Residential and Commercial Buildings Sector

Part 2 of 6 Supporting Documents

Sector-Specific Issues and Reporting Methodologies Supporting the General Guidelines for the Voluntary Reporting of Greenhouse Gases under Section 1605(b) of the Energy Policy Act of 1992

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2.0 Residential and Commercial Buildings Sector

This document supports and supplements the General Guidelines for reporting greenhouse gas information under Section 1605(b) of the Energy Policy Act (EPAct) of 1992. The General Guidelines provide the rationale for the voluntary reporting program and overall concepts and methods to be used in reporting. Before proceeding to the more specific discussion contained in this supporting document, you should read the General Guidelines. Then read this document, which relates the general guidance to the issues, methods, and data specific to the residential and commercial buildings sector. Other supporting documents address the electricity supply sector, the industrial sector, the transportation sector, the forestry sector, and the agricultural sector.

The General Guidelines and supporting documents describe the rationale and processes for estimating emissions and analyzing emissions-reducing and carbon sequestration projects. When you understand the approaches taken by the voluntary reporting program, you will have the background needed to complete the reporting forms.

The General Guidelines and supporting documents address four major greenhouse gases: carbon dioxide, methane, nitrous oxide, and halogenated substances. Although other radiatively enhancing gases are not generally discussed, you will be able to report nitrogen oxides (NO_x), nonmethane volatile organic compounds (NMVOCs), and carbon monoxide (CO) after the second reporting cycle (that is, after 1996).

The Department of Energy (DOE) has designed this voluntary reporting program to be flexible and easy to use. For example, you are encouraged to use the same fuel consumption or energy savings data that you may already have compiled for existing programs or for your own internal tracking. In addition, you may use the default emissions factors and stipulated factors that this document provides for some types of projects to convert your existing data directly into estimated emissions reductions. The intent of the default emissions and stipulated factors is to simplify the reporting process, not to discourage you from developing your own emissions estimates.

Whether you report for your whole organization, only for one project, or at some level in between, you will find guidance and overall approaches that will help you in analyzing your projects and developing your reports. If you need reporting forms, contact the Energy Information Administration (EIA) of DOE, 1000 Independence Avenue, SW, Washington, DC 20585.

2.1 Residential and Commercial Buildings: Overview

In 1990, the residential and commercial buildings sector accounted for 24 percent of the natural gas, 7 percent of the fuel oil, and 65 percent of the electricity consumed annually in the United States. This represents 35 percent of all the primary energy consumed in the United States, and an expenditure of over $192 billion dollars (EIA 1991). Included in the residential sector are all single family detached dwellings, multifamily dwellings, condominiums, townhouses, and manufactured homes. The commercial sector includes Federal government buildings, post offices, colleges and universities, hospitals, elementary and secondary schools, churches, and the non-residential buildings owned and operated by private businesses, including commercial buildings that are part of industrial and agricultural complexes.

The residential and commercial buildings sector does not include industrial or agricultural processes, which are covered in the supporting documents for those sectors.

2.1.1 Reporting Entities

This sector contains a wide range of potential reporters, from individuals to large organizations. On the residential side, reporters could include electric and natural gas utilities (especially from a demand-side management [DSM] perspective), consumer groups, Federal agencies, state governments, municipal housing authorities, multifamily complex owners, homeowners/renters, builders and developers, and energy service companies. The commercial side of the sector could include many of these same reporters, plus businesses, churches, industrial plants, educational institutions and individual schools—indeed, any entity that owns, operates, or provides energy-related services for buildings may report in this sector.

2.1.2 Sector-Specific Issues

Two factors create reporting challenges in this sector. The first is that many of the emissions reductions activities do not reduce emissions directly; instead, they cause reductions in energy demand or use energy more efficiently. Typically, that energy is in the form of electricity, so the energy savings must be traced back through the transmission and generation system to gauge how emissions change as a result of these activities. The second factor is that many potential reporters may be involved in the same or related activities that reduce emissions.

Estimating emissions reductions resulting from energy savings can be complicated. However, the process will be simplified if you use the default emissions factors supplied in Appendix B (for fuels) and Appendix C (for electricity); both appendixes are at the end of this volume. These default factors are not as accurate as factors specific to your site, because there is not a direct one-for-one relationship between energy production and greenhouse gas production. Different generating resources have different greenhouse gas production characteristics. Nuclear power and renewable energy sources such as hydroelectric, wind, and solar have essentially zero emissions whereas natural gas, oil, and coal (fossil fuels) powered electric generating stations produce significant greenhouse gas emissions (with natural gas typically producing the least and coal the most). If carbon flows are accounted for, biomass powered generation has a zero emissions factor.

Moreover, the generation mix changes from time to time. Since electric utility loads are not steady by hour of the day or by season, utilities will typically have several plants that they phase in and out of production to meet their loads. These plants are used or dispatched (in industry terms) based on economics. Depending upon availability, the plant producing power at the lowest marginal cost will be dispatched first and the plant producing power at the highest cost last.

This process is further complicated by time-of-day and magnitude issues. For example, building envelope and heating, ventilating, and air conditioning (HVAC) improvements reduce loads depending on weather, but retrofitting high-efficiency equipment and appliances cause reduced consumption whenever they are used.

Some technologies simply shift the load to another time period. For example, a thermal storage system shifts heating or cooling load from the utilities on-peak period to an off- or partial-peak period. The greenhouse gas impact depends entirely on the generating plant mix and how that mix is changed by the measure. For example, if the base load plant is nuclear and the peaking plant is natural gas fired, then reducing the peak load while increasing the base load would lead to reductions in greenhouse gas emissions. If the base load plant is coal and the peaking plant is natural gas, then reducing the peak load while increasing the base load could result in increased greenhouse gas emissions.

The potential for multiple reporting and joint reporting is another key issue in this sector. For example, a utility may wish to report energy savings data for its commercial lighting efficiency rebate program. A company that utilized the rebates offered by the electric utility may wish to report emissions reductions also. An organization that has two or more structural levels may wish to report at each level. Both agencies that promulgate and enforce building codes and standards and building owners who comply with the standards may wish to report resulting greenhouse gas emissions reductions. In some instances, you may wish to cooperate with other reporters to develop more complete reports than each of you could submit independently. At the least, you should identify other potential reporters of the same activity.

2.2 Estimating and Reporting Greenhouse Gas Emissions

The General Guidelines ("What is Involved in Reporting Emissions?") explain that reporting information on greenhouse gas emissions for the baseline period of 1987 through 1990 and for subsequent calendar years on an annual basis is considered an important element of this program. If you are able to report emissions for your entire organization, you should consider providing a comprehensive accounting of such emissions so that your audience can gain a clear understanding of your overall activities.

Your emissions may be direct (from fuel used on-site) or indirect (from grid-supplied electricity). To report direct emissions, determine your fuel use for the reporting year and use the table in Appendix B to calculate the emissions from that fuel use. To calculate emissions resulting from electricity use, you may use the default state level factors in Appendix C or calculate factors specific to your electricity source using the guidance in Section 2.8.

2.3 Analyzing Emissions Reduction Projects

Section 2.2 discussed estimating emissions; this section and the following sections provide guidance for analyzing and reporting projects that have reduced those emissions. This section provides an overview and rationale for the process, relating the General Guidelines to the residential and commercial buildings sector. The following sections discuss specific emissions-reducing measures and methods for estimating the reductions achieved.

Figure 2.1 presents a simplified view of the project analysis process in the residential and commercial buildings sector. This process is discussed in the General Guidelines; this and the following sections augment the general guidance with considerations specific to this sector.

Define the project. In the project definition step, you determine whether to report emissions levels for your whole organization (entity-level reporting) or some part of it. This decision may be based, in part, on what data you have, what effects are associated with the project (for example, will effects show up at the overall organization level?), and who the audience for your report will be (for example, will interested environmental groups find a partial report credible?).

The analysis of emissions reductions projects in the residential and commercial buildings sector consists of the basic steps that are discussed in the General Guidelines under the heading "How Should I Analyze Projects I Wish to Report?":

Establish a reference case to use as a basis for comparison with the project. You may determine your reference case in conjunction with defining your project, since you must establish a basis for comparison. If you wish to compare overall emissions from the project year with those of an earlier year, you may choose a basic reference case. If, however, your purpose is instead to highlight the effects of a specific emissions reductions project for which no historical comparison exists, you may choose a modified reference case.

Identify effects of the project. If you identify significant effects outside your current project boundaries, you may choose to redefine your project. In any case, you should identify all effects you are able to and, if they are large, quantify them to the extent possible.

Estimate emissions for the reference case and the project. If you have monitored data on your total emissions and you are reporting at the entity level, you are ready to report after you identify any external effects. Otherwise, whether emissions are direct or indirect may be important in choosing estimation methods. Direct emissions may be estimated from fuel consumption data and from stipulated factors associated with technologies used to generate electricity. However, many of the projects in this sector involve indirect emissions, especially activities whose purpose is to conserve electricity or reduce its use. Indirect emissions are estimated from energy savings data (for example, reducing the amount of electricity used to light buildings) that are then traced back to the generation system to determine the associated emissions reductions.

