

Chapter I

Fossil and Biomass Fuels

This section includes emissions produced from energy-related activities. The sectors using fuel are residential, commercial, industrial, transportation and electric utility. The fuel types defined in reference sources include asphalt, aviation gasoline, distillate fuel oil, jet fuel kerosene, kerosene, liquified petroleum gas, lubricants, motor gasoline, residual fuel oil, bituminous coal, coke, natural gas and wood.

Overview

Energy-related activities are the most significant contributor to U.S. greenhouse gas emissions, accounting for almost 89 percent of total emissions in 1990. Emissions from fossil fuel combustion comprise the vast majority of these energy-related emissions. These emissions were produced from a variety of fossil fuel combustion activities, including heating in residential and commercial buildings, energy combustion to generate electricity, steam production for industrial processes, and gasoline consumption in automobiles and other vehicles, (U.S. EPA, 1995).

As fossil fuels burn, they emit carbon dioxide (CO₂) as a result of oxidation of the carbon in the fuel. In 1990, CO₂ accounted for 96 percent of all greenhouse gas emissions from fossil fuel combustion. The remaining four percent can be attributed to emissions of other gases, such as carbon monoxide (CO), methane (CH₄), or nonmethane volatile organic compounds (NMVOCs), which are emitted as a by-product of incomplete combustion. These gases are then oxidized to CO₂ within anywhere from a few days to 10 or 11 years. For purposes of this analysis, emissions of these other gases are considered to be a subset of CO₂ emissions. This includes all carbon emitted to the atmosphere and reported as CO₂ emissions, while a much smaller portion of the carbon will be reported as these other gases. This "double counting" is intentional. By reporting emissions in this fashion, state estimates of CO₂ will reflect total loadings of carbon. Also, since all of these gases oxidize to CO₂ eventually, they should be viewed as a subset of carbon emitted as CO₂ (U.S. EPA, 1995).

To estimate state emissions of carbon dioxide from fossil and biomass fuels, seven steps should be performed: 1) obtain the required energy data; 2) estimate total carbon content of the fuels; 3) estimate total carbon stored in the products; 4) estimate carbon potentially emitted from bunker fuel consumption; 5) estimate carbon emitted from interstate electricity consumption; 6) calculate net potential carbon emissions; 7) estimate the carbon actually oxidized from energy uses; and 8) convert net carbon emissions from energy consumption to total CO₂ emissions (U.S. EPA, 1995). Separate tables are presented for statewide and county-level fuel consumption. Statewide totals are given in Tables are I-1 and I-2. County-level data are given in the Appendix.

The required energy data were taken from the *State Energy Data Report 1993* of the Energy Information Administration for the years 1990 and 1993. Additional energy data were taken from

the *Utah Energy Statistical Abstract*, by the Utah Office of Energy and Resource Planning; and the *Coal Industry Annual 1993*, by the Energy Information Administration. Conversion factors and calculation procedures were taken from the *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions*, by the U.S. Environmental Protection Agency, 1995.

Table I-1 CO₂ Emissions from Fossil and Biomass Fuels - 1990

Fuel	Consumption MMBTU ¹	Carbon Content Coefficient lb C/MMBTU ²	Total Carbon Tons C	Stored Carbon Tons C ³	International Bunkers Tons C	Net Carbon Tons C	Total Oxidized Tons C ⁴	CO ₂ Emissions Tons C
Asphalt and Road Oil	9,144,408	45.5	208,035	208,035	-	0	0	0
Aviation Gasoline	535,088	41.6	11,130	-	-	11,130	11,019	40,401
Distillate Fuel Oil	42,749,675	44.0	940,493	-	-	940,493	931,088	3,413,989
Jet Fuel:Kerosene	29,108,872	43.5	633,118	-	-	633,118	626,787	2,298,218
Jet Fuel:Naptha	-	43.5	-	-	-	-	-	-
Kerosene	79,380	43.5	1,727	-	-	1,727	1,709	6,267
LPG	4,303,803	37.8	81,342	65,074	-	16,268	16,106	59,054
Lubricants	1,855,890	44.6	41,386	20,693	-	20,693	20,486	75,116
Misc. Petroleum Prod.	-	44.7	-	-	-	-	-	-
Motor Gasoline	87,341,631	42.8	1,869,111	-	-	1,869,111	1,850,420	6,784,873
Naptha<104 deg F	-	40.0	-	-	-	-	-	-
Naptha>104 def F	-	44.0	-	-	-	-	-	-
Pentane Plus	-	40.2	-	-	-	-	-	-
Petroleum Coke	-	61.4	-	-	-	-	-	-
Residual Fuel Oil	2,338,764	47.4	55,429	55,429	-	0	0	0
Still Gas	-	38.6	-	-	-	-	-	-
Waxes	-	43.7	-	-	-	-	-	-
Anthracite Coal	-	62.1	-	-	-	-	-	-
Bituminous Coal	375,956,930	56.0	10,526,794	-	-	10,526,794	10,421,526	38,212,262
Sub Bituminous Coal	-	57.9	-	-	-	-	-	-
Lignite Coal	-	58.7	-	-	-	-	-	-
Coke	-	-	-	-	-	-	-	-
Natural Gas	119,480,000	31.9	1,905,706	-	-	1,905,706	1,896,177	6,952,651
Wood (5)	9,000,000	0.5	2,138	-	-	2,138	1,924	7,054
Ethanol	-	41.8	-	-	-	-	-	-
Other	17,586,300	44.6	392,174	-	-	392,174	390,214	1,430,783
Total-Statewide	699,480,741	-	16,668,582	-	-	16,319,352	16,167,455	59,280,669

Data Source:

1. *Utah Energy Statistical Abstract*, 1995.
2. Energy Information Administration, *State Energy Data Report 1993*, pp 293-298.
3. U.S. Environmental Protection Agency, Policy Planning and Evaluation, *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions*.
4. *Ibid*, p 1-12.
5. *Ibid*, p 1-13.
6. Energy Information Administration, *Household Energy Consumption and Expenditures 1993*, p 61, 1995.

Note: C=Carbon

Table I-2 CO₂ Emissions from Fossil and Biomass Fuels - 1993

Fuel	Consumption MMBTU ¹	Carbon Content Coefficient lb C/MMBTU ²	Total Carbon Tons C	Stored Carbon Tons C ³	International Bunkers Tons C	Net Carbon Tons C	Total Oxidized Tons C ⁴	CO ₂ Emissions Tons C
Asphalt and Road Oil	11,480,280	45.5	261,176	261,176	-	0	0	0
Aviation Gasoline	575,472	41.6	11,970	-	-	11,970	11,850	43,450
Distillate Fuel Oil	46,600,000	44.0	1,025,200	-	-	1,025,200	1,014,948	3,721,476
Jet Fuel:Kerosene	30,415,216	43.5	661,531	-	-	661,531	654,916	2,401,357
Jet Fuel:Naptha	-	43.5	-	-	-	-	-	-
Kerosene	45,360	43.5	987	-	-	987	977	3,581
LPG	3,120,558	37.8	58,979	47,183	-	11,796	11,678	42,818
Lubricants	1,728,525	44.6	38,546	19,273	-	19,273	19,080	69,961
Misc. Petroleum Prod.	-	44.7	-	-	-	-	-	-
Motor Gasoline	98,919,243	42.8	2,116,872	-	-	2,116,872	2,095,703	7,684,245
Naptha<104 deg F	-	40.0	-	-	-	-	-	-
Naptha>104 def F	-	44.0	-	-	-	-	-	-
Pentane Plus	-	40.2	-	-	-	-	-	-
Petroleum Coke	-	61.4	-	-	-	-	-	-
Residual Fuel Oil	1,810,656	47.4	42,913	42,913	-	0	0	0
Still Gas	-	38.6	-	-	-	-	-	-
Waxes	-	43.7	-	-	-	-	-	-
Anthracite Coal	-	62.1	-	-	-	-	-	-
Bituminous Coal	378,608,720	56.0	10,601,044	-	-	10,601,044	10,495,034	38,481,790
Sub Bituminous Coal	-	57.9	-	-	-	-	-	-
Lignite Coal	-	58.7	-	-	-	-	-	-
Coke	-	-	-	-	-	-	-	-
Natural Gas	143,170,000	31.9	2,283,562	-	-	2,283,562	2,272,144	8,331,194
Wood (5)	9,000,000	0.5	2,138	-	-	2,138	1,924	7,054
Ethanol	-	41.8	-	-	-	-	-	-
Other	16,280,900	44.6	363,064	-	-	363,064	361,249	1,324,579
Total-Statewide	741,754,930	-	17,467,980	-	-	17,097,435	16,939,502	62,111,506

Data Source:

1. *Utah Energy Statistical Abstract*, 1995.
2. Energy Information Administration, *State Energy Data Report 1993*, pp 293-298.
3. U.S. Environmental Protection Agency, Policy, Planning and Evaluation, *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions*.
4. *Ibid*, p 1-12.
5. *Ibid*, p 1-13.
6. Energy Information Administration, *Household Energy Consumption and Expenditures 1993*, p 61, 1995.

Note: C=Carbon

Methodology

A. Carbon Dioxide

The following is a discussion of how the fuel consumption tables were constructed, including Tables I-1 and I-2 and the county-specific tables in the Appendix, Tables A-1 to A-10.

Statewide Emissions

Units of energy are listed as million British Thermal Units (MMBTU). Conversion factors located in Table 1-2 of the EPA *State Workbook* provide conversion factors for other systems of units.

The column label *carbon content coefficient* represents the fractional molecular weight of carbon in the fuel. This quantity of carbon is the amount that would be emitted if 100 percent of the carbon content in the fuel were released to the atmosphere. Tables 1-3 of the EPA *State Workbook* show carbon content coefficients of several fuels and is partially reproduced in Tables I-1 and I-2 of this report. To estimate the carbon content released from individual fuels, multiply the energy consumption from each fuel type by the appropriate carbon content coefficient. This calculation is repeated for all fuel types in each sector under the column label *total carbon*. The equation is in the following form:

$$T_{ci} = C_i * CCC_i / 2000$$

where T_{ci} = Total carbon contained in fuel_i {tons C}
 C_i = Fuel consumption for fuel_i {MMBTU}
 CCC_i = Carbon content coefficient for fuel_i {lbs C/MMBTU}

Note that special brackets are used for units, e.g., {} and do not signify multiplication. Multiplication is indicated by an asterisk.

Divide the result by 2,000 to convert to tons of carbon and then sum the totals of each fuel type and create a grand total, leaving out biomass consumption (e.g., wood). CO₂ emissions resulting from bioenergy consumption (e.g., wood) should not be included in a state's official emissions inventory in order to avoid double counting CO₂ emissions. The double counting would occur because biofuels tend to be produced on a sustainable basis such that no net increase of CO₂ occurs or CO₂ from biofuels burned on a non-sustainable basis would result in land use changes (U.S. EPA, 1995).

The column labeled *stored carbon* is an estimate of carbon stored in non-fuel products such as asphalt and road oil. Tables 1-4 in the EPA *State Workbook* is used as a source for this information. The fraction stored of individual fuel types are listed. The fraction stored is multiplied by the carbon content as shown in the following equation:

$$Sc_i = TC_i * FSi$$

where Sc_i = Stored carbon {tons C}
 TC_i = Total carbon contained in fuel_i {pounds C}
 FS_i = Fraction stored

Estimates of carbon from bunker fuel consumption involve international bunker fuels which are calculated in the same manner as fossil fuel combustion.

where $Tc_i = C_i * CCC_i$
 TC_i = Total carbon contained in bunker fuel_i {lbs C}
 C_i = Consumption of bunker fuel_i {MMBTU}
 CCC_i = Carbon content coefficient for bunker fuel_i {lbs C/MMBTU}

The total carbon contained in each bunker fuel should be entered in the table under bunker fuels, and should only be subtracted if the international bunker fuels have been captured in the total carbon data. If the carbon values do not include international bunker fuels, then values under bunker fuels should not be subtracted.

Estimates of carbon emitted from interstate electricity consumption are determined from quantities of energy imported into and exported from the state. Sources of interstate electricity are divided by type of generation (e.g., coal, hydroelectric, etc.). The following equation summarizes the steps outlined above:

where $Ei_i = Imp_i * HR_i * CCC_i$
 $EE_j = Exp_j * HR_j * CCC_j$
 Ei_i = emissions from imports from source_i {lbs C}
 EE_j = emissions from exports from source_j {lbs C}
 Imp_i = electricity from source_i {KWH}
 Exp_j = electricity from source_j {KWH}
 Hr_i = heat rates of generating facilities {BTU/KWH}
 CCC_{ij} = carbon content coefficients from source fuels {lb C/BTU}

Emissions from interstate electricity consumption are summed over all fuel types, and exported electricity emissions are subtracted from imported electricity emissions.

where $NE = SUM (EI_i - EE_j)$
 NE = Net emissions from interstate consumption {lbs C}
 SUM = Summation of ...
 EI_i = Emissions of carbon due to imports from source_i {lbs C}
 EE_j = Emissions of carbon due to exports from source_j {lbs C}

The resulting values are reported separately from other emissions of fossil fuel consumption. A negative number indicates a net export of carbon from interstate electricity. A positive number indicates a net import.

Calculation of net potential carbon emissions is accomplished by subtracting carbon stored and bunker fuel consumption from the total carbon for each fuel type. This calculation will take the following form:

$$\text{Net potential carbon emissions \{tons\}} = \text{total carbon \{tons\}} - \text{carbon stored \{tons\}} - \text{bunker fuel \{tons\}}$$

Multiply the net carbon content for each fuel and sector by the fraction of carbon oxidized to obtain the amount of carbon oxidized to carbon dioxide from the combustion of the fuel. The fraction of carbon oxidized is 0.99 for solid and liquid fuels, 0.995 for natural gas, and 0.90 for wood (U.S. EPA, 1995). This calculation will take the following form:

$$\text{Net carbon content \{tons\}} * \text{fraction oxidized} = \text{total oxidized carbon \{tons C\}}$$

Sum the results to obtain the total amount of carbon oxidized from all fuel types. Carbon biomass consumption should not be included in total emissions.

To convert carbon oxidized to total CO₂ emissions, multiply by the molecular weight ratio of CO₂ to C (e.g., 44/12) to obtain total CO₂ emissions. Sum across each fuel and sector to find total state emissions of CO₂ from energy consumption. Carbon consumption from biomass should not be included.

$$\text{Total CO}_2 \text{ \{tons\}} = \text{carbon oxidized \{tons\}} * 44 \text{ \{tons CO}_2\} / 12 \text{ \{tons C\}}$$

Uncertainties

Uncertainties in emission estimates include inaccuracies in the carbon content coefficient for each fuel, since the coefficients are average quantities. Second, the apportionment of emissions from state-wide to county-specific estimates, excluding electric utilities, is made using a population ratio, which is assumed to equal the fuels distribution. This was the most realistic assumption available since county-specific fuel data was unavailable. In the case of electric utilities, emission estimates were based on actual quantities of fuel burned at individual power plants.

B. Methane and Nitrous Oxide

Methane and nitrous oxide emissions are dependent on the combustion process and emission factors vary for different sectors and different combustion technologies in the same sector. Chapter D-12 of the EPA *State Workbook*, published by the U.S. Environmental Protection Agency in 1992, gives emission factors. Insufficient information is available to determine which emission factors to use.

County Emissions

County fuel consumption was determined using ratios of population and employment with the statewide fuel consumption totals. Residential totals were determined using the ratio of county population to statewide multiplied by the residential fuel consumption total for the state. All other categories were determined by using ratios of employment relative to the statewide total. The table showing the ratios is provided in the appendix as Table A-11.

A. Residential Sector

Methodology

The methodology for calculating greenhouse gas emissions is stated in the General Methodology in Section I of this report.

Residential energy use by fuel type is calculated for counties by means of a ratio of county-to-statewide population (*State of Utah Economic and Demographic Projections 1994*, published by the Utah Governor's Office of Planning and Budget, Demographic and Economic Analysis Work Group, 1994). Emissions by county are given in Appendix A.

Results

The residential sector was responsible for about 2.9 million tons of greenhouse gas emissions in 1990 and 3.3 million tons in 1993. The major fuel used by the residential sector is natural gas. Natural gas accounted for 89 percent of residential greenhouse gas emissions in 1990 and 94 percent in 1993.

B. Commercial Sector

Methodology

The Standard Industrial Classifications (SIC) code designates specific manufacturing activities. The commercial sector is defined by SIC codes 50-99.

The methodology for calculating greenhouse gas emissions is stated in the General Methodology in Section I of this report.

Commercial energy use by fuel type is calculated for each county by means of a ratio of county-to-statewide commercial employment (*State of Utah Economic and Demographic Projections 1994*, published by the Utah Governor's Office of Planning and Budget, Demographic and Economic Analysis Work Group, 1994). Emissions by county are given in Appendix A.

Results

Fuel combustion in the commercial sector generated 1.6 million tons of greenhouse gases in 1990 and 1.8 tons in 1993. The major fuel used in the commercial sector is natural gas. Natural gas produced 60 percent of the emissions in 1990 and 79 percent in 1993.

C. Industrial Sector

Methodology

The industrial sector is defined as SIC codes 20-39. The methodology for calculating greenhouse gas emissions is stated in the General Methodology in Section I of this report.

Industrial energy use by fuel type is calculated for counties by means of a ratio of county-to-statewide industrial employment (*State of Utah Economic and Demographic Projections 1994*, published by the Utah Governor's Office of Planning and Budget, Demographic and Economic Analysis Work Group, 1994). Emissions by county are given in Appendix A.

Results

Fuel combustion in the industrial sector generated 10.2 million tons of greenhouse gases in 1990 and 9.8 tons in 1993. The major fuel used in the industrial sector is natural gas. Natural gas produced 45 percent of the emissions in 1990 and 43 percent in 1993.

D. Transportation Sector

Methodology

The transportation sector is defined as SIC codes 46 and 49. The methodology for calculating greenhouse gas emissions is stated in the General Methodology in Section I of this report.

Transportation energy use by fuel type is calculated for counties by means of a ratio of county-to-statewide population. (*State of Utah Economic and Demographic Projections 1994*, published by the Utah Governor's Office of Planning and Budget, Demographic and Economic Analysis Work Group, 1994). Emissions by county are given in Appendix A.

Results

Fuel combustion in the industrial sector generated 11.6 million tons of greenhouse gases in 1990 and 12.9 million tons in 1993. The major fuel used is motor gasoline in the transportation sector. Motor gasoline caused 58 percent of the emissions in 1990 and 59 percent in 1993.

E. Electric Utility Sector

Methodology

The electric utility sector is defined as SIC 4911 through 4931. The methodology for calculating greenhouse gas emissions is stated in the General Methodology in Section I of this report.

Electric utility energy use by fuel type is calculated for counties by means of actual utility combustion in each county and data from the *State Energy Data Report 1993*, from the Energy Information Administration. The data were taken from 1990 and 1993 air emission inventories at the Utah Division of Air Quality. Electric utilities are listed for each county in Appendix A. Emissions by county are given in Appendix A.

Results

Fuel combustion in the electric utility sector generated 33.0 million tons of greenhouse gases in 1990 and 34.4 million tons in 1993. The major fuel used in the electric utility sector is bituminous coal. Bituminous coal produced 99.7 percent of the emissions in 1990 and 98.9 percent in 1993.

Interstate Electricity Imports and Exports

The California Energy Commission, through the Energy Facilities Siting and Environmental Protection Division, supplied data on electricity imports and exports for the year 1990. The source of information is the Energy Information Administration Forms EIA-412 and EIA-860 for purchases and pounds carbon per gigawatthour (California Energy Commission, 1995).

Total exports from Utah to California for 1990 were 126,150 gigawatthours. Total imports from California to Utah for 1990 were 381 gigawatthours. Using emission data from another study of 0.91 tons CO₂ per gigawatthour yields 114,796 tons CO₂ for imports from California and 347 tons for exports from Utah (San Martin, 1989). A summary of the power exchanges is provided in a California Energy Commission document in the appendix. PacifiCorp also has many power exchanges between states other than California, but this information is not currently available.

Summary of Power Transactions from Utah Utilities to Out-of-State Utilities

Greenhouse gases generated from electric power generation generally fall into one of three categories. Power generated as "Sold" refers to all in-state contract power generated for domestic and external consumption. "Exchanged" power includes all energy transactions between utilities where electricity imported is returned at a pre-specified date or accumulated as energy balances until the end of a defined period, after which a cash settlement may occur. Finally, "Wheeled" power refers to contractual shipments of electricity from one system to another over transmission lines of intervening systems. Currently, there is no category of wheeled power in the state of Utah.

As indicated in Table I-3, Utah has a number of power contracts involving two producers, Intermountain and UAMPS, which have out-of-state contracts with California. In servicing regions of southern California, the Intermountain Power Agency generates over 12,000 GWh or roughly 3.3 million tons of carbon. For customers in the Northwest, primarily PacifiCorp, approximately 435 GWh are generated under firm contract, equivalent to about 120,000 tons of carbon.

