Evaluation, Measurement and Verification (EM&V)

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TENNESSEE ENERGY EDUCATION INITIATIVE
Power. Positive. Progress.

What will be covered

- ***What is Evaluation, Measurement, and Verification?***
- ***How does EM&V help my projects or programs?***
- ***What EM&V resources are available?***
- ***International M&V Protocol***
- ***Measurement and Conversion units***

EM&V

Catchall acronym for determining both program and project impacts.

Evaluation

Studies and activities aimed at determining the effects of a program or portfolio.

Measurement and Verification

Data collection, measurements, monitoring, and analysis associated with determining energy and demand savings from individual sites or projects. M&V can be a subset of program evaluation.

Why Evaluate, Measure and Verify?

"Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it."

- H. James Harrington

"Things that are measured tend to improve"

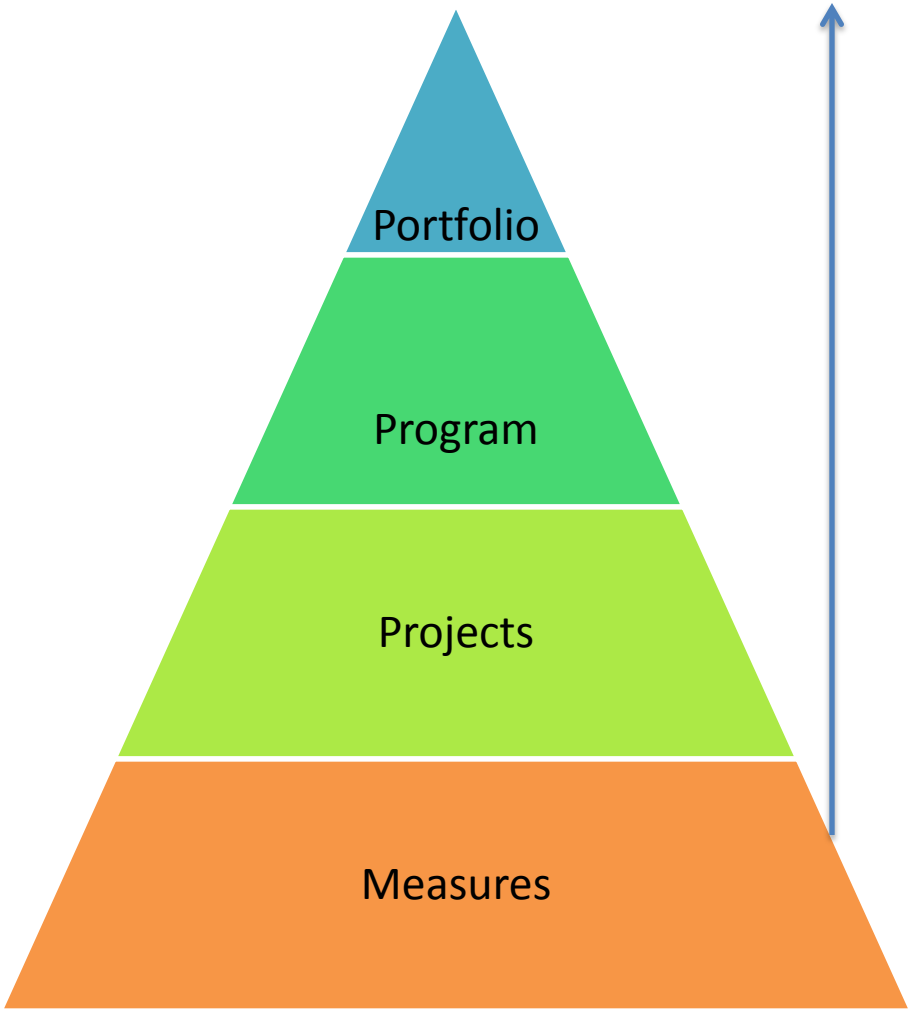
- John Kenneth Galbraith

"Doveryai, no proveryai" (Trust, but verify)

- President Ronald Reagan

EM&V: Hierarchy

- Fundamental savings unit is the measure, equipment or strategy that reduces energy use while maintaining or improving service
- Projects are coordinated activities to install one or more measures at a facility
- Programs are collections of similar projects that are intended to motivate customers in a specific to implement more energy efficiency
- Portfolios are multiple program initiatives in specific market sectors



Evaluation

Involves real time and/or retrospective assessments of the performance and implementation of a program.

There are two key objectives of evaluations:

1. To document and measure the effects of a program and determine whether it met its goals with respect to being a reliable energy resource.
2. To help understand why those effects occurred and identify ways to improve current programs and select future programs.

Evaluation Planning

1. Defining evaluation goals and scale (program benefits to evaluate).
2. Setting a time frame for evaluation and reporting expectations.
3. Setting a spatial boundary for evaluation (i.e., what energy uses, emission sources, etc., the analyses will include).
4. Defining a program baseline, baseline adjustments, and data collection requirements.
5. Establishing a budget in the context of expectations for the quality of reported results.
6. Selecting the individual or organization that will conduct the evaluation.

How do we evaluate EM&V?

Two Categories and Six Types of Evaluations

Evaluation Category	Phase at Which Implemented	Evaluation Type	Assessment Level
Formative	Pre-program Planning Phase	Market Assessment (includes characterization, baseline)	Market, Portfolio, Program
		Potential or feasibility	Portfolio, Program, Project
	Implementation Phase - ongoing	Process	Portfolio, Program
Outcomes	Implementation Phase – ongoing and/or ex-post	Impact	Program, Project, Measure
		Market Effects Evaluation	Market, Portfolio
		Cost Effectiveness	Portfolio, Program, Project

Most useful for new programs and initiatives.

How do we evaluate EM&V?

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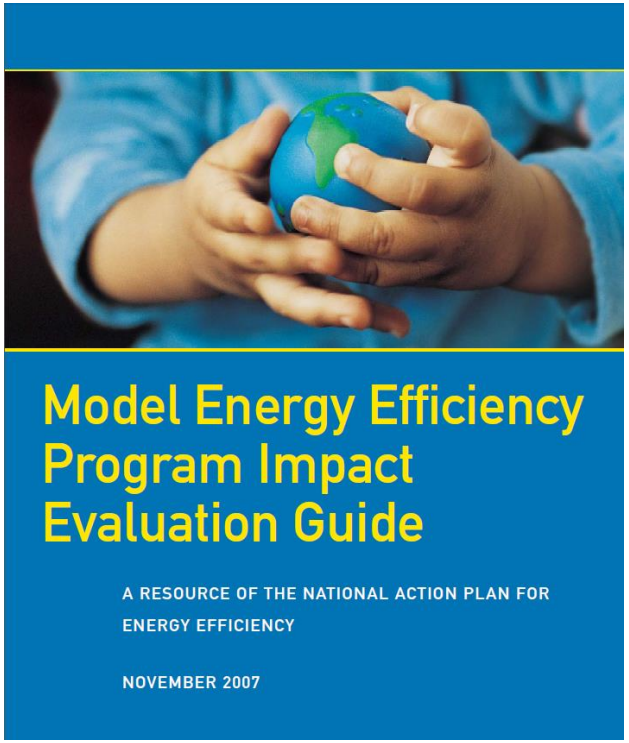
		Cost Effectiveness	Portfolio, Program, Project

Ensure assumptions used to estimate baseline energy usage in program impact evaluations are consistent with the assumptions used in load and peak demand forecasts of utilities and independent System Operators.

- One or more measurement and verification (M&V) methods, from the IPMVP, are used to determine the savings from a sample of projects. These savings are then applied to all of the projects in the program.

- Deemed savings, based on historical and verified data, are applied to conventional energy efficiency measures implemented in the program.

