Electricity Consumption Greenhouse Gas Inventory Tool for States

Andrea Denny, Art Diem
U.S. Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Avenue NW
Mail Code: 6202J, Washington, DC 20460
denny.andrea@epa.gov

Lauren Pederson, Anne Choate, Joseph Herr
ICF International, 1725 Eye St. NW, Suite 1000, Washington, DC 20006
LPederson@icfi.com

ABSTRACT

The U.S. EPA State and Local Branch has been developing guidance and providing technical support to states on their greenhouse gas (GHG) emission inventories since 1990. EPA has developed a suite of Microsoft Excel-based tools—the State Inventory Tool (SIT)—to facilitate development of GHG inventories in a cost effective and transparent manner. The Electricity Consumption module is the eleventh, and newest, module developed as part of the SIT suite of modules. This module is designed to fill the gap between generation-based estimation methodologies (recommended at the state level to avoid double counting and to align with readily available data) and consumption-based estimates. The importance of consumption-based estimates is highlighted in the action planning phase, as states scrutinize emissions and screen potential mitigation actions. While electricity is used in all states, the magnitude and carbon intensity of electricity generation varies significantly by state.

The Electricity Consumption module calculates carbon dioxide equivalent (CO_2 Eq.) emissions from electricity consumption of various equipment types in four end-use sectors. Based on state electricity consumption data from the Energy Information Administration's State Energy Data System, the module enables states to estimate emissions from industrial, transportation, residential, and commercial sources consuming electricity. Data provided in the module are based on publicly available information. In this paper, we will provide an overview of the new Electricity Consumption model and provide some examples of how the outputs of this module can inform mitigation actions at the state level.

INTRODUCTION

The State Inventory Tool (SIT) was developed to assist states in the inventory process. Prior to the development of the SIT, EPA developed the States Workbook for estimating GHG emissions. In 1998, EPA revised the States Workbook under the EPA's state Emission Inventory Improvement Program (EIIP).The EIIP was a joint program sponsored by EPA and the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (STAPPA/ALAPCO). The goal of EIIP was to promote the development and use of standard procedures for collecting, calculating, storing, reporting, and sharing air emissions data. During this revision, the States Workbook was expanded it to follow the format of EIIP guidance documents for criteria air pollutants and renamed as EIIP Volume VIII. The result was a comprehensive, stepwise approach to estimating GHG emissions at the state level. This detailed methodology was appreciated by states with the capacity to devote considerable time and resources to the development of emission inventories. For other states, the EIIP guidance was overwhelming and impractical for them to follow from scratch. EPA recognized the resource constraints facing the states and developed the SIT. The SIT covers most major sources of GHG emissions and incorporates state-of-the-art accounting methods into a user-friendly, worksheet-style format that reduces the resource intensity of developing GHG estimates while increasing accuracy and consistency across states. The SIT is divided into modules based on the source

of emissions inventoried, as shown in Figure 1. A synthesis tool and a projection tool accompany the source modules.

Figure 1. Modules and Sectors Included in the State Inventory Tool

Modules	Sub-sectors	
Carbon Dioxide from Fossil Fuel Combustion (CO_2)	• Residential • Commercial • Transportation	• Electric Power • Bunker Fuels • Industrial
Indirect Emissions from Electricity Consumption (CO_2 Eq.)	• Residential • Commercial • Transportation	• Industrial
Stationary Combustion (CH_4, N_2O)	• Residential • Commercial	• Electric Power • Industrial
Mobile Combustion (CH_4, N_2O)	• Highway Vehicles • Aviation • Boats & Vessels	• Locomotives • Other Non-Highway Sources • Alternative Fuel Vehicles
Coal (CH_4)	• Coal Mining	• Abandoned Underground Coal Mines
Natural Gas and Oil (CO_2, CH_4)	• Natural Gas - Production • Natural Gas -Transmission • Natural Gas - Distribution	• Natural Gas - Venting & Flaring • Petroleum Systems
Industrial Processes (CO_2, CH_4, N_2O)	• Cement Production • Lime Manufacture • Limestone and Dolomite Use • Soda Ash Manufacture and Consumption • Iron and Steel Production • Ammonia Manufacture • Nitric Acid Production • Adipic Acid Production	• Aluminum Production • HCFC-22 Production • Consumption of Substitutes for Ozone-Depleting Substances • Semiconductor Manufacture • Electric Power Transmission and Distribution • Magnesium Production and Processing
Agriculture (CH_4, N_2O)	• Enteric Fermentation • Manure Management • Agricultural Soil Management	• Rice Cultivation • Agricultural Residue Burning
Land Use, Land Use Change, and Forestry (CO_2, CH_4, N_2O)	• Forest Carbon Flux • Liming of Agricultural Soils • Urban Trees	• N_2O from Settlement Soils • Non-CO_2 Emissions from Forest Fires • Landfilled Yard Trimmings and Food Scraps
Solid Waste (CO_2, CH_4)	• Landfills	• Waste Combustion
Wastewater (CH_4, N_2O)	• Municipal Wastewater	• Industrial Wastewater - Fruits & Vegetables, Red Meat, Poultry, Pulp & Paper
Synthesis Tool	• Gathers emissions from all modules into one summary table	
Projection Tool	• Projects emissions estimates into the future	