In terms of exchanged power, Table I-4 presents the Utah-based power which is generated to balance production from PacifiCorp's facilities in the state of Oregon. The DG&T produces two-thirds of this power, followed by UAMPS, and a small fraction from the Provo City Corporation. All told, exchange power is responsible for just over 3,000 GWh and approximately 894,000 tons of carbon.

Table I-3 Power Sales from Utah Utilities to Out-of-State Utilities - 1990

Based on EIA-412,EIA-860, and the California Energy Commission 1992 Electricity Report

Intermountain Power Agency	Power Sold	Carbon Emission Factor	Carbon Emission
California			
Firm Power			
Anaheim City of	1,693,678 MWh	550,731 Lbs C/GWh	466,380 tons C
Burbank City of	533,210 MWh	550,731 Lbs C/GWh	146,827 tons C
Glendale City of	278,484 MWh	550,731 Lbs C/GWh	76,684 tons C
Los Angeles County	8,014,724 MWh	550,731 Lbs C/GWh	2,206,978 tons C
Pasadena City of	771,037 MWh	550,731 Lbs C/GWh	212,316 tons C
Riverside City of	979,253 MWh	550,731 Lbs C/GWh	269,652 tons C
Northwest			
Firm Power			
PacifiCorp	435,542 MWh	550,731 Lbs C/GWh	119,933 tons C
Total Utility Sales	12,705,928 MWh		3,498,774 tons C
Utah Associated Mun Power Sys			
California			
Economic Power			
Burbank City of	884 MWh	309,590 Lbs C/GWh	136 tons C
Pasadena City of	1,011 MWh	309,590 Lbs C/GWh	156 tons C
Firm Power			
Santa Clara City of	9,866 MWh	309,590 Lbs C/GWh	1,527 tons C
Northwest			
Economic Power			
PacifiCorp	7,313 MWh	309,590 Lbs C/GWh	1,132 tons C
Southwest			
Economic Power			
Western Area Power Admin	163,990 MWh	309,590 Lbs C/GWh	25,384 tons C
Total Utility Sales	183,064 MWh		28,337 tons C

Table I-4 Exchange Power between Utah Utilities and Out-of-State Utilities - 1990
 With Out-of-State Utilities as the reporting party

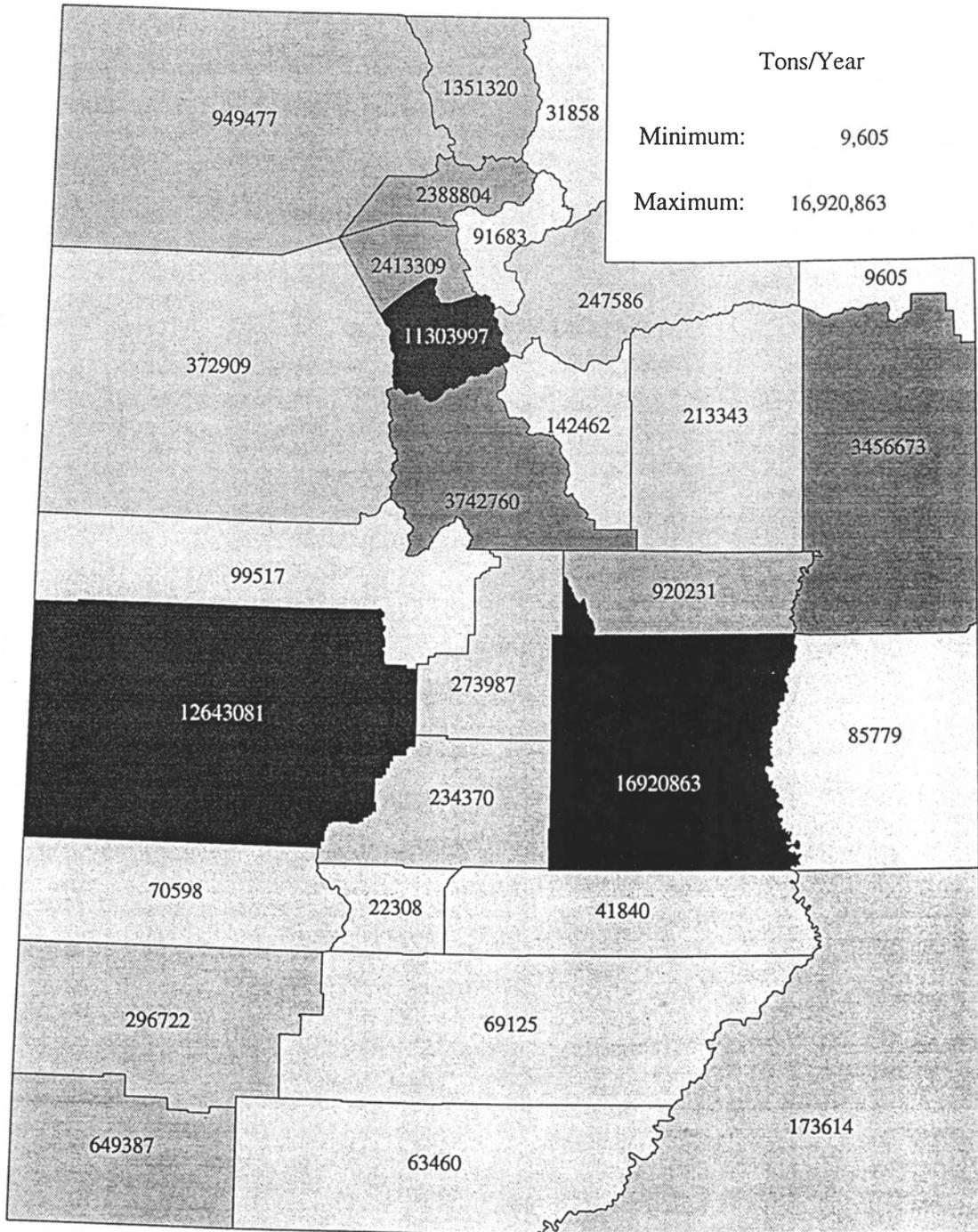
	Power Produced, Utah	Carbon Emission, Utah
Deseret Generation & Tran Coop		
PacifiCorp	2,156,780 MWh	625,088 tons C
Utility Total	2,156,780 MWh	625,088 tons C
Provo City Corp		
PacifiCorp	23,838 MWh	4,753 tons C
Utility Total	23,838 MWh	4,753 tons C
Utah Municipal Power Agency		
PacifiCorp	961,003 MWh	264,627 tons C
Utility Total	961,003 MWh	264,627 tons C
Oregon		
PacifiCorp	3,141,621 MWh	894,469 tons C
State Total	3,141,621 MWh	894,469 tons C

Based on EIA-412, EIA-860, and the California Energy Commission 1992

References

- California Energy Commission. *California Power Purchases from Utah Based Facilities, 1990*. Energy Facilities Siting and Environmental Protection Division (memo: Joseph Loyer), 1995.
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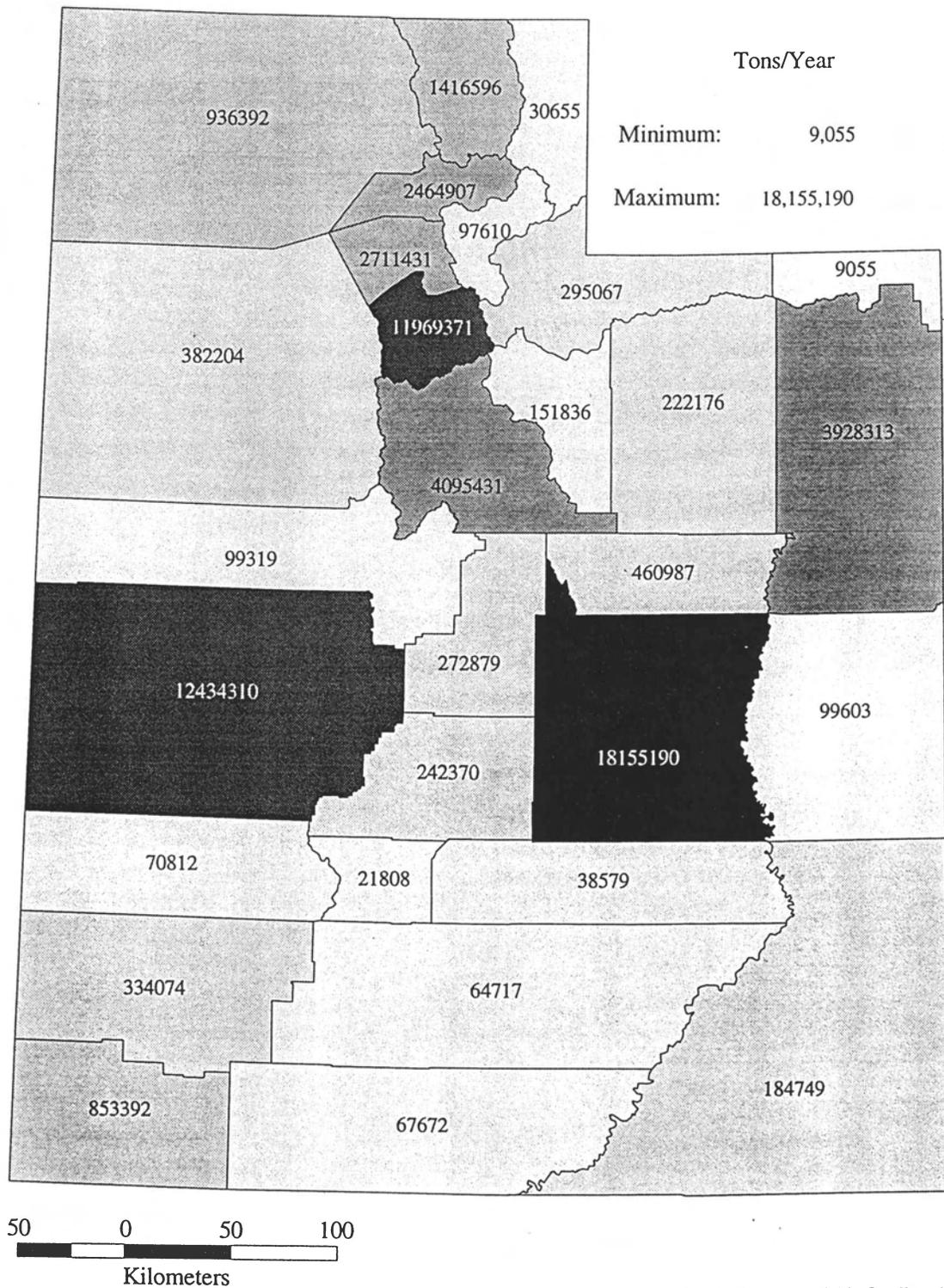
CO₂ Emissions from Fossil Fuel Combustion - 1990



Utah Division of Air Quality 1996

Figure I-1

CO₂ Emissions from Fossil Fuel Combustion - 1993



Utah Division of Air Quality 1996

Figure I-2

Chapter II

Production Processes

This section includes emissions produced from non-energy related activities. The production processes included in this section are: 1) lime and cement production; 2) limestone use; 3) nitric acid production; 4) adipic acid production; 5) soda ash production and use; 6) CO₂ manufacture; 7) aluminum production; and 8) HCFC-22 production.

A. CO₂ from Lime and Cement Production

Overview

The cement production process represents the most significant non-energy source of industrial CO₂ emissions. Carbon dioxide is created when calcium carbonate (CaCO₃) is heated in a cement kiln to form lime (calcium oxide -- CaO) and CO₂. This process is known as calcination or calcining:



The lime is then combined with silica-containing materials to form dicalcium or tricalcium silicates (U.S. EPA, 1995). This lime mixture is then combined with more materials to produce clinker. Clinker is an intermediate product from which finished Portland and masonry cement are made.

Methodology

Lime Production

The mass of CO₂ emitted per unit of lime produced can be calculated based on the molecular weights of CO₂ and lime (CaO.) The equation is as follows:

$$EF_{lime} = \frac{44.01(\text{g/mole } CO_2)}{56.08(\text{g/mole } CaO)} = 0.785 \left(\frac{\text{ton } CO_2}{\text{ton Lime}} \right)$$

In Utah, lime is produced by Continental Lime, Inc. in Millard County, and Chemical Lime Company in Tooele County. The tons of lime produced by each company in 1990 and 1993 were found in the Division of Air Quality (DAQ) database using the Standard Industrial Classification (SIC) codes 3274 and 1422 and source classification code (SCC) 3-05-016 for lime manufacturing. The lime produced in 1990 and 1993 and the CO₂ emitted in Utah are as follows:

Table II-1 Lime Production by County

Company Name		Continental Lime		Chemical Lime	Total Statewide
County		Millard	Tooele		
Lime Production	Throughput (tons)	1990	365,000	40,000	405,000
		1993	414,250	55,090	469,340
	Emission Factor (ton/ton)		0.785	0.785	
CO ₂ Emissions (tons)		1990	286,525	31,400	317,925
		1993	325,186	43,246	368,432

Uncertainties

Uncertainties in emission estimates can be attributed to slight differences in the chemical composition of lime. Lime typically contains trace amounts of impurities, and few plants manufacture lime with exactly the same composition.

A portion of the CO₂ emitted during lime production will be reabsorbed when the lime is used. Typically, the CO₂ reacts with the lime to create calcium carbonate (CaCO₃). Due to many unknowns, the amount of CO₂ reabsorbed cannot be presently quantified (U.S. EPA, 1995).

Cement Production

As recommended in the EPA *State Workbook*, the emission factor used for clinker production is the product of the fraction of lime used in the cement clinker and a constant reflecting the mass of CO₂ released per unit of lime. The emission factor was calculated as follows:

$$EF_{clinker} = \%CaO * \frac{44.01(g/moleCO_2)}{56.08(g/moleCaO)} = 0.507 \frac{(tonCO_2)}{(tonClinker)}$$

Masonry cement requires additional lime over and above the lime used in the clinker. During the production of masonry cement, additives such as lime, slag and shale are added to the cement, increasing the weight by five percent. Lime accounts for 60 percent of the added substances (U.S. EPA, 1995). The emission factor used to account for the additional lime is as follows:

$$EF_{cement} = \left(\frac{fw}{1-fw}\right) * (fl) * \frac{44.02(g/moleCO_2)}{56.08(g/moleCaO)} = \left(\frac{0.05}{1+0.05}\right) = 0.0244 \left(\frac{tonCO_2}{tonCement}\right)$$

where

fw = weight fraction of added substances = 0.05

fl = fraction of lime in added substances = 0.6

Holnam Inc., located in Morgan County and Ash Grove Cement Company, located in Juab County, are the only companies in Utah that produce cement. The amount of clinker and cement produced by these companies was found in the DAQ database using SIC code 3241 and SCCs 3-05-006 and 3-05-007 for cement manufacturing.

Using the emission factors found in the EPA *State Workbook*, the amount of clinker and cement produced by county and the corresponding CO₂ emitted are as follows:

Table II-2 Clinker and Cement Production by Company

Company Name		Holnam Inc. Ash Grove Cement Co.			
County		Morgan	Juab	Total Statewide	
Clinker Production	Throughput (tons)	1990	366,327	594,600	960,927
		1993	350,400	581,071	931,471
	Emission Factor (ton/ton)		0.507	0.507	
		CO ₂ Emissions (tons)	1990	185,728	301,462
	1993		177,653	294,603	472,256
	Cement Production	Throughput (tons)	1990	364,698	626,675
1993			348,841	612,427	961,268
Emission Factor (ton/ton)			0.022	0.022	
		CO ₂ Emissions (tons)	1990	8,169	14,038
1993			7,814	13,718	21,532
Total CO ₂ (tons)		1990	139,897	315,500	509,397
		1993	185,467	308,321	493,788

Uncertainties

As in lime consumption, some amount of CO₂ is reabsorbed when the cement is used for construction. As cement reacts with water, alkaline substances are formed. During the curing process, these compounds may react with CO₂ in the atmosphere to create CaCO₃. This reaction only occurs in roughly the outer 0.2 inches of surface area. Since the amount of CO₂ reabsorbed is thought to be minimal, an emission estimate is not included here (U.S. EPA, 1995).

B. CO₂ from Limestone Use

Overview

Limestone is a basic raw material used by a wide variety of industries, including construction, agriculture, chemical and metallurgical industries (U.S. EPA, 1995). The two types of limestone, calcite or dolomite, are typically heated during use, generating CO₂ as a by-product.

Methodology

As recommended in the EPA *State Workbook*, the CO₂ emitted per unit of limestone used is the product of the carbon contained in the limestone (calcite or dolomite) and the ratio of the molecular weight of CO₂ to the molecular weight of C.

The emission factors for calcite and dolomite are as follows:

Calcite

$$EF_{\text{Calcite}} = 0.12 \frac{\text{tonC}}{\text{tonCalcite}} * \frac{44(\text{g/moleCO}_2)}{12(\text{g/moleC})} = 0.44 \left(\frac{\text{tonCO}_2}{\text{tonCalcite}} \right)$$

Dolomite

$$EF_{\text{Dolomite}} = 0.13 \frac{\text{tonsC}}{\text{tonDolomite}} * \frac{44(\text{g/moleCO}_2)}{12(\text{g/moleC})} = 0.4767 \left(\frac{\text{tonCO}_2}{\text{tonDolomite}} \right)$$

A query of the DAQ database for limestone use was conducted to determine the applicable sources in the state. The query focused on limestone, calcite or dolomite, throughput. The query found five companies in Utah that use calcite and/or dolomite. The limestone (calcite and dolomite) use and associated CO₂ emissions in the state for 1990 and 1993 are as follows:

Table II-3 Calcite and Dolomite Use by County

Company Name	County	Throughput (tons)		CO ₂ Emissions (ton/yr)	
		1990	1993	1990	1993
Calcite Use (EF=0.44 ton CO₂/ton Calcite)					
Ash Grove Cement Company	Juab	770,900	780,768	339,196	343,537
Chemical Lime Company	Tooele	83,024	79,712	36,531	35,073
Continental Lime, Inc.	Millard	730,000	828,500	321,200	364,540
Geneva Steel	Utah	58,289	95,021	25,647	41,809
Intermountain Power Service Co.	Millard	63,045	67,677	27,740	29,778
State Total		1,705,258	1,851,678	750,314	814,738
Dolomite Use (EF=0.44 ton CO₂/ton Dolomite)					
Geneva Steel	Utah	30,899	41,240	14,730	19,659
State Total		30,899	41,240	14,730	19,659
Total Statewide CO₂ from Limestone				765,043	834,398

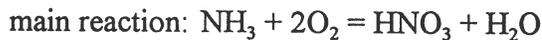
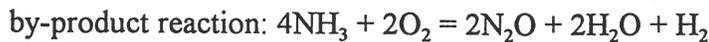
Uncertainties

Emission estimation uncertainties can again be attributed to variations in the chemical composition of limestone. Uncertainties also exist in the activity data. Much of the limestone consumed in the United States is reported as "other unspecified uses." As a result it is difficult to disaggregate by type (U.S. EPA, 1995).

C. Nitric Acid

Overview

The production of nitric acid produces nitrous oxide as a by-product. Ammonia is oxidized to form nitrous oxide in the reaction shown below. Nearly all the nitric acid produced is by the catalytic oxidation of ammonia. La Roche Chemicals in Utah County is the only company in Utah which produces nitric acid.



Methodology

The mass of N_2O emitted per unit of ammonia is 0.0171 ton per ton at Montercatini and 0.0114 ton per ton at Weatherly divisions of La Roche Chemical, higher than the 1990 U.S. average of 0.0055 ton/ton (U.S. EPA, 1995). These results are based on control equipment and stack gas measurements of NO content. The total NO released is 514 tons in 1990 and 504 tons per year in 1993 at La Roche Chemical.

The tons of nitric acid produced in 1990 and 1993 was found in the Division of Air Quality (DAQ) database using the Standard Industrial Classification code 2873 and source classification code 3-01-013-04 for nitric acid manufacturing.

Table II-4 Nitric Acid Emissions for La Roche Chemicals of Utah County

Company Name	La Roche Chemicals			
Product	Year	Throughput (Tons)	Emission Factors (ton / ton)	NO Emissions (Tons)
Nitric Acid Production	1990	93,381	0.0055	514
Nitric Acid Production	1993	91,678	0.0055	504

Uncertainties

The uncertainty in emissions estimates are based on the emission factors which are based on national averages, not on the emissions from this one manufacturing operation.

D. Adipic Acid Production

Overview

Adipic acid is a white crystalline solid used in the manufacture of synthetic fibers, coatings, plastics, urethane foams, elastomers and synthetic lubricants. Ninety percent of all adipic acid produced in the United States is used in the production of nylon 6,6, as well as production of some low-temperature lubricants. It is also used to provide foods with a "tangy" flavor (U.S. EPA, 1995).

