

Greenhouse Gas Inventory Tools for States

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ABSTRACT

In conjunction with the U.S. EPA State and Local Climate Change Program (SLCCP), 38 states and Puerto Rico have developed greenhouse gas (GHG) inventories as the first step in assessing opportunities for mitigation. The Emission Inventory Improvement Program (EIIP) offers guidance on inventory preparation that is consistent with methods used at the national level. While comprehensive, this approach is resource- and data-intensive. As part of its continuing efforts to facilitate development of state inventories, the SLCCP has developed a set of spreadsheet tools. This paper describes the tools, which cover energy, landfills, industrial processes, agricultural sources, stationary and mobile sources (of methane and nitrous oxide), and forest carbon sequestration. The tools have been developed and applied in conjunction with inventory efforts in California and Texas, are being reviewed as part of inventory updates in Pennsylvania and Maryland, and will soon be available on the EPA Global Warming Web Site (www.epa.gov/globalwarming).

INTRODUCTION

In much the same way that emission inventories are a fundamental tool for developing strategies for air quality management, inventories are also useful when considering state efforts to reduce greenhouse gas (GHG) emissions. State GHG inventories generally have four objectives:

- Identify the principal GHG sources and sinks;
- Evaluate their relative importance;
- Provide the basis for assessing mitigation opportunities, i.e., policies and technologies to reduce emissions or enhance sinks; and
- Provide the foundation for state registries of GHG emission reductions.

Thirty-eight states and Puerto Rico have already prepared baseline GHG emission inventories. Generally, these inventories were completed according to guidance provided by EPA's State and Local Climate Change Program and documented in the Emission Inventory Improvement Program's (EIIP) *Volume VIII: Estimating Greenhouse Gas Emissions* (available on the internet at <http://www.epa.gov/ttn/chief/eiip/techreport/volume08/index.html>). The approach mirrors the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, identifying 14 greenhouse gas source categories and over 50 specific sources, each with its own estimation method. As with criteria pollutants, the basic framework for emission estimation is to multiply emission factors (which are generally constant for a given source) by activity data (which vary at the state level).

Of the states that have developed inventories, almost all estimated emissions for 1990, and only a handful have updated emissions for more recent years. In much the same way that criteria pollutant inventories build a foundation on a profile of emissions over several years, inventory updates provide a better foundation for action planning. A time series can be used to track progress, identify trends in emissions, account for changing economic and demographic conditions, relate changes in environmental regulations (e.g., landfill gas controls) to changes in GHG emissions, and evaluate GHG mitigation actions for program evaluation.

For example, California conducted its baseline inventory for 1990, which was a very dry year. As a result, hydroelectric generation was unusually low, and fossil fuel-fired power plants burned more fuel than usual to meet the electricity demand. California has twice updated its inventory, and found that its increases with respect to 1990 are much lower than for the nation as a whole, due at least in part to the high baseline in 1990. The California Energy Commission (which is responsible for the inventory) has been able to analyze the trends in emissions and relate them to several air quality and energy efficiency initiatives in the state.

The inventory tools described below make it much easier for states to develop time series of emissions, and to analyze the factors responsible for trends. Of course, they also make it much easier for states that have not yet conducted inventories to do so.

TOOL DEVELOPMENT

The inventory tools being developed by EPA's State and Local Climate Change Program are intended to lower the technical and resource barriers to inventory development. They have been developed in conjunction with three recent inventory efforts – the Florida inventory, which serves as a baseline for initial assessment efforts, the Texas inventory, which provides a basis for considering development of complementary air pollution and GHG controls, and the California inventory, which updates two earlier inventories and serves as a reference point for the state's effort to develop a GHG registry. The following paragraphs describe the strategy behind the tools, the scope of the tool development effort, and the basic design principles employed.

Strategy

Most states that have systematically addressed climate change have followed a three-phase approach: inventory development, mitigation planning, and implementation of actions. While inventory development is an important activity from the standpoint of building institutional knowledge, it is the third phase that actually yields GHG emission reductions. EPA's strategy is to offer tools to make the inventory process more efficient, thus reducing the resources and time required for the inventory and allowing those resources to be used for planning and, most importantly, implementation.