The original ten SIT source modules correspond to EIIP chapters and automate the steps states would need to take in developing their own emission estimates in a manner consistent with prevailing

national and state guidelines. The Electricity Consumption module is the eleventh, and newest, module developed as part of the SIT suite of modules. EPA recognized a need for a module and guidance to estimate indirect greenhouse gas emissions from electricity consumption at the state level, including emissions at the point of consumption (i.e., indirect emissions from electricity consumption) that would help states achieve the goal of encouraging action and reducing emissions. This paper provides an overview of the development of the Electricity Consumption module including the activity data and emission factors used by the module, and summarizes potential uses for the electricity consumption emission estimates.

BODY

The Electricity Consumption Module

The Electricity Consumption module's emissions estimates highlight an important distinction between direct and indirect greenhouse gas emissions. Direct emissions (estimated in the separate CO_2 from Fossil Fuel Combustion module) result from the combustion of fossil fuels at the electricity generating station, whereas indirect emissions are attributed to the point of use (e.g., residential electricity consumption). State inventories can include direct emissions associated with electricity generation occurring in the state and/or indirect emissions associated with electricity consumed within the boundaries of the state. Because electricity consumption within a state does not necessarily correspond to electricity generated in that state, emissions from consumption (indirect emissions) are not likely to be the same as emissions from generation (direct emissions). In addition, emission estimates from generation do not typically include transmission and distribution losses. EPA encourages states to include direct emissions in their inventory estimates, and include indirect emissions as a separate line item to inform potential mitigation actions. Including both direct and indirect estimates into the inventory totals may lead to double counting.

Emissions from electricity consumption are categorized into the four main end-use sectors used to measure and analyze energy use: industrial, transportation, residential, and commercial. Electricity is consumed in these sectors primarily for lighting, heating, electric motors, appliances, electronics, and air conditioning. The Electricity Consumption module calculates CO_2 equivalent emissions for each of these sectors by multiplying electricity consumption of end-use equipment in each sector by emission factors, while taking into account electricity losses resulting from the transmission and distribution of electricity. The general equation used to calculate indirect CO_2 emissions from electricity consumption is shown in Equation (1) below.

Equation (1) Indirect Electricity Emissions = Total State Consumption (kWh) × End-Use Equipment Consumption (%) × [Emission Factor (lbs CO2E/kWh) × (1+ Transmission Loss Factor (%))]

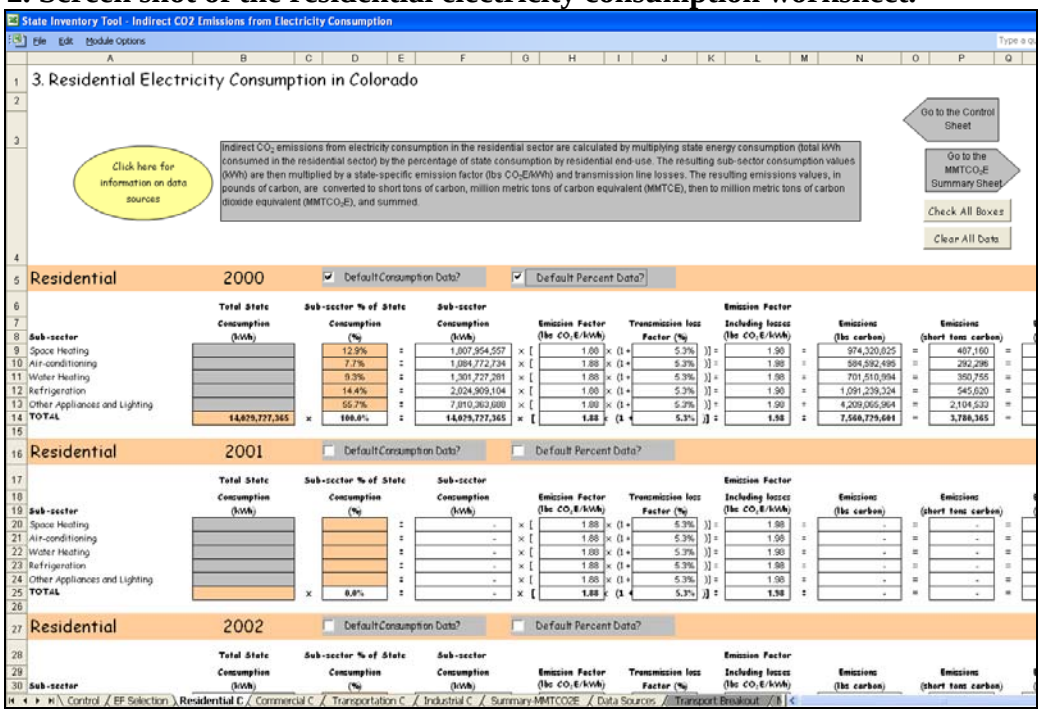
Using this equation as a guide, the following sections describe the state electricity consumption data, end-use equipment percentages, and transmission loss and emission factors used to calculate indirect greenhouse gas emissions from electricity consumption for each sector.