Negative Declaration

Adipic acid is not produced in Utah. Therefore, no emissions are generated by this process in the state of Utah.

E. CO₂ from Soda Ash Manufacture and Consumption

Overview

Commercial soda ash (sodium carbonate) is used in many consumer products such as soap, glass, detergents, paper, textiles and food. About 75 percent of world production is synthetic ash made from sodium chloride; the remaining 25 percent is produced from natural sources. The United States produces only natural soda ash. During the production process, trona (the principal ore from which natural soda ash is made) is calcined in a rotary kiln and chemically transformed into a crude soda ash that requires further processing. CO₂ and water are generated as a by-product of the calcination process (U.S. EPA, 1995).

CO₂ is also released when soda ash is consumed. Glass manufacture represents about 49 percent of domestic soda ash consumption, with smaller amounts used for chemical manufacture, soap and detergents, flue gas desulfurization, and other miscellaneous uses (U.S. EPA, 1995).

Methodology

Soda ash is not manufactured in the state of Utah. However, soda ash consumption did occur as reported by Dyce Chemical. Dyce Chemical is a distributor of soda ash which is manufactured outside of Utah. Dyce Chemical reported the tons of soda ash sold to Utah businesses in 1990 and 1993. It is assumed that all soda ash sold to Utah customers was consumed within the state. As stated in the EPA *State Workbook*, a mole of carbon is released for every mole of soda ash consumed, which equates to 0.113 tons of carbon per ton of soda ash consumed, or 0.415 tons of CO₂ per ton of soda ash consumed.

This factor results in the following equation:

$$CO_2 = SA_{consumed}(tons) * 0.145 \frac{tonCO_2}{tonSA}$$

where SA= Soda Ash

Soda ash consumption is known for the entire state. An assumption was made that the emissions are distributed among each county of the state by population. The resulting emissions for soda ash consumption in 1990 and 1993 are in the following tables.

Table II-5 Soda Ash Consumption and CO₂ Emissions

Soda Ash Consumed Statewide		CO ₂ Emissions Statewide	
1990	1993	1990	1993
500	1,000	207.5	415

F. CO₂ Manufacture

Overview

Typically, CO₂ is produced as a by-product from the production of other chemicals, such as ammonia, or obtained by separation from crude oil or natural gas. The by-product CO₂ from these production processes should be accounted for in the emission estimates from fossil fuel consumption (either during combustion or from non-fuel use) (U.S. EPA, 1995).

Negative Declaration

CO₂ is not manufactured in the state of Utah. Handlers of CO₂ in the state, Bagley Ice & Carbonic and Bevco, report that CO₂ used in Utah comes from ammonia wells in Idaho and Wyoming. Therefore, no CO₂ is estimated for this category of the inventory.

G. CF₄ and, C₂F₆ Emissions from Aluminum Smelting

Overview

The aluminum production industry is thought to be the largest source of two PFCs -- CF₄ and C₂F₆. Emissions from aluminum production occur during the reduction of alumina in the primary smelting process. PFCs are formed during disruptions of the production process known as anode effects. The more frequent and long-lasting the anode effects, the greater the emissions (U.S. EPA, 1995).

CO₂ is also emitted during the aluminum production process when alumina is reduced to aluminum. These emissions, however, would fall into the non-fuel use portion of CO₂ emissions from fossil fuel consumption.

Table II-6 CO₂ Emissions from Soda Ash Consumption (tons)

County	1990	1993
Beaver	0.58	1.11
Box Elder	4.38	8.47
Cache	8.46	16.92
Carbon	2.42	4.60
Daggett	0.08	0.16
Davis	22.56	45.80
Duchesne	1.51	2.93
Emery	1.23	2.31
Garfield	0.47	0.93
Grand	0.79	1.67
Iron	2.51	5.29
Juab	0.70	1.38
Kane	0.62	1.21
Millard	1.35	2.60
Morgan	0.66	1.37
Piute	0.15	0.30
Rich	0.21	0.40
Salt Lake	87.37	172.76
San Juan	1.51	2.91
Sanpete	1.95	4.02
Sevier	1.85	3.65
Summit	1.88	4.38
Tooele	3.20	6.25
Uintah	2.66	5.25
Utah	31.93	64.70
Wasatch	1.21	2.49
Washington	5.89	13.05
Wayne	0.26	0.49
Weber	19.08	37.58
Total	207.50	415.00

Negative Declaration

Aluminum production does not occur in the state of Utah. Therefore, neither CF₄ nor C₂F₆ is emitted from this process in the state of Utah.

H. HCFC-22 Production

Overview

HFCs are chemicals containing hydrogen, carbon and fluorine. The only type of HFC known to be emitted in significant quantities at present is HFC-23, which is emitted as a by-product of HCFC-22 production.

Negative Declaration

No HCFC-22 is produced in the state of Utah. Therefore, no HFC-23 is emitted in the state of Utah.

References

Dyce Chemical Inc. Fax dated August 22, 1995.

U.S. Environmental Protection Agency (U.S. EPA). *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions*. Office of Policy, Planning, and Evaluation (EPA-230-B-95-001). Washington, D.C.: Government Printing Office, 1995.

State of Utah. Utah Division of Air Quality. DAQ Access Database, 1995.

State of Wisconsin. *Wisconsin Greenhouse Gas Emissions Inventory*. Department of Natural Resources, Bureau of Air Management, 1990.

CO₂ Emissions from Production Processes - 1990



Figure II-1

Chapter III

Natural Gas and Oil Systems

Overview

Emissions from natural gas and oil systems are primarily methane, although smaller quantities of non-methane VOCs, carbon dioxide and carbon monoxide can be emitted. Methane emissions occur throughout the total fuel cycles of oil and natural gas. From natural gas, methane emissions occur during field production, processing, refining, storage, injection, transmission and distribution, as well as from engine exhaust. From the production and refining of petroleum liquids, methane emissions occur during field production, storage, refining, and from venting and flaring of natural gas.

To estimate these emissions, the following steps should be taken: 1) obtain the required data on activity levels for different segments of the fuel systems; 2) multiply activity levels by the appropriate emission factor; and 3) sum across activity types to calculate total emissions.

Methodology

Information required to estimate emissions from this source is based on activity by sector whether oil or gas. Information was collected from the Utah Division of Oil, Gas, and Mining. Units are million British Thermal Units or MMBTU. Emissions factors are taken from the EPA *State Workbook*, 1995. Emission factors are expressed in pounds of methane per MMBTU. Three factors are provided (e.g., low, medium, and high). The factors provide estimates in three ranges based on average emissions across the United States. The calculation is shown in the equation below:

$$\text{Activity Level (MMBTU)} \times \text{Emissions Factor (high, lbs CH}_4\text{/MMBTU)} = \text{lbs CH}_4\text{, high}$$

$$\text{Activity Level (MMBTU)} \times \text{Emissions Factor (low, lbs CH}_4\text{/MMBTU)} = \text{lbs CH}_4\text{, low}$$

$$\text{Activity Level (MMBTU)} \times \text{Emissions Factor (medium, lbs CH}_4\text{/MMBTU)} = \text{lbs CH}_4\text{, medium}$$

The total methane emissions are calculated by summing across activity types as shown below:

$$\text{SUM tons CH}_4\text{, high} = \text{Total CH}_4\text{ Emissions from Oil and Gas Systems (high estimate)}$$

$$\text{SUM tons CH}_4\text{, low} = \text{Total CH}_4\text{ Emissions from Oil and Gas Systems (low estimate)}$$

$$\text{SUM tons CH}_4\text{, medium} = \text{Total CH}_4\text{ Emissions from Oil and Gas Systems (medium estimate)}$$

Table III-1 shows the 1990 and 1993 methane emissions for oil and gas activities. Oil and gas is assumed to be produced within the state of Utah and does not include imports or exports. Net

oil imports were 33,226,000 barrels in 1990 and 34,596,000 barrels in 1993. Net gas imports were 84,922 MMCF in 1990 and 32,227 MMCF in 1993.

Crude oil transportation, as shown in Table III-1, is assumed to be the same quantity as oil production, since oil in Utah is trucked to the refinery. The quantity of oil reported as refining is the number of crude oil runs, or the amount of oil actually processed by the refinery. The quantity shown as storage tanks is the stock at yearend 1990 and 1993.

Emissions from oil and gas production and distribution for counties are by means of a county-to-statewide population ratio (*State of Utah Economic and Demographic Projections 1994*, published by the Utah Governor's Office of Planning and Budget, Demographic and Economic Analysis Work Group, 1994).

Uncertainties

Uncertainties in the emission estimates include the emission factors associated with the categories of oil and gas production and distribution. Since these values are nationwide averages, the potential exists for large regional variations.

Table III-1 Natural Gas and Oil Emissions Factor and Emissions Sector

Sector	Activity MMBTU	Emissions Factor lb CH ₄ /MMBTU * 10 ⁶			Emissions Sector (tons CH ₄)		
		Low	High	Medium	Low	High	Medium
1990							
OIL & GAS PRODUCTION							
Oil ¹	2,769,376,686	700	11,600	6,150	969	16,062	8,516
Gas ²	337,852,000	106,770	194,960	150,870	18,036	32,934	25,486
Venting and Flaring ³	1,338,000	6,960	32,490	19,730	5	22	13
CRUDE OIL TRANSPORTATION AND REFINING							
Transportation ⁴	337,852,000	1,730	1,730	1,730	292	292	292
Refining ⁵	285,279,375	210	3,250	1,730	30	464	247
Storage Tanks ⁶	4,362,925	50	580	310	0	1	1
NATURAL GAS PROCESSING, TRANSPORTATION, AND DISTRIBUTION							
Gas processing, transportation, and distribution ⁷	337,852,000	132,300	273,880	203,390	22,349	46,265	34,358
				Total	41,681	96,040	68,912
1993							
OIL & GAS PRODUCTION							
Oil ¹	127,098,052	700	11,600	6,150	44	737	391
Gas ²	337,852,000	106,770	194,960	150,870	18,036	32,934	25,486
Venting and Flaring ³	2,152,000	6,960	32,490	19,730	7	35	21
CRUDE OIL TRANSPORTATION AND REFINING							
Transportation ⁴	127,098,052	1,730	1,730	1,730	110	110	110
Refining ⁵	285,279,375	210	3,250	1,730	30	464	247
Storage Tanks ⁶	4,025,075	50	580	310	0	1	1
NATURAL GAS PROCESSING, TRANSPORTATION, AND DISTRIBUTION							
Gas processing, transportation, and distribution ⁷	337,852,000	132,300	273,880	203,390	22,349	46,265	34,358
				Total	40,577	80,546	60,613

Notes: 1 gross oil production for state
 2 gross gas production for state
 3 venting and flaring
 4 assumed to be same as 1
 5 gross crude oil runs
 6 ending refinery stocks
 7 assumed to be same as 2

5.825 x bbl = MMBTU
 5.825 x bbl = MMBTU
 1,000 x MMCF = MMBTU

Source: *Utah Energy Statistical Abstract, 1995*

Table III-2 CH₄ Emissions from Oil and Gas Production and Distribution

County	Low Emissions		Medium Emissions		High Emissions		Population	
	1990	1993	1990	1993	1990	1993	1990	1993
	tons/yr	tons/yr	tons/yr	tons/yr	tons/yr	tons/yr		
Beaver	1,226	1,201	1,829	1,793	2,898	2,382	4,800	5,000
Box Elder	9,320	9,153	13,911	13,662	22,038	18,148	36,500	38,100
Cache	18,002	18,282	26,870	27,287	42,566	36,248	70,500	76,099
Carbon	5,158	4,973	7,699	7,423	12,196	9,860	20,200	20,700
Daggett	179	168	267	251	423	333	700	700
Davis	48,005	49,489	71,653	73,867	113,509	98,124	188,000	206,001
Duchesne	3,217	3,171	4,802	4,733	7,608	6,288	12,600	13,200
Emery	2,630	2,498	3,926	3,729	6,219	4,954	10,300	10,400
Garfield	1,009	1,009	1,505	1,506	2,385	2,001	3,950	4,200
Grand	1,685	1,802	2,515	2,689	3,985	3,572	6,600	7,499
Iron	5,337	5,718	7,966	8,534	12,619	11,337	20,900	23,800
Juab	1,481	1,489	2,211	2,223	3,502	2,953	5,800	6,200
Kane	1,315	1,309	1,963	1,954	3,109	2,596	5,150	5,450
Millard	2,885	2,811	4,307	4,195	6,823	5,573	11,300	11,700
Morgan	1,417	1,477	2,115	2,205	3,351	2,929	5,550	6,150
Piute	319	324	476	484	755	643	1,250	1,350
Rich	447	432	667	645	1,057	857	1,750	1,800
Salt Lake	185,892	186,663	277,464	278,615	439,547	370,108	728,000	777,001
San Juan	3,217	3,147	4,802	4,697	7,608	6,240	12,600	13,100
Sanpete	4,162	4,348	6,212	6,490	9,842	8,622	16,300	18,100
Sevier	3,932	3,940	5,869	5,880	9,298	7,811	15,400	16,399
Summit	4,009	4,733	5,984	7,064	9,479	9,384	15,700	19,700
Tooele	6,818	6,751	10,176	10,076	16,121	13,385	26,700	28,100
Uintah	5,669	5,670	8,461	8,462	13,404	11,241	22,200	23,600
Utah	67,922	69,909	101,381	104,346	160,604	138,612	266,000	291,001
Wasatch	2,579	2,691	3,849	4,016	6,098	5,335	10,100	11,200
Washington	12,537	14,102	18,714	21,049	29,645	27,961	49,100	58,701
Wayne	549	529	819	789	1,298	1,048	2,150	2,200
Weber	40,600	40,600	60,600	60,600	96,000	80,500	159,000	169,001
State Total	441,519	448,388	659,015	669,268	1,043,985	889,044	1,729,100	1,866,452

References

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Methane Emissions from Natural Gas and Oil - 1993

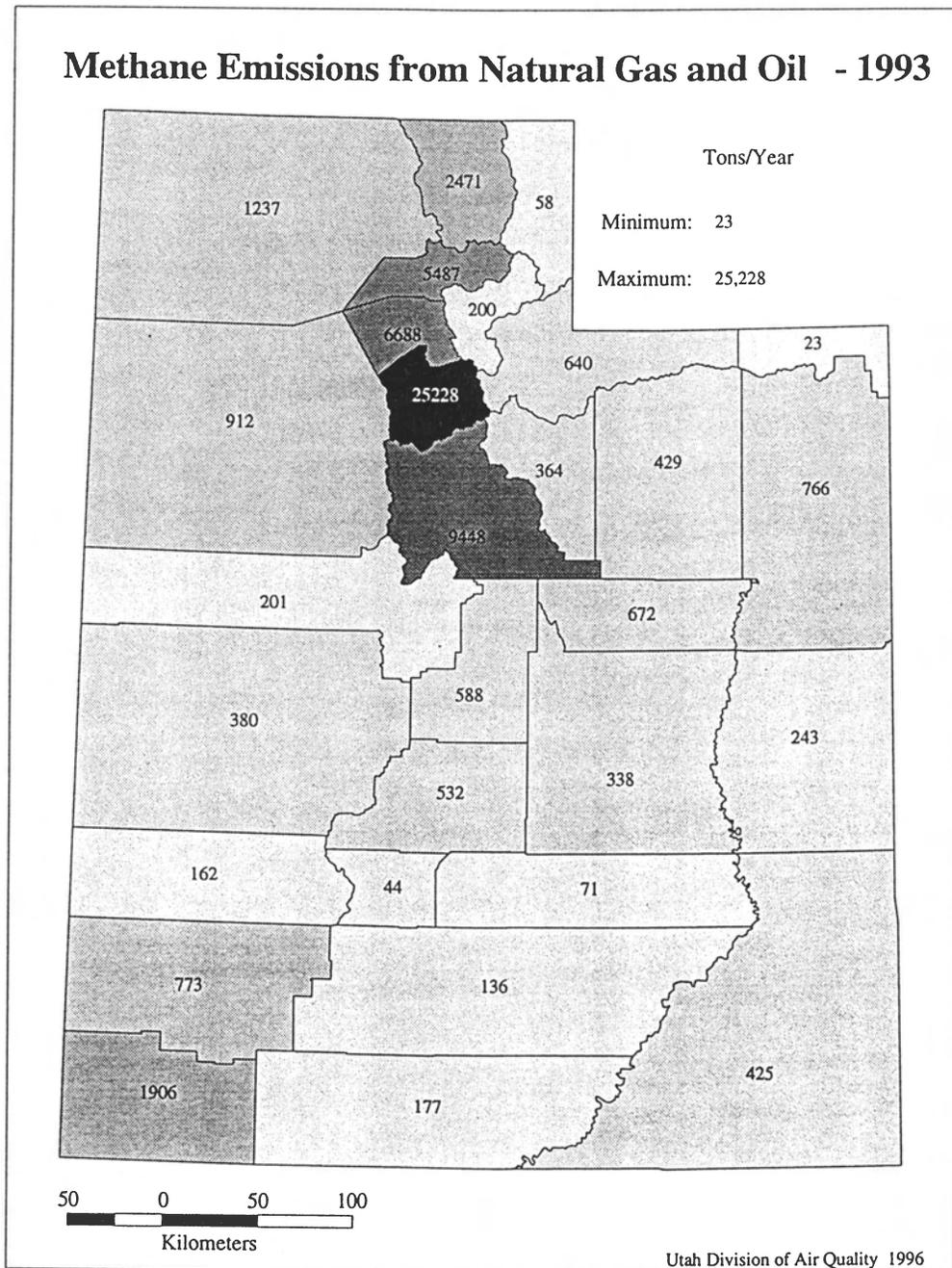


Figure III-2

Chapter IV

Coal Mining

Overview

Methane and coal are formed during coalification, a process in which vegetation is converted by geological and biological forces into coal. Methane is released when pressure within a coalbed is reduced, either through mining or through natural erosion or faulting (U.S. EPA, 1995).

Methodology

The EPA *State Workbook* specifies that methane emissions from coal mining should be based on 1) the annual coal production; 2) mining activity; 3) post-mining activity; and 4) the amount of gas recovered for pipeline sales. Some methane remains in the coal after it has been mined and can be emitted during transportation and handling of the coal; these emissions are called post-mining emissions. The *State Workbook* also recommends using a more detailed, alternate methodology for estimating methane emissions from underground mines within the state of Utah. The data furnished in the workbook for this more detailed method appear erroneous. Consequently, the original method, as described in Chapter 4 of the workbook is used.

All coal mining in Utah is underground. These mines are located in Carbon, Emery, and Sevier Counties. The underground coal mining data as well as methane gas recovery data were obtained from the *1990 Annual Review and Forecast of Utah Coal Production and Distribution* and the *Utah Energy Statistical Abstract*. The data was supplied for both 1990 and 1993. One company in Utah recovers methane gas produced by coal mining activities, and then sells the gas. Through an operations contractual agreement with the Soldier Creek Coal Company, Western Natural Gas Inc. collects and markets recovered methane and provides the volumetric data for gas production.

The appropriate emissions coefficients were taken from the EPA *State Workbook* for both underground mining and post-mining. Both a low and high emissions coefficient were used so that the potential range of emissions could be calculated. The average of the low and high emissions was calculated to represent a single approximation of state coal mining methane emissions. Note that a degree of uncertainty is associated with this single estimate, and the range developed from the low and high values represents the best approximation of state emissions (U.S. EPA, 1995).

Total million cubic feet of methane emissions from mining in Utah is the product of underground coal production and the emission coefficients for mining and post-mining, less the amount recovered. The total cubic feet are then converted to tons by multiplying by 20.66 tons per million cubic feet. Total methane emissions are calculated as follows:

$$CH_{4(total)}(tons) = \left(\frac{CH_{4(low)} + CH_{4(high)}}{2} - CH_{4(captured)} \right) * 20.66 \left(\frac{tons}{10^6 cf} \right)$$

where

$$CH_{4(low)}(10^6 cf) = \text{coal production}(ton) * (370(\frac{cf_{act}}{ton}) + 55(\frac{cf_{post}}{ton}))$$

$CH_{4(captured)}$ = CH₄ captured for pipeline sales
 cf_{act} = cubic feet of emissions from mining activity
 cf_{post} = cubic feet of emissions from post-mining activity

Following the table format given in the workbook, coal production, methane gas emissions, and methane gas recovery data were entered in the appropriate formulas. It should be noted again that *there are no active surface coal mines in the state of Utah. All coal mining activities take place underground.* The attached table shows the calculations performed.

