M&V Fundamentals

& the

International Performance Measurement and Verification Protocol

What is M&V?

"Measurement & Verification (M&V) is the process of using measurements to reliably determine actual saving created within an individual facility by an energy management program."

Ref: IPMVP Vol I, 2007, Section 9

EVO

Efficiency Valuation Organization (EVO)

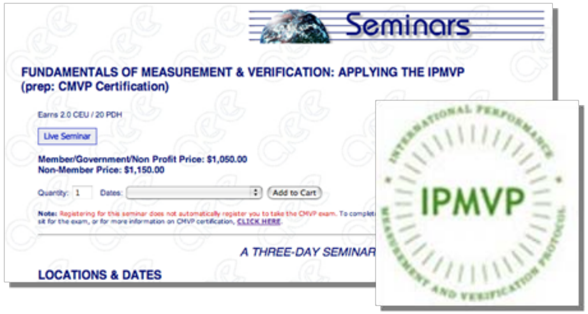
www.evo-world.org

- The home of the IPMVP
- A non-profit U.S. corporation
- Led by volunteers around the world
- Administrative office in Sofia, Bulgaria.

EVO

- **Protocols**
  - M&V, Financing

- **Training, Certification**
  - Certification (CMVP) is joint with the Association of Energy Engineers



- **Building Community, Promoting Efficiency**
  - Subscriber services through www.evo-world.org: industry newsletter, blog, library, discounts, pre-release access to public documents
  - World wide partnerships for communication, training and development

IPMVP - Overview

- Presents a **framework** and **defines terms** used in determining ‘savings’ after implementation of a project.
- Specifies the topics to be addressed in an **M&V Plan** for a specific project.
- **Allows flexibility** in creating M&V Plans, while adhering to the principles of: **accuracy, completeness, conservativeness, consistency, relevance and transparency**.

Why M&V?

- The Spectrum of M&V
- Purposes of M&V
- Your reasons?

⟵ The M&V Spectrum ⟶

No M&V

- No extra cost (or more left to spend on retrofits)
- Most energy retrofits since 1975
- **K.I.S.S.** (Low cost M&V without the M, just the V)

Full M&V

- Maximize savings
- Savings persistence
- Energy users needing performance demonstration or guarantee (mostly utilities & public buildings) - since 1990
- emission traders

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The Purpose of M&V

Simply

M&V provides

PROOF

of the effectiveness of energy management

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For Energy Managers and Emission Traders

Key Concepts

Key Concepts - Program

- Measurement?
- IPMVP's basic equation
- Four Options
- Common M&V issues

The “M” in M&V

The **M** in M&V stands for:

Measurement

Not *Monitoring*

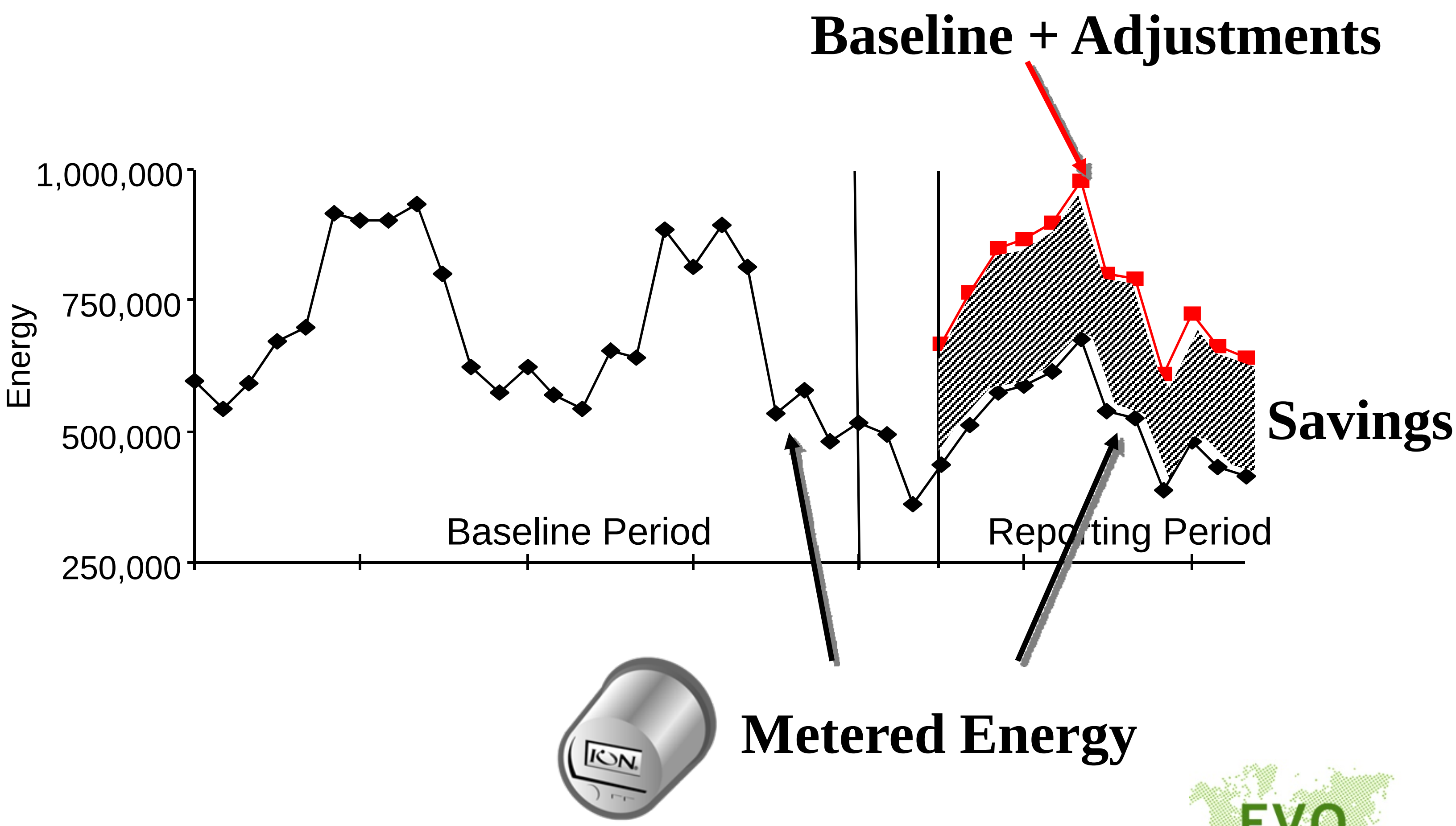
(Monitoring is an activity which takes place ***after*** the Measurement of savings. Monitoring is the evaluation of the savings and taking any necessary action.)

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.

A Notional Baseline



IPMVP Basic Equation

The Basic IPMVP Savings Equation #1:

Savings reported for any period

= Baseline Period energy

- Reporting Period energy

+/- Adjustments

Ref: IPMVP Volume I, 2007, Chapter 4.1

Adjustments

An example of why we need Adjustments:

An energy retrofit was performed but plant *production was also lower* this year than last.

How much of the resultant cost reduction was due to the retrofit, and how much was due to the production change?

Adjustments (continued)

Performance measurement requires an **“apples to apples”** comparison.

Baseline Period

Reporting Period

We adjust baseline and reporting period energy use to the **same** set of conditions, for valid comparisons.

‘Savings’ or ‘Avoidance’?

- 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 energy or cost they **avoided**.
- To report **avoided cost**, M&V engineers ***adjust*** baseline period energy use to the conditions of the reporting period. They sometimes simply call cost avoidance ‘savings,’ at risk of confusion with accountant reports.