Activity Data

State electricity consumption data by consuming sector is one of the key pieces of activity data required to estimate emissions in the module. The Electricity Consumption module provides input cells where states enter total electricity consumption data (in kilowatt-hours). In cases where state-specific data are unavailable, default electricity consumption data from the Energy Information Administration's State Energy Data System (EIA, 2009a) are provided in the module by consuming sector (e.g.,

residential, commercial, transportation, and industrial). Figure 2 shows an example of the residential electricity consumption worksheet with default data entered for Colorado.

Figure 2. Screen shot of the residential electricity consumption worksheet.



The second piece of activity data required to estimate indirect emissions from electricity consumption is the percent of electricity consumed by specific end-use equipment for each sector. The end-use equipment types associated with each sector in the Electricity Consumption module are provided in Figure 3. The Electricity Consumption module calculates electricity consumption for each sector by multiplying total state electricity consumption by the percent energy consumption of end-use equipment. The end-use equipment statistics are provided from a variety of publicly available publications, discussed for each sector below. For most sectors, the publications provide an estimate of regional end-use equipment percent consumption for the United States. EPA assigned end-use consumption percentages for each state based on the regional categorization from each data source. For the transportation sector, state-level percentages were available.

Figure 3. End-Use Equipment by Sector in the Electricity Consumption module.

Sector	End-Use Equipment	
Residential	• Space Heating • Air-conditioning • Water Heating	• Refrigeration • Other Appliances and Lighting
Commercial	• Space Heating • Cooling • Ventilation • Water Heating • Lighting	• Cooking • Refrigeration • Office Equipment • Computers • Other
Industrial	**Indirect Uses- Boiler Fuel** • Conventional Boiler Use • CHP and/or Cogeneration Process **Direct Uses- Total Process** • Process Heating • Process Cooling and Refrigeration • Machine Drive • Electro-Chemical Processes	• Other Process Use **Direct Uses- Total Nonprocess** • Facility HVAC • Facility Lighting • Other Facility Support • Onsite Transportation • Other Nonprocess Use
Transportation	• Automated Guideway • Bus (charged batteries) • Cable Car • Commuter Rail • Heavy Rail	• Inclined Plane • Light Rail • Trolleybus • Other

Residential end-use equipment default consumption percentages used in the Electricity Module are from the Residential Energy Consumption Survey (RECS) (EIA, 2008a). The Residential Energy Consumption Survey (RECS) provides information on energy use in residential housing units in the United States. This information includes: the physical characteristics of the housing units; the appliances utilized including space heating and cooling equipment; demographic characteristics of the household; the types of fuels used; and other information that relates to energy use. The RECS also provides energy consumption and expenditures data for: natural gas, electricity, fuel oil, liquefied petroleum gas (LPG), and kerosene. The RECS is published in 4 year intervals and, as a result, the Electricity Consumption Module uses 2001 and 2005 RECS regional data, and interpolates to estimate intervening years. Activity data provided in the module beyond 2005 is proxied to the 2005 values.

Commercial end-use equipment default consumption percentages are from the Commercial Building Energy Consumption Survey (CBECS) (EIA, 2008b). The Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures. Commercial buildings include all buildings in which at least half of the floorspace is used for a purpose that is not residential, industrial, or agricultural. The survey includes building types that might not traditionally be considered "commercial," such as schools, correctional institutions, and buildings used for religious worship. The CBECS is published in 4 year intervals and, as a result, the Electricity Consumption Module uses 2003 regional data and proxies other years in the time series to this 2003 estimate.

