

## Determining Thresholds for Mandatory Reporting of Greenhouse Gas Emissions

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A number of countries are considering implementation of reporting requirements for greenhouse gases. Some reporting systems have been proposed that would require each entity or facility exceeding an annual emissions threshold to report their emissions to a governmental agency. The analysis presented here provides a first approximation of the number of facilities in selected U.S. economic sectors that would report under several different reporting thresholds. Results indicate that thresholds below 10 000 Mg of carbon dioxide equivalent (CO<sub>2</sub>E) per year may bring in relatively large numbers of facilities while minimally increasing the percentage of reported emissions. None of the reporting thresholds considered in this analysis would account for the majority of greenhouse gas emissions from the U.S. agricultural, transportation, or residential and commercial building sectors. If these sectors, in which large numbers of farms, vehicles, and buildings each emit relatively small amounts of greenhouse gases, are to be included in a reporting framework, additional or alternative approaches to reporting should be considered. Alternative approaches may include creating separate thresholds for individual greenhouse gases instead of using an aggregated CO<sub>2</sub>E unit, creating separate reporting thresholds for individual sectors, or combining sources of small emissions into a single reporting entity.

### Introduction

Concentrations of carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O), commonly referred to as greenhouse gases, have been increasing in the atmosphere since about 1750. These gases together accounted for about 86% of the increase in annual mean radiative forcing since 1750 and are considered the primary cause of increased average global temperature over the past century (1). In 2000, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions accounted for 83%, 9%, and 6% of total U.S. greenhouse gas emissions, respectively (2). As these gases continue to increase in the atmosphere, there is an increased potential for adverse effects on regional and global climate, ecosystem structure and function, and human health (3). In accordance with the United Nations Framework Convention on Climate Change, many countries have undertaken reports that document annual emissions of greenhouse gases at the

national level. In an effort to obtain information on individual sources of emissions, some governments are now considering mandatory or voluntary reporting of greenhouse gas emissions.

One approach to emissions reporting is to establish reporting thresholds, which require entities or facilities to report if direct (on-site) emissions exceed a predetermined annual amount. At the time of this analysis, the U.S. Congress was considering a bill, the Energy Policy Act of 2002, which called for the development of a National Greenhouse Gas Database (Title XI) that would have required an entity to report greenhouse gas emissions if total annual emissions at any facility owned by the entity exceeded 1000 Mg of CO<sub>2</sub>E (4). The bill defined an entity as a person or a public or private entity operating in the United States and defined a facility as all buildings, structures, or installations on contiguous or adjacent property under the common control of the same entity. Information developed in the course of this analysis contributed to the reporting threshold being raised to 10 000 Mg of CO<sub>2</sub>E in a revised version of the bill that was passed by the U.S. Senate in April 2002 (5). In the revised bill, emissions reporting would become mandatory only if 60% of U.S. greenhouse gas emissions were not being reported following a 5-yr voluntary reporting period.

Reporting of emissions using reporting thresholds is also part of efforts in the EU and Canada to inventory greenhouse gas emissions. At the time of this analysis, the European Commission had legislation pending on the implementation of a European Pollutant Emissions Register (EPER). The EPER would require reporting of pollutants by individual facilities if they annually emit over 100 000, 100, or 10 Mg of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, respectively (6). The Ontario Ministry of the Environment (MOE) currently has a Mandatory Emissions Monitoring and Reporting program that requires facilities to report if emissions exceed 100 000, 5000, or 3 Mg of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, respectively (7). While details in some of the proposed legislation are expected to change as it moves through the legislative process, the issue of voluntary or mandatory emissions reporting and the development of a reporting framework continues to be debated and should be addressed.

In considering the creation and implementation of emissions reporting thresholds, two important questions arise. What threshold represents a desirable tradeoff between maximizing the amount of emissions reported and minimizing the number of facilities reporting? Second, should separate reporting thresholds be established for individual greenhouse gases, as in the EPER and MOE reporting programs, or should one threshold be established for all gases collectively based on units of CO<sub>2</sub>E? The analysis presented here uses publicly available data on U.S. emissions from a number of economic sectors to illustrate one method that can be used to address these questions.

