Module 14: Savings Verification

Learning Objectives

After completing this module, you will be able to:
- Identify the key concepts involved in savings verification;
- Define the kinds of data required for energy performance analysis, and analyze energy consumption as a function of degree-days using linear regression;
- Define the fundamental relationship for determining savings for a given ECM;
- Describe the elements of a verification plan;
- Describe and select from the four methods of savings verification;
- Identify the data and information required to define base year conditions;
- Describe techniques for developing an energy performance model;
- Apply adjustments to the base year conditions.

14.1   An Overview of Measurement and Verification (M&V)

The central purpose of M&V is to **verify the energy savings achieved by building retrofits**, either to satisfy internal financial accounting and reporting requirements, or to meet the terms of third-party contracts for project implementation and management.

14.1.1 Working Definitions

The statistical analysis of energy consumption is commonly done for two reasons:

- ***Measurement and Verification***: this is a process of quantifying energy consumption before and after an energy conservation measure is implemented in order to verify and report on the level of savings actually achieved.

- ***Monitoring and Targeting***: this is a management technique that can—and should—be utilized with or without specific facility retrofits in order to "keep operations efficient", and to "monitor utility costs"; these are management strategies designed to drive energy costs downwards as a continuous improvement cycle.

  The statistical principles that are used are the same regardless of the purpose of the analysis. Because of its importance in energy performance contracts, and increasingly, in Clean Development Mechanism (CDM – under the Kyoto Protocol) projects involving greenhouse gas emission reduction credits, M&V methodology has been standardized in the International Performance Measurement and Verification Protocol (IPMVP).

14.1.2 Why Measure & Verify?

M & V is an additional cost in the retrofit project—what is the payoff?

The **IPMVP** offers six answers to this question:

- M & V increases energy savings.
- M & V reduces the cost of financing projects.
- M & V encourages better project engineering.
- M & V helps to demonstrate and capture the value of reduced emissions from energy efficiency and renewable energy investments.

- M & V increases public understanding of energy management as a public policy tool.
- M & V helps organizations promote and achieve resource efficiency and environmental objectives.

Spend more to reduce costs? . . . This isn't a contradiction in terms. The **IPMVP** explains that a thorough M & V process designed into the project helps to reduce the total cost of a financed project by:

- Increasing the confidence of funders that their investments will result in a savings stream sufficient to make debt payments
- Thereby reducing the risk associated with the investment
- Thereby reducing the expected rate of return of the investment—and your costs of borrowing.

14.1.3 General Approach to M&V – The IPMVP

In principle, M&V simply quantifies energy savings by comparing consumption before and after the retrofit. The "before" case is defined as the "baseline performance", and the "after" case is referred to as the post-installation period. In its simplest form,

Savings = (Baseline Energy Use)_{adjusted} – (Post-installation energy use)

The complicating factors concern:
- what adjustments to the Baseline performance are required, and how are they carried out;
- what measurements are required to determine post-installation performance, and how are they carried out.

The **International Performance Measurement & Verification Protocol (IPMVP),** published by the US Department of Energy, defines four approaches to M&V that determine how these factors are addressed. These approaches are termed M&V Options A, B, C and D. A critical decision in M&V planning is the selection of one of these options.

> *IPMVP Volume I: Concepts and Options for Determining Energy and Water Savings* and *Volume II: Concepts and Practices for Improved Indoor Environmental Quality* can be downloaded at no charge from www.ipmvp.org

M&V Options
IPMVP M&V Options A, B, C and D are summarized in Table 14.1. They differ one from another in terms of:
- the degree to which the retrofit can be measured separately from other facility components;
- the extent to which performance variables can be measured.

Option A applies to a retrofit or system level assessment where performance or operational factors can be spot or short-term measured during the baseline and post-installation periods. Factors that cannot or are not measured are "stipulated", based on assumptions, analysis of historical performance, or manufacturer's data. Stipulation is the easiest and least expensive method of determining savings, but is also subject to the greatest level of uncertainty.

Option B applies to a retrofit or system level assessment where performance or operational factors can be spot or short-term measured at the component or system level during the baseline and post-installation periods. In this Option, the performance of the retrofit can be measured separately from other measures or performance factors. No factors are stipulated; consequently, Option B involves more

end-use metering than Option A and is correspondingly both more expensive and less subject to uncertainty.

Option C applies to the impact of a "bundle" of retrofit measures on a facility. It relies on baseline and post-installation total building energy performance data typically obtained from the utility meter at the service entrance, and involves regression analysis against independent performance variables such as weather factors, facility usage, or production (as in water pumping stations or wastewater treatment facilities).

Option D uses computer simulation models of component or whole-building energy consumption to determine project energy savings. Simulation inputs are linked to baseline and post-installation conditions; some of these inputs may be determined from performance metering before and after the retrofit. Long-term whole-building energy use data may be used to calibrate the simulation models.

Table 14.1: Overview of M&V Options
Source: U.S. Department of Energy, M&V Guidelines: Measurement and Verification for Federal Energy Projects

M&V Option	Performance and Operation Factors[1]	Savings Calculation	M&V Cost[2]
Option A – Stipulated and measured factors	Based on a combination of measured and stipulated factors. Measurements are spot or short-term taken at the component or system level. The stipulated factor is supported by historical or manufacturer's data.	Engineering calculations, component, or system models.	Estimated range is 1% - 3%. Depends on number of points measured.
Option B – Measured factors (Retrofit isolation)	Based on spot or short-term measurements taken at the component or system level when variations in factors are not expected. Based on continuous measurements taken at the component or system level when variations are expected.	Engineering calculations, components, or system models.	Estimated range is 3% - 15%. Depends on number of points and term of metering.
Option C – Utility billing data analysis (whole building)	Based on long-term, whole-building utility meter, facility level, or sub-meter data.	Based on regression analysis of utility billing meter data.	Estimated range is 1% - 10%. Depends on complexity of billing analysis.
Option D – Calibrated computer simulation	Computer simulation inputs may be based on several of the following: engineering estimates; spot, short-, or long-term measurements of system components; and long-term, whole-building utility meter data.	Based on computer simulation model with whole-building and end-use data.	Estimated range is 3% - 10%. Depends on number and complexity of systems modelled.

[1] Performance factors indicate equipment or system performance characteristics such as kW/ton for a chiller or watts/fixture for lighting; operating factors indicate equipment or system operating characteristics such as annual cooling ton-hours for chillers or operating hours for lighting.
[2] M&V costs are expressed as a percentage of measure or project energy savings.

Notes to Table 14.1
1. Option A—partial retrofit isolation with stipulation—is best used when:
- *the magnitude of savings is relatively low for the entire project or the portion of the project to which this M&V Option is applied;*
- *the risk of not achieving projected savings is low, or ESCO payments are not directly tied to the actual savings.*

2. Option B—retrofit isolation—is typically used when:
- *energy savings from equipment replacement projects are less than 20% of the total facility energy use;*
- *energy savings arising from individual measures must be determined;*
- *interactive effects of multiple measures are deemed unimportant;*
- *the independent variables that affect energy use—for example, operating schedule— are neither complex nor difficult to monitor;*
- *sub-meters already exist to measure the energy use of the systems being considered for retrofit.*

3. Option C—whole building, billing analysis—is used when:
- *the retrofit project is complex, involving a number of systems;*
- *predicted energy savings are relatively large (greater than 10% to 20% of total facility energy use);*
- *the measurement of energy savings arising from individual measures is not required;*
- *interactive effects of multiple measures are to be included in the analysis;*
- *the independent variables that affect energy use may be complex, and are difficult or expensive to monitor.*

4. Option D—calibrated simulation—is used in situations similar to Option C, or when:
- *new construction projects are involved (i.e. there is no historical data for baseline determination);*
- *energy savings per measure are required;*
- *Option C tools cannot assess particular measures or their interactions when complex baseline adjustments are anticipated.*

14.2   A Statistical Basis for M&V

11.2.1 Relating energy use to weather

As a basis for our analysis we must establish a simple but physical relationship between energy use and weather in a building. In simple terms, the energy required to heat the building during the heating season is equal to the heat lost from the building into the surrounding environment, through building walls, windows, and vents; and the energy required to cool the building in the cooling season is equal to the heat gained from the surrounding environment. In each case, the internal heat load is a factor—subtracting from the heat requirements or adding to the cooling requirements.

