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Project Summary

National- and State-level Emissions Estimates of Radiatively Important Trace Gases (RITGs) from Anthropogenic Sources

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This report documents the development of national- and state-level emissions estimates of radiatively important trace gases (RITGs) that were prepared in support of the staff committee of the National Governors' Association's Task Force on Global Climate Change. Emissions estimates are presented for the principal anthropogenic sources of carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), and ozone precursors. The national annual emissions of CO_2, CH_4, CFCs, volatile organic compounds (VOCs), nitrogen oxides (NO_x) and carbon monoxide (CO), in units of thousands of tons per year, are estimated to be 5,517,223; 33,000; 440; 22,072; 20,541; and 60,938, respectively. Emissions were estimated for these species from readily available databases and other information. Thus, the emissions estimates presented in this report are not totals of all possible sources and should be interpreted only as estimates of the contributions of some of the major source categories. No estimates of any natural sources of these compounds are presented in this report. The data sources used to estimate the emissions are discussed and referenced.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

Increased atmospheric concentrations of carbon dioxide (CO_2) and other radiatively important trace gases (RITGs) — methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), and tropospheric ozone (O_3) — have raised concerns about potential climate change among the general public and members of the scientific community. Since volatile organic compounds (VOCs), oxides of nitrogen (NO_x), and carbon monoxide (CO) are involved in atmospheric chemistry processes which form tropospheric ozone, they are also of concern.

Much uncertainty exists about how climate change may affect specific geographic regions or ecological systems. To reduce this uncertainty, research is underway to estimate the potential magnitude and timing of climate change, the relative contribution of anthropogenic and natural sources of the implicated trace gases, the atmospheric/chemical processes in which these gases participate, and the extent of ecological effects resulting from climate change.

Emissions from human activities such as fossil fuel combustion, industry, and agriculture are a primary cause of the increasing concentrations of RITGs in the Earth's atmosphere. In order to evaluate the extent to which these human activities will influence future atmospheric composition and climate, it is necessary to characterize all significant sources and to identify their locations and strengths.

Project Description

This report presents state-level estimates of emissions of RITGs — with the exception of N_2O — resulting from anthropogenic activities. The emissions estimates presented here were developed in a short time frame to assist the National Governors' Association and should be considered *preliminary* estimates. Considerable

research is currently underway which could improve these estimates, particularly for gases (such as CH_4) whose emission estimates have a high degree of uncertainty.

The geographic scope of the emissions estimates includes the 48 contiguous U.S. and the District of Columbia. Table 1 cross-references the gases and sources for which emissions estimates were developed. These emissions estimates were developed from readily available databases and include most of the significant sources of RITG emissions. Some potentially significant sources were not included because, at the time this report was prepared, representative data were not readily available (e.g., CH_4 emissions from surface mining operations and manure piles were not included). Emissions of CO_2 from cement manufacturing were not included because of its relatively minor role on the national scale and because of project resource constraints.

The state-level emissions estimates presented here are for sources within the boundaries of each state. Therefore, the results of this study do not quantify the emissions which occur outside a state that may be attributable to activities within the state. For example, power plants and fuel production facilities located outside of California provide electricity and natural gas to users within the state. Although the energy is provided to satisfy demand in California, the emissions associated with these sources are not attributed to California. Rather, they are attributed to the state in which the power plants and natural gas transmission lines are located. Clearly, significant greenhouse gas emissions may be associated with the interstate transport of energy and other commodities. However, developing the energy and commodity balances necessary to take this into account was beyond the scope of this study.

Historically, major anthropogenic emissions inventory development activities performed by the Environmental Protection Agency have focused on issues related to the potential health effects of air pollutants. Atmospheric concentrations of CO_2, CH_4 and CFCs have not been associated with health hazards; therefore, the available emissions estimates for these species are not as complete as for other air pollutants. Tropospheric ozone is recognized as a health hazard; however, ozone is not emitted directly from anthropogenic activities. Ozone is formed in the near surface troposphere by a complex reaction mechanism that involves reactive hydrocarbons (VOCs), NO_x, and CO in the presence of sunlight.

Table 1. Sources and Gases Included in This Study

Source	Trace Gases
Fuel Combustion[a]	*CO_2, CO, NO_x, VOC*
Industrial	
Residential	
Commercial	
Transportation	
Electric Power Plants	
Major Sources of Methane[b]	*CH_4*
Landfills	
Underground Coal Mines	
Domestic Animals	
General Industrial/Other[c]	
Natural Gas Transmission/Distribution	
Sources of Chlorofluorocarbons	*CFC-11, CFC-12, HCFC-22 CFC-113*
Refrigeration	
Air conditioning	
Blowing Agents	
Solvents	
Aerosols	
Other	
Industrial Processes	*CO, NO_x, VOC*

[a] *Fuels include coal, oil, natural gas, biomass, gasoline, diesel, process gas.*
[b] *Note that rice cultivation is not included here and is not thought to be a major source in the U.S. Emissions from manure piles are also not included but these sources may be significant in the U.S.*
[c] *Includes the methane emissions from significant sources included in the National Acid Precipitation Assessment Program (NAPAP) inventory: transportation, wood combustion, coke manufacturing, and others.*

Discussion of Results

State total emissions for each RITG are listed in Table 2. Emissions estimates are included for CO_2, CH_4, NO_x, VOCs, CO, and CFCs. Emissions were aggregated at the state level to assist in interpretive analyses of the relative contributions of various states and RITGs to the national totals of these emissions. The national summary presented in Table 2 clearly shows the dominance of CO_2 emissions among the principal greenhouse gases. The anthropogenic sources of CO_2 are primarily fossil fuel and biomass combustion. The largest fuel combustion sector in the U.S. is electric utilities. Industrial combustion, commercial/residential combustion, and transportation are other important fuel combustion activities. The utility sector is estimated to contribute 35% of the total CO_2 emissions. Industrial combustion and transportation fuel use are estimated to contribute 26 and 24%, respectively. In general, these sources are reasonably well characterized, particularly the fossil fuel sources, and the uncertainty associated with these emissions estimates is low.