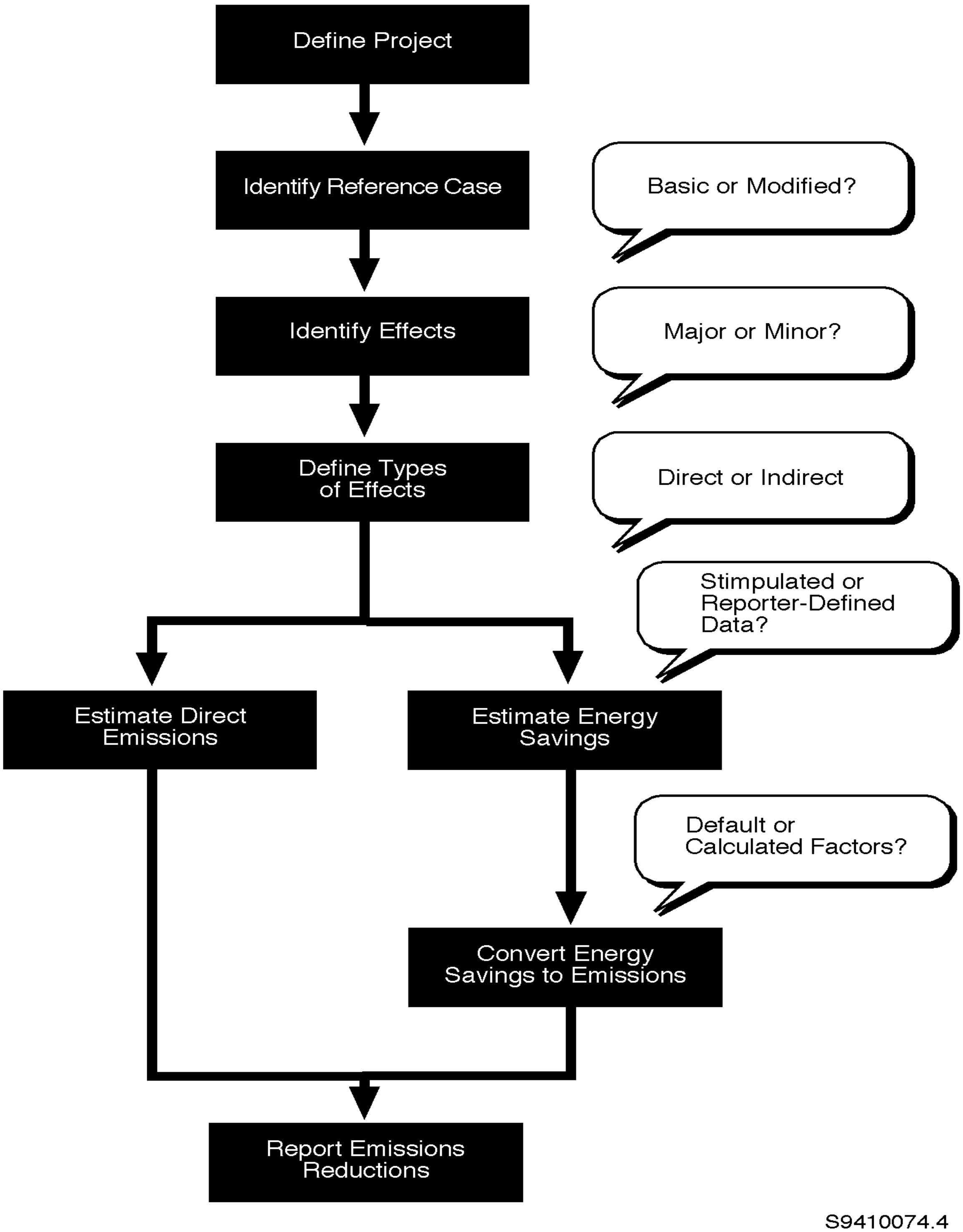

Figure 2.1. Many Projects in the Residential and Commercial Buildings Sector Involve Estimating Energy Savings and Converting Those Savings to Emissions Reductions.

The choice of method for estimating the effects of projects that act primarily on a single device or group of devices depends upon the nature and timing of the load involved. Loads can be categorized according to whether they involve constant or variable levels, and whether the hours that those loads occur are fixed.

Project analysis can be simple or complex, depending upon a number of factors involved in each step. This section discusses the major methodologies used to calculate emissions reductions, but you have the flexibility to choose how to define your project and reference cases and how to estimate emissions reductions. If you wish to report a standard project, you will find the descriptions of projects and the stipulated factors that you need in Section 2.6.1. If you intend to develop a reporter-designed project, you can use whatever methods you choose, providing your analysis and report meet the minimum reporting requirements described in the General Guidelines, "What Are the Minimum Reporting Requirements?"

2.4 Energy-Conservation Measures

A multitude of demand-side, energy-conservation activities can be applied in commercial and residential buildings to reduce energy use. In addition, new technologies are constantly being developed and marketed that increase the efficiency of mechanical and electrical systems in buildings. Some of these activities are listed in Table 2.1, along with pointers to the subsections that discuss appropriate estimation methods. The activities listed are further supplemented in Appendix 2.A. Project types not explicitly included in either list can be reported as long as they meet minimum project analysis and reporting requirements.

2.5 Estimation Techniques

Energy conservation in buildings includes a broad range of activities. No general protocols for verifying energy-conservation savings can anticipate every kind of conservation technology, program, or activity that can be undertaken by reporting entities. Therefore, procedures for verifying the energy savings must be flexible enough to accommodate verification of the common conservation measures as well as new developments in efficiency.

Flexibility is also important in addressing other emissions-reducing activities, such as fuel switching and renewable-energy technologies. Both of these types of activities can be estimated using any of the above techniques. For example, utility bill monitoring alone can provide accurate savings estimates for solar thermal projects where the original fossil fuel use was dedicated to the end-use requirement met by the solar system.

Following is a list of techniques currently in use; Appendix 2.B presents more information on each technique.

Table 2.1. Activities with a Basic Reference Case Discussed in this Supporting Document

Activities	Section	Estimation Methods
Constant Load with Fixed Hours		
High-Efficiency Motors with Constant Load Exit Sign Light Replacements Amorphous Metal Distribution Transformers High-Efficiency Refrigerators High-Efficiency Street Lights Water Heater Insulation Blankets	2.6.1	Engineering analysis Stipulated equations Stipulated savings Manufacturer's estimate Run-time meters with spot meters Run-time meters with end-use meters Billing history analysis Statistical analysis
Constant Load with Variable Hours		
Water Flow Restrictors High-Efficiency Lights High-Efficiency Motors High-Efficiency Lights with Occupancy Sensors High-Efficiency Lights with Daylight Dimmers	2.6.2	Run-time meters with spot metering Run-time meters with end-use metering
Constant Load: Fixed Hours to Variable Hours		
Occupancy Sensors EMS Demand Control, Direct Load Control Daylight Switch	2.6.3	Run-time meters with spot metering End-use metering Post retrofit monitoring
Variable Load		
Chillers Variable Speed Drives Variable Frequency Motors Daylight Dimmers	2.6.4	Short-term monitoring and calculation of part-load curves
Combination/Interactive Loads		
High-Efficiency Lighting High-Efficiency HVAC Building Shell Measures	2.6.5	Billing history analysis Load research data analysis (whole building) Building simulation
DSM Program Analysis		
	2.6.6	Billing history analysis Econometric models End-use metering Building simulation Statistical analysis

Engineering analysis. Engineering analyses are used to develop estimates of energy savings based on technical information from manufacturers in conjunction with assumed operating characteristics of the equipment.

Building simulation models. Building simulation models are really a collection of engineering equations. Building simulations can be used to develop end-use load shapes for utility forecasting and DSM planning, trade-off analysis for standards development, and estimation of energy savings from various energy-conservation activities.

Analysis of past utility bills. This technique can be used to develop a facility's baseline energy use. Energy savings are determined by comparing the metered energy use in the current year to the baseline year. For space heating and cooling, energy use can be normalized for weather changes. In addition, energy use figures may be adjusted to account for changes in site operations. Past utility bills can also be used in a statistical pre/post or normal/control framework.

Metering. Energy savings can be measured for specific equipment with fixed operating hours (spot metering), for specific equipment with variable operating hours (end-use metering), at the building or account level (metering or load-research data), or in pipes for a nonelectric fuel source (flow metering). Metering can also be used to record ambient weather conditions, such as outdoor temperature, humidity and wind speed, the actual temperature and humidity levels inside a conditioned space, and other parameters that are inputs for control systems (for example, the humidity level in an air duct).

Manufacturers' estimates. Several appliance manufacturers (refrigerators, water heaters, clothes washers and dryers, etc.) provide estimates of energy consumption in the form of Energy Guide labels.