The rate at which heat loss or gain occurs is determined mainly by two key factors: the temperature difference driving force, being the difference between the indoor and outdoor temperature; and the thermal performance of the building.

A convenient way of quantifying this driving force is the heating degree day (HDD) and the cooling degree day (CDD). The HDD is defined as the sum of the differences of the daily mean temperature from a reference temperature, such as 18°C (or whatever temperature represents the thermal neutral point—at which neither heating

nor cooling is required to maintain the desired indoor temperature—for the building in question), for each day on which the temperature falls below that value in a specified period.

(For any building, there is an outside temperature at which no heat needs to be added by the temperature control plant in order to maintain the set point.   This is the thermal neutral temperature at which normal activity—heat given off by people, lights, and other equipment—generates sufficient heat to just maintain the desired temperature in spite of air changes and heat loss through the building envelope. The monitoring methods addressed later in this section require the use of this thermal neutral as the base temperature, rather than necessarily 18 ^{o}C.)

Table 14.1 gives average temperatures for Cape Town for the period 1961 to 1990. From these data, we can calculate the number of degree days, both HDD and CDD for selected base temperatures (we are using 18°C for HDD, 20°C for CDD to illustrate.)

Similarly, the CDD is defined as the sum of the differences between the average outdoors temperature and a suitable reference, such as 20°C.

Table 14.1: Degree-Day Calculations for Cape Town

Month	Days	Tavg.	HDD18	CDD20
J	31	20.9	0.0	27.9
F	28	21.0	0.0	28.0
M	31	19.8	0.0	0.0
A	30	17.5	15.0	0.0
M	31	14.8	99.2	0.0
J	30	13.0	150.0	0.0
J	31	12.2	179.8	0.0
A	31	12.7	164.3	0.0
S	30	14.0	120.0	0.0
O	31	16.0	0.0	0.0
N	30	18.4	0.0	0.0
D	31	19.9	0.0	0.0
Yearly			**728.3**	**55.9**

So in July, we see the heating degree-days indicated as 179.8 for the recorded average daily mean temperature o 12.2^{o}C. Note that the calculation yields negative answers in HDD when the average temperature is greater than 18, or in CDD when the average temperature is less than 20; however, negative answers are meaningless because they simply indicate that no heating was required in the first case, or no cooling was required in the second case.

Although oversimplifying a complex physical situation, we might think of the overall building having a coefficient of heat loss—let's call it U—which relates the rate of heat loss to the temperature difference driving force. The total heat lost in a period is then the integral of the instantaneous heat loss rate. We can then say that the heat lost is directly proportional to the driving force, or the HDD measure:

$$H \: \alpha \: HDD$$
$$Or \: H = U \times HDD$$

with the constant of proportion being the heat transfer coefficient of the building. This provides a theoretical basis for the empirical expectation that energy plotted against HDD is a straight line. A more rigorous development of this relationship follows below.

What we have established so far is that it is reasonable to plot energy against HDD or CDD and to expect a straight line. Indeed, that is what is commonly found, with a straight line produced of the form:

$$y = mx + c$$

where **c**, the intercept, and **m**, the slope, are empirical coefficients. For our working example this is shown in Figure 14.1 in which the base year (1999/2000) heating season data are used. In fact, there are three features in Figure 14.1. Apart from **c** and **m**, another feature is the **scatter**. The graph points in Figure 14.1 represent the energy consumption on a billing period basis, plotted against the HDD for that period

As expected, the kWh energy consumed increases with HDD, although there is some scatter, in particular one or two points that fall well below the trend established by the others.

Figure 14.1 Energy Consumption vs. HDD Scatter Plot
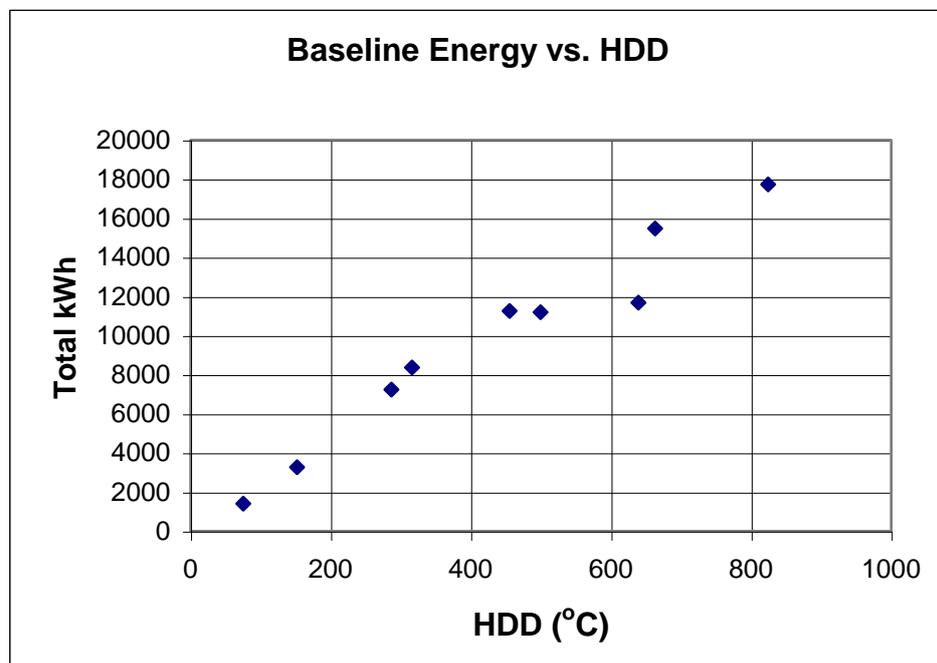
11.2.2 Heating Requirements and Weather – A Rigorous Development of the Relationship

The heat needs of a building are primarily determined by the need to maintain the temperature of the building by adding heat through the heating system to offset heat lost through the building envelope and ventilation. The relationship between heat requirement and temperature is expressed as follows:

$$H = U\,A\,(T_i - T_o) + C_p\,N\,V\,(T_i - T_o) \quad \text{(Equation 14.1)}$$

where:
H is the heat input to the building per unit of time

U is the heat transfer coefficient of the building envelope, taking into account its components such as glazing, interior wall finish, insulation, exterior wall, etc.

A is the external area of the building envelope

C_p is the specific heat of air

N is the number of air changes of per unit of time

V is the volume of the building being ventilated

T_i-T_o is the difference between the inside and outside temperatures.

The two terms of this equation represent heat requirements to overcome heat loss through the building envelope, and to replace heat lost by ventilation respectively. Algebraically they can be combined to simplify the equation, as follows:

$$H = (U A + C_p N V)(T_i\text{-}T_o) \qquad \textbf{(Equation 14.2)}$$

U, A, C_p, N, and V are all characteristic constants of the building, and usually T_i is controlled at a constant set value. Therefore, the only variable in the equation is T_o, and it may be higher or lower than the inside temperature depending on the season. When T_o is less than T_i, H is a positive number indicating that heat must be added to the building—the heating season; conversely when T_o is greater than T_i , H is a negative number indicating that heat must be removed from the building—the cooling season.