Definitions, Formulas, Coefficients, and Calculations

Coal Production:	Actual tons of coal mined.
Emissions Coefficient:	Given by the handbook in cubic feet of methane per ton of coal mined. Due to the variability of coal quality, a range of low to high is given for both underground mines and post-mining activity.
Methane Emissions:	Obtained by multiplying the low and high emissions coefficients by the coal production tonnage amounts and dividing that product by 1,000,000. Units are million cubic feet of methane gas.
Total Emissions:	Obtained by adding the methane emissions from mining and post-mining activities and dividing the sum by 1,000,000. Units are million cubic feet of methane.
Average Emissions:	Obtained by adding the high and low total emissions and dividing by two. Units are million cubic feet of methane.
Methane Recovered:	Provided by the company making the recovery, in million cubic feet of methane per year.
Total Emissions:	Obtained by subtracting the amount of methane recovered from the average emissions calculated. Units are million cubic feet of methane gas.
Total Emissions:	Obtained by multiplying the total emissions in million cubic feet by a conversion factor of 20.66 to get tons of methane gas.

Table IV-1 Greenhouse Gas Emissions from Coal Mining

Statewide	Year	Underground		Post Mining (underground)		Carbon County		Emery County		Sevier County	
		Mines	Mines	Mines	Mines	Mines	Mines	Mines	Mines	Mines	Mines
Coal Production (tons)	1990	22,012,000	22,012,000	8,810,000	10,315,000	2,887,000	10,315,000	2,887,000	2,887,000	2,887,000	2,887,000
	1993	21,723,000	21,723,000	2,642,000	15,528,000	3,553,000	15,528,000	3,553,000	3,553,000	3,553,000	3,553,000
Emissions Coefficient (cf/ton)	1990 Low	370	55	370	55	370	55	370	55	370	55
	1990 High	470	90	470	90	470	90	470	90	470	90
	1993 Low	370	55	370	55	370	55	370	55	370	55
	1993 High	470	90	470	90	470	90	470	90	470	90
Methane Emissions (10 ⁶ cf)	1990 Low	8,144	1,211	3,260	485	3,817	567	3,817	567	1,068	159
	1990 High	10,346	1,981	4,141	793	4,848	928	4,848	928	1,357	260
	1993 Low	8,038	1,195	978	145	5,745	854	5,745	854	1,315	195
	1993 High	10,210	1,955	1,242	238	7,298	1,398	7,298	1,398	1,670	320
Total Emissions (10 ⁶ cf)	1990 Low	9,355		3,744		4,384		4,384		1,227	
	1990 High	12,327		4,934		5,776		5,776		1,617	
	1993 Low	9,232		1,123		6,599		6,599		1,510	
	1993 High	12,165		1,480		8,696		8,696		1,990	
Average Emissions (10 ⁶ cf)	1990	10,841		4,339		5,080		5,080		1,422	
	1993	10,699		1,301		7,648		7,648		1,750	
Methane Recovered (10 ⁶ cf)	1990	127		127		0		0		0	
	1993	383		383		0		0		0	
Total Emissions (10 ⁶ cf of CH ₄)	1990	10,714		4,212		5,080		5,080		1,422	
	1993	10,315		918		7,648		7,648		1,750	
Total Emissions (tons of CH ₄)	1990	221,360		87,029		104,956		104,956		29,375	
	1993	213,114		18,964		157,998		157,998		36,152	

Table showing statewide and county by county coal production, methane gas recovery, and methane gas emissions.

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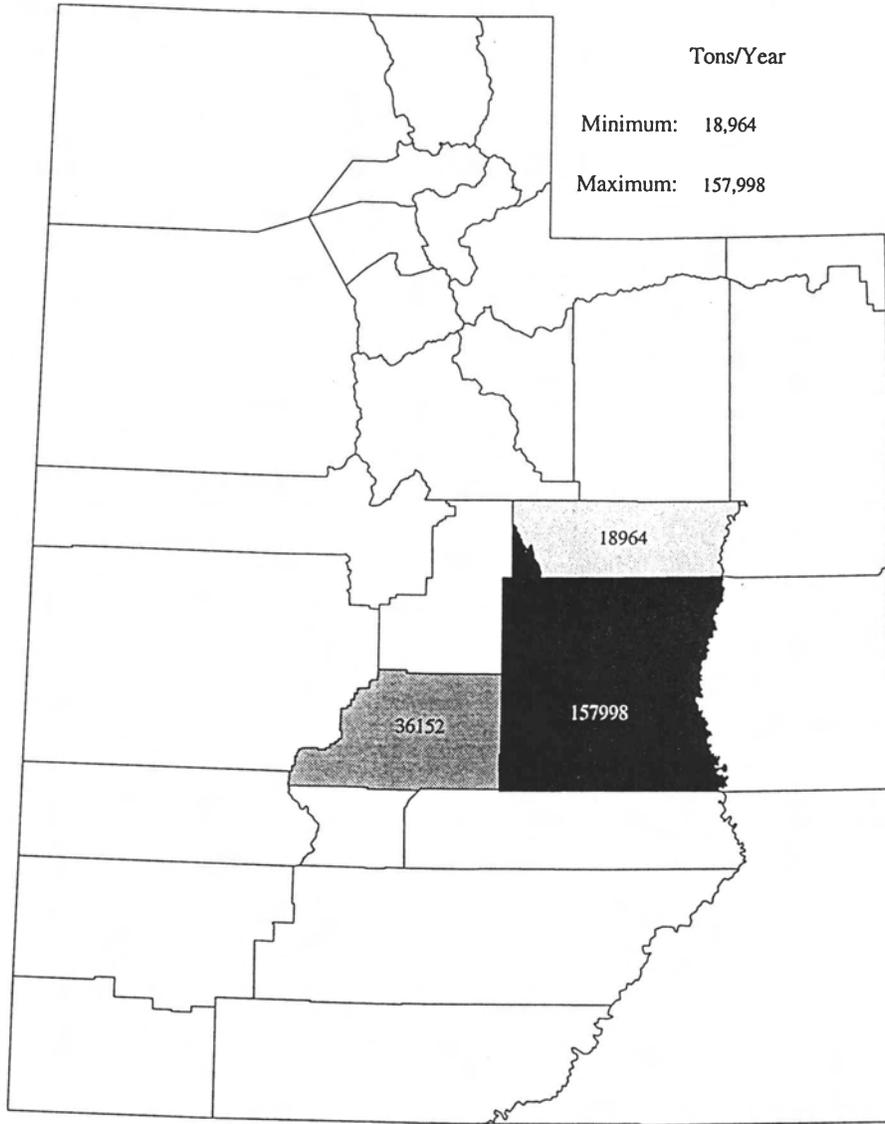
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Methane Emissions from Underground Coal Mines - 1990



Utah Division of Air Quality 1996

Figure IV-1

Methane Emissions from Underground Coal Mines - 1993

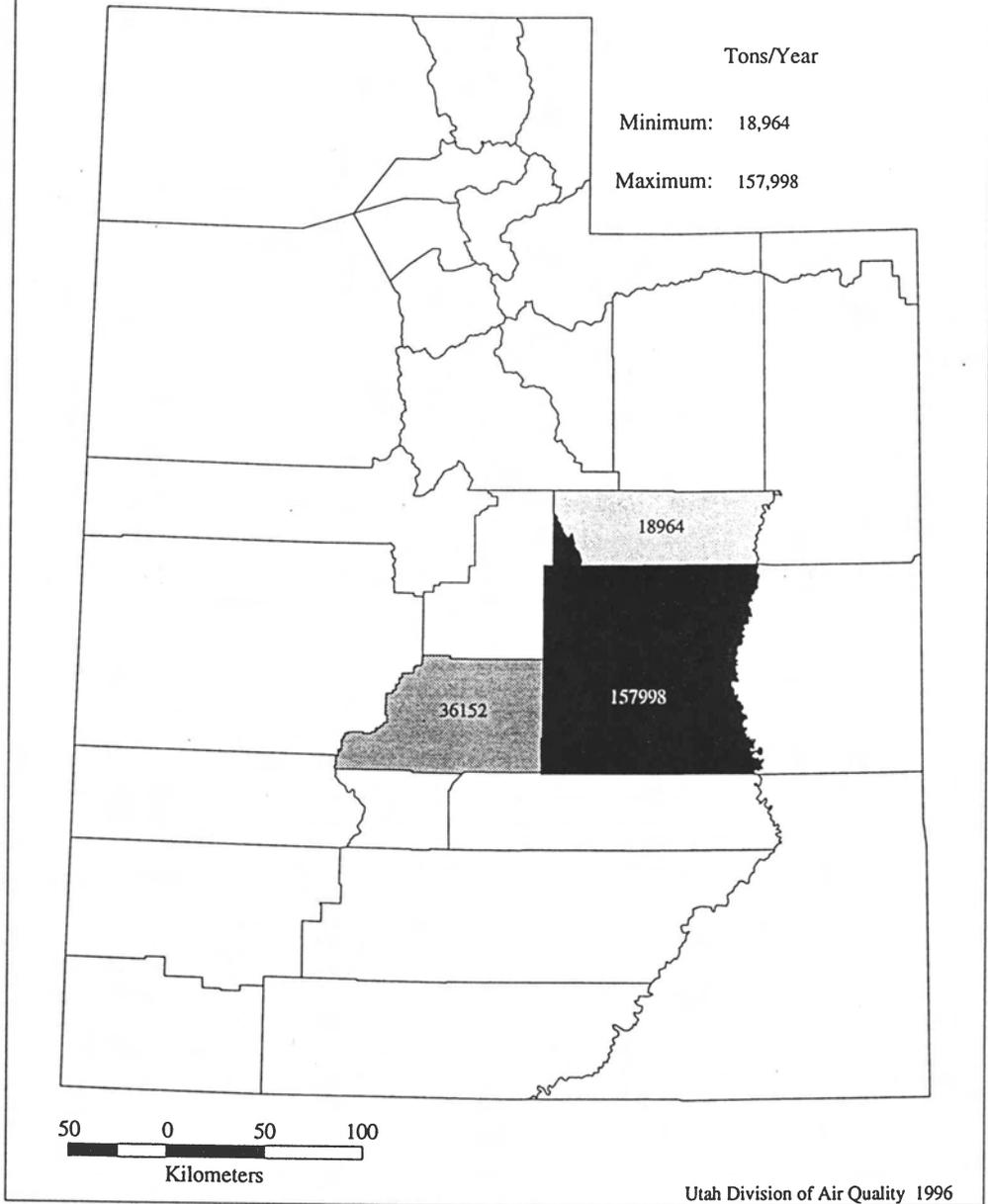


Figure IV-2

Chapter V

Methane Emissions from Landfills

Overview

Landfill gas, consisting primarily of methane (CH₄) and carbon dioxide (CO₂), is produced as a result of the decomposition of organic waste in an anaerobic environment. Most landfill gas is emitted directly to the atmosphere. However, at a few landfills, the gas is recovered and either flared or used as an energy source. Landfill gas production typically begins one to two years after waste placement in a landfill, and may last from ten to sixty years (U.S. EPA, 1993). Municipal solid waste (MSW) landfills are estimated to account for more than 90 percent of all methane emissions from landfills in the United States (U.S. EPA, 1993). Industrial landfills, which receive nonhazardous waste from factories, processing plants, and other manufacturing activities, account for the remainder of landfill methane emissions.

Methodology

Methane emissions from landfills are estimated using the method provided in the EPA *State Workbook* (U.S. EPA, 1995). The methodology used to estimate methane emissions from Utah landfills can be summarized as follows:

A. Estimate Waste in Place at MSW Landfills

Waste in place is estimated based on: 1) the current population of the state; 2) the average annual population growth rate over the past thirty years; 3) the per capita waste generation rate; and 4) the portion of waste that is land filled.

Waste in Place (tons)

$$= 30 \text{ years} * \text{Current State Population} * \text{Per Capita Waste Generation Rate} \\ * \text{Percent Landfilled} * \text{Population Growth Correction Factor} \div 2,000$$

where:

- The default range of per capita waste generation rate provided by EPA is from 1,460 to 1,825 lbs/person/year. A mean value of 1,642.5 lbs/person/year is used for estimating waste in place at Utah landfills.
- A default value of 70 percent, given by EPA, is used for the portion of landfilled waste.
- Average annual population growth rates over the past thirty years are calculated based on the population information listed in the *State of Utah Economic and Demographic Projections 1994*.
- Population growth correction factors are calculated by curve-fitting default values provided in the EPA *State Workbook*, Table 5-1. A linear relationship has been

established between average annual growth rates and growth correction factors as follows:

$$\text{Growth Correction Factor} = (-0.0719) * \text{Average Annual Growth Rate} + 0.9011$$

B. Estimate Waste Fraction Generated in Large Versus Small MSW Landfills

EPA defines a large landfill as having more than 1.1 million tons of waste in place. EPA gives a default value for Utah of 86 percent for the waste fraction in large versus small MSW landfills.

$$\text{Waste in Place at Large Landfills (tons)} = \text{Waste in Place (tons)} * 0.86$$

$$\text{Waste in Place at Small Landfills (tons)} = \text{Waste in Place (tons)} * (1 - 0.86)$$

C. Classify State as Arid or Non-arid

Moisture is an important factor in the production of methane in landfills. EPA has developed different methane emission estimates for arid and non-arid states. EPA defines arid states as states that have average rainfall of less than 25 inches per year. Utah is considered to be an arid state (EPA *State Workbook*, Table 5-3).

D. Estimate Methane Generated from Waste in Place at Small MSW Landfills

The following equation is used to estimate the methane emissions from small MSW landfills:

$$\begin{aligned} & \text{Methane Generated at Small MSW Landfills (tons/year)} \\ &= 0.27 * \text{Waste in Place at Small MSW Landfills (tons)} * 0.0077 \\ &= 0.27 * \text{Waste in Place (tons)} * (1 - 0.86) * 0.0077 \end{aligned}$$

where 0.0077 is a conversion factor from ft³/day to tons/year.

E. Estimate Methane Generated from Waste in Place at Large MSW Landfills

According to information provided by Utah Department of Environmental Quality, Division of Solid and Hazardous Waste, the nine landfills that have or will soon have more than 1.1 million tons of waste in place in Utah are Salt Lake County, Davis County, Cache County, Utah County, Weber County, Washington County and Carbon County.

The following equation is used to estimate the methane generated at large MSW landfills:

$$\begin{aligned} & \text{Methane Generated at Large MSW Landfills (tons/year)} \\ &= N * (419,000 + 0.16 W_{\text{avg}} \text{ (tons)}) * 0.0077 \end{aligned}$$

where

$$N = \text{Number of large landfills in each county and}$$

$$W_{\text{avg}} = \text{Average waste in place at large landfills (tons)} = \frac{\text{Waste in place (tons)} * 0.86}{9}$$

F. Estimate Total Methane Generated from MSW Landfills

Total methane generated from MSW landfills is the sum of methane generated at small landfills and methane generated at large landfills.

$$\begin{aligned} &\text{Total MSW Landfill Methane Generation} \\ &= \text{Methane Generated at Small Landfills} + \text{Methane Generated at Large Landfills} \end{aligned}$$

G. Estimate Methane Generated from Industrial Landfills

Precise estimates of the quantity of waste in industrial landfills and its methane generation rates are not available. EPA estimated that methane generation from industrial landfills in the United States is approximately seven percent of methane generation from MSW landfills in the United States (1993). This seven percent default value is used to estimate methane generation from industrial landfills in Utah.

$$\text{Industrial Landfill Methane Generation} = \text{MSW Landfill Methane Generation} * \text{seven percent}$$

Total methane generation then equals MSW landfill methane generation plus industrial landfill methane generation.

$$\begin{aligned} &\text{Total Methane Generation} \\ &= \text{MSW Landfill Methane Generation} + \text{Industrial Landfill Methane Generation} \end{aligned}$$

H. Adjust for Flaring and Recovery

Methane that is flared or recovered should be subtracted from total methane generated. No landfill gas is flared or recovered in Utah, according to information provided by Utah Department of Environmental Quality, Division of Solid and Hazardous Waste.

I. Adjust for Oxidation

Some methane may be oxidized in the top layer of soil over the landfill, and thus not emitted to the atmosphere. The amount of oxidation that occurs is uncertain and depends on the characteristics of the soil and the environment. It is assumed that 10 percent of methane generated that is not recovered is oxidized in the soil. Methane generated (after the adjustment for flaring and recovery) is multiplied by 90 percent to account for oxidation. Once the adjustment for oxidation has been made, the result is total methane emissions from landfills.

$$\begin{aligned} &\text{Total Methane Emissions} \\ &= (\text{Total Methane Generation} - \text{Methane Flared or Recovered}) * 90 \text{ percent} \end{aligned}$$

Results

The 1990 and 1993 methane emissions from landfills in Utah are shown in Tables V-1 and V-2, respectively. The total 1990 methane emitted from landfills in Utah is 56,237 tons. The total 1993 methane emitted from landfills in Utah is 58,143 tons. The difference is likely due to the recent rapid population growth in Utah.

Nationally, it is estimated that landfills emitted 37 percent of total U.S. 1990 methane emissions, (U.S. DOE, 1993). Many factors may cause Utah's results to differ from the national average.

Uncertainties

Many uncertainties are associated with using this method for estimating methane emissions from landfills in Utah. First, many default values were used in the calculations due to limited availability of information. For example, default values are used for: 1) the waste fractions in large MSW landfills; 2) small MSW and industrial landfills; 3) the per capita waste generation rate; 4) the portion of landfilled waste; and 5) the oxidized portion of methane generation. These assumptions may skew estimated results from actual methane emissions in Utah. Other sources of uncertainties in estimating methane emissions from landfills are the 30-year time period assumed, the effects of climate on methane emission rates, and the impact of landfill design characteristics and maintenance procedures.

Table V-1 Estimates of Methane Emissions from Landfills in Utah - 1990

County	Total Methane (Tons/Year)
Beaver	20.22
Box Elder	148.33
Cache	5,824.22
Carbon	5,659.38
Daggett	3.29
Davis	11,734.58
Duchesne	45.78
Emery	36.52
Garfield	16.59
Grand	30.13
Iron	75.06
Juab	23.43
Kane	18.26
Millard	44.35
Morgan	19.99
Piute	5.68
Rich	7.50
Salt Lake	13,753.18
San Juan	49.02
Sanpete	62.22
Sevier	59.80
Summit	48.74
Tooele	105.35
Uintah	80.42
Utah	6,428.80
Wasatch	35.67
Washington	5,687.45
Wayne	8.80
Weber	6,204.43
Statewide Total	56,237.22

Table V-2 Estimates of Methane Emissions from Landfills in Utah - 1993

County	Total Methane from Landfills (Tons/Year)
Beaver	20.72
Box Elder	156.95
Cache	6,010.41
Carbon	5,825.01
Daggett	3.09
Davis	12,142.79
Duchesne	47.13
Emery	36.81
Garfield	17.21
Grand	33.52
Iron	81.17
Juab	24.79
Kane	19.12
Millard	44.58
Morgan	21.57
Piute	5.90
Rich	7.66
Salt Lake	14,230.66
San Juan	48.59
Sanpete	67.20
Sevier	62.03
Summit	56.23
Tooele	113.22
Uintah	85.66
Utah	6,663.36
Wasatch	38.51
Washington	5,866.24
Wayne	8.96
Weber	6,403.90
Statewide Total	58,143.01

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Methane Emissions from Landfills - 1990