Of the CH_4 sources examined in this study, offgasing from landfills is the most significant national source of methane. Methane emissions from landfills are estimated to account for 48% of the total emissions associated with all the sources examined here. Emissions associated with farm animals are the second largest source (21% of the total) while emissions from natural gas pipeline transmission/distribution systems are the third largest (14% of the total). Underground coal mines contribute 10% of CH_4 emissions to the national total. This estimate understates emissions from coal mines because it does not include CH_4 emissions from surface mines. The emissions from surface mining operations are potentially significant, but available data are inadequate for estimating state level emissions. Current estimates of emissions from the most significant sources of CH_4 (landfill offgasing, coal mines, domestic animals, natural gas transmission/distribution, and general industrial) are highly uncertain.

Although the national total emissions of CFCs presented in Table 2 are orders of magnitude less than the emissions totals for other RITGs included in these analyses, the relative importance of CFCs on global climate change processes should

Table 2. State Level Emissions Estimates for All Radiatively Important Trace Gases (10^3 tons/year)

State Name	CO	VOCs	NO_x	CH_4	CO_2	CFC
Alabama	1,274	498	460	1,200	129,163	7
Arizona	701	240	248	350	68,031	6
Arkansas	653	223	238	370	71,113	4
California	5,436	2,185	1,245	2,200	452,615	49
Colorado	1,139	301	293	670	73,512	6
Connecticut	532	231	128	290	41,903	7
Delaware	177	87	68	61	16,401	1
Dist. of Col.	93	30	20	54	5,512	1
Florida	2,605	797	680	1,100	161,178	20
Georgia	1,763	604	588	650	165,060	11
Idaho	1,065	186	88	230	14,197	2
Illinois	2,406	947	969	1,400	345,814	20
Indiana	2,026	557	885	710	264,793	12
Iowa	674	214	267	640	71,620	5
Kansas	673	243	423	660	77,557	4
Kentucky	1,020	410	520	700	124,089	7
Louisana	1,654	626	763	800	213,892	7
Maine	335	105	67	100	21,925	2
Maryland	785	276	282	360	81,857	8
Massachusetts	924	416	274	530	83,989	12
Michigan	2,282	778	656	1,000	189,598	18
Minnesota	1,315	423	354	660	83,502	8
Mississippi	783	270	237	370	51,722	5
Missouri	1,303	494	536	810	120,585	9
Montana	865	163	155	260	30,155	1
Nebraska	402	126	165	540	37,776	3
Nevada	275	82	113	130	24,821	1
New Hampshire	229	82	55	86	15,318	2
New Jersey	1,156	595	356	710	99,472	14
New Mexico	752	165	283	260	65,429	2
New York	2,412	989	628	1,500	201,125	29
North Carolina	1,839	669	501	640	119,947	17
North Dakota	188	62	185	190	56,299	1
Ohio	2,857	1,008	1,017	1,200	286,392	20
Oklahoma	989	342	398	770	101,290	5
Oregon	1,056	302	169	380	36,216	4
Pennsylvania	2,496	904	956	1,800	270,653	21
Rhode Island	121	68	30	85	9,275	2
South Carolina	882	363	258	340	60,078	7
South Dakota	382	87	73	310	14,146	1
Tennessee	1,339	535	508	630	117,431	10
Texas	4,620	2,329	2,512	3,100	517,239	29
Utah	745	168	171	280	47,543	3
Vermont	160	49	25	70	7,871	1
Virginia	1,404	572	390	1,200	103,508	12
Washington	1,948	455	274	530	79,805	7
West Virginia	578	307	457	1,100	108,234	3
Wisconsin	1,250	420	348	690	104,299	9
Wyoming	374	89	224	160	73,273	1
Totals[a]	60,938	22,072	20,541	33,000	5,517,223	440

[a] *Differences between national totals and the sum of state totals are the result of roundoff error.*

not be minimized. These compounds have lifetimes that are on the order of tens of years; therefore, past emissions as well as current and future emissions will have impacts. The extremely long lifetimes of these compounds result in their accumulation in the stratosphere, where they disrupt the stratospheric ozone equilibrium. In addition to having greater lifetimes, CFCs are generally much more radiatively active on a per molecule basis than the other greenhouse gases. The principal CFC compounds are CFC-12, HCFC-22, CFC-11 and CFC-113. These compounds are used in many different applications including air conditioning, refrigeration, blowing agents, solvents, and in aerosols; and national emissions for 1985 are estimated to be 440,000 tons. The most significant of these applications include activities related to air conditioning and refrigeration. Data pertaining to emissions estimates from these sources are less readily available and a great deal of uncertainty is associated with them.

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The complete report, entitled "National- and State-level Emissions Estimates of Radiatively Important Trace Gases (RITGs) from Anthropogenic Sources," (Order No. PB91-103572/AS; Cost: $17.00, (subject to change) will be available only from:
National Technical Information Service
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