When degree-days are used as the determinant of heat load, equation 14.2 becomes:

$$H = (U A + C_p N V) \times \text{degree-days} + c \quad \textbf{(Equation 14.3)}$$

which you will recognize as the equation of a straight line, as in Figure 14.2, when H is plotted against degree-days, having a slope = (U A + C_p N V) and an intercept on the y-axis = c. This constant c is the 'no load' energy provided whatever the weather conditions by such things as office equipment, the losses from the boiler, lighting, and people.
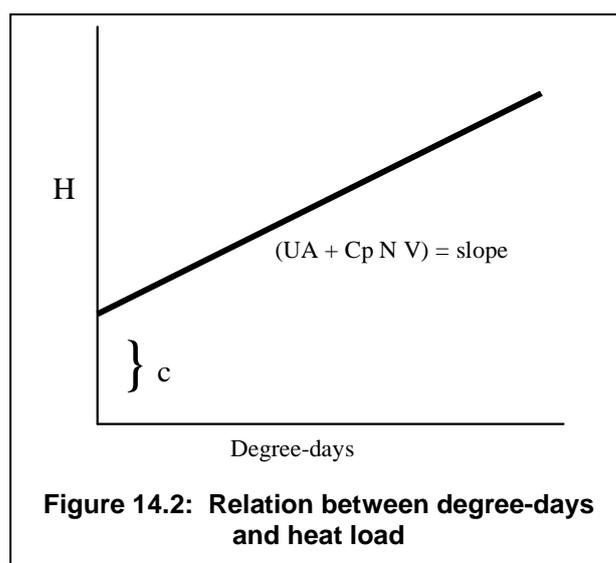
**Figure 14.2: Relation between degree-days
and heat load**

CUSUM is an application of the regression model seen previously in its use for savings verification. As a management tool, the relationship between energy consumption and key determining parameters, HDD in this example, is used to monitor current performance against the standard of the baseline relationship.

We have seen how to do linear regression previously. For the example in this discussion, we know that no measures were implemented until the end of the first

heating season; therefore, the 1999/2000 data are used for the determination of the baseline relationship. Figure 14.3 shows the result of the regression along with the baseline performance equation.

It is important to note that care must be taken in establishing the baseline relationship. If measures have been implemented to change energy performance, the regression relationship will be less valid—it may be meaningless—as a predictor of future performance.

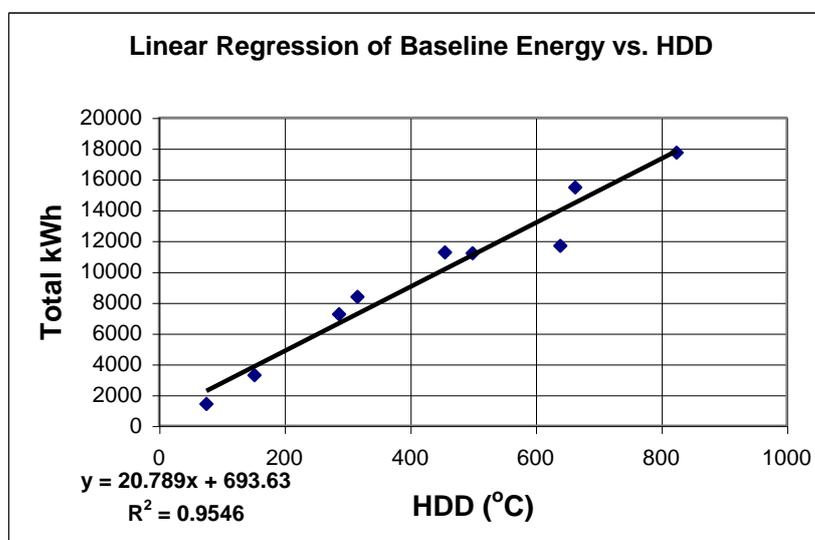**Linear Regression of Baseline Energy vs. HDD**

$$y = 20.789x + 693.63$$
$$R^2 = 0.9546$$

Figure 14.3: Linear Regression of Baseline Energy Use

11.2.3 Variants of the Regression Pattern for Buildings and Processes

The straight line graph of Figure 14.3 is the most common form for buildings, but it is not the only one. A great deal can be deduced about a building or whole site from the form of the graph of energy against degree-days.

The straight line graph with an intercept means that there are two components to energy use:

- A degree-day unrelated independent part, which is consumed regardless of how warm or how cold the weather is;
- A degree-day related part, in which the energy use per degree-day is a constant.

In a building, the degree-day unrelated part consists mainly of the non-space heating needs of the building, such as domestic hot water production, and the degree-day related part is mainly the heat input to make up the losses through the building envelope and ventilation, or the cooling required to deal with the internal heat load and heat gain from the outside. A straight line is expected only if the inside temperature is constant. These conditions are violated in some buildings, and the patterns shown in Figure 14.4 may result.

Type 1 is the normal type of building.

Type 2 shows the case where there is no energy use at all until the weather reaches a given number of degree days; this usually indicates an internal temperature that is different from the degree-day base (usually 18°C), requiring adjustment in the analysis process.
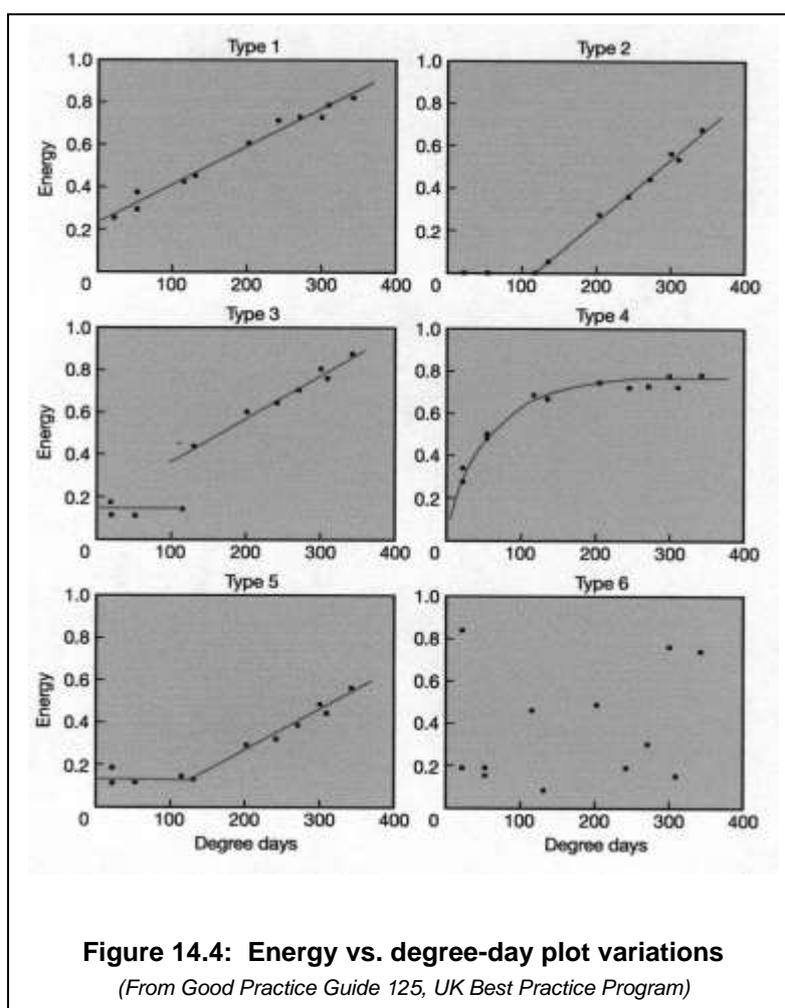
Type 3 indicates losses unrelated to the weather, usually in the distribution system. The difference between the y-axis intercepts of the two lines represents energy used which is not related to the weather when the heating is on.

Type 4 is an extremely important case where the line is curved and appears to be levelling off at some high value of degree-days. It usually indicates a fault in the building where the heating system is poorly matched to the heat losses. A very large proportion of the potential savings of heating energy is in buildings of this type.

Type 5 is where there are separate sources for winter heating and for summer hot water. The horizontal portion of the graph represents the portion of heating energy not used for space heating, and needs to be subtracted from the total energy of the sloped portion to give the space-heating energy consumption, as in Type 1.

Type 6 obviously yields no linear relationship whatever. With this type of graph, there are usually two possible explanations of the scatter:
- Problems in the data gathering—the energy and degree-day data are not coordinated properly by being measured in the same time interval, for example
- Variations in production or some other variable overwhelm the effect of weather.