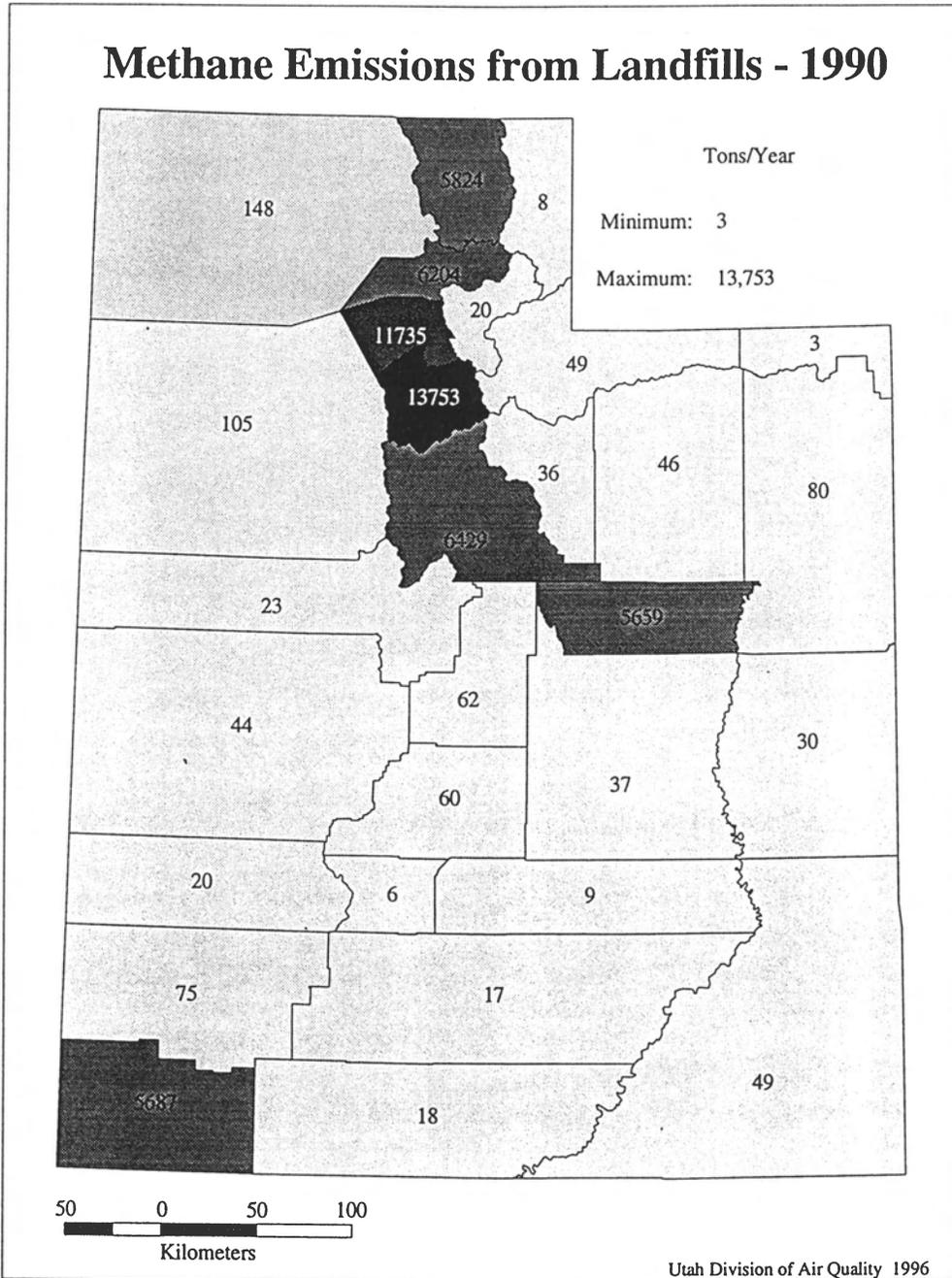


Figure V-1

Methane Emissions from Landfills - 1993

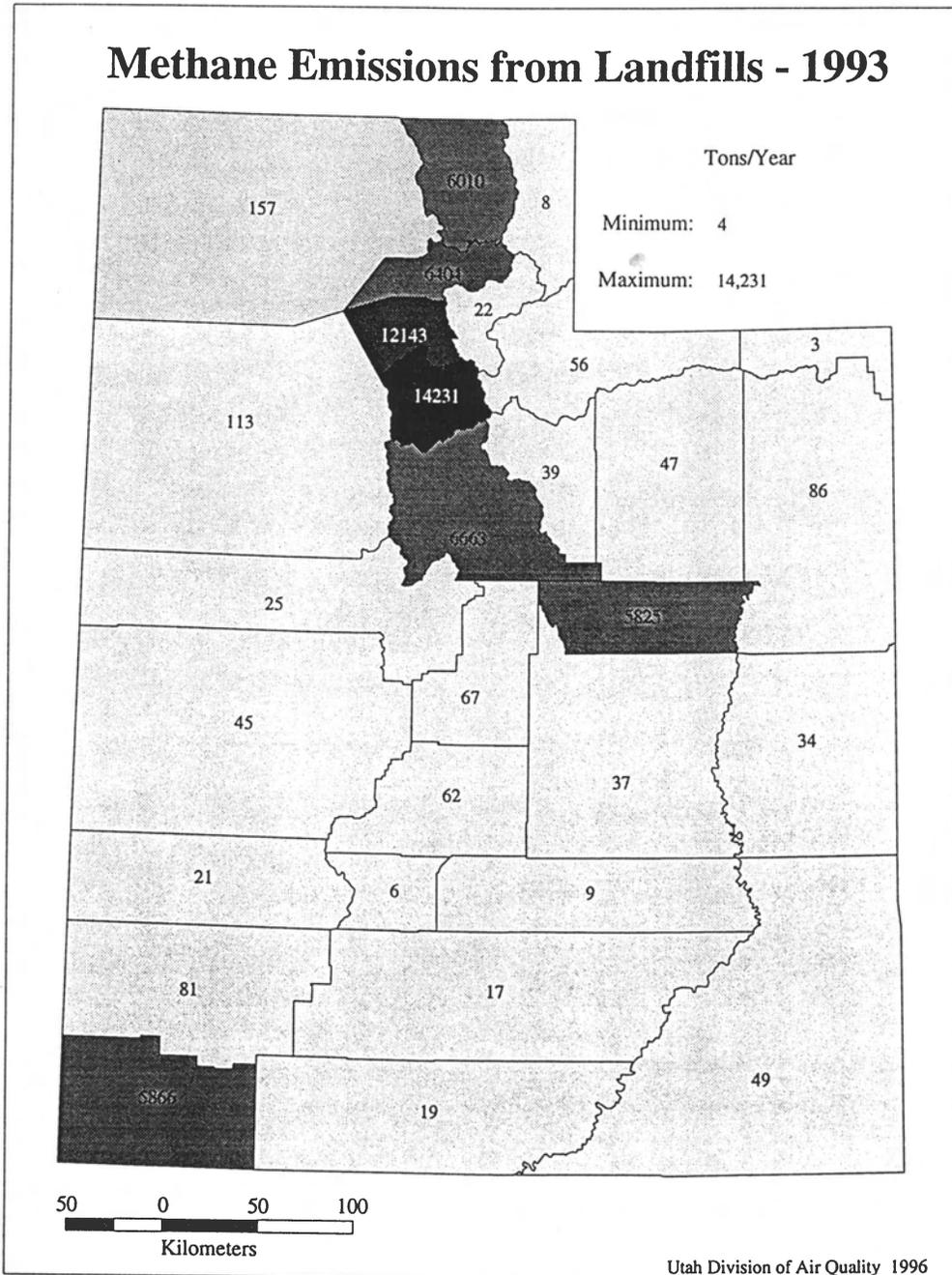


Figure V-2

Chapter VI

Methane from Domesticated Animals

Overview

Livestock production contributes to greenhouse gas emissions as methane is produced in the normal digestive process of animals. Methane is produced through a process referred to as *enteric fermentation*, in which microbes that reside in animal digestive systems break down feed consumed by the animal.

Ruminants, which include cattle, buffalo, sheep, and goats, have the highest methane emissions among all animal types because of their unique digestive system. Ruminants possess a rumen, or large "fore-stomach" in which a significant amount of methane-producing fermentation occurs. Non-ruminant domestic animals, such as pigs and horses, have much lower methane emissions than ruminants because much less methane-producing fermentation takes place in their digestive systems. The amount of methane produced and excreted by an individual animal depends upon its digestive system (whether or not it possesses a rumen), and the amount and type of feed it consumes.

Methodology

The methane emissions from domestic animals are estimated using the method provided in the EPA *State Workbook*, (U.S. EPA, 1995). This method applies a regional emission factor to each animal population to obtain pounds of methane for each animal type. Emissions are then summed for all animal types to obtain total methane emissions from domesticated animals.

$$Animal_i * (CH_4EF)_i * 1\text{ton}/2,000\text{lbs.}$$

Where: $Animal_i$ = population of animal category i
 $(CH_4EF)_i$ = methane emission factor for animal category i
(lbs CH₄/animal/year)

Domestic Animal populations for 1990 and 1993 were obtained from the annual Utah Department of Agriculture publication, *Utah Agricultural Statistics*, for 1991 and 1994. However, the suggested EPA animal types for cattle did not correspond directly to the types provided in the *Agricultural Statistics*. Classification estimates for cattle were changed in Utah in 1971 from sex and age to sex and weight. Steers, Heifers, and Bulls under 500 lbs were assumed to be less than 12 months old. Their total is estimated by calculating a ratio tied to the Beef and Dairy zero to 12 month replacements category based on the total beef and dairy cows for 1991 and 1994. Steers and bulls over 500 lbs are included in the Beef Cattle category only. Goats, horses and mules/asses populations were obtained from a 1992 Utah Department of Agriculture census, as

they are not categories in the *Agricultural Statistics* publication. Buffalo populations, along with other big game populations, were obtained from regional Division of Wildlife Resources staff, as no statewide census of big game is maintained.

The Regional Emission Factors were obtained from the EPA *State Workbook* tables for the Western region.

The contribution of individual counties to the statewide methane emissions was more difficult to calculate. The *Agricultural Statistics* publication provided only selected information at the county level, so several assumptions were made:

1) For all counties dairy and beef cow populations were provided, so the populations for the two subcategories (zero to 12 month replacements and 12 to 24 month replacements) were generated by dividing the county's dairy or beef cow population by the statewide population to get the county fraction of the statewide population. Each replacements subcategory statewide population was then multiplied by the county fraction to get each estimated dairy and beef cattle replacement population.

2) For other animal categories where county populations were not provided, an estimate was made using the fraction of each county's total livestock cash receipts as compared with the total state livestock cash receipts. That fraction was then multiplied against the statewide animal category population to obtain an estimated county population.

3) In cases where the only 1993 population estimate provided was "< 500" head, several estimation methods were used. The previously discussed fraction of a county livestock cash receipts value was used only once successfully to estimate a cattle population, as the resulting value was less than 500. In all other cases, if the 1990 value was zero or 100, the 1993 value would be set to match. If the 1990 value was 1,000 or greater, the 1993 value would be set to 499 as an assumption that the population would be unlikely to drop by over 50 percent in three years.

Results

Domesticated Animal Populations, methane emission factors, and total emissions for 1990 and 1993 are summarized in the following table. Dairy and Beef cattle combined accounted for 92 percent of the methane emissions in 1990 with 59,922 tons of a total 65,273 tons. In 1993, the same categories accounted for 93 percent with 62,477 tons of a total 67,234 tons. Beef cattle alone accounted for 70 percent of the methane emissions in 1990 and 72 percent in 1993.

Table VI-1 Methane Emissions from Domesticated Animals

Average Animal Population (head)	State Wide Population		Western US Emission Factor (Lbs Methane/Head/yr)	Emissions (Tons)	
	1990	1993		1990	1993
Cattle					
Dairy					
0-12 month replacements	27,000	26,000	45.5	614.25	591.50
12-24 month replacements**	52,000	45,000	134.6	3,499.60	3,028.50
Mature Cows	80,000	80,000	262.5	10,500.00	10,500.00
Total Dairy	159,000	151,000		14,613.85	14,120.00
Beef					
0-12 month replacements	108,000	110,000	49.9	2,694.60	2,744.50
12-24 month replacements**	58,000	69,000	142.7	4,138.30	4,923.15
Mature Cows	321,000	340,000	152	24,396.00	25,840.00
Bulls #	19,000	20,000	220	2,090.00	2,200.00
Steers ##	109,000	115,000	220	11,990.00	12,650.00
Total Beef	615,000	654,000		45,308.90	48,357.65
Buffalo	950	950	220	104.50	104.50
Sheep	509,000	440,000	17.6	4,479.20	3,872.00
Goats^	2,120	2,129	11	11.66	11.71
Swine	33,000	40,000	3.3	54.45	66.00
Horses^^	34,700	34,778	39.6	687.06	688.60
Mules/Asses^^^	560	565	48.5	13.58	13.70
Total	1,354,330	1,323,422		65,273.20	67,234.17
Big Game	428,505	232,260		8,223.02	6,012.00
Total Including Big Game	1,782,835	1,616,682		73,496.22	73,246.16

* Beginning 1/1/71, classification estimates for Cattle were changed from sex and age to sex and weight.

** Heifers 500 lbs and over are assumed to be at least 12 months old, and will be categorized as 12-24 month replacements.

Bulls 500 lbs and over are categorized only as Beef Cattle.

Steers 500 lbs and over are added to the Bulls category for Beef Cattle, Steers, Heifers, and Bulls under 500 lbs are assumed to be less than 12 months old, and are ratioed to the Beef and Dairy 0-12 month replacements category based on the total beef cows and dairy cows for 1/1/91.

^ Goat populations are based on a 1992 Department of Agriculture census.

^^ Horse populations are based on a 1992 Department of Agriculture census. Category includes ponies.

^^^ Mules/Asses populations are based on a 1992 Department of Agriculture census. Category includes Mules, Burros, Donkeys.

Methane from Big Game Animals

Overview

Emissions from big game animals are estimated because the state of Utah manages its game populations for the sake of hunting. Although game animals are not categorized as domesticated animals, as an "animal crop" their populations and emissions could be controlled.

Emission factors for big game animals were obtained from Crutzen et al for moose, elk, mule deer, antelope, bighorn sheep, and mountain goats. The formula used to calculate methane emissions is the same as for domesticated animals, substituting game populations and factors for domesticated animal populations and factors.

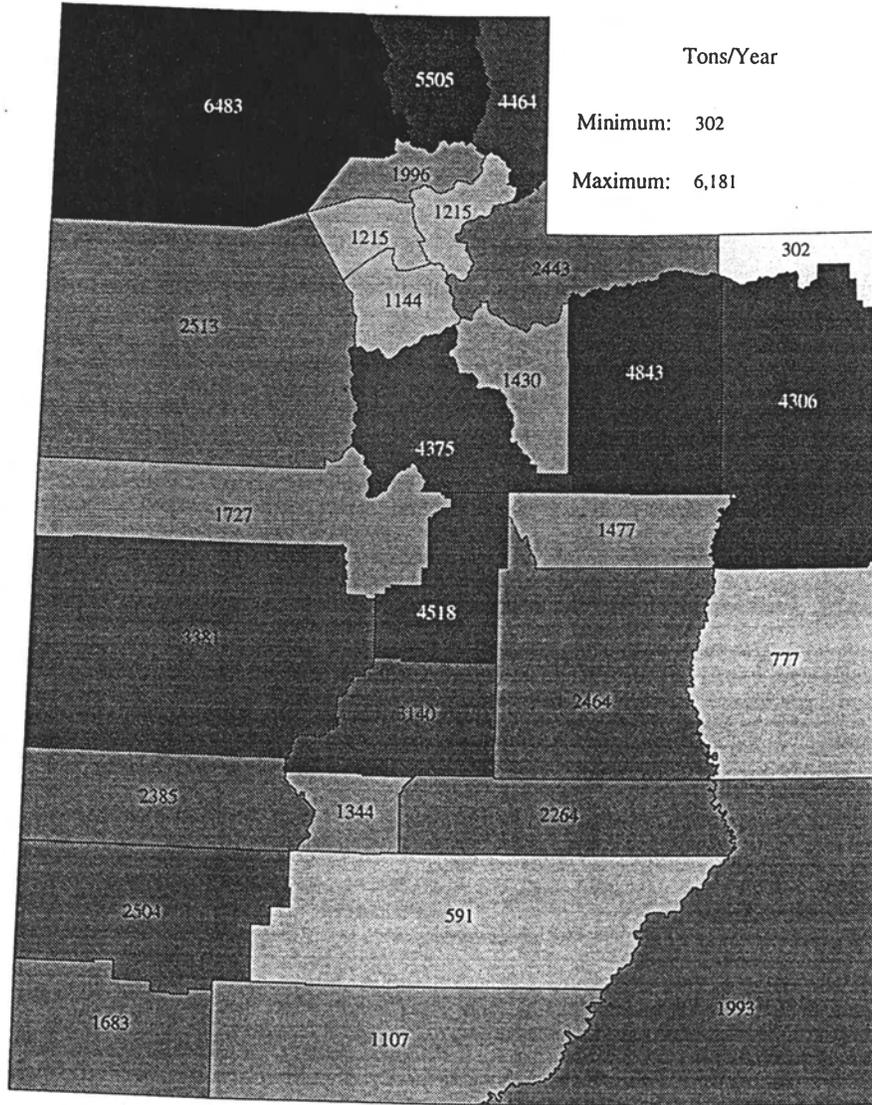
Results

The combined methane emissions for big game animals, less the buffalo category already accounted for in the previous section, totals 8,170.66 tons in 1990, and 5,959.63 tons in 1993.

Table VI-2 Methane Emissions from Big Game Animals

Emission Factors (from Crutzen et al.) (Kg/head/year)	Populations		Total kg/year	
	1990	1993	1990	1993
Buffalo	50	950	47,500	47,500
Moose	31	1,775	55,025	57,460
Elk	31	61,750	1,914,250	1,963,850
Mule Deer	15	350,500	5,257,500	3,210,000
Antelope	15	11,000	165,000	160,500
Bighorn Sheep	8	2,200	17,600	18,000
Mountain Goats	5	330	1,650	1,750
		428,505	7,458,525	5,453,060
			Total lbs/yr	16,446,048
			Total tons/yr	8,223
				12,023,997
				6,012
			<i>Total tons (with buffalo emissions removed)</i>	8,171
				5960

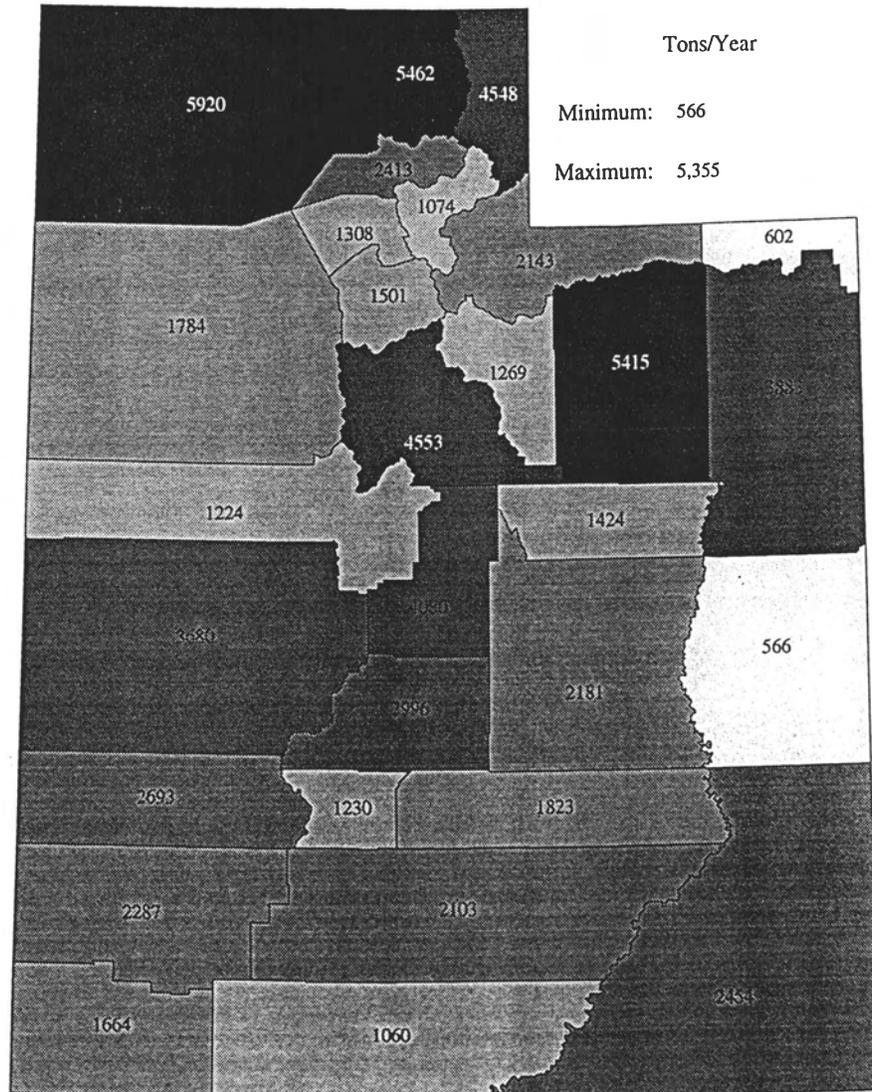
Methane Emissions from Domesticated Animals - 1990



Utah Division of Air Quality 1996

Figure VI-1

Methane Emissions from Domesticated Animals - 1993



Utah Division of Air Quality 1996

Figure VI-2

B_i = max. methane producing potential of manure;
depends on animal type ($\text{ft}^3 \text{CH}_4/\text{lb VS}$)

Step 3: Estimate CH_4 emissions for each manure management system for each animal category.

$$\text{MethaneEmissions}_i(\text{ft}^3 \text{CH}_4) = \text{Max.Potential}(\text{CH}_4)_i * \text{MCF}_j * \text{WS}\%_{ij}$$

where: Max. Potential (CH_4)_{*i*} was calculated for animal category *i*
 MCF_j = methane conversion factor for manure management system *j*
 $\text{WS}\%$ = percent of animal manure type *i* managed in management system type *j*

Step 4: Convert to tons of methane.

For each animal category *i* and management system *j*, multiply by the density of methane ($0.0413 \text{ lbs CH}_4/\text{ft}^3$) to convert to pounds, then divide by 2,000 to convert to tons. Sum the emissions across all manure management systems for each animal category *i* to obtain total manure emissions for that animal category.

Results

The following tables present 1990 and 1993 methane emissions from animal manure management.