Transportation end-use equipment default consumption percentages are from the National Transit Database (NTD) (FTA 2007). The NTD was established by Congress to be the Nation’s primary source for information and statistics on the transit systems of the United States. The data contained in the 2007 National Transit Database (NTD) is one of three publications comprising the National Transit

Database Program's Annual Report. It provides detailed summaries of financial and operating data submitted to the Federal Transit Administration (FTA) by the nation's mass transit agencies for the report year ending on or between January 1 and December 31, 2007. The Electricity Consumption Module uses 2007 state-level data from the NTD, and proxies other years in the time series to 2007.

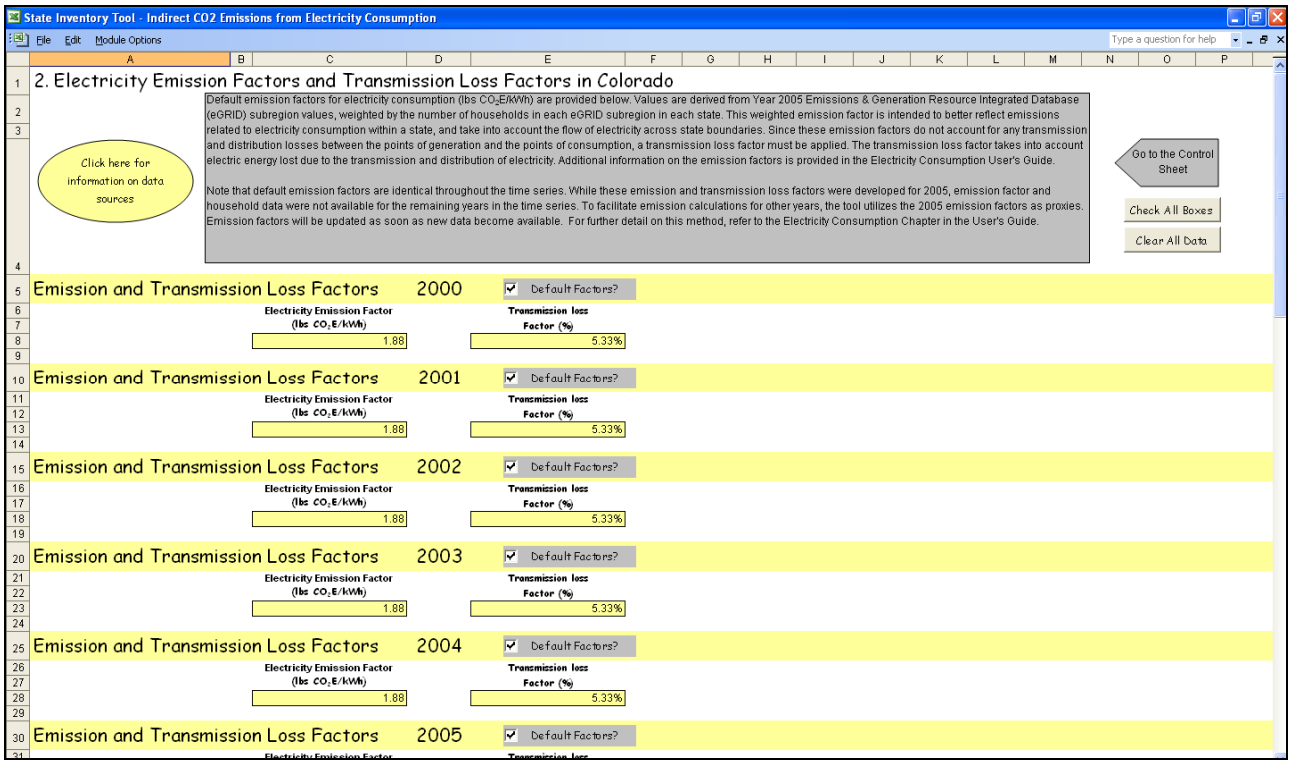
Industrial end-use equipment default consumption percentages are from the Manufacturing Energy Consumption Survey (MECS) (EIA 2009b). The Manufacturing Energy Consumption Survey (MECS) is the Federal Government's comprehensive source of information on energy use by U.S. manufacturers. The survey collects data on energy consumption and expenditures, fuel-switching capability, onsite generation of electricity, byproduct energy use, and other energy related topics. The Electricity Consumption Module uses 2002 regional data from the MECS, and proxies other years in the time series to 2002. The Electricity Consumption Module utilizes regional-level data available from the MECS.