Figure 14.4: Energy vs. degree-day plot variations
(From Good Practice Guide 125, UK Best Practice Program)

11.2.4 Baseline Definition

The definition of the baseline conditions involves not only quantifying energy consumption data, but also specifying those factors that affect energy consumption. Data and information required for a complete baseline definition include:

✓ **Energy consumption data:**
- Electricity consumption information—bills and derived information (kW, kVA, PF), meter readings (especially for subsystem measurements), demand profiles;
- Fuel consumption information—bills, monthly consumption profiles, fuel-by-fuel data (quantity, calorific value of fuels consumed, etc.);
- Water consumption information
- Other energy sources—e.g. purchased steam, etc.

✓ **Independent variable data:**
- Weather factors—HDD or CDD;
- Facility occupancy or usage data—operating hours, number of patrons, etc.;
- Throughput or production—as in volume of water pumped or wastewater treated;
- Space conditions—set points on heating/cooling systems;
- Equipment malfunctions—records of outages.

Baseline Adjustments

The fundamental relationship for savings verification includes "adjustment" of the baseline performance. Baseline adjustments potentially represent the most contentious aspect of energy performance contracts, and may be the most difficult aspect of savings verification to quantify. Simply put, "adjustment" places the baseline energy performance on a "level playing field" with post-installation performance in terms of those independent variables that affect energy consumption.

ESCOs must specify as part of their M&V plan how they will adjust the baseline if the post-installation operating conditions are different from those used to determine the baseline. These specifications should address the independent variables listed above, as relevant to the project.

The following are examples of baseline adjustments:

- **Changes in weather or occupancy**: adjustments might include recalculating the baseline consumption rates using post-installation period weather data (HDD or CDD) or occupancy data based on a mathematical expression of how energy consumption depends on these factors;

- **Changes in operating schedule or tenant improvements**: the real impact of the retrofit project is independent of decreases or increases in operating hours of the facility or system and, therefore, the baseline consumption needs to be scaled up or down to correspond to such changes if any occur; similarly, tenant improvements—new plug loads, improved lighting levels unrelated to the retrofit itself, etc.—that may increase energy consumption in the post-installation period must be separated from the post-installation period performance.

- **Changes in the actual function of the facility**—office space being converted to storage, for example—and their impact on energy performance separate and apart from the retrofit, need to be quantified as adjustments to baseline performance.

The extent to which baseline adjustments need to be considered depends to some extent on the M&V Option being employed:

- Baseline adjustments are less likely to be needed when M&V Option A is being used since many of the performance factors are stipulated.

- Option B or retrofit isolation involves metering of energy consumption pre- and post-installation; non-metered factors that impact on energy performance therefore need to be applied to the measured baseline consumption.

- Option C involves regression analysis to determine a functional relationship between energy consumption and independent variables; adjustment to the baseline performance for changes in these variables is typically carried out by using that functional relationship or performance model.

- Option D accommodates adjustment within the simulation model itself; once calibrated using actual or typical data, no other adjustments should be required.

14.3   A Framework for Verification

14.3.1 M&V Process Flow Chart

Figure 14.5 is a flow chart to outline the steps involved in planning and implementing an M&V process. A planning template follows in Figure 14.6.

14.3.2 M&V Option Selection Decision Model

Figure 14.7 is a decision tree for the selection of the IPMVP Option to be employed in a given project.

The selection of an M&V Method from the Options described in the IPMVP is based on:
- project costs;
- expected savings;
- complexity and number of measures installed;
- anticipated changes to post-installation facility or system usage;
- tolerance for uncertainty or risk of savings being achieved;
- risk allocation between the owner and the contractor.

There is a trade-off between the cost of doing M&V and uncertainty. In general, the lower the acceptable level of uncertainty, the higher the cost. For example, a project with anticipated annual savings of R2,500,000 and estimated uncertainty of 20% has a savings risk of R500,000; if an M&V program costing R125,000 can reduce that risk to 10% or R250,000, there is a cost/benefit ratio of 2/1 for the M&V program that may be deemed a good investment. This kind of analysis needs to be done to evaluate the cost of reducing risk.

Figure 14.5: M&V Process Flow Chart

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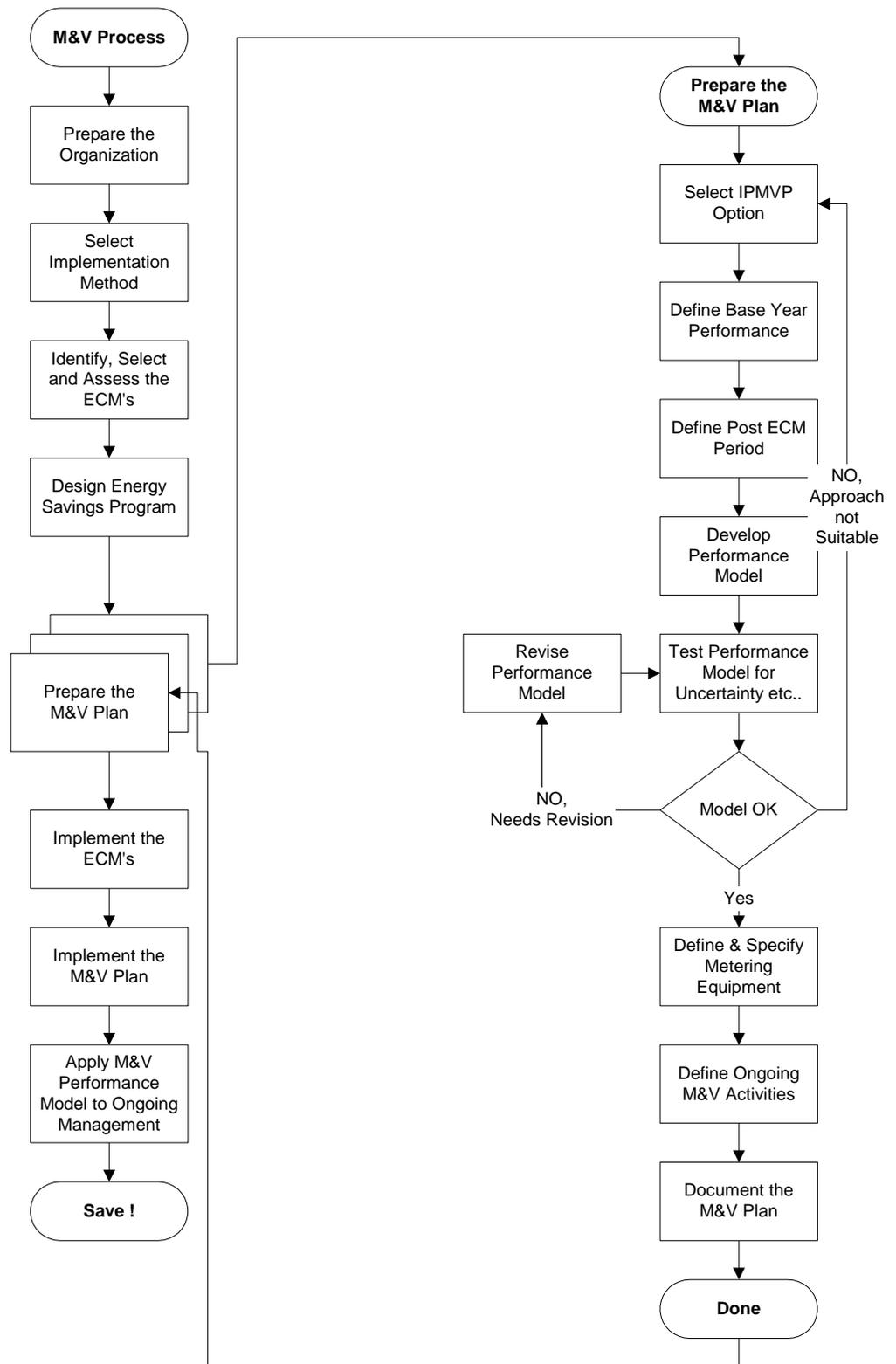
Figure 14.6   M&V Planning Template

Source: ***Federal Energy Management Program (FEMP) Sample Measurement & Verification Plans***, *Draft for Public Review, Prepared by Schiller Associates for Lawrence Berkley National Laboratory, January 25, 2001*

The following are section headings that are recommended for M&V plans for government energy management retrofit projects. Under each section heading is a description of the required information.