- Statistical analyses of large volumes of metered energy usage data are conducted.



In some cases these approaches are combined, particularly the deemed savings and M&V.

History: Energy Measurement

1887 First commercial flowmeter by Clemens Herschel

1888 First commercial electrical meters (DC)

1889 First kilowatt-hour meter (AC)

1890s The metering of electricity closely paralleled the spread of electricity into cities. Inventors needed to recover the cost from electric utility customers.

5 Steps of Measurement and Verification

What are we measuring?

KPI's
Use vs. Cost vs. GHG vs. ???

Collection Methods
Utility Bills, Metering Equipment, 3rd party software, etc.

Qualitative vs. Quantitative
Words or Numbers?

Uncertainty rate/tolerances
70% or 80% or 95%

Can it be measured?

Why Measure and Verify?

Why Measure and Verify?

Goals of M&V

1. Confirm energy savings
2. Document financial transactions
3. Ultimately enhance ability to finance efficiency projects
4. Improve design, operations and maintenance
5. Account for variances from the utility budget
6. Support evaluation of efficiency programs
7. Educate facility users about their energy impacts

History: Measurement and Verification (M&V)

2003 - IPMVP – 2003 Volume III (new construction)
2002 - ASHRAE Guideline 14 – 2002
2001 - IPMVP -2001 Volume I &II
1998 - Texas State Performance Contracting Guidelines
1997 - IPMVP (revised NEMVP)
1996 - FEMP Guidelines
1996 - NEMVP
1995 - ASHRAE Handbook (Building Energy Monitoring)
1994 - PG&E Power Saving Partner "Blue Book"
1993 - NAESCO M&V Protocols
1993 - New England AEE M&V Protocols
1992 - California CPUC M&V Protocols
1989 - Texas LoneSTAR Program
1988 - New Jersey M&V Protocols
1985 - First Utility Sponsored Programs to include M&V
1985 - ORNLs "Field Data Acq. For Bld. & Eqp. Energy Use Monitoring
1983 - International Energy Agency "Guiding Principles for Measurement"
1980s - USDOE funds End Use Load and Consumer Assessment Program (ELCAP)
1973 – Oil Embargo
1970s - First Validation of Simulators
1960s - First Building Energy Simulations on Mainframe Computers.
1950s - Slide rules and desktop calculators

Americans are lead to believe that energy is abundant and cheap.

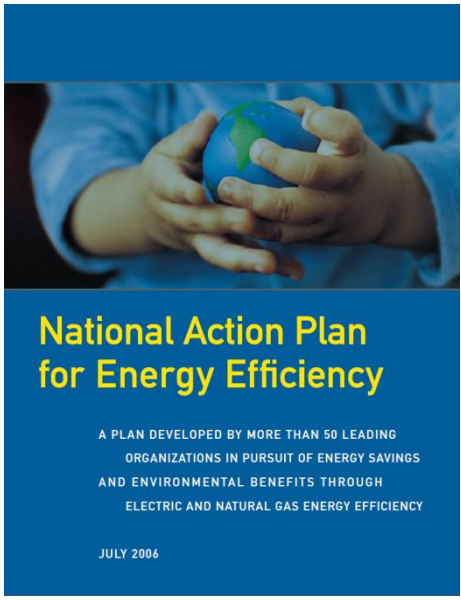
History: Measurement and Verification (M&V)

- Year: 2005 - 2010
- U.S. Department of Energy
- U.S. Environmental Protection
- Leadership Group,:
  - Representatives from electric and gas utilities, state utility regulators and energy agencies, energy consumers, energy service providers, environmental groups, and energy efficiency organizations.
  - More than 60 leading organizations participated in this effort.

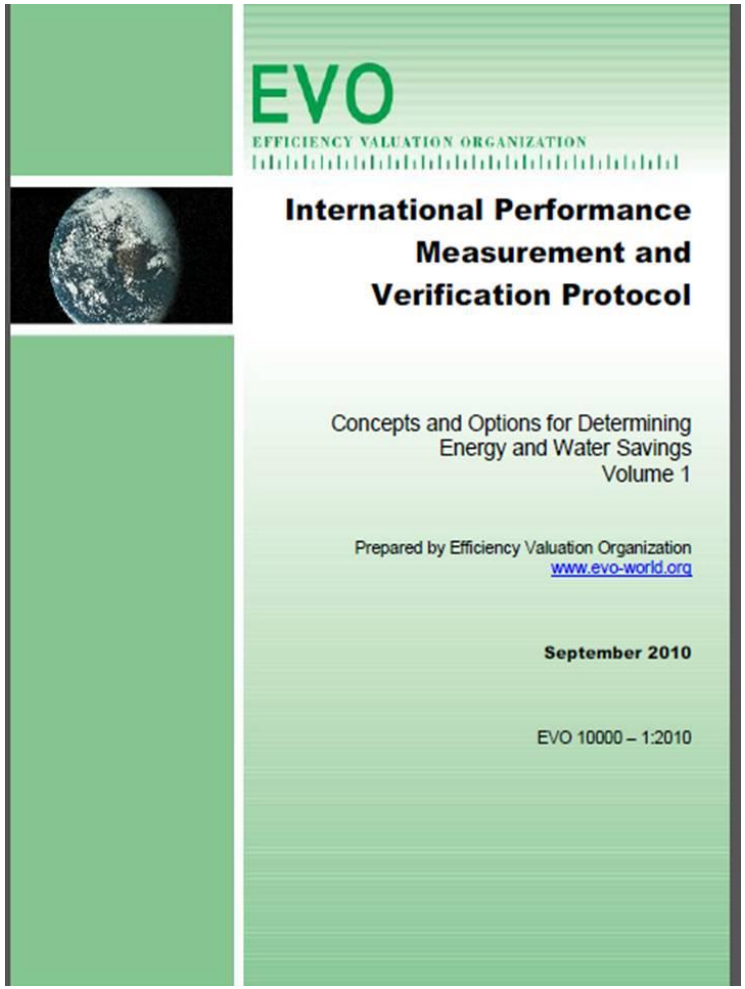
The goal:

- Create a sustainable, aggressive national commitment to energy efficiency through gas and electric utilities, utility regulators, and partner organizations.

We need Common Procedures and Protocols!!!!