Statistical analysis. Statistical analysis can be used in conditional demand models, econometric models, and weather normalization. Weather normalization is used to separate out the HVAC energy from the total energy use in the facility; this could be a requirement if billing history or load research data are used to examine the energy savings from an HVAC activity.

Hybrid techniques. Hybrid techniques combine one or more of the above methods to create an even stronger analytical tool.

2.6 Estimating Energy Savings for Projects with a Basic Reference Case

The basic reference case is based solely on historic levels of emissions. (Section 2.7 addresses projects involving a modified reference case.) The choice of estimation technique is influenced by the complexity of the energy conservation activity being implemented as well as the project definition. You may identify your project's primary effects as occurring at the level of a single activity or device, a group of similar activities, or a group of very dissimilar energy-efficiency activities.

The energy savings may be calculated at any desired level of aggregation (see Example 2.1). Some groups are best suited (or even restricted) to specific estimation techniques because of their load characteristics, such as fixed or variable operating hours, a constant or variable load, and a disaggregated or aggregated estimate.

Example 2.1 - Defining Projects and Effects

***Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors*.**

A commercial building owner and an electric utility may have different scopes for their projects' effects as described below:

- A commercial building owner may report greenhouse gas reductions in its facility at the device level (for example, separate activity classifications for greenhouse gas reductions resulting from high-efficiency lighting and lighting controls), for a group of devices (for example, the estimated greenhouse gas reductions from all lighting activities), or for a whole building (for example, estimated greenhouse gas reductions from lighting, HVAC, and all other energy-efficiency activities implemented at the facility).

- An electric utility may group its estimates into different categories—perhaps the same categories as it uses to report DSM program results. At a disaggregated level, a utility could report greenhouse gas reductions separately at the device level (for example, lighting control activities, high-efficiency lighting activities, HVAC efficiency activities, and HVAC control activities). Or, if the program is defined at the end-use level, it could report "program-level" estimates (for example, lighting program savings and HVAC program savings). Or the utility could define its program at a higher aggregate level (for example, commercial savings, residential savings, industrial savings).

The following load characteristics are useful for categorizing activities:

- constant load with fixed hours
- constant load with variable hours
- constant load: fixed hours to variable hours
- variable load
- combination/interactive loads
- demand-side management program analysis.

Based upon the load characteristics an activity exhibits, an appropriate estimation technique can be used to determine energy savings. Energy savings is defined as the difference between the project energy use with the activity in place and the reference case energy use, that is, the energy that would have been required had the project not taken place.

2.6.1 Constant Load with Fixed Hours

These activities run at a constant load either continuously throughout the year (with down time for maintenance) or on a fixed schedule (via time clocks, an energy management control system, or other scheduling control strategy). When your project involves changing only the load level and not the number of hours at which the load operates—that is, you are using a basic reference case and the hours of operation with your project are the same as those for your reference case—the following expression provides an estimate of your energy savings:

$$\text{Energy Savings} = H \bullet \left[P_{bref} - P_{proj}\right]$$

where Energy Savings = annual energy savings resulting from the project, in kWh
H = annual hours of operation
P_{bref} = power requirement, in kW, under the basic reference case
P_{proj} = power requirement, in kW, with the project.

If your project involves changing both the load level and the number of hours of operation from the basic reference case, the estimation must be modified as follows:

$$\text{Energy Savings} = \left[H_{bref} \bullet P_{bref}\right] - \left[H_{proj} \bullet P_{proj}\right]$$

where H_{bref} = the annual hours of operation in the basic reference case
H_{proj} = the annual hours of operation with the project.

Note that the above expression is simply another way of saying that the energy savings is the difference between energy use in the reference case and energy use with the project. This could also be expressed as follows:

$$\text{Energy Savings} = \left[E_{bref} - E_{prof}\right]$$

where E_{bref} = the annual energy use in the basic reference case
E_{proj} = the annual energy use with the project.

Example calculations

The following examples illustrate several cases where the devices exhibit constant loads with fixed hours both before and after the project. These approaches for estimating energy savings for constant-load applications that have fixed operating hours are best suited to single energy-conservation activities, as opposed to groups of energy-conservation measures that have different load characteristics.

Example 2.2 illustrates the use of engineering analysis for constant loads with fixed operating hours.

Example 2.2 - Engineering Analysis for Relighting with High-Efficiency Fluorescent Fixtures

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

A retail store replaced 100, 3-lamp, 8-foot standard fluorescent fixtures that have a standard magnetic ballast with 96, two-lamp, high-efficiency fluorescent fixtures that have electronic ballasts. The store lighting was on a fixed schedule: 100 percent of the lights are on from 6 a.m. until 9 p.m. Monday through Friday, 8 a.m. until 10 p.m. on Saturday, and 11 a.m. until 7 p.m. on Sunday.

First, the store identified a basic reference case using the operating characteristics of the lighting system immediately before the project's implementation. This reflected an assumption that the lighting system would have continued to operate unchanged, but for the intervention of the project.

Second, the store identified the effects of this project. The most obvious effect was to decrease electricity use for lighting; another effect was that the more efficient light generates less heat. This latter effect is generally positive during a cooling season and negative during the heating season.

Third, the store estimated the energy savings, using the following five steps:

Step 1. Determine the power before and after the activity, using the following equation:

$$P = \text{Rating} \bullet \text{Number of Fixtures}$$

where P = required power
Rating = rated power (from manufacturer's data).

For the basic reference case, the power was estimated as

$$\begin{aligned} P_{bref} &= 273 \text{ Watts} \bullet 100 \text{ Fixtures} \\ &= 27.3 \text{ kW} \end{aligned}$$

After the project, the power requirement was

$$\begin{aligned} P_{proj} &= 108 \text{ Watts} \bullet 96 \text{ Fixtures} \\ &= 10.4 \text{ kW} \end{aligned}$$

Step 2. Determine the annual hours of operation for the fixtures. Based on the schedules identified above, the annual operating hours were estimated to be 5,058 hours per year.

Step 3. Calculate the annual energy savings:

$$\begin{aligned} \text{Energy Savings} &= H \bullet [P_{bref} - P_{proj}] \\ \text{Energy Savings} &= 5{,}058 \text{ hours} \bullet [27.3 \text{ kW} - 10.4 \text{ kW}] \\ &= 85{,}500 \text{ kWh} \end{aligned}$$

Step 4. Estimate the magnitude of the heating effect. The determination of cooling bonus vs. heating penalty was primarily a function of the heating and cooling system efficiencies. For this example, the effect is assumed to be negligible.

Step 5. Calculate the estimated reduction in emissions associated with the energy savings (85,500 kWh), as discussed in Section 2.8).

The chief advantages of using the engineering analysis described in Example 2.2 are its simplicity and low cost, relative to more complex estimation techniques. However, an inexpensive improvement can be made to the energy savings estimate by performing short-term monitoring with run-time meters to obtain an improved estimate of annual operating hours and by using spot metering to measure the instantaneous power requirements before and after the activity has been implemented, as illustrated in Example 2.3.

Example 2.3 - Run-Time Meters with Spot Meters for Relighting with High-Efficiency Fluorescent Fixtures

***Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors*.**

An alternative method of obtaining the annual hours of operation in Example 2.2 is to use a run-time meter to monitor the actual average hours of operation for the fixtures that are being retrofitted. Assume that a run-time meter is placed on the desired lighting circuit and that the annual hours of operation are found to be 5,170 hours. Spot meters measure the old power requirement as 26.8 kW and the new power requirement as 10.9 kW. The energy savings can now be estimated as

$$\begin{aligned} \text{Energy Savings} &= H \bullet [P_{bref} - P_{proj}] \\ &= 5{,}170 \text{ hours} \bullet (26.8 \text{ kW} - 10.9 \text{ kW}) \\ &= 82{,}203 \text{ kWh} \end{aligned}$$

Again, the estimated reduction in emissions associated with this energy savings can be computed as discussed in Section 2.8.

The main advantage of using the run-time and spot meters relative to the engineering analysis is the increased accuracy. In addition, these types of meters are inexpensive, leading to small cost increases. However, to be more accurate and increase the credibility of the results, end-use metering should be considered as an alternative, as shown in Example 2.4.

End-use (and load-research) meters record the continuous demand requirements of an energy-consuming device or electrical circuit and report the results at specified intervals. (Electrical demand meters typically use a 15-minute interval). The reported power requirements are integrated over the monitoring period to obtain the energy use for that period. Finally, the energy use for the period needs to be extrapolated to estimate the annual energy use for the energy-consuming device. While the end-use meter provides a more accurate energy savings estimate relative to the other techniques, it is also the most expensive.

Example 2.4 - End-Use Metering of Devices or Circuits

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

If the activity is monitored both before and after implementation, the annual energy savings can be calculated using the following equation:

$$\text{Energy Savings} = [E_{bref} - E_{proj}]$$

If the E_{bref} were found to be 143,170 kWh, and the E_{proj} were estimated at 52,300 kWh, then the annual savings would be estimated as

$$\text{Energy Savings} = [143{,}170 \text{ kWh} - 52{,}300 \text{ kWh}]$$
$$= 90{,}870 \text{ kWh}$$

Again, the estimated reduction in emissions can be computed as discussed in Section 2.8.