Scope

Initial development of these tools has focused on those sectors that represent the most significant sources. Although an inventory can cover more than 50 different source subcategories, a handful are usually most significant – carbon dioxide (CO₂) from fossil fuel combustion, nitrous oxide (N₂O) from agricultural soils, methane (CH₄) from landfills, CH₄ from enteric fermentation, CH₄ from manure management, and carbon flux from land use change and forestry. The first three are generally dominant sources in a state inventory (they comprise 81 percent, 5 percent, and 3 percent of total U.S. emissions, respectively); enteric fermentation and manure management are also significant sources (2 percent and 1 percent of emissions) and use some of the same data as the agricultural soils analysis; and land use change and forestry is the largest sink (comprising about 99 percent of U.S. carbon storage). Mobile and stationary sources of CH₄ and N₂O emissions, and industrial processes (e.g., cement production) also can be important. The plan is to eventually expand the inventory tools to cover the full range of source categories covered in the EIIP guidance, including natural gas and oil systems, coal mining, rice cultivation, agricultural waste burning, municipal waste combustion, and wastewater treatment.

Design

The tools are structured as Excel® workbooks. They prompt the user to provide state-specific data when possible; where the data reside in national databases (for example, reported to the Energy Information Administration or U.S. Department of Agriculture), the data sets have been imported into the spreadsheet. The tools use a variety of macros and user-friendly displays to facilitate calculation. They also provide the capability of estimating a complete sequence of emissions and sinks from 1990 – 1999 (and may be updated as additional data become available). The tools are designed to emphasize transparency in the calculations, so that state experts can make modifications where appropriate.