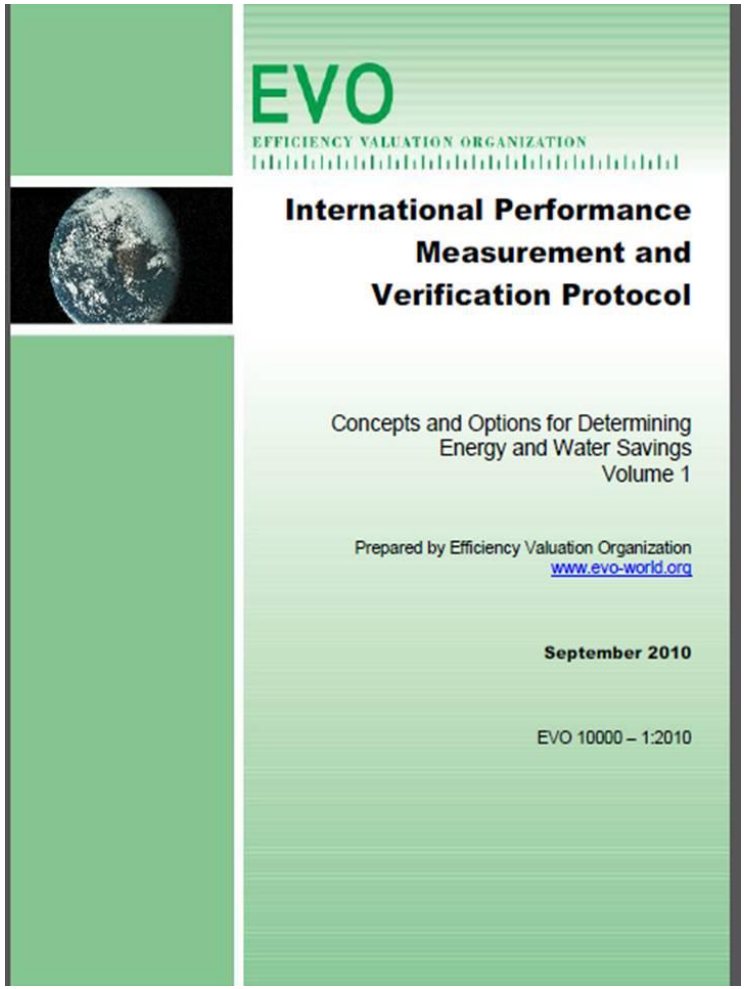


International Performance Measurement and Verification Protocol



- Established a general framework and terminology to assist buyers and sellers of M&V services.
- Defines broad techniques for determining savings from both a "whole facility" and an individual technology.
- Applies to a variety of facilities including residential, commercial, institutional and industrial buildings, and industrial processes.
- Provides outline procedures which can be applied to similar projects throughout all geographic regions
- Internationally accepted, impartial and reliable.
- Living document that includes a set of methodologies and procedures that enable the document to evolve over time.

International Performance Measurement and Verification Protocol



IPMVP Volume I

Concepts and Options for Determining Energy and Water Savings

Defines terminology and suggests good practices for documenting the effectiveness of energy or water efficiency projects that are implemented in buildings and industrial facilities.

IPMVP Volume II

Indoor Environmental Quality (IEQ) Issues

Reviews IEQ issues as they may be influenced by an energy efficiency project. It highlights good project design and implementation practices for maintaining acceptable indoor conditions under an energy efficiency project.

IPMVP Volume III

Applications

Contains specific application guidance manuals for Volume I.

IPMVP fundamental principles of good *M&V*

Accurate

M&V reports should be as accurate as the M&*V* budget will allow.

Complete

The reporting of *energy savings* should consider all effects of a project. *M&V* activities should use measurements to quantify the significant effects, while estimating all others.

Conservative

Where judgments are made about uncertain quantities, *M&V* procedures should be designed to under-estimate *savings*.

Consistent

The reporting of a project's *energy* effectiveness should be consistent. 'Consistent' does not mean 'identical,'

Relevant

The determination of *savings* should measure the performance parameters of concern, or least well known, while other less critical or predictable parameters may be estimated.

Transparent

All *M&V* activities should be clearly and fully disclosed.

IPMVP Options

Option A :

Retrofit Isolation: Key Parameter Measurement

Option B:

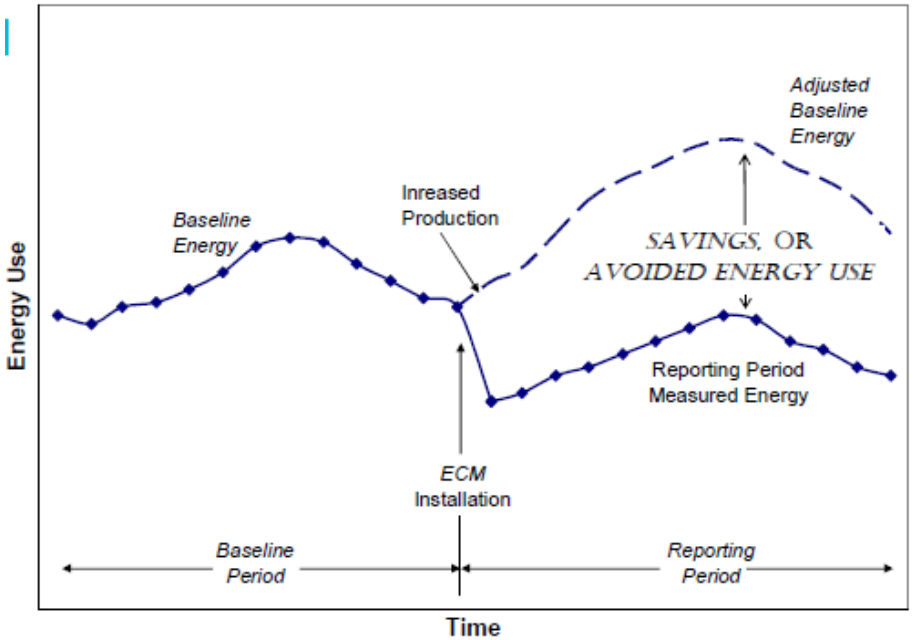
Retrofit Isolation: All Parameter Measurement

Option C:

Whole Facility Parameter

Option D:

Calibrated Simulation



IPMVP Option A: Best Applications

- *Least expensive of option due to estimations.*
- *Estimation* of non-key parameters may avoid possibly difficult *non-routine adjustments* when future changes happen within the *measurement boundary*.
- The uncertainty created by *estimations* is acceptable.
- The continued effectiveness of the *ECM* can be assessed by simple routine re-testing of key parameters.
- *Estimation* of some parameters is less costly than measurement of them in Option B or simulation in Option D.
- The key parameter(s) used in computing *savings* can be readily identified. Key parameters are parameters used to judge a project's or contractor's performance.

IPMVP Option B: Best Applications

- Meters added for isolation purposes will be used for other purposes such as operational feedback or tenant billing.
- Measurement of all parameters is less costly than simulation in Option D.
- *Savings* or operations within the *measurement boundary* are variable.

IPMVP Option C: Best Applications

- The *energy* performance of the whole *facility* will be assessed, not just the *ECM*s.
- There are many types of *ECM*s in one *facility*.
- The *ECM*s involve activities whose individual *energy* use is difficult to separately measure (operator training, wall or window upgrades).
- The *savings* are large (>10%) compared to the variance in the *baseline* data.
- When Retrofit-Isolation techniques (Option A or B) are excessively complex.
- Major future changes to the facility are not expected during the *reporting*
- Reasonable

IPMVP Option D: Best Applications

- *Unreliable or unavailable baseline* or *reporting-period energy* data.
- There are too many *ECM*s to assess using Options A or B.
- *ECM*s involve diffuse activities, which cannot easily be isolated
- The performance of each *ECM* will be estimated individually within a multiple-*ECM* project.
- Interactions between *ECM*s or *ECM interactive effects* are complex, making the isolation techniques of Options A and B impractical.
- Major future changes to the facility are expected during the *reporting period,* and there is no way to track the changes and/or account for their impact on *energy* use.
- *Facility* and the *ECM*s can be modeled by well documented simulation software.

ECM Project Characteristic	Suggested Option			
	A	B	C	D
Need to assess *ECM*s individually	X	X		X
Need to assess only total facility performance			X	X
Expected *savings* less than 10% of utility meter	X	X		X
Significance of some *energy* driving variables is unclear		X	X	X
Interactive effects of ECM are signficant or unmeasurable			X	X
Many future changes expected within *measurement boundary*	X			X
Long term performance assessment needed	X		X	
Baseline data not available				X
Non-technical persons must understand reports	X	X	X	
Metering skill available	X	X		
Computer simulation skill available				X
Experience reading utility bills and performing regression analysis available			X	

What Option is right for my project?