Standard projects and stipulated factors

This subsection provides specific factors and calculations for estimating the energy savings for the following projects:

- high-efficiency motors with constant load
- exit sign light replacements
- amorphous metal distribution transformers
- high-efficiency refrigerators
- higher-efficiency street lights
- water heater improvements.

The specific factors and calculation methods use the Environmental Protection Agency's (EPA's) Conservation Verification Protocols (CVPs) approach, which allows electric energy savings from these types of activities to be calculated using stipulated savings equations.

For a more detailed overview of the assumptions and source references, see *Conservation Verification Protocols: A Guidance Document for Electric Utilities Affected by the Acid Rain Program of the Clean Air Act Amendments of 1990* (EPA 1993). Although the EPAct Section 1605(b) voluntary reporting program does not disallow or require any specific estimation techniques such as the CVPs, default equations and factors are presented here. Thus, for the purpose of this reporting program, these are defined as standard projects.

High-efficiency motors with constant load. This activity applies to motor upgrades or retrofits of standard motors being used to power a continuous load for at least 8,500 hours a year. The energy savings can be calculated as follows:

$$\text{Energy Savings} = 8{,}500 \bullet \left(P_{bref} - P_{proj}\right)$$

where Energy Savings = annual energy savings resulting from the activity, in kWh

8,500 = number of operating hours per year, assuming 3 percent average down time for maintenance

P_{bref} = power consumption of existing motor (in kW)

P_{proj} = power consumption of new motor (in kW).

Exit sign light replacements. In most situations, exit signs are required to operate 24 hours a day. As an energy-conservation measure, the existing incandescent fixture is replaced by either fluorescent fixtures or light-emitting diodes. The savings can be calculated as follows:

$$\text{Energy Savings} = 8{,}760 \bullet (P_{bref} - P_{prof})$$

where Energy Savings = annual energy savings resulting from the activity, in kWh
8,760 = number of operating hours per year
P_{bref} = power consumption of existing exit sign (in kW — typically 0.03 kW)
P_{proj} = power consumption of new exit sign, in kW).

Amorphous metal distribution transformers. No-load losses can be reduced by 60 to 70 percent over those found in conventional silicon-steel transformers. This reduction in loss occurs during every hour of the year. The savings can be calculated as follows:

$$\text{Energy Savings} = C^{0.75} \bullet 3.1 \times 10^{-3} \bullet 8{,}760$$

where Energy Savings = annual energy savings resulting from the activity, in kWh
8,760 = number of hours per year
C = rated capacity of replaced transformer (in kVA)
3.1×10^{-3} = decrease in no-load losses per unit capacity$^{3/4}$ (in kW/kVA$^{3/4}$).

High-efficiency refrigerator replacement. This activity involves replacing an existing refrigerator with a higher-efficiency unit and removal of the old unit from service. The savings for a single refrigerator can be calculated as follows:

$$\text{Energy Savings} = E_{bref} - E_{proj}$$

where Energy Savings = annual energy savings resulting from the activity, in kWh
E_{bref} = energy use of old refrigerator (kWh per year) = 750 kWh per year
E_{proj} = annual energy use of new refrigerator from the energy label.

Higher-efficiency street lights. This activity involves replacing existing street lighting fixtures with higher-efficiency lighting fixtures. The annual energy savings is calculated as follows:

$$\text{Energy Savings} = 4{,}000 \bullet (P_{bref} - P_{proj})$$

where Energy Savings = annual energy savings resulting from the activity
4,000 = operating hours per year
P_{bref} = power consumption of old lighting fixtures, in kW
P_{proj} = power consumption of new lighting fixtures, in kW.

Energy-conservation measures for residential water heaters. This activity involves wrapping a residential electric water heater storage tank with an insulating blanket, anti-convection valves to reduce the standby losses, and adding pipe insulation. The expected electric energy savings for the activities are shown in Table 2.2.

Table 2.2. Expected Electricity Savings from Water Heater Conservation Measures

Activity	Expected Savings (kWh/Year)
Insulation Blanket Around Tank	400
Anti-Convection Valves	200
Pipe Insulation	200
Source: *Conservation Verification Protocols* (EPA 1993)	

2.6.2 Constant Load with Variable Hours

These activities are assumed to run at a constant load on a variable (or unknown) schedule throughout the year. While business hours are known, the hours of operation for energy-consuming appliances may not be known, even for indoor lighting. For example, one activity that people may not consider when estimating their lighting hours of operation is the presence of cleaning crews in their facility. A typical tracking mechanism that cleaning crews use to know which rooms have been cleaned is to enter the facility after business hours and turn on all of the lights in the facility; after cleaning the rooms, they turn off the lights. Other factors include employees forgetting to turn off lights when they leave. These types of behaviors can result in inaccurate estimates of hours of operation. Some of the energy-conservation activities that fall in this category include the following:

- water-flow restrictors
- high-efficiency lights
- high-efficiency motors
- high-efficiency lights with occupancy sensors
- high-efficiency lights with daylight dimmers.

If the hours of operation are highly variable or not controlled, then simple engineering analysis alone cannot be used to accurately estimate the annual energy savings. The two methods that work best for this type of estimation are run-time meters with (1) spot metering and (2) end-use metering. Examples 2.5 and 2.6 illustrate these techniques for projects where there is a constant load with variable hours both before and after the project, and analysis is based on a basic reference case.

Example 2.5 - Run-Time Meters for High-Efficiency Production Motors

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Assume that a manufacturing facility planned to upgrade a line of production motors (20 motors, 10 hp, 75 percent efficiency) with smaller, high-efficiency (7.5 hp, 85 percent efficiency) motors. These motors operated at a constant loading of 6 horsepower (or 60 percent) each, but the production schedule was not fixed. A basic reference case was defined, based on the operating characteristics of the motors for the three months immediately prior to the project. To estimate the annual energy savings, the following steps are necessary.

Step 1. Estimate annual operating hours. Run-time meters were put in place on 5 of the 20 motors (that were representative of all the motors) for three months and measured an average of 1,435 hours of operation. Extrapolating the results to a single year and assuming 3 percent down time in the course of a typical year implied that each motor operates 5,568 hours per year.

Step 2. Calculate the power consumption of the motors for both the reference case and the project using the following equation:

$$P = \left(\frac{hp \bullet load\ factor}{\eta} \right) \cdot 0.746 \frac{kW}{hp}$$

where P = power requirement of the motor (in kW)
hp = rated horsepower of the motor
load factor = ratio of actual load on motor over rated load
η = full-load efficiency of the motor (a more accurate approach is to obtain the actual efficiency at the particular loading condition from the manufacturer).

The reference case power requirement was

$$P_{bref} = \left(\frac{10\ hp \bullet 0.6\ loading}{0.75} \right) \cdot 0.746 \frac{kW}{hp}$$
$$= 6.0\ kW\ per\ motor$$

The power requirement with the project was

$$P_{proj} = \left(\frac{7.5\ hp \bullet 0.8}{0.85} \right) \cdot 0.746 \frac{kW}{hp}$$
$$= 5.3\ kW\ per\ motor$$

Step 3. Calculate the energy savings:

$$Energy\ Savings = 5{,}568\ hours \bullet 20\ motors \bullet (6.0\ kW - 5.3\ kW)$$
$$= 77{,}950\ kWh$$

Step 4. Calculate the greenhouse gas emissions reductions (see Section 2.8).

Example 2.6 - End-Use Meters for High-Efficiency Production Motors

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

The other method that could be used for constant loads with variable operating hours is to monitor the energy use of each of the motors for a couple of representative months before and after the activity is in place, extrapolate the results to an annual basis, and calculate the estimated energy savings. In Example 2.5, a sample of motors would have had its energy use monitored for two to three months, both before and after the motors were changed. The reference case and project energy use would have been extrapolated to annual usages, and the energy savings would have been calculated using the equation from Section 2.6.1:

$$\text{Energy Savings} = \left[E_{bref} - E_{proj}\right]$$

Again, the greenhouse gas emissions reductions would then have been computed as discussed in Section 2.8.

2.6.3 Constant Load: Fixed Hours to Variable Hours

Sections 2.6.1 and 2.6.2 discussed situations where the load is constant and hours were either fixed or variable. The examples used illustrations where both the reference case and the project had the same type of hours. But it is also possible to undertake projects where the hours change from fixed before the projects—that is, in the basic reference case—to variable after the project. This type of activity occurs when the scheduling of a load on a device is changed with respect to some defined condition, generally by adding a controlling mechanism, such as occupancy sensors, an energy management control system, or some other controls. While the previous hours of operation (before the schedule change was implemented) were known, the new hours of operation are not known. Some of the energy-conservation technologies that cause a device to fall in this category include the following:

- occupancy sensors
- EMS demand control
- direct load control
- daylight dimmers.