### Method of Analysis

This analysis considers CO<sub>2</sub> emissions from fossil fuel combustion within the electric power industry and the manufacturing, transportation, residential, and commercial sectors. Emissions of CO<sub>2</sub> resulting from the combustion of fossil fuels are responsible for approximately 80% of total U.S. greenhouse gas emissions (2). The analysis also considers the agricultural sector, which is a substantial source of N<sub>2</sub>O emissions from the application of nitrogen fertilizers, CH<sub>4</sub> emissions from enteric fermentation (a digestive process of

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**TABLE 1. Estimated Number of Manufacturing Facilities and Associated Carbon Dioxide Emissions Reported under Three Emissions Reporting Thresholds<sup>a</sup>**

NAICS <sup>b</sup> code	product manufactured	total no. of facilities	total annual CO <sub>2</sub> emissions (Mg of CO <sub>2</sub> × 10 <sup>3</sup> )	1000 Mg of CO <sub>2</sub>			10 000 Mg of CO <sub>2</sub>			100 000 Mg of CO <sub>2</sub>		
				no. of facilities reporting	size <sup>c</sup>	% CO <sub>2</sub> emissions reported	no. of facilities reporting	size <sup>c</sup>	% CO <sub>2</sub> emissions reported	no. of facilities reporting	size <sup>c</sup>	% CO <sub>2</sub> emissions reported
311	food	26 302	52 338	8 726	g	92.2	1 353	j	48.1	0	0.0	
312	beverage and tobacco	2 727	6 609	625	h	92.8	55	k	54.4	4	m	13.7
313	textile mills	4 694	9 343	1 516	h	94.1	145	k	35.0	0	0.0	
314	textile product mills	7 899	2 169	188	j	72.8	13	l	21.5	0	0.0	
315	apparel	16 989	1 614	172	k	39.8	3	m	2.5	0	0.0	
316	leather and allied products	1 861	267	74	j	42.3	0	0.0	0	0.0		
321	wood products	17 367	6 153	1 373	i	65.6	0	0.0	0	0.0		
322	paper	5 868	77 917	4 681	f	99.0	457	j	79.3	192	k	61.9
323	printing and related support	42 863	2 594	417	j	39.4	0	0.0	0	0.0		
324	petroleum and coal	2 146	221 437	2 146	d	100.0	992	f	98.3	224	i	92.2
325	chemicals	13 454	174 906	7 882	f	98.7	1 776	i	84.5	287	k	44.1
326	plastics and rubber	16 821	8 124	2 725	i	71.1	54	l	13.5	0	0.0	
327	nonmetallic mineral	16 310	65 889	5 287	g	95.7	1 005	i	77.0	1	m	0.3
331	primary metals	5 059	138 042	3 077	g	99.4	1 378	i	94.4	218	k	75.8
332	fabricated metal	62 384	14 679	3 618	i	55.6	46	l	4.2	0	0.0	
333	machinery	30 599	6 220	1 061	j	58.3	116	l	23.5	0	0.0	
334	computer and electronics	17 435	3 508	651	k	69.6	74	m	29.0	0	0.0	
335	electrical equipment	6 930	3 315	610	j	67.9	11	m	5.5	0	0.0	
336	transportation equipment	12 887	15 720	1 343	j	84.4	293	l	60.8	0	0.0	
337	furniture and related products	20 738	1 650	440	j	60.2	5	m	3.7	0	0.0	
339	miscellaneous	31 476	4 934	522	j	39.0	1	m	0.3	0	0.0	
	total manufacturing	362 829	817 431	47 134		95.5	7 777		80.1	926		53.2

<sup>a</sup> This analysis includes only direct (on-site) CO<sub>2</sub> emissions from fossil fuel combustion; it does not include upstream emissions from electricity use or non-fossil fuel CO<sub>2</sub> emissions from cement production. Waste wood and pulping liquor used for energy by wood and paper industries is considered renewable; hence, CO<sub>2</sub> emissions associated with the combustion of these waste products were not included here. Carbon dioxide emissions per facility were estimated using data on energy and fossil fuel use (8), carbon coefficients (2, 9), and average facility size (10). Summed data may not equal totals because of independent rounding. <sup>b</sup> North American Industry Classification Code. <sup>c</sup> Smallest employment size class of facilities required to report under respective thresholds; d–m are 1–4, 5–9, 10–19, 20–49, 50–99, 100–249, 250–499, 500–999, 1000–2499, and >2500, respectively.

ruminant animals), and CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management. Methane emissions from municipal waste landfills are also considered. The analysis does not consider emissions of other greenhouse gases, including HFCs, PFCs, and SF<sub>6</sub>. Indirect emissions from the use of electricity were not included when estimating emissions associated with facilities because these emissions are accounted for within the electric power industry. Our analysis is limited to direct (on-site) emissions at the facility level.