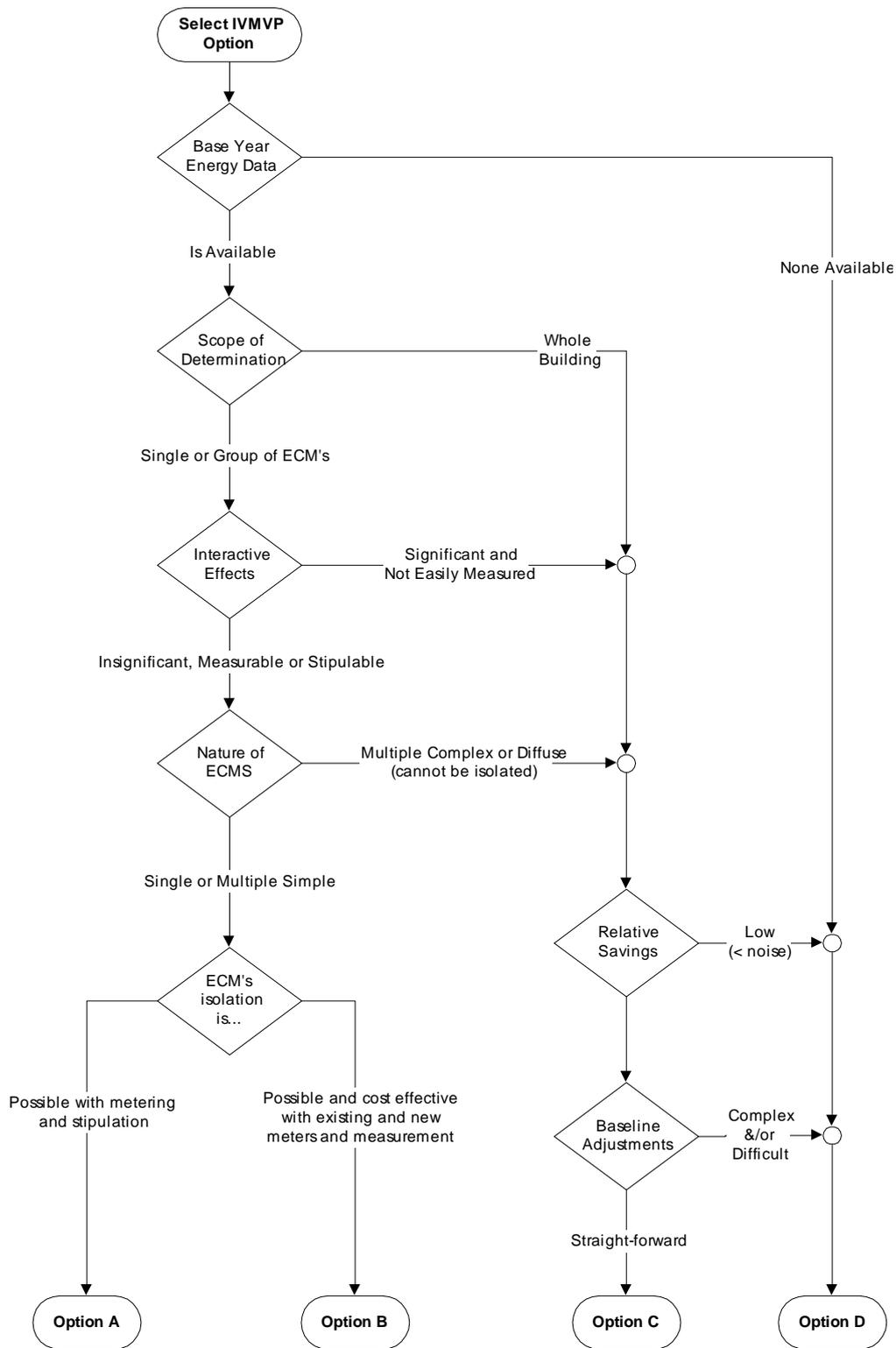| Section Headings	Description
Project-level components	
Project Description	• Project goals; • Building details – size, location, use, equipment, energy consumption characteristics; • ECMs – how they save energy, water or O & M costs; • Applicable EE or performance standards;
Project Savings and Costs	• Anticipated energy and cost savings for each ECM and in total; • Anticipated costs for M&V;
Responsibility Matrix	• Important risks and their potential impact; • Responsibility for managing risks;

Schedule	• Schedule for ECM installation, M&V activities, reporting intervals, including:
	  o Pre- and post-installation audits and inspections;
	  o Monitoring and analysis activities;
	  o Reporting milestones;
	  o Commissioning reports;
	  o Quarterly or annual M&V reports;

Reports to be Prepared	• Frequency, format, content of reports;
Measure-level components	
Measure Description	• Specific details about each ECM; • Savings to be claimed; • Vintage, condition, usage, operational and maintenance history of equipment to be replaced or modified; • Equipment standards;
M&V Approach	• IPMVP Option; • General description of approach; • Accuracy of M&V method; • Savings uncertainty and confidence level; • Factors most uncertain or difficult to quantify;
Assumptions	• Baseline and post-installation assumptions that affect energy consumption (building occupancy schedules, equipment efficiencies, equipment operating strategies, load shapes, weather data, etc.); • Energy price schedules, facility staff labour rates, etc.;
M&V Activities: *Baseline Period*	• Who will do M&V activities; • List of activities before and after installation; • List of variables affecting energy consumption and how they will be quantified; • Equipment surveys: location, type, quantity, measured data, model numbers, etc.;

Post-installation Period	• Critical baseline condition factors: comfort conditions, lighting intensities, temperature set points, etc.; • List of variables affecting energy consumption, variance from baseline case, and how they will be quantified; • New equipment surveys; • Critical post-installation condition factors; • Activities to ensure equipment operating as intended;
Calculations and Adjustments	• Equations, calculations and analysis procedures for baseline and post-installation consumption; • How performance models will be developed; • How energy savings will be calculated; • How adjustments will be made;
Metering Plan	• Who will provide and maintain metering equipment; • Specifications of metering equipment, accuracy, calibration procedures; • How data will be collected, maintained and reported; • Accuracy and quality assurance procedures;
M&V Budget	• Time and material costs to implement M&V activities.

Figure 14.7: M&V Option Selection Decision Model

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Worksheet 14.1: M&V Option Selection

1. Examine the municipal facility case assigned to your group. Make an initial selection of the M&V option best suited to the facility and the ECM's outlined.