This category of loading includes activities that change the schedule of operation but not the loading on the device (such as variable-speed drives), which is covered under variable loading. Two methods that are particularly effective for this type of estimation are run-time meters with spot metering (Example 2.7), and end-use metering (Example 2.8).

Example 2.7 - Run-Time Meters with Spot Meters for Occupancy Sensor Controls

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Assume that a retail store had 96, two-lamp, high-efficiency fluorescent fixtures with electronic ballasts. It wanted to add occupancy-sensor controls to all of its office and warehouse space. Assume that the basic reference case was the operation characteristics immediately before the occupancy sensor project, and that this project had no other appreciable effects. The steps necessary to complete the estimation of energy savings were as follows:

Step 1. Monitor the operating hours for the reference case and the project, using run-time meters on a representative number of fixtures. Assume that the store found the average reference case hours to be 4,865 hours per year, but the average hours with the occupancy sensor control project were 3,406 hours per year.

Step 2. Measure kW using spot meters. The required power was the same for both the reference case and the project: 10.9 kW when all the lights were on.

Step 3. Calculate the energy savings using the following equation:

$$\text{Energy Savings} = P \bullet \left[H_{bref} - H_{proj}\right]$$

where P = power requirements, kW
H_{bref} = annual operating hours in the basic reference case
H_{proj} = annual operating hours with the occupancy sensor project.

$$\begin{aligned}\text{Energy Savings} &= 10.9\ \text{kW} \bullet [4{,}865\ \text{hours} - 3{,}406\ \text{hours}] \\ &= 15{,}903\ \text{kWh}\end{aligned}$$

Step 4. Calculate the reduction in greenhouse gas emissions (see Section 2.8).

Example 2.8 - End-Use Meters for Occupancy Sensor Controls

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

A more expensive approach to estimating the energy savings is to use short-term, end-use metering for both the reference case and the project. These results need to be extrapolated to an annual representation, and the energy savings in kWh per year is calculated using the equation from Section 2.6.1:

$$\text{Energy Savings} = \left[E_{bref} - E_{proj}\right]$$

Again, the reduction in greenhouse gas emissions would be computed as discussed in Section 2.8.

2.6.4 Variable Load

The previous three sections discussed projects only involving constant loads. Another pattern of loading, called variable (or partial) loading, occurs when a device has a continuously changing load placed on it. Part-load curves indicate what fraction of input energy a piece of equipment must use to generate the desired output levels. The full-load condition is also sometimes referred to as the "design condition"—the equipment has generally been designed to operate most efficiently at the full-load condition. The part-load ratio may also be expressed in terms of the input and output units for the equipment (for example, chiller manufacturers may provide a part-load curve that provides kW of energy required per ton of cooling at various loading conditions).

Some typical applications of variable-load devices include chillers, variable-speed drives, variable-frequency motors, and default dimmers.

Example 2.9 demonstrates one method—part-load curves—that is effective for this type of application. Example 2.10 illustrates the replacement of a single-stage absorption chiller with an electric chiller.

Example 2.9 - Part-Load Curves for Fan Motor Upgrades

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

A restaurant upgraded its ventilation system from a constant-speed fan motor in conjunction with inlet vanes to one using a variable-speed drive that varied the load on the fan motor with the varying amount of ventilation required. The analysis used a basic reference case, based on fan operating characteristics immediately prior to the project's implementation.

Assume that the project had no significant secondary effects. Also assume that the fan, both before and after project implementation, was rated at 3 thousand cubic feet per minute (MCFM). The estimation was completed as follows:

Step 1. Perform short-term monitoring with a data logger to measure the air volume (CFM) that the fan is moving, along with time stamp information. Remember to monitor performance long enough to ensure that the recorded data are typical of the fan's operation during the year.

Step 2. For each hour, calculate the part-load factor of the fan as the CFM for that hour divided by the full CFM capacity of the fan.

Step 3. Decide how many bins are required to accurately represent the true operational conditions of the fan. In this example, 10 bins were used.

Step 4. For each bin, aggregate the power requirements for the reference case (in kW per MCFM) from the monitoring data and determine the power requirements for the project from manufacturer's data, as presented in the following table.

Part-Load Curves

Part-Load Factor % Full CFM Capacity	Operating Hours	Reference Case kW/MCFM	Project kW/MCFM
10	20	0.9	0.6
20	350	0.8	0.5
30	700	0.7	0.4
40	800	0.6	0.3
50	900	0.5	0.2
60	1000	0.4	0.2
70	1250	0.3	0.1
80	1100	0.2	0.05
90	900	0.3	0.1
100	800	0.4	0.2

Step 5. Calculate the energy savings as the rated capacity of the fan multiplied by the sum of the products of the part-load factor and the operating hours and the change in kW/MCFM between the pre-and post-conditions in each bin. In equation form, this is shown as follows:

$$\text{Energy Savings} = \text{RC} \bullet \sum_i \left[\text{H}_i \bullet \text{PLF}_i \cdot \left(\frac{\text{kW}}{\text{MCFM}_{\text{bref}}} - \frac{\text{kW}}{\text{MCFM}_{\text{proj}}} \right) \right]$$

$$= (3 \ \text{MCFM}) \bullet \left(1{,}065 \ \frac{\text{kWh}}{\text{MCFM}} \right)$$

$$= 3{,}195 \ \text{kWh}$$

Example 2.9 - (cont'd)

where RC = rated capacity of the fan

H_i = hours in bin i

PLF_i = part-load factor in bin i

$(kW/MCFM)_{bref}$ = measured kW per thousands of CFM before the installation of the activity

$(kW/MCFM)_{proj}$ = measured kW per thousands of CFM after the activity has been implemented.

The advantage of this method is that it can be used to predict an accurate energy savings estimate. Once the energy savings are calculated, the emissions reductions can be computed as discussed in Section 2.8.

Example 2.10 - Chiller Replacement

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

A commercial building located in Washington, DC, planned to install a new chiller. The existing equipment was a single-stage absorption chiller (22,000 Btu/ton-hr heat rate), fueled by natural gas, which could have continued to function at the current service level for many more years. The building manager explored two types of chillers, a two-stage absorption chiller and an electric chiller. Using the management company's established method, she calculated the payback period and chose the electric chiller. Since her management company had announced an intention to report under the EPAct 1605(b) voluntary reporting program, she analyzed the chiller replacement as an emissions reduction project.

She established the reference case as emissions from the old chiller (a basic reference case). Her assistant, who performed the estimations, suggested that the performance of the two-stage absorption chiller, which met current efficiency guidelines, should be used as the reference case. However, the basic reference case better showed actual emissions. (Had the company installed a new chiller where none had existed, the two-stage absorption-chiller might well have been a credible modified reference case.) Cooling load was expected to remain at 150,000 ton-hours per year.

To calculate how each equipment choice will affect the amount of emissions produced, the manager first determined the amount of energy (or fuel) used by each chiller and then applied emission factors.

Reference Case: Single-Stage Absorption Chiller (natural gas-fired)

The building manager calculated the annual fuel input:

$$22{,}000 \text{ Btu/ton-hr} \bullet 150{,}000 \text{ ton-hr/yr} = 3.3\text{x}10^9 \text{ Btu/yr}$$

Using this figure and the emissions factor for natural gas from Appendix B of this volume (see the discussion in Section 2.8), she estimated annual fuel emissions:

$$3.3\text{x}10^9 \text{ Btu/yr} \bullet 52.8\text{x}10^6 \text{ MTCO}_2/10^{15} \text{ Btu} = 174.2 \text{ MTCO}_2$$

She then determined annual auxiliary (electricity) energy consumption under the reference case:

$$0.3 \text{ kW/ton} \bullet 150{,}000 \text{ ton-hr/yr} = 45{,}000 \text{ kWh} = 45 \text{ MWh}$$

Using the emissions factor for the District of Columbia from Appendix C of this volume, she estimated the annual auxiliary emissions:

$$45 \text{ MWh} \bullet 1.324 \text{ STCO}_2/\text{MWh} = 59.6 \text{ STCO}_2 = 54.2 \text{ MTCO}_2$$

To estimate total emissions for the reference case, she added fuel-based emissions and auxiliary emissions:

$$174.2 \text{ MTCO}_2 + 54.2 \text{ MTCO}_2 = 228.4 \text{ MTCO}_2$$

Project Case: Electric Chiller

The building manager calculated annual energy consumption for the new electric chiller:

$$0.7 \text{ kW/ton} \bullet 150{,}000 \text{ ton-hr/yr} = 105{,}000 \text{ kWh} = 105 \text{ MWh/yr}$$

She estimated total emissions, using the same electricity emissions factor as she used in the reference case:

$$105 \text{ MWh} \bullet 1.324 \text{ STCO}_2/\text{MWh} = 139.0 \text{ STCO}_2 = 126.4 \text{ MTCO}_2$$

Emissions Reductions:

$$228.4 \text{ MTCO}_2 - 126.4 \text{ MTCO}_2 = 102 \text{ MTCO}_2$$

2.6.5 Combination/Interactive Loads

Combination loads occur when a group of energy-conservation activities has been applied at a site. It is often difficult to identify the discrete effects of each individual activity. In this case, you may more easily examine the interactive effect from all of the activities as a single energy-savings estimate. Conservation activities such as high-efficiency lighting, high-efficiency HVAC, and building-shell measures (for example, ceiling and wall insulation) commonly combine to form interactive loads. Rather than attempting to define the effects of these activities narrowly at the device level, it may simplify analysis to define the effects at the building level. This method can also be used to observe the true savings resulting from a large energy conservation activity.