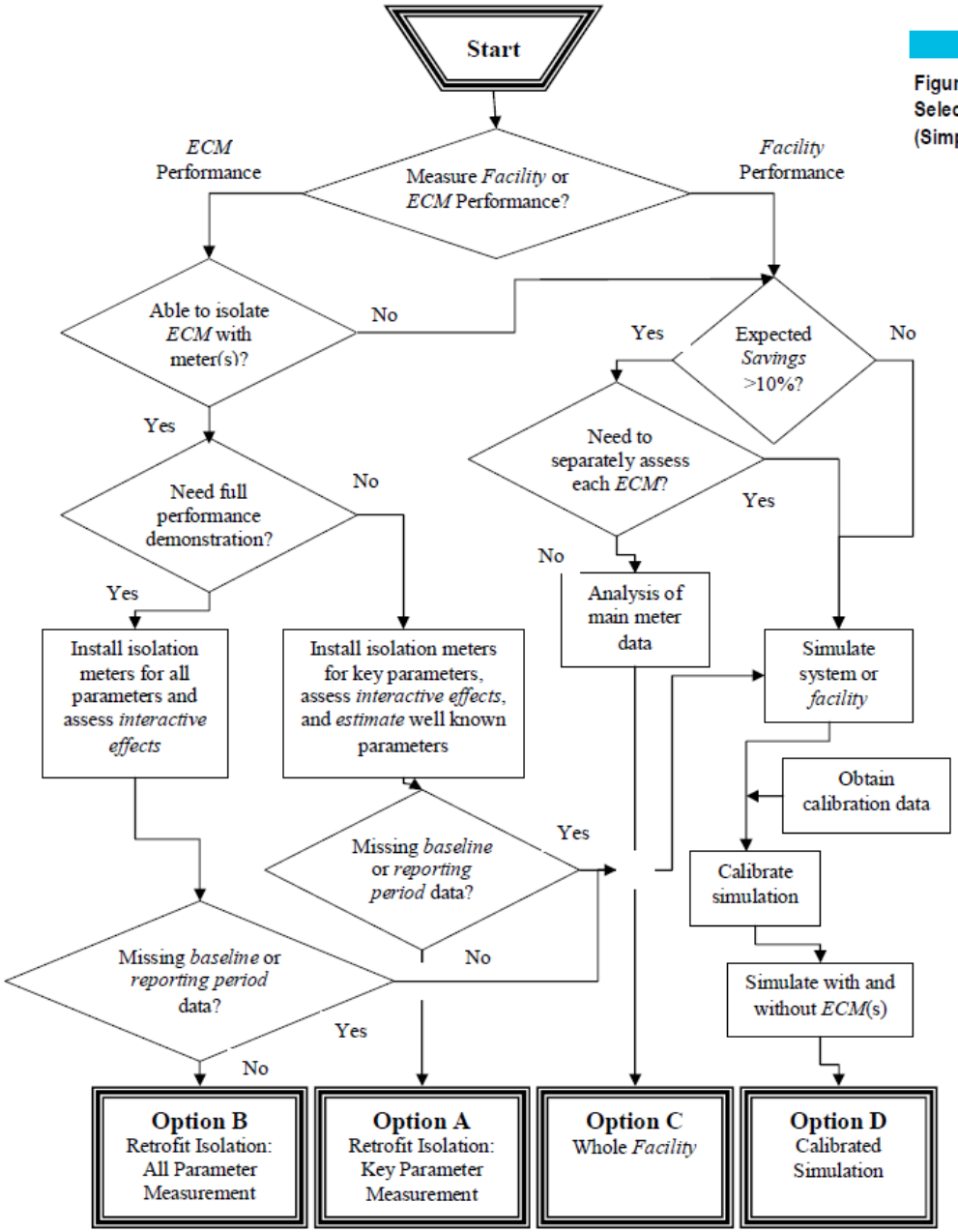


Figure 4 Option Selection Process (Simplified)

Group Question: IPMVP Best Option?

A lighting retrofit where power draw is the key performance parameter that is measured periodically. A baseline report was completed, but operating hours of the lights based on estimated *facility* schedules and occupant behavior.

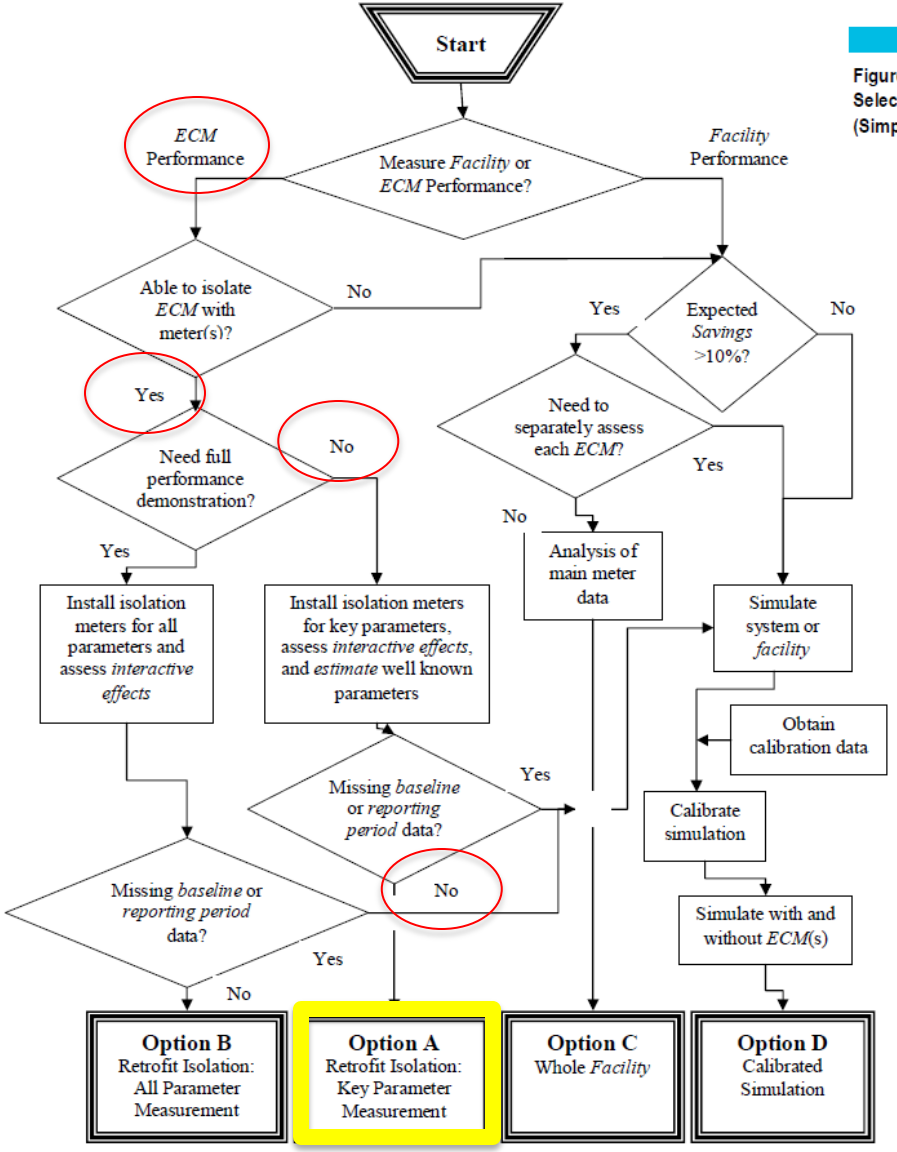


Figure 4 Option Selection Process (Simplified)

Group Question: IPMVP Best Option?

Multifaceted energy management program affecting many systems in a *facility*. Measure energy use with the gas and electric utility meters for a twelve month *baseline period* and throughout the *reporting period*.