Use the attached Option Selection Flowchart along with the Criteria for Selection from the FEMP M&V Guidelines and Best Application from IPMVP as follows:

Best Applications
Option A   IPMVP page 26
Option B   IPMVP page 27
Option C   IPMVP page 31
Option D   IPMVP page 34

Criteria for Selection of M&V Approach:
FEMP M&V Guidelines section 2.5.3, page 26

2. Provide reasons for your selection:

3. Clearly, a final option selection would require more detailed analysis. List any factors that may in further detailed analysis necessitate the use of another option. Identify which option may be required:

Worksheet 14.2: Responsibility Matrix worksheet	
Financial Risks	**Management Strategy**
Interest rates Neither the ESCO nor the agency has significant control over the prevailing interest rate. During all phases of the project interest rates will change with market conditions. Higher interest rates will increase project cost, finance term, or both. The timing of the Delivery Order signing may affect the available interest rate and project cost. Clarify when the interest rate is locked in, and if it is a fixed or variable rate.	
Energy prices Neither the ESCO nor the agency has significant control over actual energy prices. For calculating savings, the value of the saved energy may either be constant, change at a fixed inflation rate, or float with market conditions. If the value changes with the market, falling energy prices place the ESCO at risk of failing to meet cost savings guarantees. If energy prices rise, there is a small risk to the agency that energy saving goals might not be met while the financial goals are. If the value of saved energy is fixed (either constant or escalated), the agency risks making payments in excess of actual energy cost savings.	
Construction costs The ESCO is responsible for determining construction costs and defining a budget. In a fixed-price design/build contract, the agency assumes little responsibility for cost overruns. However, if construction estimates are significantly greater than originally assumed, the ESCO may find that the project or measure is no longer viable and drop it. In any design build contract the agency loses some design control. Clarify design standards and the design approval process (including changes), and how costs will be reviewed.	
M&V costs The agency assumes the financial responsibility for M&V costs directly or though the ESCO. If the agency wishes to reduce M&V cost, it may do so by accepting less rigorous M&V activities with more uncertainty in the savings estimates. Clarify what performance is being guaranteed (equipment performance, operational factors, energy cost savings), and that the M&V plan is detailed enough to satisfactorily verify it.	
Delays Both the ESCO and the agency can cause delays. Failure to implement a viable project in a timely manner costs the agency in the form of lost savings, and can add cost to the project. Clarify schedule, and how delays will be handled.	
Major changes in facility The agency (or Congress) controls major changes in facility use, including closure. Clarify responsibilities in the event of a premature facility closure, loss of funding, or other major change.	

Operational Risks	Management Strategy
Operating hours The Agency generally has control over the operating hours. Increases and decreases in operating hours can show up as increases or decreases in "savings" depending on the M&V method (e.g. operating hours times improved efficiency of equipment vs. whole building utility analysis). Clarify if operating hours are to be measured or stipulated, and what is the impact if they change. If the operating hours are stipulated, the baseline should be carefully documented and agreed to by both parties.	
Load Equipment loads can change over time. The agency generally has control over hours of operation, conditioned floor area, intensity of use (e.g. changes in occupancy or level of automation). Changes in load can show up as increases or decreases in "savings" depending on the M&V method. Clarify if equipment loads are to be measured or stipulated and what is the impact if they change. If the equipment loads are stipulated, the baseline should be carefully documented and agreed to by both parties.	
Weather A number of energy efficiency measures are affected by weather. Neither the ESCO nor the agency has control over the weather. Changes in weather can increase or decrease "savings" depending on the M&V method (e.g. equipment run hours times efficiency improvement vs. whole building utility analysis). If weather is "normalized," actual savings could be less than payments for a given year, but will "average out" over the long run. Weather corrections to the baseline or ongoing performance should be clearly specified and understood.	
User participation Many energy conservation measures require user participation to generate savings (e.g. control settings). The savings can be variable and the ESCO may be unwilling to invest in these measures. Clarify what degree of user participation is needed, and utilize monitoring and training to mitigate risk. If performance is stipulated, document and review assumptions carefully, and consider M&V to confirm the capacity to save (e.g. confirm that the controls are functional).	

Performance Risks	Management Strategy
Equipment performance Generally the ESCO has control over the selection of equipment and is responsible for its proper installation and performance. Generally the ESCO has responsibility to demonstrate that the new improvements meet expected performance levels including standards of service and efficiency. Clarify who is responsible for initial and long-term performance, how will it be verified, and what will be done if performance does not meet expectations.	
Operation Responsibility for operation is negotiable, and it can impact performance. Clarify how proper operation will be assured. Clarify responsibility for operations and implications of equipment control.	
Maintenance & Repair Responsibility for maintenance and repair is negotiable, however it is often tied to performance. Clarify how long-term maintenance and repair will be assured, especially if the party responsible for long-term performance is not responsible for maintenance. Clarify who is responsible for ECM overhaul, component or equipment repair required to maintain operational performance throughout the contract term.	
Equipment Replacement Responsibility for replacement of contractor-installed equipment is negotiable, however it is often tied to ECM performance. Clarify who is responsible for replacement of failed components or equipment throughout the term of the contract. Specifically address potential impacts on performance due to equipment failure. Life of equipment is critical to ECM performance during the contract term. Specify equipment life expected for all installed equipment and specify warranties proposed for the installed ECMs.	

Source: FEMP M&V Guidelines, Responsibility Matrix, April 2001

14.4   Verification Applied

11.4.1 Determining Base Year Data and Conditions

Worksheet 14.3: Base Year Data and Conditions

Take a moment to list the base year data and conditions from Option C Example: Whole Building Multiple ECM Project on page 64 of the IPMVP.

_____

_____

_____

_____

_____

_____

_____

_____

With a checkmark, indicate the data actually used in the baseline determination.

11.4.2 Hierarchy of Available Energy Use Data

Worksheet 14.4: Hierarchy of Available Energy Use Data

List and organize in the following table the kinds of information that you are aware of being currently available to describe the energy performance of facilities in your portfolio. This is a table that may be useful for summarizing information availability in the early stages of your M&V planning process.

Building[1]	System[2]	Data[3]	Source[4]

[1] **Building** – for which facility or group of facilities does this information exist
[2] **System** – for what energy consuming systems or specific devices does this information exist
[3] **Data** – what kind of data is currently available (e.g. monthly energy costs, utility meter readings)
[4] **Source** – who has the data

Typically, in this table we will find a pattern structured as an hierarchy of information, in which:

- **Strategic** level information can be derived from financial accounting systems—the utilities cost centre;
- **Portfolio** information can be found in comparative energy consumption data for a group of similar buildings (rinks or recreation centres, for example);
- **Building** performance data can be determined from utility billings, service entrance meter readings, building management system data, correlated with building use and weather data;
- **System** information can be derived from name-plate data, run-time and schedule information, sub-metered data on specific energy consuming systems.

11.4.3 Computing Savings Using the Performance Model

Worksheet 14.5: Computing Savings Using the Performance Model

Refer to the Option C Example: Whole Building Multiple ECM Project on page 64 of the IPMVP. Consider the case of the natural gas account #KHJR3333-597.

1. Document the Performance Model

When DD <= 25

Projected Energy Use = _____ ft^3/day x days

When DD > 25

Projected Energy Use = _____ ft^3/day x days + _____ ft^3/DD x DD

Apply the Performance Model

	Post Retrofit Conditions		Projected Post Retrofit Gas Use(ft^3)	Actual Post Retrofit Gas Use (ft^3)	Savings (ft^3)
	Degree Days	**# of days**			
Jan	725	33		1,750	
Feb	540	28		1,246	
Mar	382	31		905	
Apr	195	30		635	
May	50	31		290	
Jun	15	29		120	
Jul	1	30		90	
Aug	4	27		80	
Sep	23	34		130	
Oct	112	31		278	
Nov	350	30		690	
Dec	576	31		1150	
Total	n/a	365			

11.4.4 Non-Routine Adjustments

Worksheet 14.6: Non-routine Adjustments - Computing Savings with Non-Routine Adjustments

Consider the case of a gas fired pottery kiln being added to the school of the Option C example. Assume that the kiln was installed early in the July billing period.

1. Model the Adjustments

When school is "open"
Kiln Energy Use = _____ ft^3/day x days

When school is "closed"
Kiln Energy Use = 0 ft^3

2. Apply the Performance Model

Post Retrofit Conditions			Projected Post Retrofit Gas Use(ft^3)	Actual Post Retrofit Gas Use (ft^3)	Adjustment for Kiln Use (ft^3)	Savings (ft^3)
	Degree Days	**# of days**				
Jan	725	33		1,750		
Feb	540	28		1,246		
Mar	382	31		905		
Apr	195	30		635		
May	50	31		290		
Jun	15	29		120		
Jul	1	30		190		
Aug	4	27		200		
Sep	23	34		260		
Oct	112	31		405		
Nov	350	30		805		
Dec	576	31		1210		
Total	n/a	365				

11.4.5 Uncertainty in Verification

Worksheet 14.7: Uncertainty in Verification

1. For the selected Municipal Case identify the possible sources of uncertainty using the M&V Option previously selected. Indicate whether you believe they can be quantified and rank them in order of significance in determining cost.