Electric power plants currently report CO<sub>2</sub> emissions in accordance with the Clean Air Act Amendments of 1990. These emissions account for 34% of total U.S. greenhouse gas emissions or 40% of U.S. CO<sub>2</sub> emissions. Emissions per facility are not currently reported by facilities in other sectors (e.g., by manufacturing facility, farm, vehicle, or building). To estimate the number of manufacturing facilities in the United States that would be required to report under various thresholds, considering only CO<sub>2</sub> emissions from fossil fuel combustion, requires data on the amount and type of fossil fuel used per facility. Since data on fossil fuel use from individual manufacturing facilities is not publicly available, data on average fuel use for each group or category of manufacturing facilities was used. The Manufacturing Energy Consumption Survey (MECS) provides data on fuel consumption by North American Industry Classification Code (NAICS) and on energy consumption per employee for six employment size categories: <50, 50–99, 100–249, 250–499, 500–999, and >1000 employees per facility (“facility” is referred to as “establishment” in the MECS data; 8). Carbon dioxide emissions per unit of fuel were calculated (9, 2, Annex R) and used to estimate emissions per employee for each employment category. Estimates of emissions per employee were then multiplied by the average number of employees per facility. This resulted in average estimates of emissions per facility within each size category. Information on the number of employees per facility is available from the U.S.

Census Bureau, Economic Census (10). For size classes where data on the total number of employees per category were not available, a value was estimated by multiplying the average number of employees in the size category (e.g., in size class 50–99, the average is 75) by the number of facilities in the category and adjusting the estimated values so the total number of employees equaled the total number provided by the U.S. Census data (10). To determine the number of facilities required to report their emissions, an estimate was made of the total number of facilities emitting greater than the reporting threshold value. If the average amount of emissions for a facility within a given size category (e.g., 20–49 employees) exceeded the annual threshold amount (e.g., 10 000 Mg CO<sub>2</sub>), then all facilities within that category were recorded as reporting under the emissions reporting threshold. This method of estimation provides a first approximation of the number of facilities and associated emissions reported for a number of predetermined emissions thresholds.

This method was applied to landfills and the agriculture and commercial building sectors by replacing the number of employees per manufacturing facility with an appropriate metric from data available in other sectors. For example, to determine emissions for livestock operations, cropland, landfills, and commercial buildings, emissions were based on the number of animals per farm, number of hectares per farm, metric tons of waste per landfill, and square meters per building, respectively. Emissions data per facility of a given size were then coupled with data on the number of facilities in each size class to estimate the total number of facilities and associated emissions reported under a number of different thresholds.

## Results and Discussion

Under a reporting threshold of 1000 Mg of CO<sub>2</sub>E, approximately 96% of CO<sub>2</sub> emitted because of fossil fuel

**TABLE 2. Estimated Number of Agricultural Farms Annually Emitting in Excess of 1000 Mg of CO<sub>2</sub>E<sup>a</sup>**

farm type	total no. of farms	total annual emissions (Mg of CO <sub>2</sub> E × 10 <sup>3</sup> ) <sup>b</sup>	1000 Mg of CO <sub>2</sub> E	
			no. of farms reporting	% CO <sub>2</sub> E emissions reported
<b>Livestock<sup>b</sup></b>				
dairy cattle	116 874	74 783	6 308	33.8
nondairy cattle	804 595	116 059	4 940	13.9
swine	109 754	24 482	5 439	57.4
sheep	65 790	22 347	391	35.0
<b>Crop Production<sup>c</sup></b>				
corn	430 711	35 872	862	3.4
soybean	354 692	9 101		
wheat	243 568	22 858	1 859	14.0