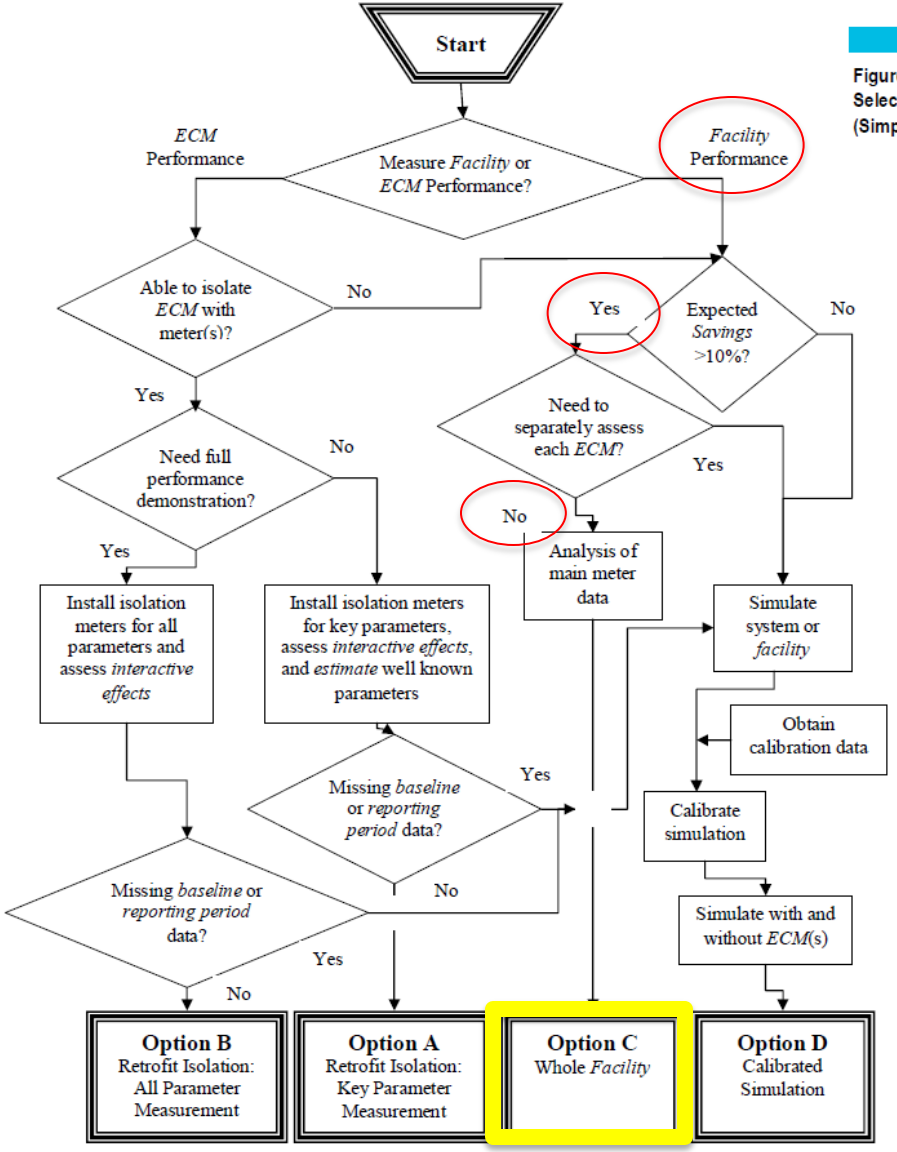


Figure 4 Option Selection Process (Simplified)

Group Question: IPMVP Best Option?

Application of a variablespeed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. The meter is in place throughout the *reporting period* to track variations in power use.

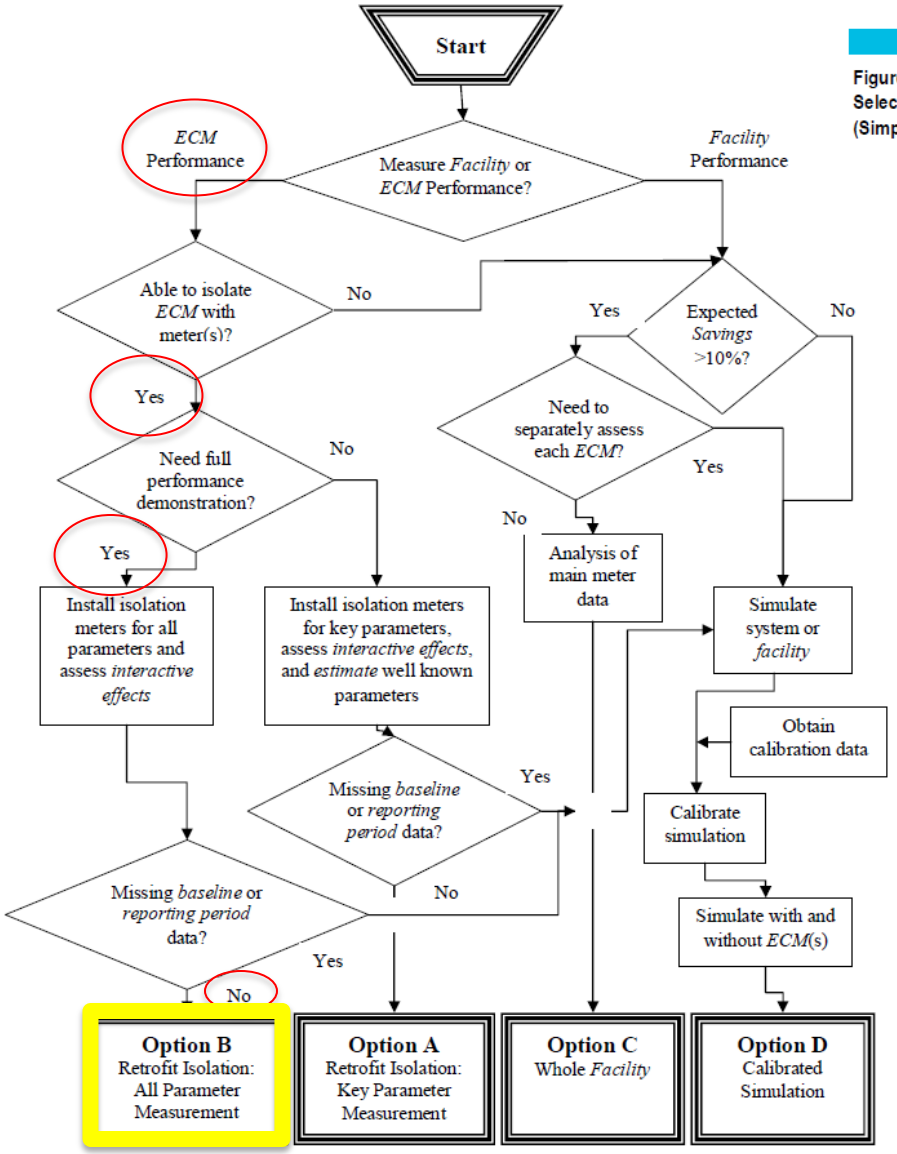


Figure 4 Option Selection Process (Simplified)

Group Question: IPMVP Best Option?

Multifaceted energy management program affecting many systems in a facility but where no meter existed in the *baseline* period.

