, with the poorest counties being least capable of adapting. Mitigation strategies that reduce greenhouse gas production could significantly reduce the amount of eventual warming, thus reducing adaptation costs and impacts substantially.

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