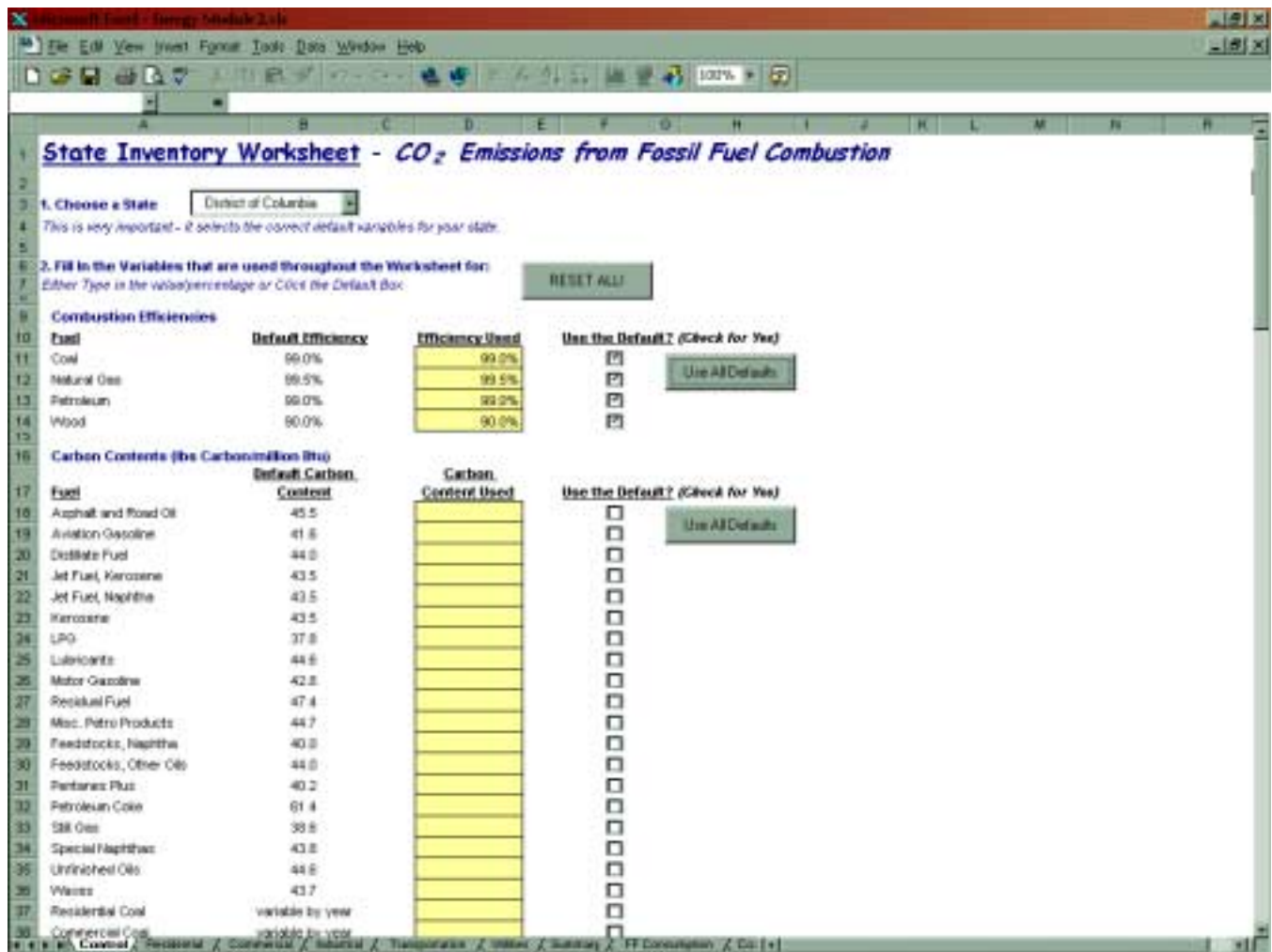
STATUS OF TOOLS

Energy

The energy tool estimates CO₂ emissions from fossil fuel combustion, a source accounting for nearly 95 percent of net U.S. energy sector emissions. The tool enables analysts to estimate emissions from the consumption of fuels such as coal, natural gas, petroleum, and wood categorized by the sectors in which they are combusted: utility, industrial, transportation, residential, and commercial. On the “Control” worksheet, users click on boxes to select default values or enter state-specific values for combustion efficiencies, carbon content of fuels, and storage factors for the non-energy use of fossil fuels (see Figure 1). Users then move through a series of worksheets corresponding to the combustion sectors identified above. On each of these input sheets, users can choose to supply their own data or use default energy consumption data obtained from the Energy Information Administration’s (EIA) State Energy Data Reports (SEDR).

Once all values have been supplied, the tool calculates annual emission estimates for over fifty fuel/source combinations and produces summary tables and graphs. A prototype was used to estimate CO₂ emissions from fossil fuel combustion in three recently completed state inventories (Florida, Texas, and California).

Figure 1. Control Sheet for the Energy Tool.



Agriculture

The agriculture tool calculates CH₄ and N₂O emissions from enteric fermentation, manure management, and agricultural soils. It follows the EIIP methodology for estimating agriculture sector

emissions. For each of the required input values, users have the option of supplying their own activity data and emission factors or using default values embedded in the tool.

The tool guides the user through the necessary inputs for each sub-source. Specifically, calculating emissions from enteric fermentation requires population data for domesticated animals, categorized into 16 sub-categories based on species, production system, and (for cattle) age. Animal population data, typical animal mass, volatile solid production per unit of animal mass, and methane emission factors drive manure management emission estimates. Agricultural soil emissions break down into three categories: (1) direct emissions due to cropping practices, (2) direct emissions due to animal production, and (3) indirect emissions induced by agricultural applications of nitrogen. The first category includes emissions from application of synthetic and organic fertilizer, production of nitrogen-fixing crops, application of crop residues to soils, and cultivation of histosols. Key data required to estimate emissions from these activities include fertilizer application tonnages, crop production data, and acres of histosols (organic soils) cultivated. The second category, direct emissions from animal production, requires animal data population and values for typical animal mass and the amount of Kjeldahl nitrogen (a measure of organically bound and ammonia nitrogen) produced per kilogram of animal mass. Indirect emissions are calculated using activity data on fertilizer application and livestock manure.

Once the user has entered available data or selected to use default data, the tool generates annual emission estimates, by sub-source, by gas. It splits out direct and indirect N₂O emissions from agricultural soils and provides summary graphs to illustrate trends. As with the energy tool, a prototype of the agriculture tool was applied to the recently completed Florida, Texas, and California inventories.