<sup>a</sup> This analysis represents a subset of U.S. farms, including those with cattle, swine, and sheep and those with continuous corn, soybean, and wheat crops. Corn, soybean, and wheat constituted 60% of U.S. crops harvested in 1999. <sup>b</sup> Based on annual Mg of CO<sub>2</sub>E per animal of 4.2, 1.8, 0.4, and 0.3 for dairy cattle, nondairy cattle, swine, and sheep, respectively. Estimates based on calculations of CH<sub>4</sub> from enteric fermentation and manure management, N<sub>2</sub>O from manure management (13), and number of animals per farm (14). Livestock farms reporting at the 1000 Mg of CO<sub>2</sub>E threshold include those stocking greater than 250, 550, 2500, or 3300 head of dairy cattle, nondairy cattle, swine, or sheep, respectively. <sup>c</sup> Based on annual Mg of CO<sub>2</sub>E/ha of 1.27, 0.34, and 0.96 for corn, soybean, and wheat, respectively, cropped continuously and using conventional tillage practices. Estimates based on calculations of on-site emissions from the use of agriculture machinery (15), approximate N<sub>2</sub>O emissions from nitrogen fertilizer use (16, 17), and number of hectares in corn, soybean, and wheat per farm (14). Of the crops analyzed here, farms reporting at the 1000 Mg of CO<sub>2</sub>E threshold include those with continuous corn, soybean, and wheat production on greater than 800, 3000, and 1000 ha, respectively. Global warming potentials used in the conversion of greenhouse gases to CO<sub>2</sub>E were based on a 100-yr time horizon and were 1, 23, and 296 for CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, respectively (7).

combustion from the manufacturing sector would be reported by roughly 47 000 facilities (Table 1). While the majority of greenhouse gas emissions would not be reported by the agricultural sector, reporting would be required from approximately 6000 dairy cattle farms, 5000 pig farms, 900 corn farms, and 2000 wheat farms in the United States (Table 2). Similarly, nearly 6000 commercial buildings would have to report while accounting for about 6% of the emissions from this sector (Table 3). Individual automobiles and residential buildings are small sources that would not be required to report under a 1000 Mg of CO<sub>2</sub>E threshold. The average passenger car in the United States in 2000 emitted 4.8 Mg of CO<sub>2</sub>, and the largest trucks (>12 Mg or 26 000 lbs) emitted 76.1 Mg of CO<sub>2</sub> (11, 9). In 1997, the average U.S. household in the highest emissions category (i.e., households with an annual income greater than \$50 000) emitted an average of 18.6 Mg of CO<sub>2</sub> (12, 9).

Increasing the reporting threshold to 10 000 Mg of CO<sub>2</sub>E effectively relieves the agriculture and commercial building sectors from reporting, substantially reduces the number of manufacturing facilities that would report while continuing to capture 80% of manufacturing emissions, and continues to account for nearly all emissions from power plants and landfills (Table 3). As the reporting threshold increases beyond 10 000 Mg of CO<sub>2</sub>E, the number of reporting facilities and associated emissions from landfills and the manufacturing sector decreases. While the number of electrical power plants reporting declines with increasing threshold values, the percentage of reported emissions is relatively unaffected (Table 3).

In general, the size of facilities having to report increases with an increase in the reporting threshold. For example, facilities that manufacture primary metals (Table 1, NAICS Code 331) and have more than 20 employees may have to report under a 1000 Mg of CO<sub>2</sub>E threshold, while only those facilities with greater than 100 employees may have to report under a 10 000 Mg of CO<sub>2</sub>E threshold. In this particular example, 61% of facilities report 99% of emissions from this sector under a 1000 Mg of CO<sub>2</sub>E threshold, while 27% of facilities report 94% of emissions under a 10 000 Mg of CO<sub>2</sub>E threshold. From the standpoint of optimizing the reporting framework (i.e., maximizing emissions reported while minimizing the number of facilities reporting), a 10 000 Mg of CO<sub>2</sub>E threshold appears reasonable.