Three methods that work well for examining the effects of large energy-conservation activities are (1) site-specific billing history analysis, (2) whole-building load-research data analysis, and (3) building simulation.

Site-specific billing analysis

Site-specific billing analysis is particularly appropriate when you are using a basic reference case. The advantage of this approach is that billing history data are readily available (from kept records or from the utility) and can be quickly examined for savings estimates. It is not as readily applicable, however, for use with a modified reference case, such as when you want to account for changes in building occupancy or energy-use patterns. Example 2.11 illustrates the use of this estimating method.

Example 2.11 - Site-Specific Billing History Analysis for Lighting Conservation

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Assume that a retail store's lighting energy was 60 percent of its annual energy consumption. The expected energy savings from the lighting activity was almost 14 percent of the store's annual energy use, which implied that the impact of the activity should have been easily observed in the changes in billing history. Keep in mind that billing history in institutional buildings has inherent variability in the range of 8 percent to 14 percent from year to year owing to weather, schedule changes, and other effects. Therefore, the expected energy savings should be at least 15-20 percent of the annual bills (DOE/BPA 1991).

Assume that the analysis defined a basic reference case drawn from the year immediately before the project's implementation and that the project had no significant effects other than saving energy. The estimation of energy savings proceeds as follows:

Step 1. Assemble one year (or more) of billing history data (typically available from the electricity supplier) before the conservation activity for estimating the reference case, and one year of data after the project's implementation. The following table presents the monthly billing history for the site before and after the lighting activity.

Example 2.11 - (cont'd)

Billing History Analysis

Month	**Reference Case Energy Use (kWh)**	**Project Energy Use (kWh)**
January	16,456	14,653
February	16,544	14,698
March	14,509	13,070
April	19,947	15,573
May	18,012	15,904
June	20,357	16,428
July	16,174	13,909
August	17,964	13,781
September	15,131	12,820
October	16,837	12,949
November	15,764	13,655
December	17,979	14,383
Annual Totals	205,674	171,823

Step 2. Calculate the energy savings using the equation from Section 2.6.1:

$$\text{Energy Savings} = [E_{bref} - E_{proj}]$$
$$= 205{,}674 \text{ kWh} - 171{,}823 \text{ kWh}$$
$$= 33{,}851 \text{ kWh}$$

Step 3. Calculate the reduction in emissions (see Section 2.8).

Whole-building, load-research data analysis

Whole-building, load-research data are a record of historical demand data at a facility, generally recorded in 15-minute increments. You can readily aggregate the data into monthly energy usage for analysis—resulting in data similar to monthly billing histories. The primary advantage of load-research data is that in addition to energy savings, demand savings can also be observed. The main disadvantage is that the data can be expensive to collect if you must purchase the meter, although some utilities will install meters free of charge or at a low cost.

Building simulation

Building simulation provides an effective tool for examining interactive effects and energy- conservation activities that are difficult to estimate using other techniques. The disadvantages of building simulations are that they tend to be data intensive and difficult to operate, and interpreting the results can be complex.

2.6.6 Demand-Side Management Program Analysis

In general, the previous analytical techniques have tended to be most applicable to the analysis of energy savings for a device, group of devices, or a single site (residence, facility, etc.). This is not how electric and natural gas utilities commonly report energy savings resulting from DSM programs. The calculations of energy savings can be a complex process with uncertainties introduced by economic and behavioral effects, such as free riders (entities who would have implemented DSM activities without the utility program, but take advantage of the utility rebate because of its ready availability) and, to a lesser degree, free drivers (entities who have become aware of DSM technologies through the utility program and subsequently implemented energy-conservation activities). Fortunately, a growing base of experience with DSM program management and evaluation has yielded increasingly sophisticated measurement techniques that can provide relatively solid estimates of program performance. Utilities are encouraged to use the methodologies already in place, for example, to estimate energy savings as part of their reports to public utility commissions.

Delineating specific estimating methods is beyond the scope of this supporting document. Generally, several approaches may be used to estimate net energy savings, including billing history analysis, econometric models, end-use metering, and, to a lesser degree, building simulation. For DSM programs using a basic reference case, estimation of energy savings is generally based upon pre-and post-measurement of energy savings for a sample of program participants. The sample of program participants needs to be statistically representative of all the participants in the program.

DSM programs may include collection and disposal of refrigerators and cooling equipment. If you report these activities, you may also report (as applicable) capture of chlorofluorocarbons associated with the activities. You will find guidance in the supporting document for the industrial sector.

2.7 Estimating Energy Savings for Projects with a Modified Reference Case

Most device-level and building-level analyses use a basic reference case, either because energy-use patterns from the past are not expected to change or because evaluating the change would be very difficult. If you use a modified reference case (for example, to account for projected growth), your analysis needs to reflect elements, such as DSM programs, that will affect the modified case. You may use any estimation method appropriate to your circumstances, for example, the methods you use in the integrated resource planning (IRP) process.

However, for DSM programs you may be able to develop and evaluate modified reference cases (perhaps with methods you already have in place) using the following: (1) pre- and post-measurement of energy savings from both a sample of program participants and a control group or (2) post-measured savings for a sample of participants compared to the savings from a control group.

The advantages of control group analysis are that several economic and behavioral effects can be observed, including free rider and free driver effects. In addition, the confidentiality of program participants is maintained, since no energy savings are reported for individual activities. The disadvantages are that control group analysis needs to be performed long after the energy-conservation activities have been implemented (typically one year) to capture the annual energy savings. Also, the reasons or motivations underlying the achieved energy savings may not be captured or recorded.

In some cases, a modified reference case can be used at a lower level of aggregation, even at the device level. For example, post-retrofit monitoring is ideally suited to capture changes in energy demand due to changes in hours of operations (see Example 2.9).

While thus document does not provide specific procedures for developing modified reference cases under these conditions, generally you must be sure that you are comparing your project to a credible estimate of the energy that would have been consumed if the project had not been implemented.

2.8 Estimating Emissions Reductions from Energy Savings

The previous sections have discussed how to estimate energy savings from conservation projects. But the purpose of the voluntary reporting program is to record greenhouse gas emissions and emissions reductions, not energy savings. Therefore, you must calculate the net emissions reductions resulting from energy-efficiency activities affecting both direct (fossil) and indirect (electric) fuel use, fuel-switching activities, cogeneration, and any other activities that save energy.

If you monitor greenhouse gas emissions, you may simply report the difference in measured emissions between your reference and project cases. If instead you wish to estimate emissions reductions from fuel-use or electricity-use data, you may use default emissions factors, as explained in this section, or use the more complex approaches described in the supporting document for the electricity supply sector, particularly Section 1.7.

2.8.1 Direct Monitoring of Nonelectric Activities

For nonelectric energy-conservation activities, you may directly monitor the change in greenhouse gas emissions resulting from a single activity or group of activities. You may define reference and project cases based on the data available to you. For example, if you monitor emissions for your entire operation, you may define both reference and project cases at the entity level.

2.8.2 Applying Emissions Factors to Energy Savings Data

If you do not monitor emissions directly, either because you do not have the capacity to do so or your project affects emissions indirectly (for example, electricity conservation), you can use emissions factors to calculate the emissions associated with your reference case and project case. Emissions factors translate consumption of energy into greenhouse gas emissions levels.

You can use the default emissions factors provided in Appendix B to derive carbon dioxide emissions associated with the use of various fossil fuels. Appendix C provides default emissions factors for electricity consumption on a state-by-state basis. Alternatively, you may be able to obtain data from your utility or nonutility electricity source. You may also choose to derive your own electricity emissions factors as described in Section 1.7.2 of the support document for the electricity supply sector.

Whether you use default emissions factors or factors you have derived yourself, you can use them in the following equation to calculate the total emissions reductions associated with your project:

$$\text{Emissions Reductions}_i = \sum_j \text{Energy Savings}_j \bullet \text{Emission Factors}_{ij}$$

where Emissions Reductions$_i$ = the annual decrease in emissions of greenhouse gas i that results from the energy-conservation activity

Energy Savings$_j$ = the annual reduction in use of fuel j resulting from the energy-conservation activity (note that increased use of a fuel is indicated by a negative number)

Emissions Factor$_{ij}$ = emissions factor for greenhouse gas i associated with fuel j.

The following example illustrates the use of the energy conversion factors for electricity to derive the emissions reductions attributable to an energy conservation project.