Waste

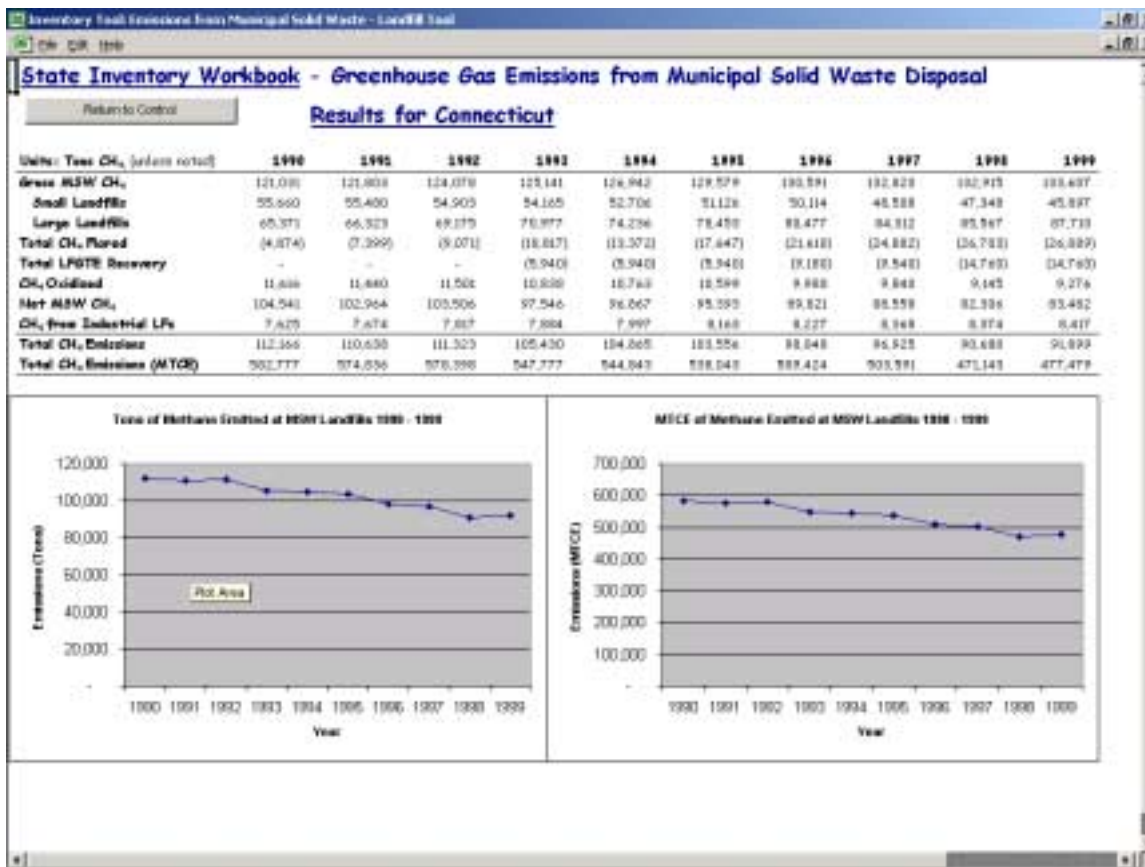
The waste tool calculates CH₄ emissions from municipal solid waste (MSW) disposal. Relying on data from sources such as the EPA's Landfill Methane Outreach Project (LMOP) database, and the U.S. Census Bureau, the tool calculates emissions estimates using as much or as little data as the user can provide. The "control" sheet of the tool asks the user to enter either landfill-specific annual disposal data, statewide annual disposal data, state waste-in-place (i.e., the volume of accumulated waste placed within the last 30 years) data, or to use default data. Similarly, the user is prompted to either input their own data on methane flaring at landfills and landfill gas recovery at landfill gas-to-energy projects, or to use default data based on statistics collected by EPA. Finally, the tool assumes that methane emissions from industrial landfills are equal to the default value of 7 percent of methane generation from MSW, but provides users with the opportunity to change that percentage.

The tool provides both a summary table and graphs displaying total CH₄ emissions in terms of tons and metric tons of carbon equivalents (MTCE) (see Figure 2). A prototype of the tool was applied to the recently completed Texas Inventory.

Industrial Processes

The industrial processes tool calculates CO₂, CH₄, N₂O, and HFC, PFC, and SF₆ emissions from non-energy related industrial activities. The industrial processes covered by the tool include cement manufacture, lime manufacture, limestone use, aluminum production, carbon dioxide manufacture, soda ash, nitric acid production, adipic acid production, use of substitutes for ozone-depleting substances (ODS), semiconductors, magnesium, electric utilities, HCFC-22 production, aluminum production, petrochemical production, and silicon carbide production. Users can choose to supply emission factors or use default factors. They then proceed through the process-specific worksheets to input activity data (generally, levels of production or consumption) or select to use default data, where available.