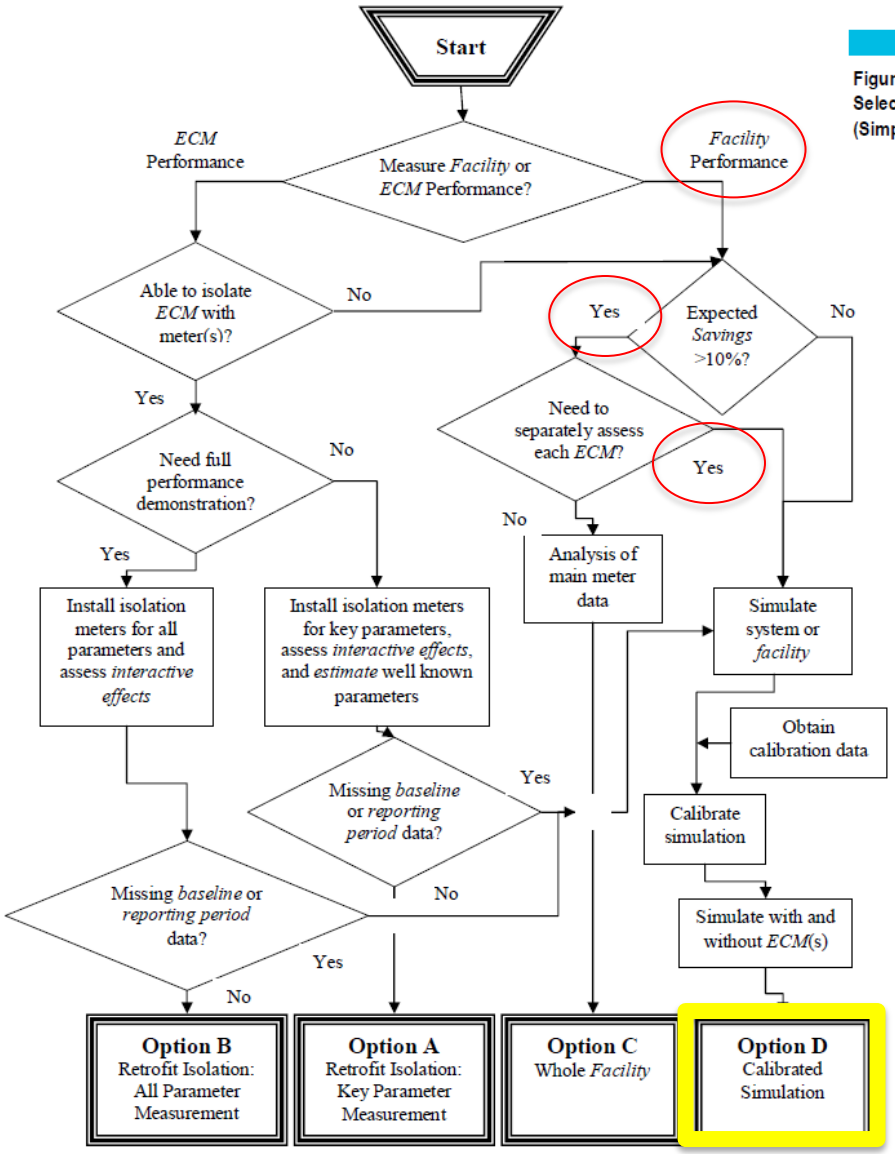


Figure 4 Option Selection Process (Simplified)

SEE Action

STATE & LOCAL ENERGY EFFICIENCY ACTION NETWORK

Our Network | Resources | Recent Actions | Events | Technical Assistance | Energy Efficiency Benefits

EVALUATION, MEASUREMENT, AND VERIFICATION RESOURCE PORTAL

The State and Local Energy Efficiency Action Network (SEE Action) Evaluation, Measurement, and Verification (EM&V) Resource Portal is an EM&V resource compendium for energy efficiency program administrators and project managers. The resources focus on tools and approaches that can be applied nationwide, address EM&V consistency, and are recognized by the industry.

This web portal identifies helpful resources in the targeted categories below:

- EM&V Guidance for Multiple Sectors
- Sector Specific EM&V Resources
- Regional Resources on EM&V Consistency
- Resources on Air Quality Impact Evaluation
- Learn More and Get Involved
- Other Resources

What is EM&V?

EM&V refers to the procedures for examining a product, service, or system to ensure that the requirements and specifications are satisfied and the intended purpose fulfilled. For energy efficiency, EM&V is the collection of approaches for determining and documenting energy and non-energy benefits resulting from end-use energy efficiency activities and programs. Effective EM&V can confirm energy savings, verify cost-effectiveness, and guide future energy efficiency investment decisions.

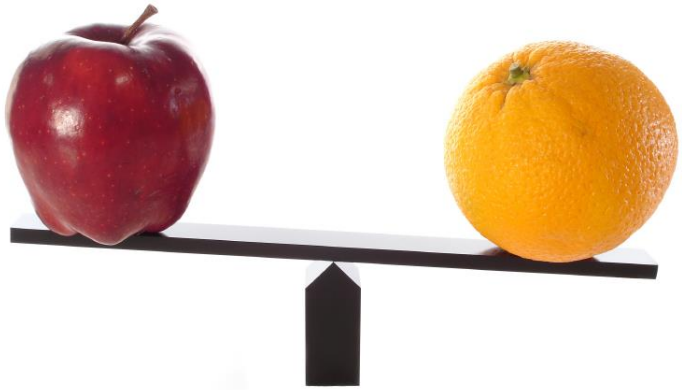
https://www4.eere.energy.gov/seeaction/evaluation-measurement-and-verification-resource-portal

Group Question:

Do We Measure Savings?

- Savings are the absence of energy use
- We can *not* measure what we do not have
- We do ***not*** ‘measure’ savings
- We ***do*** measure energy use
- We *analyze* measured energy use to **determine** savings

Accountants often use the word 'savings' to describe 'cost reductions.' They make no adjustments.

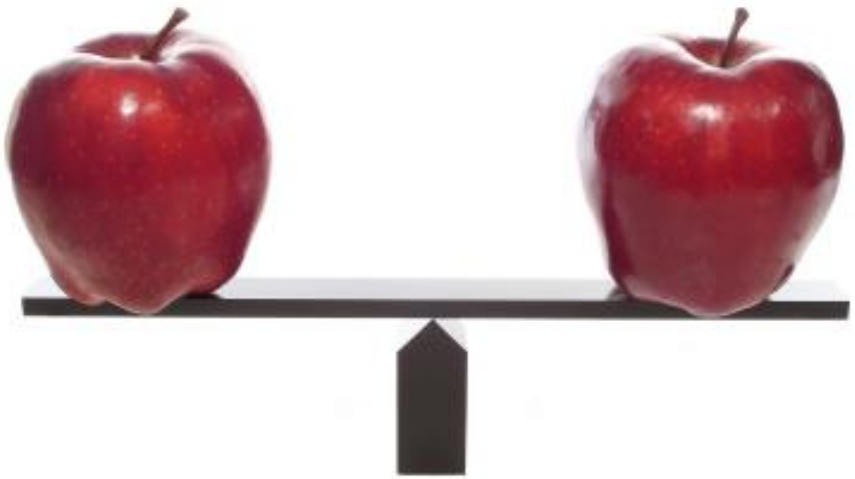


Baseline Period energy

− Reporting Period energy

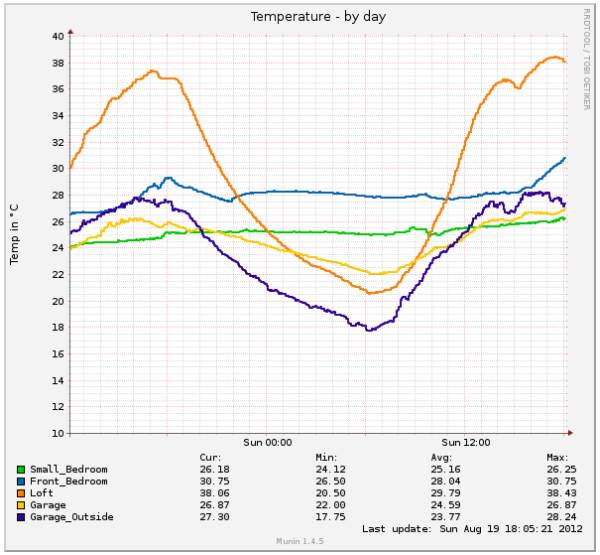
Savings

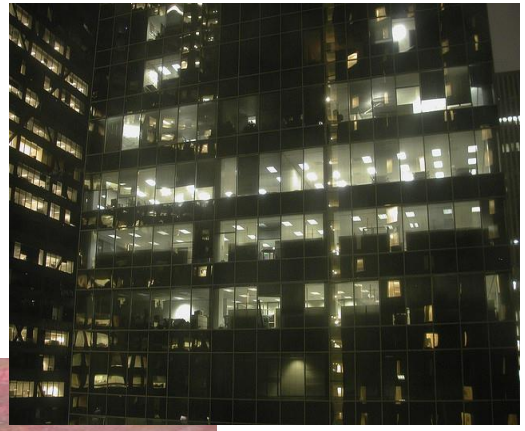
Energy users usually want to know how much their bills would have been if they had not taken energy efficiency action. They want to know how much cost they avoided.