Table VII-1 Methane Emissions from Manure Management

Animal Category	CH_4 (lbs/yr)	CH_4 (tons/yr)	
1990			
Dairy Cattle	1,212,917.29	606.46	23.10%
Beef Cattle	221,375.72	110.69	4.22%
Swine	2,845,602.23	1,422.80	54.18%
Poultry	918,474.62	459.24	17.49%
Sheep	28,272.72	14.14	0.54%
Goats	105.17	0.05	0.00%
Mules/Asses	265.66	0.13	0.01%
Horses	24,704.85	12.35	0.47%
	5,251,718.27	2,625.86	100.00%
1993			
Dairy Cattle	1,163,949.70	581.97	20.55%
Beef Cattle	235,946.41	117.97	4.17%
Swine	3,307,382.57	1,653.69	58.38%
Poultry	907,948.19	453.97	16.03%
Sheep	24,440.07	12.22	0.43%
Goats	105.62	0.05	0.00%
Mules/Asses	268.03	0.13	0.00%
Horses	24,760.38	12.38	0.44%
	5,664,800.97	2,832.40	100.00%

The largest portion of methane emissions comes from swine, with 54 percent of the total 2,625 tons in 1990, and 58 percent of the total 2,832 tons in 1993. This apparently is due to the anaerobic lagoon management method attributed to the category. The next highest emissions come from the dairy cattle category with 23 percent of the total in 1990 and 20 percent in 1993.

Methane emissions for Domestic Animals and Animal Manure Management sources, summarized by county, can be found in the table "Methane Summaries." County-specific estimates were made using two methods:

1) for counties where an animal population was known from the *Utah Agricultural Statistics* publications, the county animal population, as a percentage of the total state animal population, was multiplied by the estimated statewide emissions for that animal category.

$$(CP_i/SP_i) \times SE_i = CE_i$$

where: CP_i = reported county population of animal category I
 SP_i = reported state population of animal category I
 SE_i = statewide emissions (tons) for animal category I
 CE_i = county emissions (tons) for animal category I

2) for counties where the animal category population was not known, a percentage based on that county's portion of the total state livestock cash receipts as reported by the *Utah Agricultural Statistics* was multiplied by the estimated statewide emissions for the animal category.

$$(CR_c/SR) \times SE_i = CE_i$$

where: CR_c = cash receipts for livestock in county c
 SR = total state cash receipts for livestock
 SE_i = statewide emissions (tons) for animal category I
 CE_i = emissions (tons) for animal category I in county c

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Utah Division of Wildlife regional staff:

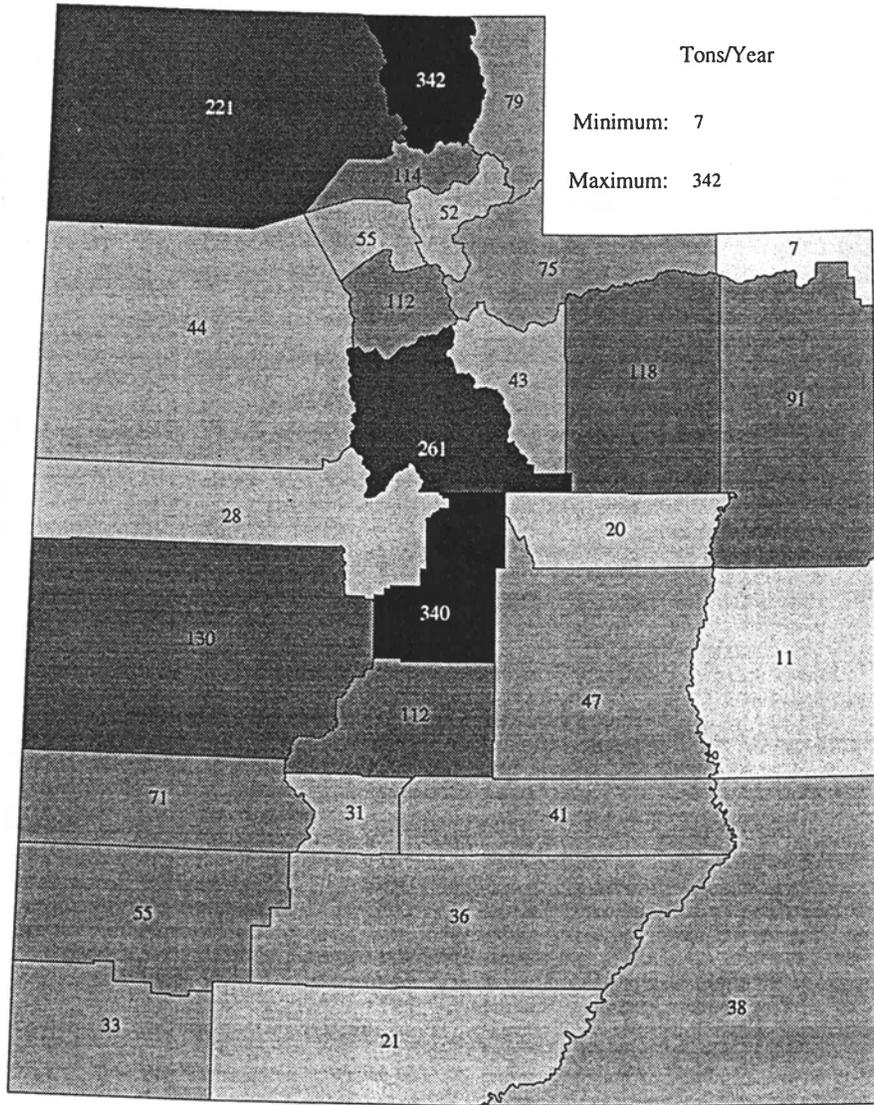
Ogden	Mike Welch, Big Game Coordinator	(801) 479-5143
Springville	Bruce Giunth, Game Biologist	(801) 489-5678
Price	Jim Karpowitz, Game Biologist	(801) 637-3310
Antelope Island	Timothy Smith, Park Director	(801) 580-1043
Cedar City	Floyd Coles, Game Biologist	(801) 586-2455
Vernal	Steve Cranny, Game Biologist	(801) 789-3103

Manure Management:

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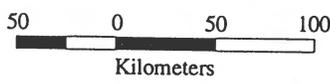
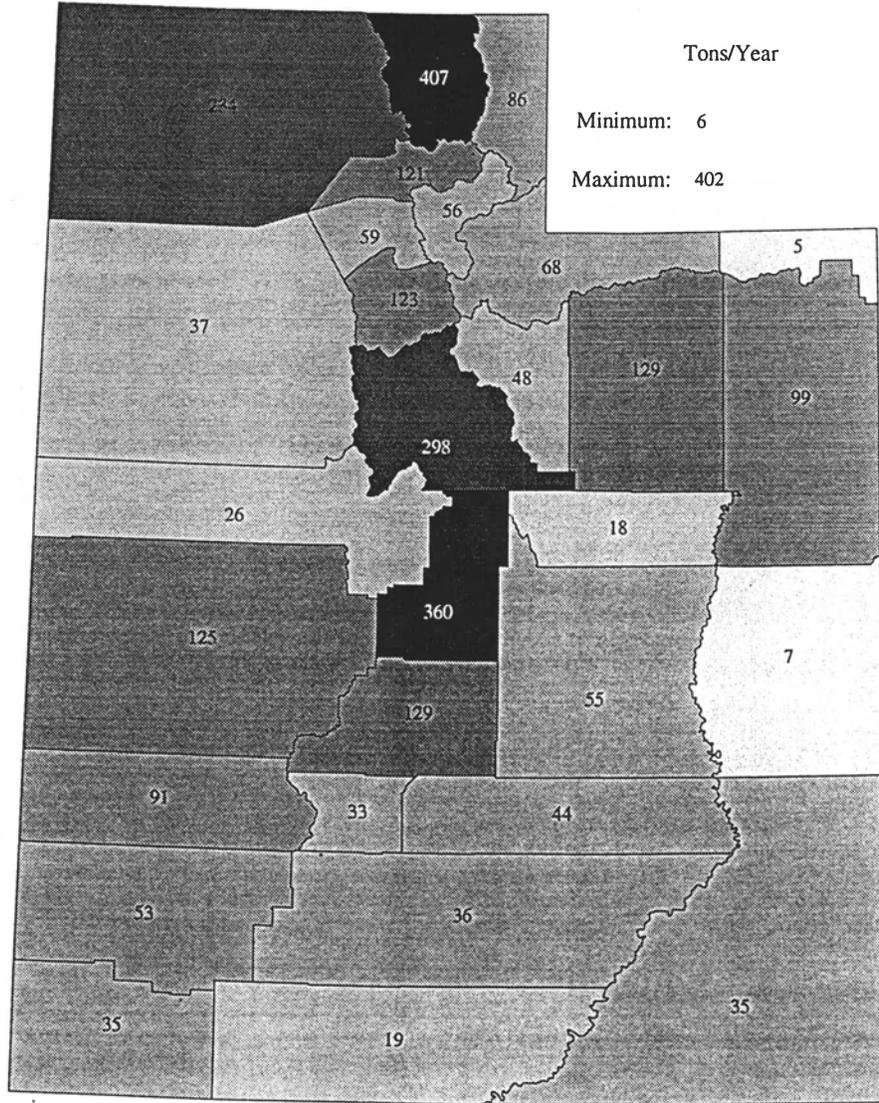
Methane Emissions from Manure Management - 1990



Utah Division of Air Quality 1996

Figure VII-1

Methane Emissions from Manure Management - 1993



Utah Division of Air Quality 1996

Figure VII-2

Chapter VIII

Agricultural Soil Management

Overview

Various agricultural soil management practices contribute to greenhouse gas emissions. The use of synthetic and organic fertilizers adds nitrogen to soils, thereby increasing natural emissions of nitrous oxide. Fertilizer use is the most significant source of N₂O in the United States (U.S. EPA, 1995). Other agricultural soil management practices such as irrigation and tilling are sinks and/or sources of carbon dioxide (CO₂), carbon monoxide (CO), methane (CH₄), and a source of nitrous oxide (N₂O). There is much uncertainty about the direction and magnitude of the effects of these other practices. Therefore, only the emissions from fertilizer use is included in this section of the inventory.

Methodology

The nitrous oxide emissions from fertilizer application are estimated using the method provided in the EPA *State Workbook*, (U.S. EPA, 1995). This method applies an N₂O emission coefficient (0.0117) per unit mass of nitrogen for each fertilizer type to yield N₂O-N emissions. A molecular weight conversion factor (44/28) is then applied to give emissions in terms of mass N₂O. Emissions are then summed for all fertilizer types.

$$N_2O(Tons) = \sum (F_f * E_f) * 44N_2O/28N$$

where: F = fertilizer nitrogen applied (tons- N applied)
 = fertilizer consumption (tons) * %(nitrogen content)
 E = emission coefficient (tons N₂O-N released/ton -N applied)
 f = fertilizer type

Normally, using the EPA methodology, a 3-year average of consumption centered on the target year (1991 and 1993) is used to calculate emissions. However, fertilizer usage for 1990 was not available with information for county usage. Therefore, a 3-year average was taken using data from 1991, 1992 and 1993, and this average is assumed to represent 1990 fertilizer consumption. The 1993 average is taken from a 3-year average of 1992, 1993 and 1994. Averaging is used to minimize annual fluctuations in consumption due to economic and weather factors that affect agricultural activity. The fertilizer consumption data was obtained from the *Utah Fertilizer Tonnage Annual Reports* published by the Utah Department of Agriculture, Division of Plant Industry (UDADPI).

To calculate mass consumption of nitrogen, fertilizer use is multiplied by the percent content of nitrogen. The EPA *State Workbook* provides nitrogen content for many of the individual fertilizers reported by the UDADPI. However, where possible, nitrogen contents specific to Utah were used as given in *Commercial Fertilizers*. Where this information was not available, the

3-year average nitrogen content as determined by the UDADPI was used for Utah fertilizers. In several cases, where neither the *State Workbook*, nor the *Commercial Fertilizers*, nor the UDADPI stated a nitrogen content for a specific fertilizer, a nitrogen content was used as given in the *Wisconsin Greenhouse Gas Emissions* report. For each fertilizer, the nitrogen content reference is specified in Table F-1 through F-4 under the heading "Content Ref." Fertilizer type, nitrogen content, and corresponding N₂O-N and N₂O emissions by county are shown in Table VIII-2. Supporting data are found in appendix F.

Table VIII-1 Fertilizer Emissions by County
Tons of N₂O from Fertilizer Use

County	1990	1993
Beaver	2.51	3.55
Box Elder	93.51	91.42
Cache	36.39	43.32
Carbon	1.82	1.95
Daggett	0.69	0.72
Duchesne	13.11	14.00
Davis	9.94	9.74
Emery	2.05	2.99
Garfield	0.00	0.00
Grand	0.00	0.00
Iron	4.42	7.70
Juab	3.18	3.57
Kane	0.02	0.02
Millard	17.11	22.12
Morgan	6.31	6.26
Piute	0.25	0.54
Rich	0.00	0.00
Salt Lake	84.80	89.90
San Juan	0.65	1.26
Sanpete	7.31	8.29
Sevier	2.54	4.78
Summit	7.44	9.53
Tooele	21.31	21.31
Uintah	20.59	19.63
Utah	65.81	67.50
Wasatch	1.29	1.25
Washington	6.49	5.94
Wayne	0.96	0.96
Weber	11.99	12.50
Statewide Tons of N₂O	422.49	450.73

Table VIII-2 Fertilizer Emissions by Type for 1990 and 1993

Fertilizer Types	Average	Total	Tons	Tons	Average	Total	Tons	Tons
	Fertilizer Consumption (Tons) 1990	Nitrogen (Tons) 1990	N ₂ O-N 1990	N ₂ O 1990	Fertilizer Consumption (Tons) 1993	Nitrogen (Tons) 1993	N ₂ O-N 1993	N ₂ O 1993
Nitrogen								
Ammonium Nitrate	29169.21	9805.19	114.33	179.66	33303.57	11190.19	130.53	205.12
Ammonium Sulfate	15981.14	3377.04	39.27	61.70	14837.83	3136.94	36.46	57.29
Anhydrous Ammonia	2122.03	1822.06	20.36	31.99	2297.61	1966.04	22.04	34.64
Calcium Nitrate	0.00	15.00	0.00	0.00	0.00	15.00	0.00	0.00
Nitrogen Solution 28%	35.05	37.81	0.11	0.18	43.49	40.18	0.14	0.22
Nitrogen Solution 30%	0.00	30.00	0.00	0.00	9.67	32.90	0.03	0.05
Nitrogen Solution 32%	8362.01	2707.84	31.31	49.20	8168.05	2645.78	30.58	48.06
Sodium Nitrate	15.97	18.55	0.03	0.05	317.71	66.83	0.59	0.93
Sulfur coated Urea	0.00	38.00	0.00	0.00	0.00	38.00	0.00	0.00
Urea	6748.20	3150.17	36.32	57.07	6482.31	3027.86	34.89	54.82
Phosphate								
Superphosphate, Triple	8728.90	0.00	0.00	0.00	8141.14	0.00	0.00	0.00
Potash								
Murite of Potash 60%	2792.04	0.00	0.00	0.00	3759.07	0.00	0.00	0.00
Potassium Sulfate	97.95	0.00	0.00	0.00	2.64	0.00	0.00	0.00
Multiple Nutrient								
Ammonium Phosphate Sulfate	227.53	47.49	0.39	0.61	127.46	32.98	0.22	0.34
Diammonium Phosphate	1895.34	369.14	4.10	6.45	2774.64	531.81	6.01	9.44
Epson Salt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum (Calcium Sulfate)	8096.43	0.00	0.00	0.00	11331.71	0.00	0.00	0.00
Lime Product-Code Unk.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Monoammonium Phosphate	7751.95	863.71	9.98	15.68	9171.42	1019.86	11.80	18.55
Potash-Not Identified	0.00	15.00	0.00	0.00	0.00	15.00	0.00	0.00
Potassium Nitrate	0.00	13.00	0.00	0.00	0.00	13.00	0.00	0.00
Sulfur	1343.48	0.00	0.00	0.00	1247.76	0.00	0.00	0.00
Unknown								
Ammonium Thiosulfate	697.45	0.00	0.00	0.00	524.63	0.00	0.00	0.00
Borax	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calcium Chelate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manure	336.28	21.81	0.20	0.31	258.89	17.94	0.15	0.24
Copper Sulfate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ferric Sulfate	165.47	0.00	0.00	0.00	82.73	0.00	0.00	0.00
Ferrous Sulfate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron Chelate	4.22	0.00	0.00	0.00	7.69	0.00	0.00	0.00
Iron Compound	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liquid Amm Polyphosphate	1607.75	187.85	2.07	3.25	1731.16	201.43	2.23	3.50
Magnesium Chelate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manganese Chelate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manganese Sulfate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mixed Grades	4844.21	850.40	9.75	15.32	4901.85	860.32	9.86	15.50
Mult. Nutrient-Code/Grade Unk	385.88	68.99	0.64	1.01	771.71	123.78	1.28	2.01
Nitric Acid	3.15	34.04	0.01	0.02	1.57	33.52	0.01	0.01
Phosphate Prod. Code Unk.	2220.06	0.00	0.00	0.00	2919.90	0.00	0.00	0.00
Zinc Chelate	5.64	0.00	0.00	0.00	0.86	0.00	0.00	0.00
Zinc Sulfate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	103637.32	22979.22	268.86	422.49	113217.08	24515.47	286.83	450.73

Uncertainties

For some fertilizer sold in Utah, the fertilizer type is unknown. The UDADPI knows how much fertilizer was sold in the State. However, for some fertilizers, the UDADPI does not know what type of fertilizer was sold. In cases where a known amount of an unknown fertilizer type was sold in a county, the unknown amount of fertilizer was distributed proportionately among the known fertilizer types sold in that county.

Similarly, for some fertilizers sold in Utah, the county in which the fertilizer was sold is not known. Again, the UDADPI knows how much fertilizer was sold in the State. However, the UDADPI does not know where some of the fertilizer was sold. Each fertilizer type of an unknown sales point was distributed among the same fertilizer type of known counties. Percentages of fertilizers were taken from each county, and the unknown county's fertilizers were distributed in proportion to the amounts of the same fertilizer sold in each county.

Due to the above uncertainties, the calculated values were checked against values found in *Summary Data 1992* and *Commercial Fertilizers 1993* by the Tennessee Valley Authority. The nitrogen content for select fertilizers calculated in *Commercial Fertilizers 1993* is 24,248 tons. Using the method described in the EPA *State Workbook*, the calculated nitrogen content is 24,515 for 1993. This result shows a difference of 1.1 percent. Other values were checked, where possible, and are in accordance with those reported by the Tennessee Valley Authority.

References

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Berry, Janice T., and Melanie H. Montgomery. *Commercial Fertilizers 1993*, Tennessee Valley Authority, National Fertilizer and Environmental Research Center, Muscle Shoals, Alabama, 1993.

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Chapter IX

Forest Management and Land Use Change

Land use change and forestry activities covered in the EPA *State Workbook* method are divided into three categories; 1) changes in forests and other woody biomass stocks; 2) forest and grassland conversion; and 3) abandonment of managed lands. For this inventory only changes in the first category were considered.

Category 2, forest and grassland conversion, is not included in this inventory because of the lack of data and high level of uncertainty about the data which do exist. Category 3, abandonment of managed lands, was not considered because Utah, unlike perhaps some states in the eastern United States, does not have areas of the state which have reverted from farmland to pre-settlement forest land.

A. Changes in Forests and Other Woody Biomass Stocks

Overview

The main gas of concern in this category is CO₂, and the method used for this reporting category is specific to CO₂. According to the workbook the most important effects of human interactions with existing forests are considered in this category. For the purposes of this inventory this includes the commercial management and logging for forest products, replanting after logging, the harvest of fuel wood, and planting trees in urban and suburban locations.

Essentially, this method estimates the annual growth increment of biomass on managed forest lands, including fuel wood cutting and urban forests, within the state. The net carbon emitted is equal to the total harvest of carbon minus the total growth increment. Emissions from soil carbon are not accounted for in this method because of the uncertainty of these effects on soil carbon.

The EPA *State Workbook* contains a discussion about the assumption that carbon emitted is equal to the net biomass harvest. This is a simplifying assumption, but one that is based on the following reasoning [pages D10-1 and D10-8].

The net change in forest carbon...is not likely to be equivalent to the net flux between forests and the atmosphere. Because most of the timber that is harvested and removed from U.S. forests is used in wood products, harvests may not always result in an immediate flux of carbon to the atmosphere. Harvesting in effect transfers carbon from one of the "forest pools" to a "product pool." Once in a product pool, the carbon is emitted over time as CO₂ through either combustion or decay, although the exact rate of emission varies considerably between different product pools and may in fact result in effective long-term carbon storage. For the purposes of the basic calculation, however, the recommended default assumption is that all carbon removed in wood and other biomass from forests is

oxidized in the year of removal. This is because new products from current harvests frequently replace existing product stocks, which are in turn discarded and oxidized. This clearly would not be accurate if the relative size of forest product pools change significantly over time, but is considered a legitimate, conservative assumption for initial calculations.