Example 2.12 - Calculated Emissions Reductions

Note: This example illustrates only one approach to analyzing a project; your analysis, methods, and calculations will vary depending on your particular circumstances, the geographic location of the project, and other factors.

Assume that a commercial facility located in Delaware has retrofitted its lighting, as described in Example 2.2. The steps necessary to complete the savings analysis were as follows:

Step 1. Calculate the energy savings resulting from the activity. Annual energy savings were previously calculated as 85,500 kWh per year.

Step 2. Derive or select the appropriate emissions factor for converting electricity reductions to emissions reductions. Default emissions factors for Delaware were extracted from Appendix C to this volume:

Default Emissions Factors

Greenhouse Gases	Emissions Factors (lbs/kWh)
Carbon Dioxide	1855
Nitrous Oxide	0.2161

Step 3. Calculate the emissions reductions for each of the greenhouse gases as follows:

The annual carbon dioxide emissions reductions were calculated using

$$\begin{aligned}\mathbf{CO_2\ Emissions\ Reductions} &= \mathbf{(Electricity\ Savings) \bullet (Emissions\ Factor)}\\ &= \mathbf{85.5\ MWh \bullet 1855\ lb\ CO_2/MWh}\\ &= \mathbf{159x10^3\ lb\ CO_2}\end{aligned}$$

The annual nitrous oxide emissions reductions were calculated thus:

$$\begin{aligned}\mathbf{N_2O\ Emissions\ Reductions} &= \mathbf{(Electricity\ Savings) \bullet (Emissions\ Factor)}\\ &= \mathbf{85.5\ MWh \bullet 0.2161\ lb\ N_2O/MWh}\\ &= \mathbf{18.47\ lb\ N_2O}\end{aligned}$$

2.9 Existing Reporting Programs

In several cases, reporters may have participated in state or Federal reporting programs that record energy-conservation activities and potentially even some reductions in either acid rain pollutants or greenhouse gas emissions. Electric utilities, investor-owned public utilities, Federal power-marketing administrations, and the Tennessee Valley Authority are required to report financial, operating, fuel-use, and DSM information periodically. Some specific examples of standardized reporting programs that contain energy-conservation information are the DOE Energy Information Administration Form EIA-861, *Annual Electric Utility Report Schedule V - Demand-Side Management Information,* and EPA's Green Lights program. Additional nonstandard sources of energy-saving accomplishments by public utilities may be found in the form of submissions to their respective public utility commissions.

2.9.1 EIA Form 861

The Federal Energy Administration Act of 1974 requires U.S. utilities to complete and return Form EIA-861 to the EIA. The form requests data on the incremental and annual energy effects (MWh) and potential and actual peak reduction (kW) for the following DSM categories: energy efficiency, interruptible load, other load management, other DSM programs, direct load control, and load building. The DSM program achievements are reported by customer class (residential, commercial, industrial and other), and there is a check box at the end of the form to indicate the end uses (heating systems, lighting, etc.).

Incremental and annual effects

"Incremental effects" are defined as the changes in energy use caused in the reporting year by new participants in existing DSM programs and all participants in new DSM programs. Effects are annualized "to indicate the program effects that would have occurred had these participants been initiated into the program on January 1 of the reporting year." "Annual effects" are defined as the total changes in energy use and peak load caused in the reporting year by all participants in all the utility's DSM programs.

Providing data on incremental effects, as defined in Form EIA-861, would not reveal actual savings if any of the savings are annualized. For example, the energy savings attributed to a utility-influenced purchase of an efficient refrigerator in September would be calculated to the entire year, as opposed to the four months of actual use. If the savings were not annualized, the incremental effects data would provide a good approximation of the actual savings for the reporting year and would partially meet the needs of this voluntary reporting program. Then, as described in Section 2.8, the energy savings could be translated into associated impacts on greenhouse gas emissions.

Energy effects and peak reduction

Although Schedule V requests information on both energy effects (MWh) and peak reduction (kW), only the energy effects data (Form EIA-861, Schedule V, page 5) are applicable to reporting under the EPAct Section 1605(b) reporting program.

EPA's Conservation Verification Protocols

The main goal of this protocol is to credit electrical utilities for SO_2 emission reductions as a result of conservation programs. As a result, this protocol is fairly flexible in what types of calculations or measurements are performed. If estimates are based on end-use metering, the utilities must use a comparison (or control) group and the reported energy savings must have a statistical confidence of at least 75 percent.

If engineering analyses are used instead of monitoring techniques, the savings results are discounted to reflect the lower confidence and accuracy of the results. The protocol suggests that engineering calculations only be used in the following conditions:

- Measurement cost would exceed 10 percent of the program cost.
- Program-wide energy savings are small (< 5000 MWh per year).
- Energy savings are less than 5 percent of the smallest isolatable circuit.

- Energy savings are less than 5 percent of the total household electricity use.

The Conservation Verification Protocols (CVPs) also allow engineering estimates for seven specific categories:

- constant load motors
- exit signs
- amorphous metal transformers
- commercial lighting
- new refrigerators
- street lights
- water heater insulation.

The discounting of estimates in these categories is less severe than for other areas, to reflect the higher quality of data available.

2.9.2 EPA's Green Lights Program

The Green Lights (EPA 1992) program is a cooperative program with public and private organizations to replace inefficient lighting with new, energy-efficient lighting technologies. The program provides participants with a one-page form on which to report their lighting upgrade activities. The form includes general facility information, total facility floor space, and upgraded floor space; fixture type, size, quantity, and wattage used before and after the upgrade; operating hours; electrical demand and energy savings; the percent of energy savings (relative to the base usage); the cost savings in dollars; and the reduction in emissions of CO_2, SO_x, and NO_x.

Although no methods of estimation are indicated on the form, a description of who performed the analysis (in-house personnel, energy consulting firm, etc.) is requested. As with other reporting programs, the portion that is needed for this voluntary reporting program is the annual energy savings from the energy-conservation activity. These figures can be readily obtained from the Green Lights reporting form.

2.9.3 Public Utility Commission Filings

In addition to completing EIA-861 forms, investor-owned utilities and some public utilities provide state public utility commissions with information on the effectiveness of DSM programs. This information is typically submitted as part of the utility's general rate case, which occurs every two to three years. Utilities can also provide annual information to include data on program participation rates, program costs, the duration of the measure, and free riders. State energy offices and energy service companies (ESCOs) use a wide variety of verification systems, though these may be geared toward shareholder value and cost effectiveness. Utilities use data on kWh and kW savings to evaluate program savings and cost-effectiveness.

Energy savings in buildings also reduce electric utility transmission and distribution (T&D) and generator losses. These losses have not always been explicitly considered in past public utility commission filings but are certainly relevant and could be included in submissions under this voluntary reporting program.

As noted under the EIA-861 report forms, only kWh savings data are required to estimate emissions reductions. In reporting estimated savings, you must note the method(s) you used to develop the estimates.

The natural gas industry is regulated by the Federal Energy Regulatory Commission and in some states local distribution companies are regulated by public utility commissions. In states, such as Georgia and California, where the Public Service Commission regulates natural gas, gas utilities are required to submit integrated resource plans that delineate DSM program activities. The same information reported to the public utility commissions may assist in computing greenhouse gas reductions for reporting under the EPAct Section 1605(b).

2.10 References

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Appendix 2.A

Energy Conservation Measures

Energy Conservation Measures

Space Heating
- Improved Heating Efficiency
- Hot Thermal Storage

Air Conditioning
- Improved Cooling Efficiency
- Cool Thermal Storage

Ventilation
- Improved Motor Efficiency
- Multi-Speed or Variable-Speed Motor
- Duct Sealing & Balancing
- Variable Air Volume

Water Heating
- High-Efficiency Water Heaters
- Insulation Blankets
- Flow Restrictors
- Heat Pump Water Heater

Refrigeration
- High-Efficiency Refrigeration Cases
- Defrost Control
- Variable-Speed Compressors
- Multi-Stage Compressors

Lighting
- Compact Fluorescent
- Electronic Ballasts
- High-Efficiency Magnetic Ballasts
- Reflector Systems
- Efficient Fluorescent Lamps
- Lighting Controls
- Exit Signs
- Occupancy Sensors
- High-Intensity Discharge Lamps
- Daylight Dimmers
- Daylight Switches

Building Envelope
- Insulation
- Weatherization
- Insulating Glass
- Low Emissivity Glass

Controls
- Energy Management System (EMS)
- Direct Load Control
- Distributed Load Control

Appliances
- High-Efficiency Appliances

Other
- Cogeneration
- Fuel Switching
- Renewable Energy Source
- High-Efficiency Motors
- Variable-Speed Motors
- Efficient Distribution Transformers
- High-Efficiency Office Equipment and Computers

Appendix 2.B

Energy Estimation Techniques

Energy Estimation Techniques

Engineering analysis. Engineering analyses are used to develop estimates of energy savings based on technical information from manufacturers in conjunction with assumed operating characteristics of the equipment.