Figure 2. Output sheet in the waste tool.



The emissions summary sheet provides total annual emissions by process and by gas. It also displays five different graphs showing total emissions by gas for the sum of all processes and for individual processes. A draft version of the module has been completed.

Mobile Sources

The mobile sources tool calculates N₂O and CH₄ emissions from the transportation sector. This sector is divided into the two major modes of transportation: 'Highway Vehicles' and 'Other.' The 'Other' modes of transportation include aircraft, boats and vessels, locomotives, and other non-highway sources such as agricultural machinery. The control sheet prompts users to select the modes of transport they would like to analyze. It then directs users through a series of worksheets that prompt them to select default emission factors and activity data or input their own.

Estimating emissions from Highway Vehicles requires data on the vehicle miles traveled by vehicle type, control technology distribution for vehicle type and model year, age distribution by vehicle type, and annual vehicle mileage accumulation by vehicle type and model year. Calculating emissions from 'Other' modes of transportation requires data on fuel consumption and type. Sources for default activity data include the Federal Highway Administration's *Highway Statistics* series, EPA's Office of Transportation and Air Quality, and, potentially, the U.S. Department of Transportation's Volpe Center. The tool uses national emission factors obtained from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1999* (EPA 2001) as defaults.

The emissions summary sheet displays a breakdown of emissions for the chosen mode by gas and a total of emissions from all modes by gas. A draft version of the module has been completed.

Stationary Sources

The stationary sources tool calculates CH₄ and N₂O emissions from stationary source combustion. Using EIA SEDR data, it estimates emissions based on primary fuel type (coal, oil, natural gas, or wood) and sector (residential, commercial, industrial, or utilities). The control sheet prompts users to choose Intergovernmental Panel on Climate Change (IPCC) default emission factors or enter state-specific emission factors for fuel types in each sector. It then guides them to input annual energy consumption data for each fuel type by sector or select to use the default SEDR data embedded in the tool.

The tool presents total emissions estimates and estimates by gas in a series of tables and graphs. It includes both multi-sector and individual sector graphs that display emissions by fuel type. A draft version of the module has been completed.

Forest Carbon Sequestration

This tool, still in the conceptual stages, will provide “look-up” tables based on estimates of carbon flows in aboveground biomass, understory, litter, and soils within forests, as well as carbon storage in forest products and landfills. These estimates are derived from forest sector carbon models developed by the US Department of Agriculture Forest Service and used for the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. EPA’s State and Local Climate Change Program has funded additional work to break these estimates out on a state-by-state basis.

AVAILABILITY

As noted above, most of the tools have already been applied in draft form. Beta versions of the energy, agriculture, waste, and industrial process tools are currently under review by researchers at Pennsylvania State University and the Maryland Department of Environmental Management. Later this year, after the development, review, and beta-testing process is complete, the tools will be posted on the EPA Global Warming Site (www.epa.gov/globalwarming) in a downloadable format. Meanwhile, states interested in using a draft version of the tools to assist with beta-testing can contact Andrea Denny (her contact information listed on the authors’ line at the beginning of this paper) to request a copy of the tools.

After initial development has been completed, EPA may make CDs available with the complete set of tools and the accompanying inventory methodology guidance. The State and Local Climate Change Program plans to periodically update the EIIP guidance on GHG inventories, and will make conforming changes to the inventory tools.

As the effort continues, EPA may develop an integrating spreadsheet tool that would draw results from each of the individual tools to provide summary results. EPA plans to provide updated versions of the tools as data for subsequent years become available.

REFERENCES

Emissions Inventory Improvement Program. *Volume VIII: Estimating Greenhouse Gas Emissions*. Prepared by ICF Consulting for U.S. Environmental Protection Agency. 1999. Available on the internet at <http://www.epa.gov/ttn/chief/eiip/techreport/volume08/index.html>.

U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1999*. USEPA/Office of Air and Radiation. Washington, DC, 2001. EPA 236-R-01-001. Available on the internet at <http://www.epa.gov/globalwarming/publications/emissions/index.html>.

KEYWORDS

Greenhouse gas, emission inventory, energy, agriculture, industrial processes, landfill, waste