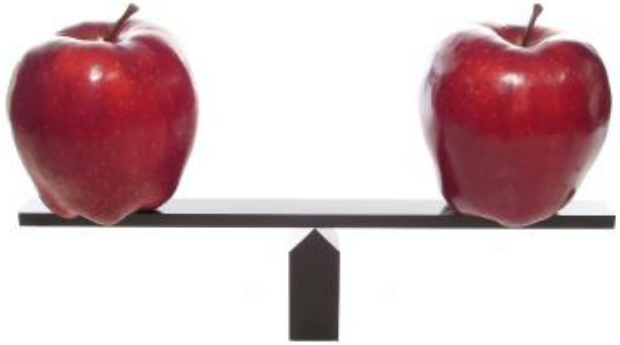


Adjustments or Normalized Data

- Weather
- Occupancy rates
- Other ECMs Changes
- Schedule Changes
- Others???







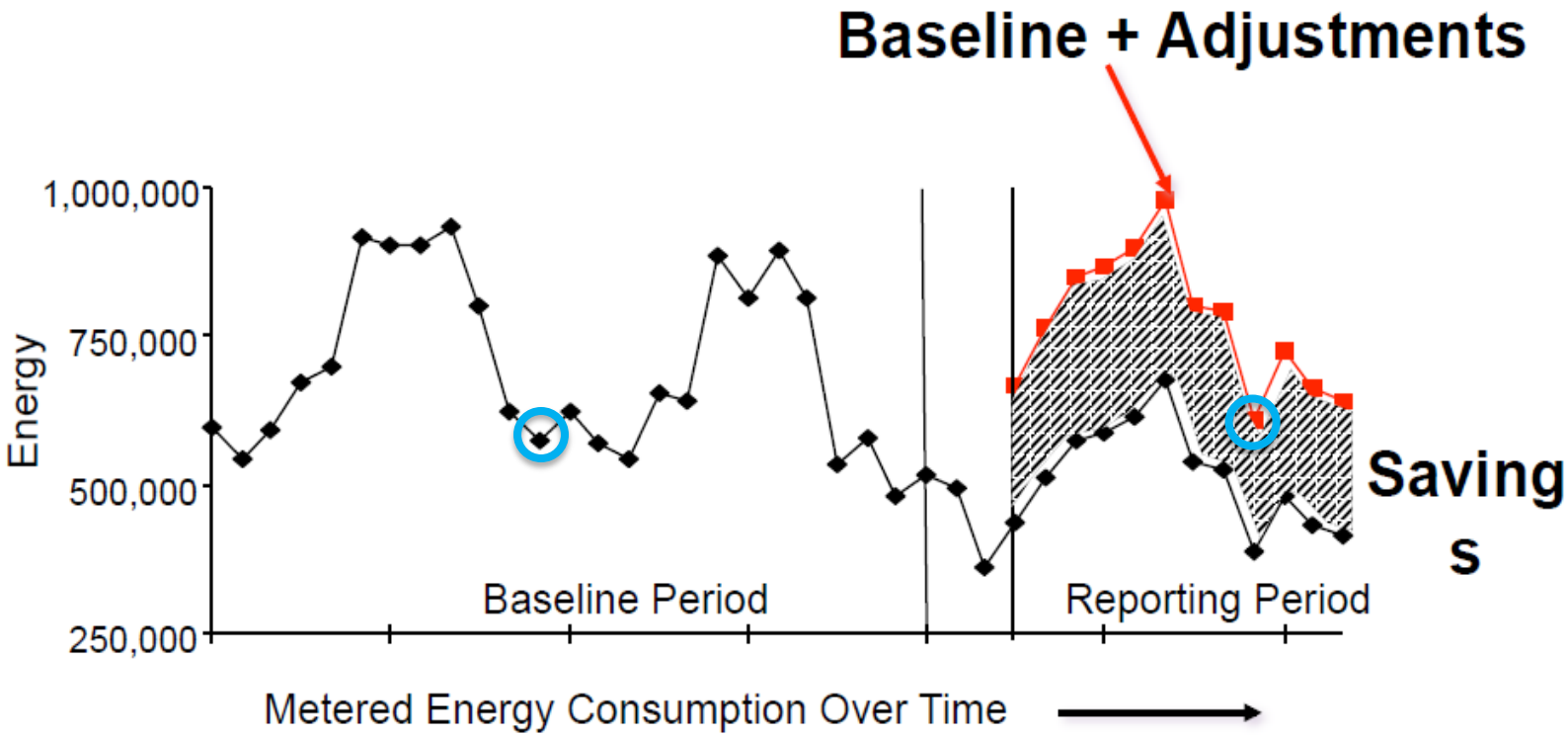
Baseline Period energy

\- *Reporting Period energy*

+/- *Adjustments*

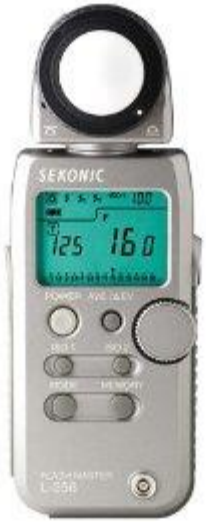
Avoided Cost

- M&V Simply

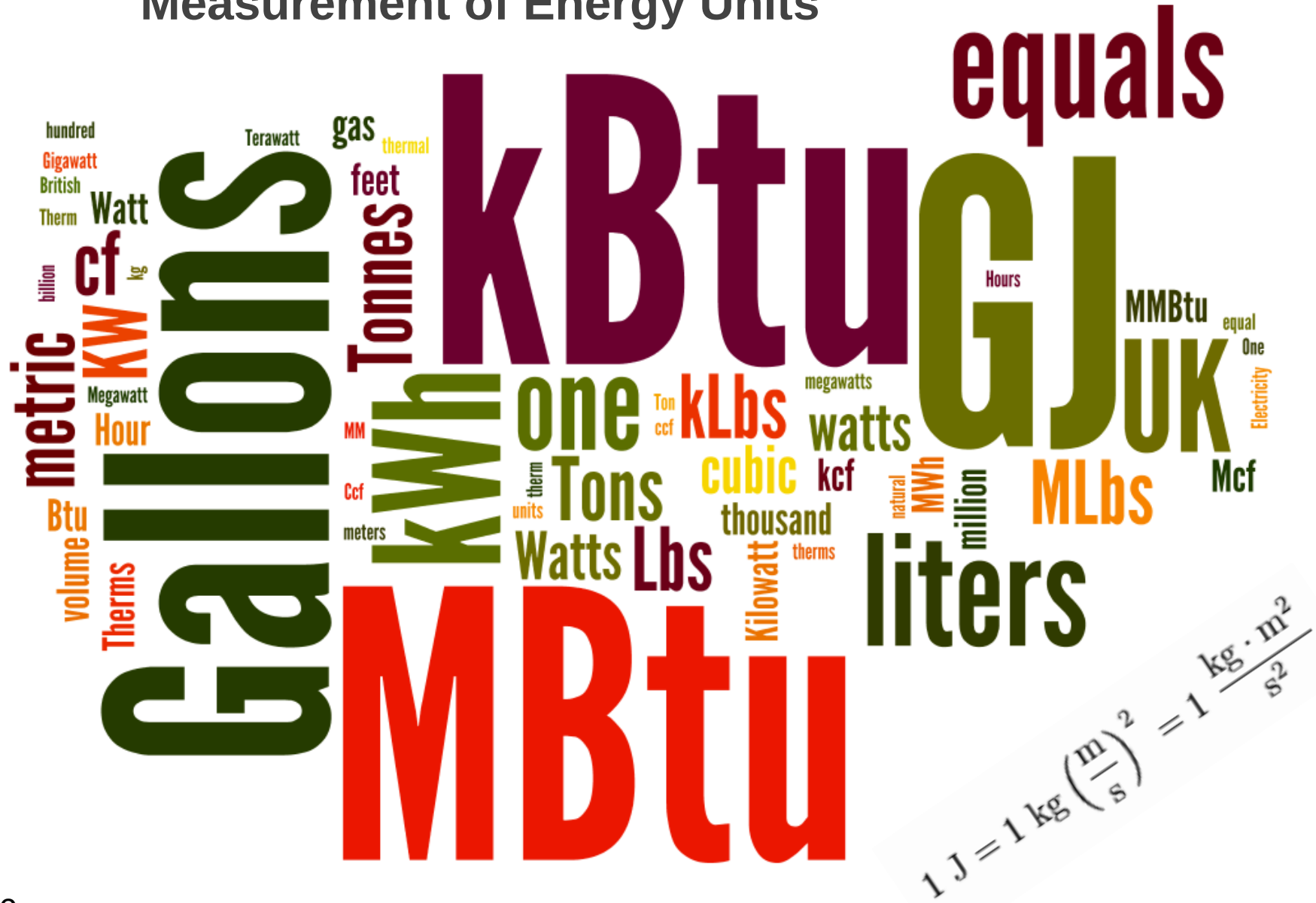

Baseline + Adjustments
1,000,000
750,000
500,000
250,000
Energy
Baseline Period
Reporting Period
Saving
s
Metered Energy Consumption Over Time

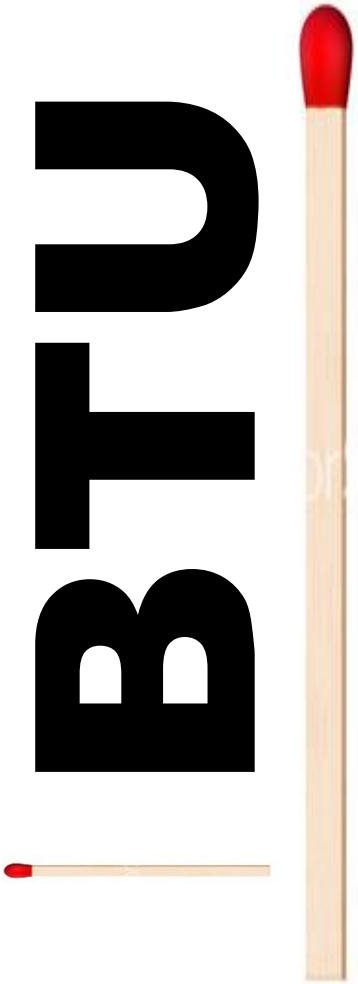
M&V Tool kit

- Plug load meter and logger
- Data logger
- Digital camera w/ video
- Event Data logger
- IR Thermometer
- RH data logger
- Clamp Meter
- Ballast Discriminator
- RH Meter
- Light Meter



Measurement of Energy Units





British Thermal Unit (BTU)

Amount of energy needed to cool or heat one pound of water by one degree Fahrenheit.

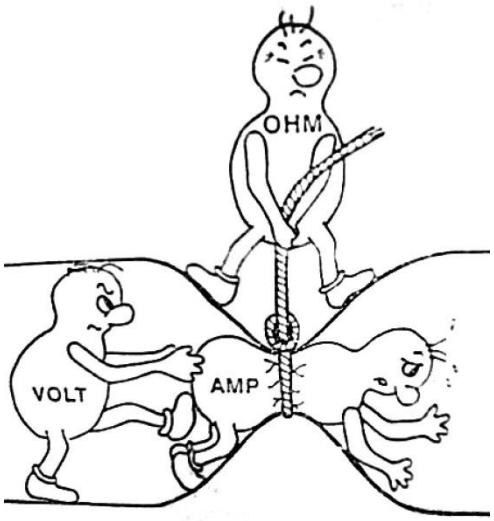
Electricity Measurement

Volt (V)

Electrical Potential

Ampere (A or I)

Electrical charge passing a point



Watt = Volts x Amps

Watt	(W)	1	W
Kilowatt	(kW)	1,000	A
Megawatt	(MW)	1,000,000	T
Gigawatt	(GW)	1,000,000,000	T
Terawatt	(TW)	1,000,000,000,000	S

According to EIA data, 2012, the U.S. consumed 3,832 TW of Electricity.

Electricity Measurement & Time

Watts (x) Time = watt-hour

Example

40W light Bulb x 4 hours/day x 365 days =

58,400 watt-hours

Kilowatt Hours	58.4	kWh
Megawatt Hours	0.0584	MWh
Gigawatt Hours	0.0000584	GWH

Gas Units of Measurement