Table IX-1 CO₂ Sources and Sinks from Commercial Forestry and Fuelwood Cutting
Normalized values 10³ tons/year

County	FIPS	1990 Inventory	1993 Inventory
Box Elder	3	-162.5	-157.3
Cache	5	-2,315.1	-2,242.2
Rich	33	-524.7	-508.2
Weber	57	-642.7	-622.3
Morgan	29	-171.5	-166.2
Summit	43	-1,856.4	-1,798.0
Davis	11	-618.1	-594.7
Tooele	45	-1,298.6	-1,257.9
Daggett	9	739.8	-585.5
Salt Lake	35	-689.8	-664.2
Uintah	47	1,177.6	-931.1
Duchesne	13	956.9	-757.3
Wasatch	51	-1,250.2	-795.7
Utah	49	-1,052.4	-805.1
(Manti-La Sal)		-312.1	-327.5
Juab	23	-435.0	-276.8
Sanpete	39	-3,891.1	-4,083.9
(Uintah)		-92.3	-58.8
Carbon	7	-312.1	-327.5
Emery	15	-2,336.3	-2,452.0
Millard	27	-2,455.6	-3,279.1
Grand	19	-574.0	-602.5
Sevier	41	-4,642.9	-6,199.9
Beaver	1	-940.4	-1,255.7
Piute	31	-1,347.8	-1,799.7
San Juan	37	-4,112.6	-4,316.3
Wayne	55	-535.4	-714.9
(Dixie)		822.8	85.3
Iron	21	2,546.4	264.2
Garfield	17	10,551.0	1,094.4
Washington	53	4,207.9	436.5
Kane	25	1,286.1	133.4

Note: Negative values represent CO₂ uptake and positive values represent CO₂ emissions.

Methodology

Procedure for Worksheet 10 (Sheet 1)

Forest Worksheet 10-1 changes in forests and woody biomass stock from directions on page 10-4.

Total Forest Acres. This is the USFS number for the size of the national forest

Column A This number is calculated on the worksheet "forest stocks." Assuming that the values for 'forest land acres' given by Rollie Saylor of USFS were a 1994 estimation, the values for the years of interest were calculated on this spreadsheet by taking the difference between what was planted and harvested in a given year and subtracting that value from forest land acres to obtain an estimation of the net change in forest stock for that year. These values are linked to column A of sheet number one.

Example: For the Ashley Forest in FY 1994 the forest land acres were 836,800. To obtain the 1993 value the following formula was applied in the spreadsheet:

(1994 forest acres) - (1993 acres planted - 1993 acres harvested) = 1993 forest acres

(836,800) - (1,350 - 0) = 835,450 acres

Column B This is the annual growth rate assumed from Table 10-1 of page 10-5. The value assumed (13.5) was chosen since it is for Douglas Fir, the most appropriate tree species for this area from among those defaults given in the workbook.

Column D The carbon fraction of dry matter is taken from Table 1.2 of Birdsey, 1992 (page 10-27 of U.S. EPA). The value (0.512) was chosen as the percent carbon for softwood. This value covers the predominant types of timber cut in Utah (spruce, fir, ponderosa pine and lodgepole).

Column E Columns C and D are multiplied and the annual totals are at the bottom of the page.

Lower Column A Number of other trees. Includes dispersed trees such as those in tree farms and urban forestry. Urban forestry is the only category used for this inventory. See description of urban forest calculations.

Lower Column B Annual growth rate. Used the default of 9 t dm/acre/yr for the annual growth rate of urban forest trees. This value is from Table 10-1 of page 10-5, as above, this is the default for Loblolly Pine.

Procedure for Worksheet 10 (Sheet 2)

Forest 2 Worksheet 10-1: Changes in Forests and Woody Biomass Stock (continued)

Volume of Convertible Timber For the years 1990, 1991, and 1992 these values were found in the 1993 *Statistical Abstract of Utah*. The 1993 values were faxed to us by Diane Gillam of the BEBR.

Column F Amount of commercial timber harvested in thousand cubic feet. This column converts the board foot value of the previous column into cubic foot by multiplying by 0.083333 and then dividing by 1,000 to acquire thousand cubic feet. (Note: one board foot is a piece of wood one square foot by one inch in thickness).

Column G Biomass conversion/expansion ratio. The default value found on page 10-5 is 16 t dm/ft³. Sixteen tons per cubic foot of wood is obviously a mistake in the workbook. After conversation with EPA contractor, ICF Inc., it was decided that 16 lb dm/ft³ is the appropriate conversion factor.

Fuelwood cut (in million board feet) Information provided by Rollie Saylor of USFS.

Fuelwood cut converted to thousand cubic feet Cell formula multiplies by 0.083333 and divides by 1,000. Same as previous column.

Column I Fuelwood consumed times the biomass conversion factor.

Column M Column K minus Column L. The totals for all four years is in the shaded area at the bottom of the column. These totals are carried to **Column O** where they are multiplied by the default carbon fraction listed in **Column N**.

Column N This default, 0.5 tons carbon/tons of dry mass, is the general default found on page 10-6 of EPA *State Workbook*.

Column P Subtract Column E from Sheet 1 (the total carbon uptake increment) from Column Q.

Column Q Multiply Column P by 44/12 to give the annual CO₂ emissions or uptake. Positive values reflect emissions while negative values indicate uptake.

Methodology for Estimating Area of Urban Forests

Spreadsheet calculations are on page 4 of "Greenhouse Gas from Forest Changes (Urban Forest)."

Since there are no real tree farms outside of urban areas in Utah, for the sake of this inventory this category represents only urban forests. There is no database in existence which counts all of the trees within a city area. Salt Lake City has the best data on its urban forest but these numbers are estimated to represent only 12 percent to 20 percent of all of the trees in an urban area. The other trees were found on private property.¹

A method for estimating the number of trees in the urban forests of the state was developed using urban tree-cover data provided by Greg McPherson.² Because of the paucity of data, it was decided to account for urban tree-cover by selecting only those municipalities within the state with a population greater than some arbitrary number. A baseline of 20,000 population was chosen because there are so few cities outside the Wasatch Front urban area with populations of 50,000 or greater.

There are fourteen municipalities in Utah with populations greater than 20,000. The number of acres contained within each city boundary was obtained and then the number of urban-forest-acres was estimated based on the average percent tree cover of Logan and Salt Lake City. These two cities are the only ones with percent of tree cover data for Utah. Because there is a large variance between these values the average of the two was used to calculate the amount of urban forest for the entire state.

Uncertainties

The estimates in urban forest area, while very rough, make up only about five percent of the forest category and so even if overestimated still would account for a small proportion of this section. As noted above, there is considerably more uncertainty surrounding the effect of conversion from grassland to urban and suburban development.

The EPA *State Workbook* is based on methods developed by the Intergovernmental Panel on Climate Change (IPCC) for an international inventory of greenhouse gas emissions.³ In the IPCC inventory process the categories of forest and land use change the emphasis was on tropical deforestation and land use development. Consequently, the effect of similar activities in temperate climates are not well understood. Another complicating factor in Utah, and this would be true throughout much of the Intermountain West, would be the proper characterization of the effect of land use changes relative to data developed for regions with higher humidity and, therefore, more dense vegetation.

In Utah, urban and suburban development may take place either on converted farm fields or scrub-type range land. In either case, the above-ground biomass will not be great and so suburban development, with the planting of lawns and shade trees may actually serve to deter CO₂. As stated in the workbook, the release of CO₂ from the soil once it is disturbed varies with the type of agricultural crop that is growing. If these potential changes are thought to be significant, more research will need to be done to differentiate between widely differing land types and regional climate conditions.

1. Based on a personal conversation with Bill Rutherford, SLC urban forester.

2. Data provided on percent tree cover for approximately 50 cities, including Salt Lake and Logan. Also number of trees per acre for Chicago and surrounding counties. From the Western Center for Urban Forest Research.

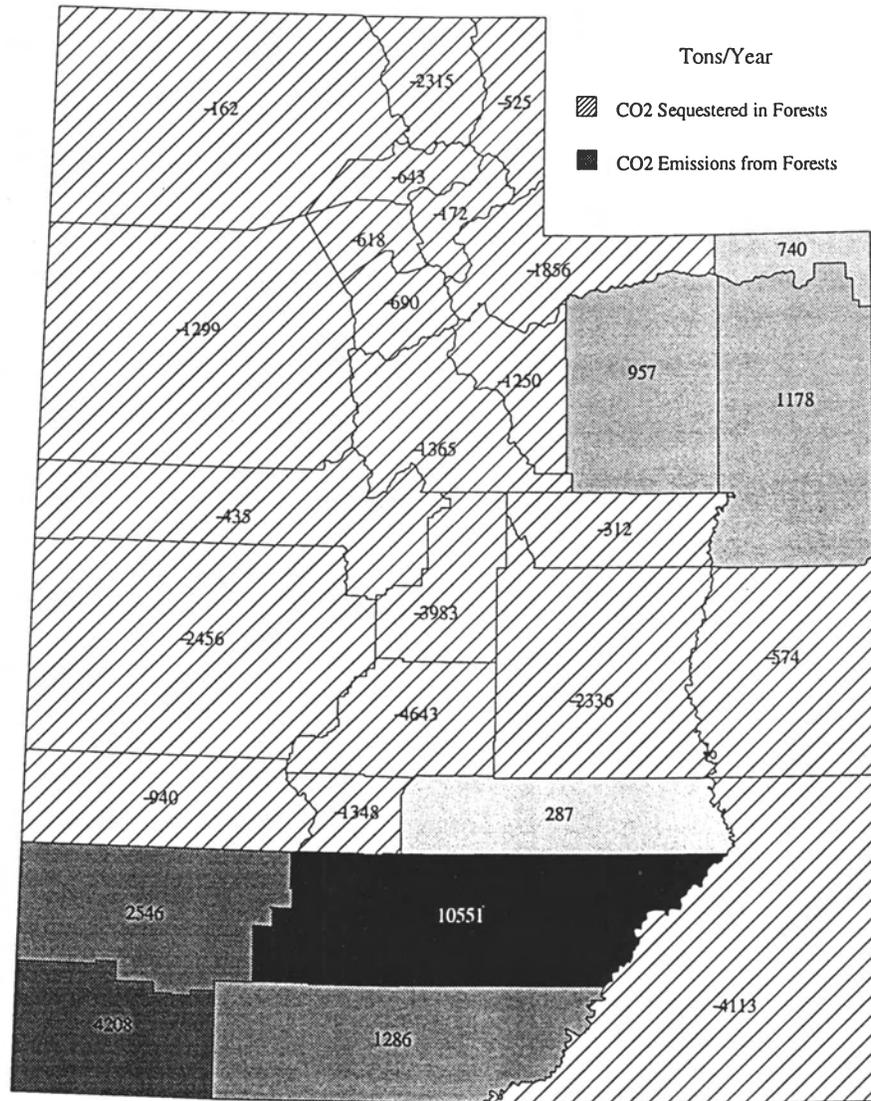
3. Personal conversation with Barbara Brantz of ICF Incorporated, EPA consultant for U.S. greenhouse gas emissions inventory.

References

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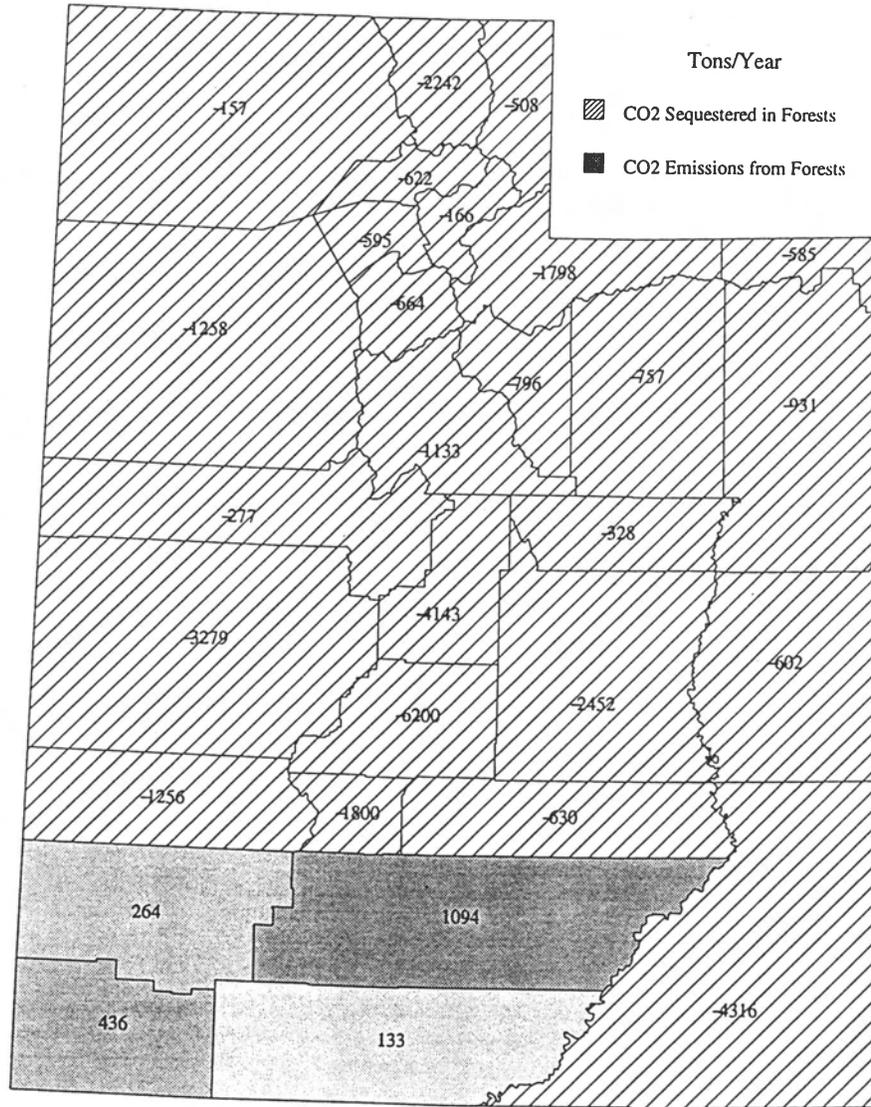
CO₂ Emissions from Forest Management - 1990



Utah Division of Air Quality 1996

Figure IX-1

CO₂ Emissions from Forest Management - 1993



Utah Division of Air Quality 1996

Figure IX-2

1990 CO2 Inventory from Forest Management Practices

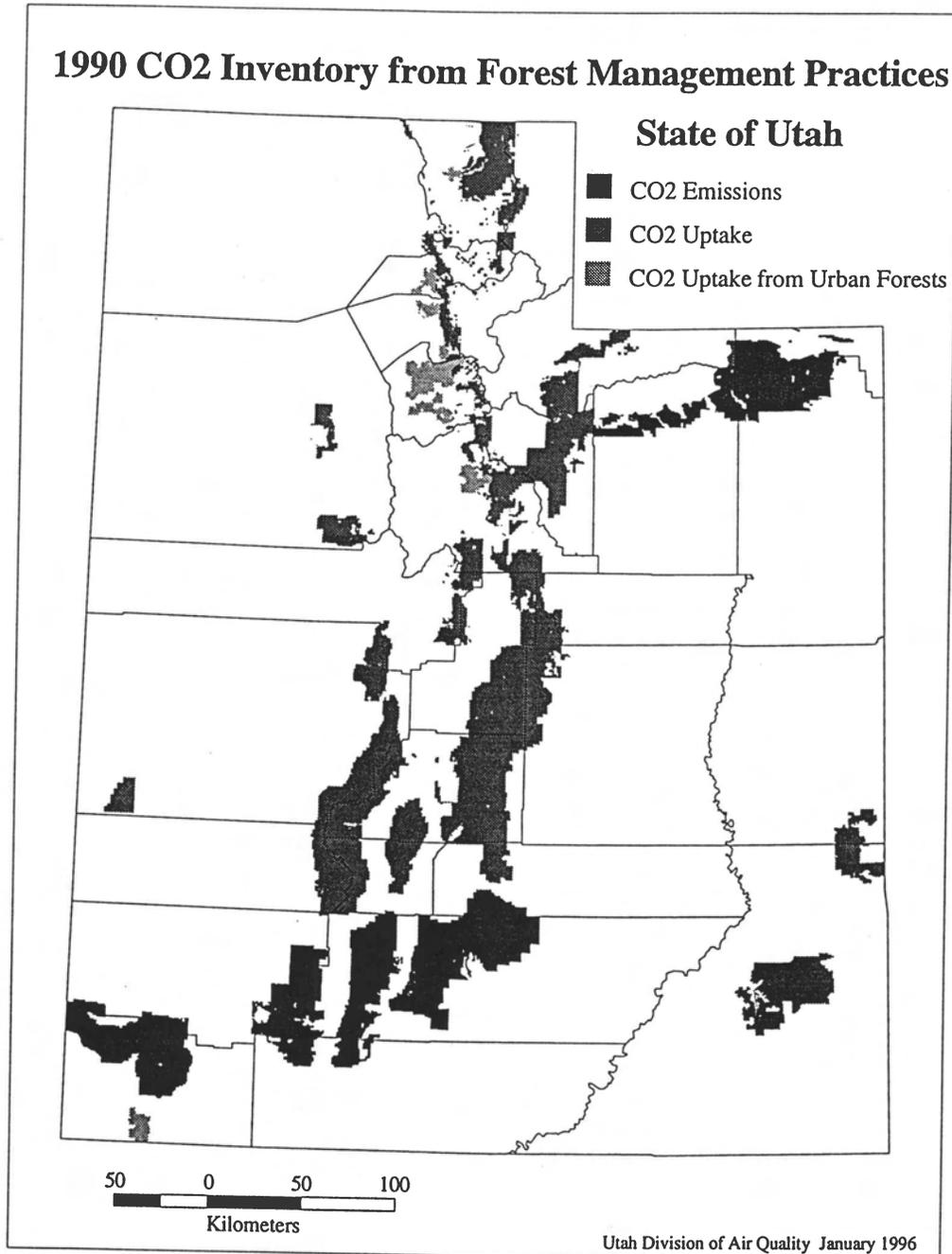


Figure IX-3

1993 CO2 Inventory from Forest Management Practices

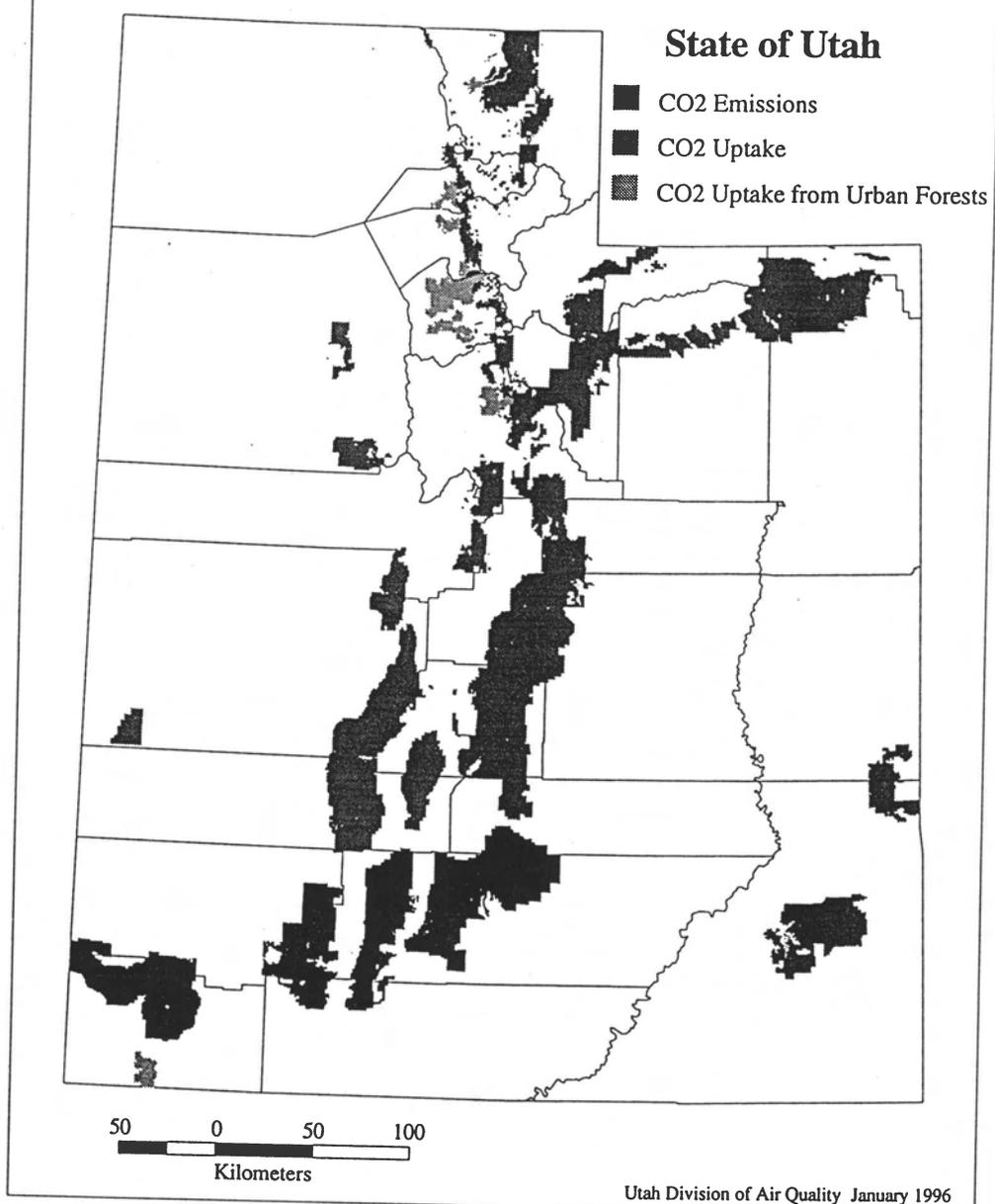


Figure IX-4

Chapter X

Burning Agricultural Crop Wastes

Overview

Crop residue burning is not thought to be a net source of carbon dioxide because the carbon dioxide released during burning is reabsorbed by crop regrowth during the next growing season. It is, however, thought to be a net source of several other greenhouse gases including methane, carbon monoxide, nitrous oxide, and oxides of nitrogen.