Neither of the reporting thresholds discussed thus far would result in the reporting of emissions from individual sources in the transportation or residential sectors nor for the majority of emissions from agriculture and commercial buildings. Emissions in these sectors, unlike that in electricity generation, manufacturing, and landfills, result from a very large number of sources, each of which emits relatively small amounts of greenhouse gases. Emissions of CO<sub>2</sub> due to fossil fuel combustion from the transportation sector alone constituted 26% of total U.S. greenhouse gas emissions in 2000, of which 72% was from passenger cars and trucks (2). A number of options may exist to account for emissions from the transportation sector. One such option may be for automobile manufacturers to report on the expected emissions over the lifetime of their products, essentially consolidating emissions from all vehicles sold into one reporting entity. This consolidation might be considered a form of entity-based reporting consistent with that envisioned in Title XI of the Energy Policy Act. Emissions attributed to agriculture accounted for only 7.6% of total U.S. greenhouse gas emissions in 2000 but constituted 74% of total N<sub>2</sub>O emissions in the United States (2). To increase coverage of the agricultural sector, separate thresholds could be established for individual gases (i.e., N<sub>2</sub>O and CH<sub>4</sub>) instead of using one collective threshold based on CO<sub>2</sub>E.

**TABLE 3. Estimated Number of Selected Facilities and Associated Emissions Reported under Four Emissions Reporting Thresholds**

reporting facility	total no. of facilities	total annual emissions (Mg of CO <sub>2</sub> E × 10 <sup>3</sup> ) <sup>b</sup>	1000 Mg of CO <sub>2</sub> E		10 000 Mg of CO <sub>2</sub> E		100 000 Mg of CO <sub>2</sub> E		1 000 000 Mg of CO <sub>2</sub> E	
			no. of facilities reporting	% CO <sub>2</sub> E emissions reported	no. of facilities reporting	% CO <sub>2</sub> E emissions reported	no. of facilities reporting	% CO <sub>2</sub> E emissions reported	no. of facilities reporting	% CO <sub>2</sub> E emissions reported
electrical power plants <sup>a</sup>	4 636	2 337 171	2 176	100.0	1 633	99.9	1038	98.9	456	90.0
manufacturing <sup>b</sup>	362 829	817 431	47 134	95.5	7 777	80.1	926	53.2		
landfills <sup>c</sup>	2 216	296 259	2 216	100.0	2 216	100.0	632	85.8	23	22.7
commercial buildings <sup>d</sup>	4 580 000	121 687	6 000	6.4						
crop production <sup>e</sup>	1 028 971	78 825	2 721	4.6						
livestock production <sup>e</sup>	1 097 013	217 671	17 078	25.8						

<sup>a</sup> Based on fossil fuel input per power plant (18). <sup>b</sup> From Table 1. <sup>c</sup> From ref 19. Landfills reporting at the 100 000 and 1 000 000 Mg of CO<sub>2</sub>E thresholds include those storing greater than 1 000 000 and 15 000 000 Mg of municipal solid waste, respectively. <sup>d</sup> Based on data on fuel use per unit area of commercial buildings (20) and carbon coefficients (9). Commercial buildings reporting at the 1000 Mg of CO<sub>2</sub>E threshold include approximately those with an area greater than 46 000 m<sup>2</sup>. <sup>e</sup> From Table 2.

The choice between separate thresholds for individual greenhouse gases and one threshold based on a unified CO<sub>2</sub>E unit depends on the objectives of the emissions reporting framework and whether specific reductions for individual greenhouse gases are preferred over a general reduction in total greenhouse gas emissions. Our limited analysis (i.e., those sources included in Table 3), which includes roughly 55% of U.S. annual greenhouse gas emissions, indicates that establishing a reporting threshold below 10 000 Mg of CO<sub>2</sub>E may bring in a relatively substantial number of facilities, including some from the agricultural sector. Setting the threshold at 10 000 Mg of CO<sub>2</sub>E, appears to restrict the reporting requirements to fewer and relatively larger facilities, while excluding some economic sectors and the reporting of some significant greenhouse gases. Options to bring in additional sectors, additional greenhouse gases, and smaller facilities may include but are not limited to establishing separate thresholds for individual sectors, establishing separate thresholds for individual gases, and consolidating smaller emission sources into one reporting entity. Prior to establishing thresholds for emissions reporting, consideration should be given to the amount or percentage of emissions to be reported, the number and size of facilities that would be required to report, and whether to separately account for specific greenhouse gases.

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