C	equals one hundred (100).
M	equals one thousand (1,000).
MM	equals one million (1,000,000).

Gas Units of Measurement

Ccf equals the volume of 100 cubic feet (cf) of natural gas.

Mcf equals the volume of 1,000 cubic feet (cf) of gas.

MMBtu — equals 1,000,000 British thermal units (Btu).

Therm — One therm equals 100,000 Btu, or 0.10 MMBtu.

Meter Type	Input Unit Options	U.S. Property Assumptions[1]		Canadian Property Assumptions[2]	
		Multiplier to get kBtu	Heat Content	Multiplier to get kBtu	Heat Content
Electricity (Grid Purchase and Onsite Renewable)	kBtu	1	Not Applicable	1	Not Applicable
	MBtu	1,000		1,000	
	kWh	3.412		3.412	
	MWh	3,412		3,412	
	GJ	947.817		947.817	
Natural Gas	kBtu	1	1,028 Btu/cf	1	1,031.43 Btu/cf
	MBtu	1,000		1,000	
	cf	1.026		1.031	
	ccf	102.6		103.143	
	kcf	1,026		1,031	
	Mcf	1,026,000		1,031,430	
	Therms	100		100	
	cubic meters	36.303		36.425	
	GJ	947.817		947.817	
Propane and Liquid Propane	kBtu	1	0.091 MBtu/gallon	1	0.09089 MBtu/gallon
	MBtu	1,000		1,000	
	cf	0.680		0.679	
	kcf	680.726		679.300	
	Gallons (US)	91		90.809	
	Gallons (UK)	109.283		109.057	
	liters	24.040		23.989	
	GJ	947.817		947.817	

Additional Reference Links

Portfolio Manager Technical Reference: Thermal Conversion Factors

https://www.energystar.gov/buildings/tools-and-resources/portfolio-manager-technical-reference-thermal-conversion-factors

Greenhouse Gas Equivalencies Calculator

http://www.epa.gov/cleanenergy/energy-resources/calculator.html

Efficiency Valuation Organization

http://www.evo-world.org/index.php?lang=en