Source of Uncertainty	Quantifiable?	Rank

2. After this assessment would you consider changing the M&V option selected? If so to which option and why?

3. Consider how much uncertainty would be tolerable / acceptable for each of the three Cases.

Case	Uncertainty	Why
Recreation Centre		
Municipal Office		
Pumping Station		

11.4.6 Cost Saving and Emission Reduction

Worksheet 14.8: Cost Saving & Emission Reduction

Basic Info	Energy		Demand	
Baseline		kWh		kVA
Post Retrofit		kWh		kVA
Adjustment		kWh		kVA
Savings (Baseline – Post Retrofit + Adjustment)		**kWh**		**kVA**
Uncertainty	% @	@ conf	% @	@ conf
Rates				
1st Block	kWh @ R	/kWh	kVA @ R	/ kVA
2nd Block	kWh @ R	/kWh	kVA @ R	/ kVA
3rd Block	kWh @ R	/kWh	kVA @ R	/ kVA
Bill Calculation				
1st Block Charges	R		R	
2nd Block Charges	R		R	
3rd Block Charges	R		R	
Post Retrofit Bill	R			
Marginal Price	R	/kWh	R	/kW
Cost Savings	**R**		**R**	
GHG Calculation				
GHG Factor		eq kg CO$_2$/kWh		eq kg CO$_2$/kWh
kWh Saved		kWh		kWh
GHG Reduction (GHG Factor x kWh)		**eq kg CO$_2$**		**eq kg CO$_2$**

14.5 Case Study: IPMVP Option C – Whole Building Multiple ECM Project (From IPMVP Volume 1)

Option C Example: Whole Building Multiple ECM Project

Situation

An energy efficiency project was implemented in a high school, involving six ECMs spanning lighting, HVAC, pool heating and operator training and occupant awareness campaigns. The objectives of the project were to reduce energy costs.

M&V Plan

An M&V Plan was developed showing that Option C was to be used for savings determination because total facility energy cost was the focus. An outline of the Plan is shown below:

- The boundary of this savings determination was defined as:
  - The main electricity account #766A234-593 including demand
  - The auxiliary electrical account #766B122-601 serving the field house
  - The natural gas account #KHJR3333-597
- The baseyear conditions are those of the 12 months immediately preceding the decision to proceed with the project. Included in the documentation of these conditions is:
  - a lighting level survey, with a count of the number of burned out lamps in January and June;
  - a summary of typical space temperatures and humidities during occupied and unoccupied periods in each of four seasons;
  - a count of the number and size of all computers, monitors and printers, along with an estimate of the operating hours of each;
  - a record of the number of day pupils and evening courses each month of the year;
  - a record of the number of public rental hours of the gym, cafeteria and pool each month;
  - a count of the number of window air conditioning units installed;
  - the temperature setting of pool water, and domestic hot water serving the pool showers, the gym showers and the rest of the school;
  - the volume of make-up water supplied to the pool each month, as recorded by a separate uncalibrated sub-meter;
  - the cafeteria kitchen hot water temperature and the number and rating of all kitchen equipment; and
  - the open hours of the cafeteria kitchen and the value of food sales each month.
- The baseyear energy use is shown on the above utility accounts spanning the period January 1998 to December 1998.
- The baseyear energy data were analyzed as follows. Multiple linear regression was performed on monthly energy use and demand, metering period length, and degree days (DD). Degree days data were derived from mean daily dry bulb temperature published monthly by the government weather service for the city where the school is located. No significant correlation with weather was found for electric demand, summer electricity use in the field house or summer gas use. Analysis found reasonable

Examples

correlation between weather and winter gas use and the main electricity meter's winter consumption. Therefore no other independent variables were sought. The energy per DD and energy per day data shown below describe the characteristics of the straight line relationship found by the regression analyses:

		Gas	Electricity		
			Demand	Consumption	Consumption
Account Number		KHJR3333-597	766A234-593		766B122-601
Units		10^3 ft^3 (10^3 m^3)	kW-mo	kWh	kWh
Annual Total		10,238 (290)	5,782	1,243,000	62,000
Winter Regression Analysis	DD Base	15°C		16°C	20°C
	Energy/DD	2.55		39.61	18.12
	Energy/Day	9.16		2,640	20.1
	CV (RMSE)	9%		18%	5%

- Savings will be determined under post-retrofit conditions.

- The savings calculation process shown below was summarized in the M&V Plan.

- The school has provided XYZ contractor authorization to receive energy use data from the electric and gas utility companies until 2008.

- Savings are to be computed and reported monthly by XYZ contractor in a format for physical plant staff to understand and quarterly in a format for teaching staff and students to understand. This reporting is to begin immediately after ECM completion. It will continue at this rate for eight years.

- Annually the school will report any changes in the baseyear conditions listed above, within a month after the end of each school year. XYZ contractor will compute the energy impact of these changes and any others that it believes are relevant and present Non-Routine Baseline Adjustments two months before the end of the school board's fiscal year.

- This savings determination process is expected to require a data entry and utility bill analyst 10 hours each year and an engineer 5 hours to review reports for accuracy and establish suitable computations for Non-Routine Baseline Adjustments. Total cost each year is expected to be about $1,000 including reporting.

The CV (RMSE) of the baseyear models range from 5% to 18% and are far less than the expected savings of 35% for both fuel and electricity. No sampling or instrumentation error exists. Therefore the reported savings will be statistically significant, subject to any error introduced through non-routine baseline adjustments which may arise.

Baseyear Energy Use

The baseyear energy use for Equation 1 is taken directly from the utility bills without adjustment. The data were tabulated in the M&V Plan.

Examples   65

Post-Retrofit Energy Use

The post-retrofit energy use for Equation 1 is taken directly from the utility bills without adjustment.

Routine Adjustments

Routine adjustments are needed to bring baseyear energy use to the conditions of the post-retrofit period. For the first year after retrofit the routine adjustments are computed as follows.

Gas:

| | Baseyear Energy Use | | Post-Retrofit Conditions | | Baseyear Energy Use Projected to Post-Retrofit Conditions | | | | |
	Consumption[a]	Days[b]	Days[c]	DD[d]	Winter Base[e]	Winter Heating[f]	Summer[g]	Total[h]	Adjustment[i]
Jan	2,239.1	29	31	742	284.0	1,892.1		2,176.1	-63.0
Feb	1,676.3	31	30	551	274.8	1,405.1		1,679.9	3.5
Mar	1,223.1	31	32	401	293.1	1,022.6		1,315.7	92.6
Apr	723.3	30	28	208	256.5	530.4		786.9	63.6
May	399.6	30	30	41	274.8	104.6		379.4	-20.3
Jun	240.1	28	30	12			257.3	257.3	17.2
Jul	201.2	31	32	0			207.7	207.7	6.5
Aug	193.6	30	30	2			193.6	193.6	0.0
Sep	288.7	30	30	20			288.7	288.7	0.0
Oct	439.1	30	31	99	284.0	252.5		536.4	97.3
Nov	1,023.6	31	30	302	274.8	770.1		1,044.9	21.3
Dec	1,591.1	33	33	521	302.3	1,328.6		1,630.8	39.7
Total	10,238.8	364	367					10,497.2	258.4

a. facts from the baseyear energy data
b. facts from the baseyear energy data
c. facts from the post-retrofit metering periods
d. facts from the post-retrofit metering periods
e. (c) x 9.16 for month where DD > 25
f. (d) x 2.55 for months where DD > 25
g. (a/b) x (c) for months where DD = 25 or less
h. (e) + (f) + (g)
i. (h) - (a)

Electricity Consumption:

Calculations for each of the two electricity consumption meters are performed separately in the same fashion as the gas meter above, using the relevant baseyear data, regression factors, metering periods and degree days. The net routine adjustments for each month are shown in the Savings section below.