Emission Factors

To calculate emissions for each sector, the Electricity Consumption module multiplies the sector specific electricity consumption for each type of end-use equipment, by state electricity emission and transmission loss factors. Default state emissions factors provided in the module are derived from the Emissions & Generation Resource Integrated Database (eGRID). eGRID is a comprehensive inventory of environmental attributes of electric power systems. The preeminent source of air emissions data for the electric power sector, eGRID is based on available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. eGRID integrates many different federal data sources on power plants and power companies, from three different federal agencies: EPA, the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC) (U.S. EPA 2009b). eGRID also provides aggregated data by state, U.S. total, company, and by three different sets of electric grid boundaries.

Within the Electricity Consumption module, states should use state-specific emission factors and transmission loss factors into the worksheet shown in Figure 4. If state-specific factors are not available, users may use default emission factors for electricity consumption (in lbs CO_2E/kWh) provided in the module. These default emissions factors were derived from 2005 Emissions & Generation Resource Integrated Database (eGRID) subregion values, and weighted by the number of households in each eGRID subregion in each state (U.S. EPA 2009b). The subregion values were weighted by the number of households in each eGRID subregion to better reflect emissions related to electricity consumption within a state, and take into account the flow of electricity across state boundaries. For example, while Texas is part of both the SPSO and ERCT eGRID subregions, the majority of the state's population is within the ERCT subregion. By weighting the subregion emissions rates by the number of households in the SPSO and ERCT subregion, the calculated rate more accurately reflects the electricity emissions profile for the state. Since emissions and emission rates in eGRID represent emissions and rates at the point(s) of generation the eGRID emission factors do not account for transmission and distribution losses between the points of generation and the points of consumption. A transmission loss factor must be entered or an eGRID default value can be used to account for transmission and distribution losses between the point of generation and the point of consumption.

Figure 4. Screen shot of the emission and transmission loss factor worksheet.



Using Module Outputs

The American Recovery and Reinvestment Act of 2009 (ARRA) included the largest single investment in energy efficiency in U.S. history and is a major recent development in state energy efficiency activity. In 2009, total budgets for electricity efficiency programs reached approximately $3.4 billion. As a result of this influx of funding, states are faced with the need to develop innovative program designs that will establish deeper and broader energy efficiency savings in order to achieve statewide savings goals significantly beyond what is currently being achieved (Barbose, Goldman, and Schlegel 2009). As part of establishing innovative program designs, numerous new states have adopted leading building energy codes to improve efficiency in all new residential and commercial building construction. Twenty-four states have adopted Energy Efficiency Resource Standards (EERS) that establishes long-term, fixed efficiency savings targets – double the number of states with this type of policy in 2006. The Electricity Consumption module could be used to analyze the GHG impact of these statewide energy efficiency efforts. The decreased electricity consumption resulting from energy efficiency programs and improved building energy codes could be measured by the Electricity Consumption module and could illustrate the relationship between greenhouse gas emissions and energy efficiency program funding.

In addition, the Electricity Consumption module could be used to inform state policies targeted at specific sectors and end-use equipment for the selected state. The emissions estimates on the summary worksheet can be used to inform mitigation actions across an array of potential state policies and incentives. For example, emissions from lighting and cooling in Colorado's commercial sector represent over 50 percent of commercial emissions for 2007. Using this information, states can develop policies and incentives that encourage increased energy efficiency in lighting fixtures and cooling systems across this sector. The same analysis can be performed for industrial sector emissions, where machine drives and facility HVAC systems comprise approximately 60 percent of emissions for Colorado's industrial sector in 2007. Policies and incentives could either increase the energy efficiency of these systems, or retrofit programs could be established to convert inefficient facilities.

CONCLUSIONS

The Electricity Consumption Module will add value to state greenhouse gas inventories by allowing states to differentiate between direct and indirect greenhouse gas emission estimates, and will avoid double counting of direct and indirect emissions by presenting separate totals. Since the Electricity Consumption module follows the same structure as the other State Inventory Tool modules, states will be able to use the module with relative ease. The outputs will not only provide valuable information state greenhouse gas inventory reports, but will also help inform mitigation across all electricity consuming sectors. Future improvements to the Electricity Consumption module may include updated emission factors and/or activity data depending on the timing and nature of future data releases.

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KEY TERMS

Indirect Greenhouse Gas Emissions; Greenhouse Gas Inventory; Electricity Consumption