Agricultural crop wastes are not burned as a matter of common practice by agricultural producers in the state of Utah. According to Larry Lewis, at the Utah Department of Agriculture, there are no statistics kept on such farming practices within the state. However, the best assessment is that in two northern Utah counties, Box Elder and Weber, some proportion of the barley farmers burn their crop stubble in the field.

Crop production statistics for 1995 from the Utah Department of Agriculture were used to determine barley production in the state. Since it is not known what percentage of barley producers burn their crop stubble, the total crop production for each inventory year was cut in half so that total greenhouse gas emissions from this category are based on fifty percent of the total barley production. The workbook methodology was followed to determine the emissions inventory for this category.

Methodology

The gases above are inventoried in a six-step process, detailed in the attached table, "Greenhouse Gas from Agricultural Burning." First, the amount of dry matter burned is calculated. From this estimate the total amount of carbon burned is calculated and from this value emissions of methane and carbon monoxide are calculated.

The nitrogen content of dry matter is estimated and from that emissions of nitrous oxide, and oxides of nitrogen are estimated. Finally, after emissions for all four trace gases are estimated, they are converted to their full molecular weights.

**Table X-1 Final Estimates for Emissions from Agricultural Burning
Full Molecular Weights**

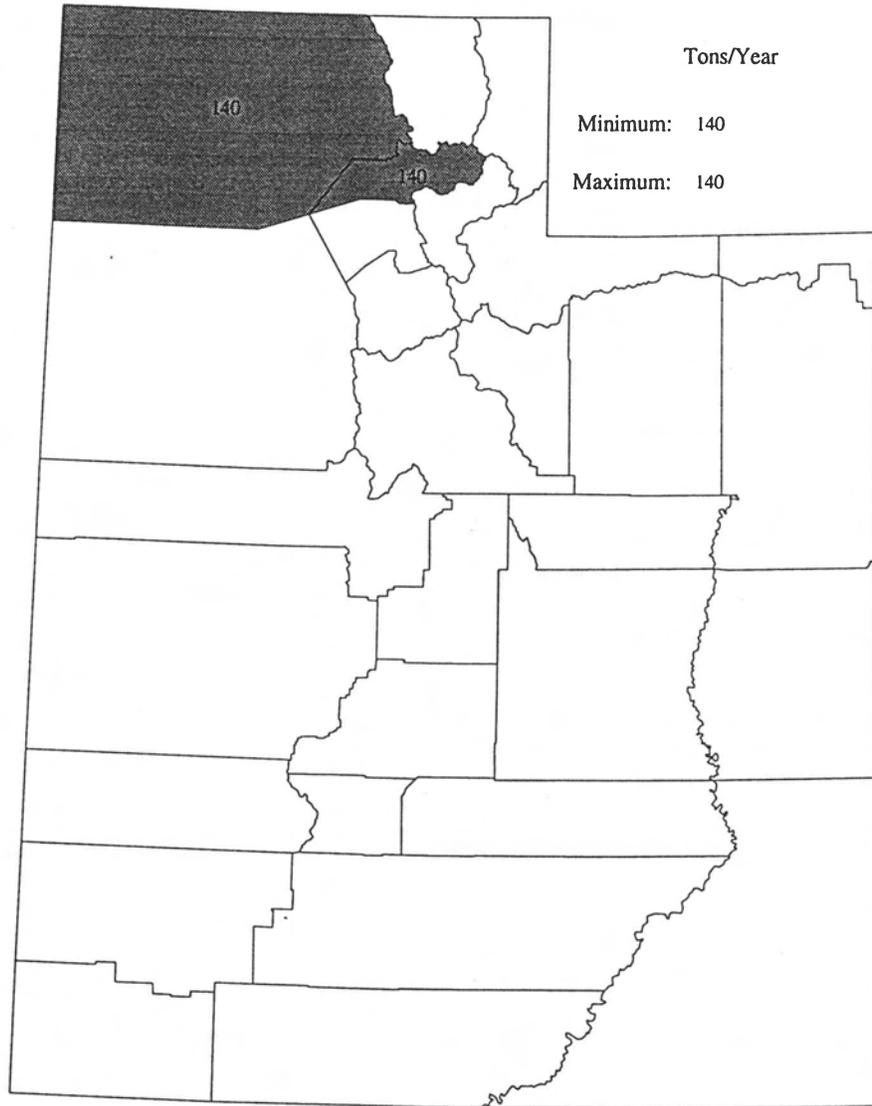
		CH ₄	CO	N ₂ O	NO _x
1990	Tons	18	619	0.13	5
1993	Tons	17	591	0.12	4

References

U.S. Department of Agriculture (U.S. DOA). *Utah Agricultural Statistics*. Washington, D.C.: Government Printing Office, 1995.

U.S. Environmental Protection Agency (U.S. EPA). *State Workbook: Methodologies for Estimating Greenhouse Gas Emission*. Office of Policy, Planning, and Evaluation (EPA-230-B-95-001). Washington, D.C.: Government Printing Office, 1995.

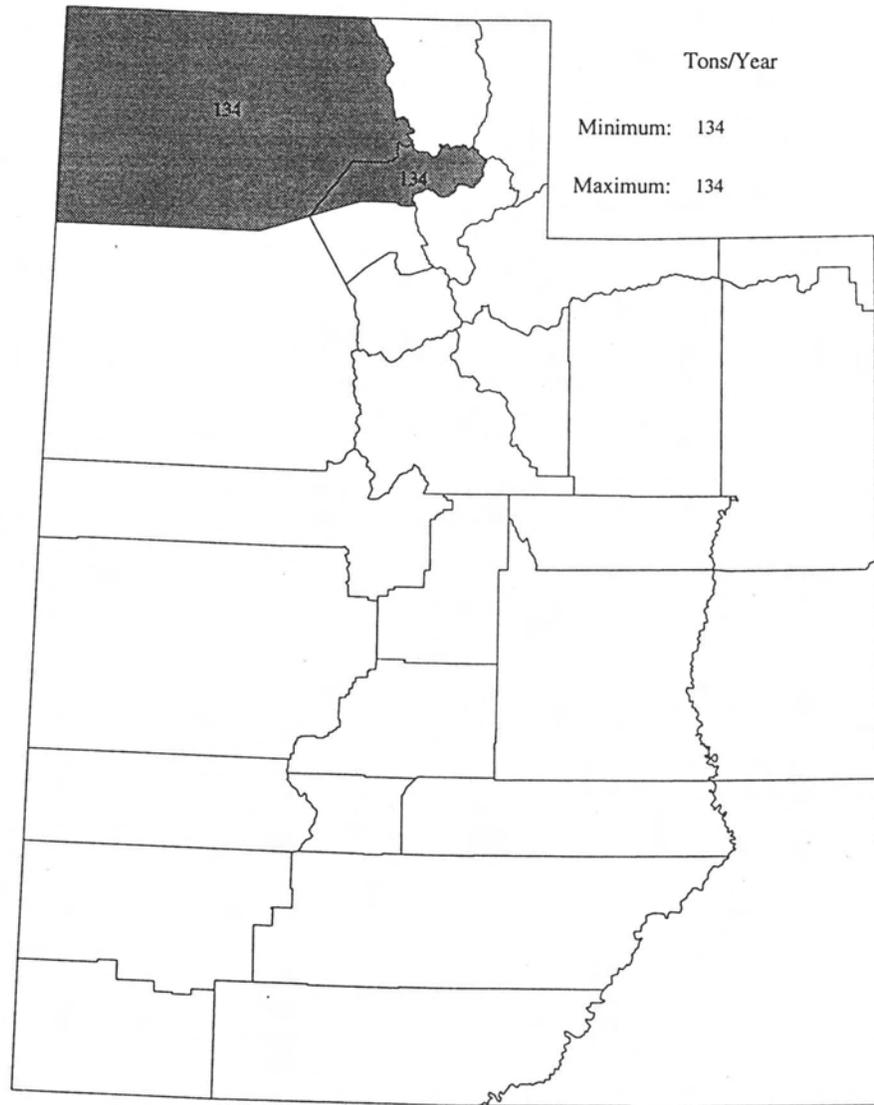
Greenhouse Gas Emissions from Agricultural Burning - 1990



Utah Division of Air Quality 1996

Figure X-1

Greenhouse Gas Emissions from Agricultural Burning - 1993



Utah Division of Air Quality 1996

Figure X-2

Chapter XI

Municipal Wastewater

Overview

Wastewater can be treated using aerobic and/or anaerobic technologies, or if untreated, can degrade under either aerobic or anaerobic conditions. Methane is produced when organic material in both treated and untreated wastewater degrades anaerobically, i.e., without the presence of oxygen. Highly organic wastewater streams such as from food processing or pulp and paper plants readily deplete available oxygen in the water stream as their organic matter decomposes. The organic content, otherwise known as "loading" of these wastewater streams, is expressed in terms of biochemical oxygen demand, or "BOD." BOD represents the amounts of oxygen taken up by the organic matter in the wastewater during decomposition. Under the same conditions, wastewater with higher BOD concentrations will produce more methane than wastewater with relatively lower BOD concentrations. BOD₅ represents the amount of oxygen taken up by organic matter in wastewater during a 5-day period.

Methodology

To estimate methane emissions from municipal wastewater, the following steps are required: 1) obtain the required data on state population; 2) estimate biochemical oxygen demand (BOD₅); 3) estimate gross annual methane emissions; and 4) estimate net annual methane emissions. The following equation summarizes the methane emissions calculation from municipal wastewater:

$$\text{CH}_4 \text{ lbs/year} = (\text{Population (thousands)} * 0.1356 \text{ BOD}_5 \text{ lbs/capita/day} * 365 \text{ days/year} * 0.1356 \text{ lbs CH}_4/\text{lbs BOD}_5 * 0.15 \text{ fraction anaerobically digested}) - 0.00 \text{ methane recovered}$$

where

CH₄ is the pounds per year of methane released to atmosphere

Population is the number of thousands of residents for each county

0.1356 BOD₅ is the biochemical oxygen demand in pounds per capita per day

0.1356 lbs CH₄/lb BOD₅ is the emission factor

0.15 is the fraction anaerobically digested of all wastewater

0.00 is the quantity of methane recovered for power generation

For the years 1990 and 1993, the data on state population was taken from *State of Utah Economic and Demographic Projections 1994* by the Governor's Office of Planning and Budget, Division of Demographic and Economic Analysis, 1994. The BOD₅ per capita per day, the pounds methane per pound BOD, the fraction of BOD anaerobically digested, and the methane recovered were taken from default values listed in the EPA *State Workbook*. The table below shows methane emissions for each county for the years 1990 and 1993.

Table XI-1 Methane Emissions from Anaerobic Treatment of Wastewater

County	Population 1990	Population 1993	Methane Emissions (lbs/yr) 1990	Methane Emissions (lbs/yr) 1993
Beaver	4,800	5,000	7,840	8,167
Box Elder	36,500	38,100	59,616	62,229
Cache	70,500	76,099	115,148	124,293
Carbon	20,200	20,700	32,993	33,809
Daggett	700	700	1,143	1,143
Davis	18,8000	20,6001	307,061	336,462
Duchesne	12,600	13,200	20,580	21,560
Emery	10,300	10,400	16,823	16,986
Garfield	3,950	4,200	6,452	6,860
Grand	6,600	7,499	10,780	12,248
Iron	20,900	23,800	34,136	38,873
Juab	5,800	6,200	9,473	10,126
Kane	5,150	5,450	8,412	8,901
Millard	11,300	11,700	18,456	19,110
Morgan	5,550	6,150	9,065	10,045
Piute	1,250	1,350	2,042	2,205
Rich	1,750	1,800	2,858	2,940
Salt Lake	728,000	777,001	1,189,044	1,269,077
San Juan	12,600	13,100	20,580	21,396
Sanpete	16,300	18,100	26,623	29,563
Sevier	15,400	16,399	25,153	26,785
Summit	15,700	19,700	25,643	32,176
Tooele	26,700	28,100	43,609	45,896
Uintah	22,200	23,600	36,259	38,546
Utah	266,000	291,001	434,458	475,293
Wasatch	10,100	11,200	16,496	18,293
Washington	49,100	58,701	80,195	95,876
Wayne	2,150	2,200	3,512	3,593
Weber	159,000	169,001	259,695	276,030
State Total	1,729,100	1,866,452	2,824,142	3,048,480

Assumptions: BOD/capita = 0.1356 lbs/capita/day
 Emission Factor = 0.22 lbs Methane/lb BOD
 f = 15%
 Methane, recovered = 0%

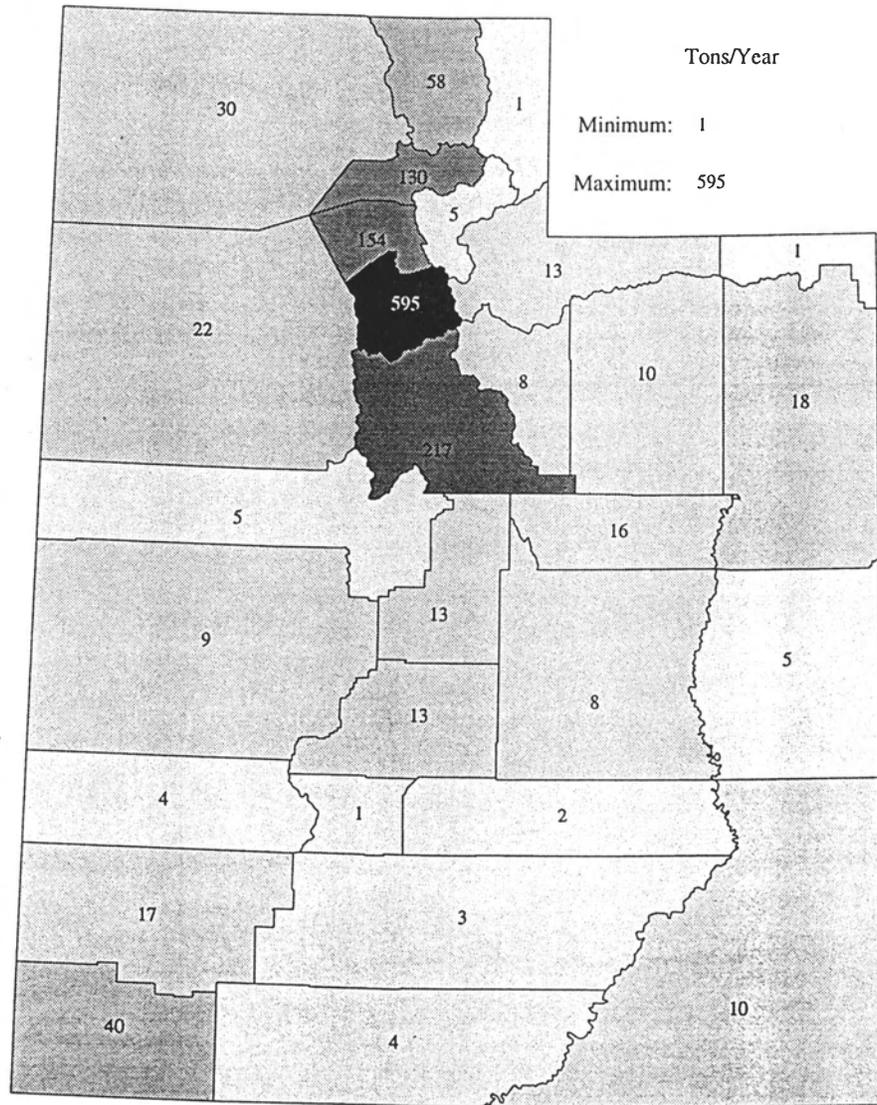
Uncertainties

Uncertainties in the emissions calculations include estimates of emissions factors for methane generated from BOD because of mixture of aerobic and anaerobic treatment facilities, the fraction of anaerobically digested wastewater, since an accurate summation was unavailable from the state, and the quantity of methane recovered. The default factors used are national averages.

Reference

U.S. Environmental Protection Agency (U.S. EPA). *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions*. Office of Policy, Planning, and Evaluation (EPA-230-B-95-001). Washington, D.C.: Government Printing Office, 1995.

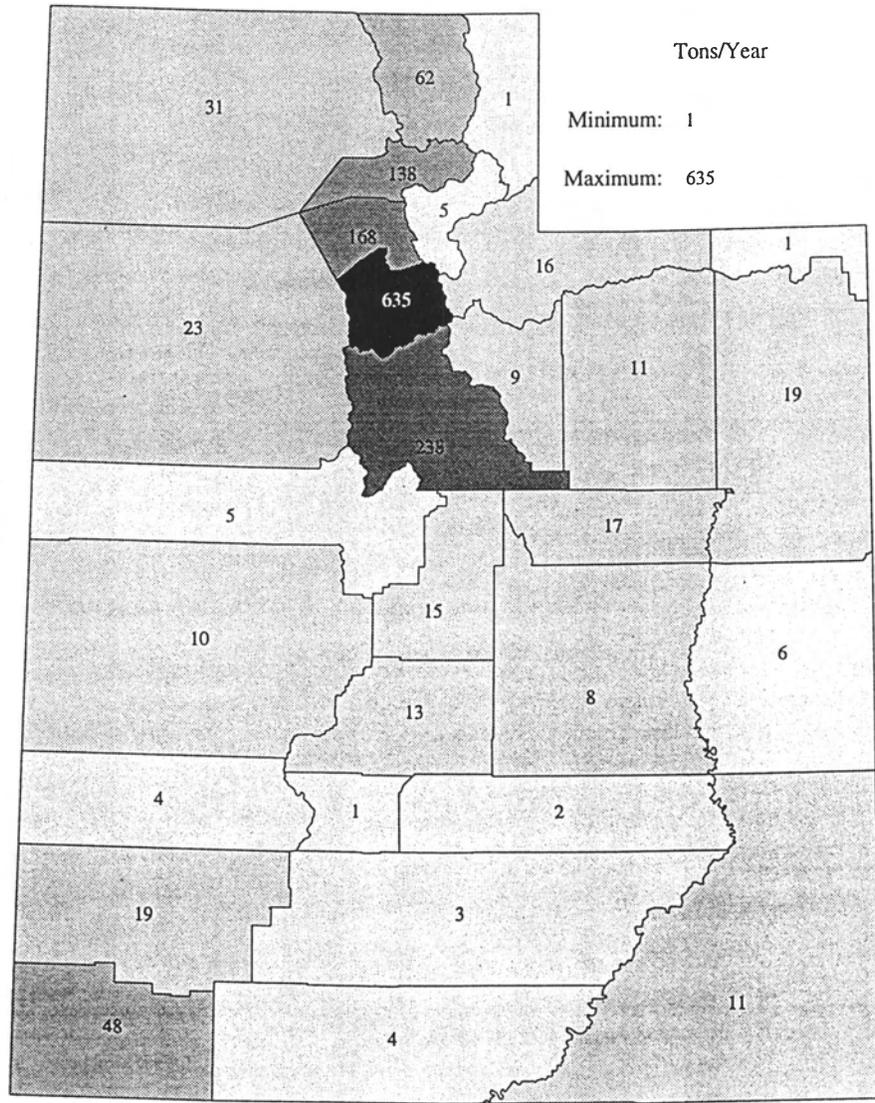
Methane Emissions from Municipal Wastewater - 1990



Utah Division of Air Quality 1996

Figure XI-1

Methane Emissions from Municipal Wastewater - 1993



Utah Division of Air Quality 1996

Figure XI-2