Electric Demand:

No routine adjustments are made since no correlation was found with weather.

Examples

Non-Routine Adjustments

During the first post retrofit period extra computer equipment was added, partially replacing older computers. The following monthly energy and demand estimates were made from nameplate ratings, typical loading and operating hours for the ten months when school is in session:

	Computer	Monitor	Printer	Total
Net Number Added	23	23	5	
Nameplate Watts	150	120	175	
Average Watts	70	110	50	
Hours Use/month	150	150	120	
kWh/month	242	380	30	652 kWh
Demand diversity	90%	90%	70%	
kW demand	1.45	2.28	0.23	3.96 kW

Though there may be a 50% error in these estimates, their impact is small relative to the savings report.

Savings

From Equation 1, the energy savings for the first year after ECM installation are determined for each account to be:

1   Gas Account #KHJR3333-597 Thousand ft^3 or Thousand m^3

	Baseyear Energy Use	−	Post-Retrofit	+	Adjustment	=	Savings
Jan	2,239.1	−	1,839.1	+	-63.0	=	337.0 (9.54)
Feb	1,676.3	−	1,233.6	+	3.5	=	446.3 (12.64)
Mar	1,223.1	−	932.1	+	92.6	=	383.6 (10.86)
Apr	723.3	−	621.1	+	63.6	=	165.8 (4.69)
May	399.6	−	301.0	+	-20.3	=	78.4 (2.22)
Jun	240.1	−	160.2	+	17.2	=	97.1 (2.75)
Jul	201.2	−	120.1	+	6.5	=	87.6 (2.48)
Aug	193.6	−	150.9	+	0.0	=	42.7 (1.21)
Sep	288.7	−	202.3	+	0.0	=	86.4 (2.45)
Oct	439.1	−	339.1	+	97.3	=	197.3 (5.59)
Nov	1,023.6	−	678.4	+	21.3	=	366.5 (10.38)
Dec	1,591.1	−	1,123.2	+	39.7	=	507.6 (14.27)
Total	**10,238.8**	**−**	**7,701.1**	**+**	**258.4**	**=**	**2,796.1 (79.16)**

2 Electricity Account #766A234-593 Consumption (kWh)

	Baseyear Energy Use	−	Post-Retrofit	+	Routine Adjustment	+	Non-Routine Adjustment	=	Savings
Jan	122,400	−	81,200	+	3,740	+	652	=	45,592
Feb	118,600	−	76,200	+	2,780	+	652	=	45,832
Mar	132,200	−	83,200	+	-1,220	+	652	=	48,432
Apr	110,800	−	77,600	+	1,890	+	652	=	35,742
May	106,000	−	65,400	+	2,120	+	652	=	43,372
Jun	101,200	−	61,200	+	120	+	652	=	40,772
Jul	30,200	−	20,800	+	-3,600	+	0	=	5,800
Aug	36,200	−	23,800	+	2,480	+	0	=	14,880
Sep	105,200	−	66,800	+	2,260	+	652	=	41,312
Oct	110,200	−	70,600	+	200	+	652	=	40,452
Nov	126,600	−	83,200	+	5,320	+	652	=	49,372
Dec	128,400	−	81,000	+	-2,240	+	652	=	45,812
Total	**1,228,000**	−	**791,000**	+	**13,850**	+	**6,520**	=	**457,370**

3 Electricity Account #766A234-593 Demand (kW)

	Baseyear Energy Use	−	Post-Retrofit	+	Routine Adjustment	+	Non-Routine Adjustment	=	Savings
Jan	561	−	402	+	0	+	4	=	163
Feb	521	−	381	+	0	+	4	=	144
Mar	502	−	352	+	0	+	4	=	154
Apr	490	−	328	+	0	+	4	=	166
May	472	−	330	+	0	+	4	=	146
Jun	470	−	336	+	0	+	4	=	138
Jul	300	−	222	+	0	+	0	=	78
Aug	470	−	324	+	0	+	0	=	146
Sep	476	−	336	+	0	+	4	=	144
Oct	480	−	350	+	0	+	4	=	134
Nov	500	−	362	+	0	+	4	=	142
Dec	540	−	390	+	0	+	4	=	154
Total	**5,782**	−	**4,113**	+	**0**	+	**40**	=	**1,709**

4   Electricity Account #766B122-601 Consumption (kWh)

	Baseyear Energy Use	– Post-Retrofit	+ Adjustment	= Savings
Jan	12,200	– 10,200	+ -1,200	= 800
Feb	9,600	– 11,200	+ 2,320	= 720
Mar	8,800	– 7,800	+ -200	= 800
Apr	4,400	– 4,800	+ 1,280	= 880
May	3,800	– 5,100	+ 2,120	= 820
Jun	1,200	– 500	+ 120	= 820
Jul	800	– 400	+ 23	= 423
Aug	600	– 300	+ -48	= 252
Sep	1,200	– 400	+ 41	= 841
Oct	4,400	– 3,800	+ 140	= 740
Nov	6,600	– 5,400	+ -290	= 910
Dec	8,400	– 9,000	+ 1,400	= 800
Total	**62,000**	**– 58,900**	**+ 5,706**	**= 8,806**

Note that in this example the savings reported are for operations under post-retrofit period conditions. Therefore the savings can be called "avoided energy use."

14.6 M & V Checklists

Worksheet 14.9: M & V Approach

❑ Project site and measures are reasonably defined
  ❑ What savings will be claimed? (energy, interactive effects, O&M, rate change, etc.)

❑ M&V approach (A, B, C, D from IPMVP) is defined for each measure.

❑ Baseline Equipment and Conditions
  ❑ Plan for defining existing equipment (inventory and performance) is described
  ❑ Plan for defining space conditions (lighting intensity, temperatures, etc.) is described
  ❑ How and why any baseline adjustments will be made is discussed.

❑ Post-installation equipment and conditions
  ❑ Plan for defining new equipment (inventory and performance) is described
  ❑ Plan for defining space conditions (lighting intensity, temperatures, etc.) is described

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Worksheet 14.10: M & V Plan and Periodic Submittals

- ❑ Project site and measures are defined
  - ❑ What savings will be claimed? (energy, interactive effects, O&M, rate change, etc.)
  - ❑ How will these ancillary savings be treated?

- ❑ M&V methods are defined.

- ❑ Details of how calculations will be made are defined. All equations are shown.
  - ❑ Provided information shows how collected data and assumptions are used.
  - ❑ Energy pricing information and assumptions are defined.

- ❑ Baseline equipment and conditions.
  - ❑ Existing equipment (inventory and performance) is defined.
  - ❑ Space conditions (lighting intensity, temperatures, etc.) are defined.
  - ❑ Assumptions and stipulations – show supporting information or measurements to be taken.
  - ❑ How and why any baseline adjustments will be made is discussed.

- ❑ Post-installation equipment and conditions.
  - ❑ Plan for defining new equipment (inventory and performance) is described.
  - ❑ Plan for defining new space conditions (lighting intensity, temperatures, etc.) is described.
  - ❑ Assumptions and stipulations –show supporting information or measurements to be taken.

- ❑ Metering equipment is specified.
  - ❑ Schedule of metering, including duration and when it will occur, is defined.
  - ❑ Who will provide equipment, establish and ensure its accuracy and perform calibration procedures, is described.
  - ❑ How data from metering will be validated and reported, including formats, are defined.
  - ❑ How electronic, formatted data, directly from a meter or data logger, will be provided.
  - ❑ Any sampling that will be used, sample sizes, documentation on how sample sizes were selected, is defined.

- ❑ Annual verification and measurement activities are defined.
  - ❑ Who will conduct the M&V activities and prepare M&V analyses and documentation is defined.
  - ❑ How quality assurance will be maintained and repeatability confirmed is defined.
  - ❑ Reports are defined, including what they will contain and when they will be provided.
  - ❑ Electronic formats and software programs to be used for reporting are defined.

- ❑ Initial and annual M&V costs for each measure (totals only) are defined.