"Stipulated measures" are defined as constant load applications that operate continuously, have known operating hours, or are new appliances (such as refrigerators) sold with Energy Guide labels indicating average energy savings.

The advantage of engineering estimates is they are relatively quick and inexpensive to calculate. The primary disadvantage is that the data used in the calculations rely on assumptions that may vary in their level of accuracy.

Building simulation models. Building simulation models are really a collection of engineering equations. They can be used to develop end-use load shapes for utility forecasting and demand-side management planning, to analyze trade-offs for standards development, and to estimate energy savings from various energy-conservation activities.

One advantage of simulation models is that they take into account such factors as weather data and interactions between the HVAC system and other end uses. A primary disadvantage is that they are very time consuming and usually require specialized technical expertise, making them costly in the long run.

Analysis of past utility bills. This technique can be used to develop a facility's baseline energy use. Energy savings are determined by comparing the metered energy use in the current year to the baseline year. For space heating and cooling, energy use is normalized for weather changes. In addition, energy use figures may be adjusted to account for changes in site operations.

The primary requirement for using past utility bills as a baseline is that the energy savings are larger than the normal bill variations. The BPA Guidelines (Harding et al. 1992) state that the annual energy use of institutional buildings may vary from 8 to 14 percent. Therefore, the energy savings adjustment should be at least 15 to 20 percent of the baseline year usage to differentiate actual savings from anomalies.

The annual savings are estimated as follows:

$$\text{Energy Savings} = \left[E_{bref} - E_{proj}\right]$$

where Energy Savings = annual energy savings resulting from the activity, in kWh

E_{bref} = typical annual energy use of the activity before installation (typically this is averaged over several years)

E_{proj} = billing history for the year following the activity implementation adjusted for weather and operational changes.

The advantage of analyzing past utility bills is that comparing the data is inexpensive, and the results are easy to understand and communicate. The disadvantages include limited applicability because of the need for stable building operations and the need to normalize for weather and changes in building use. Appropriate applications for this technique are (1) for large institutional complexes (such as the U.S. Department of Defense currently is doing) and (2) where the energy savings are at least 25 percent of the annual billing history for a given meter or site.

Statistical techniques are often used to evaluate and verify energy savings from efficiency programs. In all cases, participant samples of significant size are required for validity. Normally, billing histories of participants are used in a pre/post or sample/control experimental framework. Weather, building size, and econometric normalization will be applied to separate the net savings from the noise of naturally occurring variation. Variations of this technique are widely used to evaluate utility demand-side management programs.

Spot metering. Spot metering is a useful tool for estimating energy savings when the efficiency of the equipment is enhanced, but the operating hours remain fixed, such as with an exit sign replacement project. Spot metering of the connected load before and after the activity quantifies this change in efficiency with a high degree of accuracy. For activities where the hours of operation are variable, the actual operating (run-time) hours of the activity should be measured before and after the installation using a run-time meter.

The annual savings are estimated as follows:

$$\text{Energy Savings} = \left(P_{bref} - P_{proj}\right) \bullet \text{Hours}$$

where Energy Savings = annual energy savings resulting from the activity

P_{bref} = connected load before the activity is installed
P_{proj} = connected load after the activity is implemented
Hours = the number of hours the device runs during the year.

The advantage of the spot metering is that it is simple and easy to apply. This method is more accurate than using engineering calculations, since the parameters are measured instead of being assumed. The advantage over the billing history approach is that it can be used when energy savings are a small (<15 percent) portion of the annual energy use at a site or a meter. However, the scope of its applicability may be limited to those projects where operating hours are the same before and after treatment.

End-use metering. End-use metering is a useful tool for estimating savings that are not a function of fixed hours. Using variable-speed drives in place of variable inlet vanes, for example, reduces fan-motor loading and energy use. Extended metering is required before and after the retrofit to characterize the performance of the equipment under a variety of load conditions.

The annual savings are estimated as follows:

$$\text{Energy Savings} = \left[E_{bref} - E_{proj}\right]$$

where Energy Savings = average energy savings per unit (that is, kWh per day) resulting from the activity

E_{bref} = average energy use per unit before the activity was installed
E_{proj} = average energy use per unit after the activity is implemented.

The advantage of end-use metering is that it provides a greater degree of accuracy than engineering estimates or spot metering. In addition, the meter can calculate the energy change on an individual piece of equipment in isolation from the other end-use loads (as opposed to billing history, which captures the effect at the building or meter level). End-use metering requires specialized equipment and an equipment technician, and is typically more costly than any of the previous four methods.

Metering of load research data. Another type of data that may be available at the meter or building level is load research data (LRD). The difference between this type of metering and end-use metering is the level at which the activity is metered. End-use meters generally are used to meter a single circuit or piece of equipment, while LRD meters the building or account total. In general, utilities are required to collect LRD on a statistically valid sample of buildings for their territories.

Since the LRD meter is at the building level, the requirements are similar to the billing history analysis—that is, the energy savings need to be larger than normal variations in the load research data.

In its raw form, the LRD represent electrical demand (kW), typically in 15-minute or hourly increments. However, it is fairly straightforward to collapse this into electrical energy (kWh). Therefore, both energy and demand savings could be calculated for the activity if desired.

The annual savings are estimated as follows:

$$\text{Energy Savings} = \left[E_{bref} - E_{proj}\right]$$
$$\text{Demand Savings} = \left[P_{bref} - P_{proj}\right]$$

where Energy Savings = annual energy savings resulting from the activity
Demand Savings = reduction in load resulting from the activity
bref = typical characterization of the activity before installation (usually this is averaged over several years)
proj = the characterizations after the activity has been implemented.

The advantage of LRD analysis is that the data may already be available through the electric utility. The disadvantages include limited applicability due to the need for stable building operations, the need to normalize for weather and changes in building use, and increased computational requirements. The LRD analysis may be applied in the same circumstances as billing history analysis.

Flow meters. If an energy-conservation activity involves a nonelectric fuel source, data from flow meters may be used. When installed in pipes, these meters measure the energy used by the device. In addition, flow meters could be installed at the appliance, end-use level, similar to electric end-use meters.

Manufacturers' estimates. Several appliance manufacturers (refrigerators, water heaters, clothes washers and dryers, etc.) provide estimates of energy savings in the form of Energy Guide labels. These labels indicate the annual energy cost (in dollars) for using the appliance in a typical family or under typical conditions. Besides providing a simple, standardized method for reporting savings, these labels may be an excellent source of information for residential homeowners to use if they are assuming reporting responsibilities under this program.

Statistical analysis. Statistical analysis can be used in several ways, including conditional demand models, econometric models, and weather normalization. Weather normalization is used to separate out the heating, ventilation, and air conditioning (HVAC) energy from the total energy use in the facility; this could be a requirement if billing history or load research data are used to examine the energy savings from an HVAC activity.

Hybrid techniques. Hybrid techniques combine one or more of the above methods to create an even stronger analytical tool. For example, spot metering could be combined with engineering analysis. The hours of operation before and after are still estimated, but the before-and-after efficiency is now measured, as opposed to being estimated. Statistically adjusted engineering analysis is used by many utilities. The down side of hybrid techniques is that while they can provide more accurate results, they typically increase the complexity and expense.

Fuel-switching analysis. Fuel-switching savings can be estimated and verified using all of the techniques previously discussed. However, accounting for the shifting of energy use and related changes in emissions associated with fuel-switching activities creates a potentially more complex reporting situation.

For example, a natural gas utility wishing to increase sales provides a rebate to its commercial customers who replace electric-resistance space and water-heating equipment with high-efficiency natural gas units. The commercial building owner participating in the program would need to report a reduction in electricity use and an increase in natural gas use. Is there a net reduction in greenhouse gas emissions? The solution involves comparing the indirect emissions reductions from reduced electricity use with the new direct emissions from increased on-site fossil fuel use.

Before switching fuels, which typically involves major renovations and a large capital investment, a reporting entity will have performed a detailed engineering (and usually a life-cycle cost) analysis of the alternative fuel. The reporting entity can use this engineering analysis to estimate first-year fuel savings and also to firm up post-hoc savings typically calculated through utility bill analysis at the end of the year.

The original engineering analysis may include real-time monitoring of equipment performance and energy use (calibrated with hourly or daily temperature/weather data and projected over the entire year). Building-simulation programs and other computer-based tools for estimating and characterizing the building's energy consumption are also commonly used to provide data on the fuel savings associated with the fuel switching. All of these approaches for determining overall energy use and emissions are acceptable under the voluntary reporting program.

Renewable-energy analysis. Renewable-energy systems can be estimated and verified using all of the techniques previously discussed. For example, utility bill monitoring alone can provide accurate savings estimates for solar thermal projects where the original fossil fuel use was dedicated to the end-use requirement met by the solar system.

Reference

Harding, S., F. Gordan, and M. Kennedy. 1992. *Site Specific Verification Guidelines*. Bonneville Power Administration, Portland, OR.