Ref: IPMPV Vol I, 2007, Chapter 4.6.1

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Accounting Savings

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

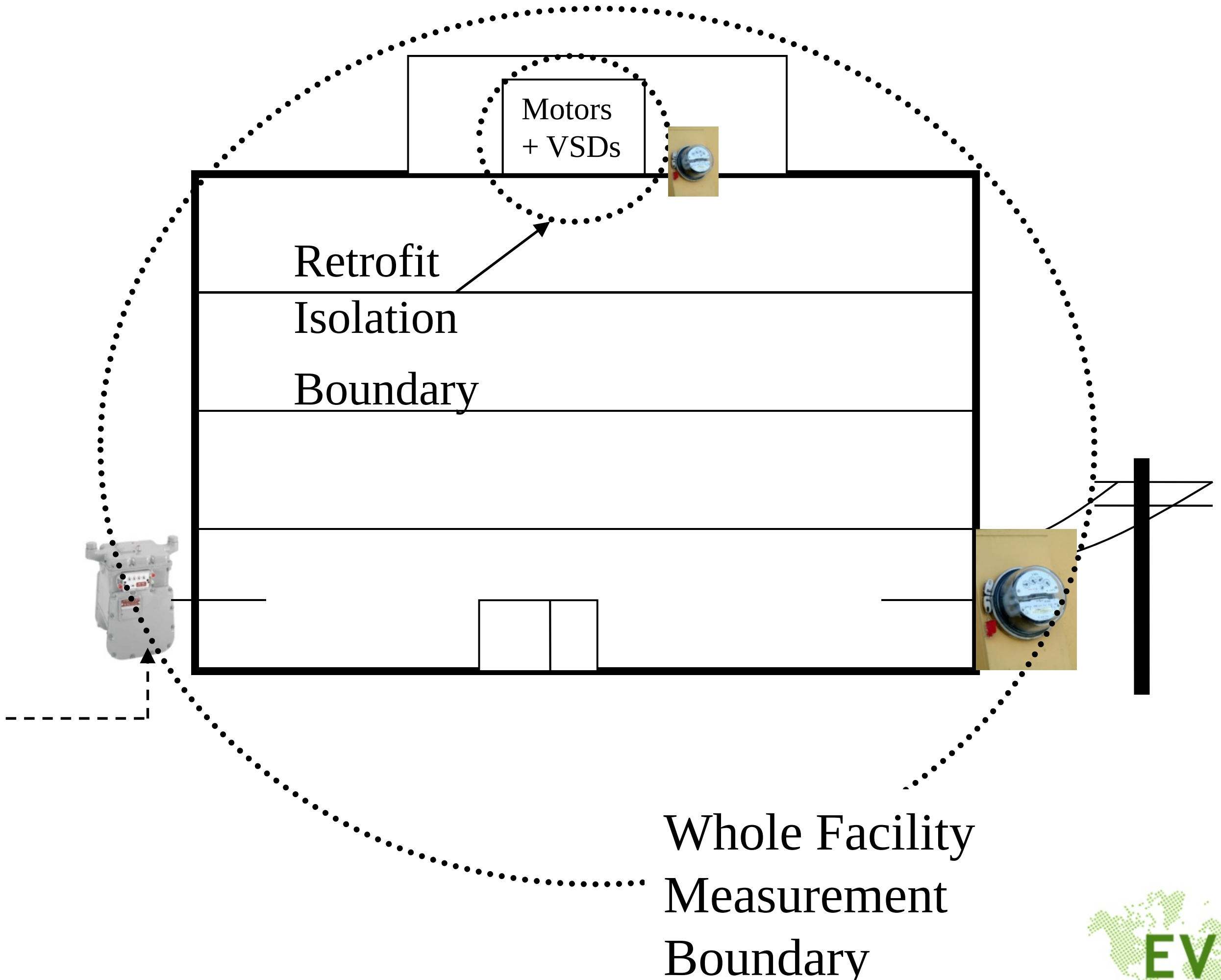
So, when talking about 'savings' we **have to be very careful to explain our meaning**.

We must report the common set of conditions (apples) we are using for stating "savings."

Adjustments

- The Adjustments can be trivial, simple or complex.
- M&V budgets usually determine how simple or complex the Adjustments are.
- The extent of the Adjustments depends on:
  - the need for accuracy,
  - the complexity of factors driving energy use, and
  - the amount of equipment having its performance assessed (i.e. 'measurement boundary').

How Much to Measure?



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Two Basic Methods

Whole Facility Method:

Measures **all** effects in the facility:

- Retrofits AND other changes (intended and **un**intended)
- Often uses the utility meter
- Adjustments can be complex

Retrofit Isolation Method:

Measures the effect of the retrofit, **only**

- Savings are unaffected by changes beyond the measurement boundary
- Usually needs a new meter
- Adjustments can be simple

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Selecting a Method

Decide what you are concerned about!

If you want to manage your **total** energy use:

- select the Whole Facility Method.

If you want to assess a particular **retrofit**:

- select the Retrofit Isolation Method.

Terminology:

- Retrofit Isolation – Option A or B
- Whole Facility – Option C or D

Two flavours of each method – to allow flexibility for various situations

Retrofit Isolation

Select between Options A and B:

Option A – Retrofit Isolation: Key Parameter Measurement

Option B – Retrofit Isolation: All Parameter Measurement

Retrofit Isolation (A and B)

	Option A	Option B
Baseline period **measurement**	**400** kW	**200,000 kWh**
Reporting period **measurement**	**300** kW	**150,000 kWh**
Estimated operating hours	*500 hrs*	
Avoided Energy	**100**kw x *500*hrs = 50,000 kWh	50,000 **kWh**

A – measure only the <u>key</u> part of the energy computation, for example: a contractor is only responsible for a load reduction (or only responsible for a reduction in operating hours, but not both)

B – measure <u>all</u> factors governing energy use, for example: a contractor is responsible for controls which dim lights automatically and control operating periods.

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Option A - Uncertainty

Option A (called Retrofit Isolation: Key Parameter Measurement) allows a **possible reduction in measurement cost**, but **introduces some uncertainty** in the estimated quantity.

All parties must accept the uncertainty associated with the estimate.

The choice between Options A and B allows flexibility to suit the situation.

Whole Facility

Select Option C or D, based data availability:

C – Whole Facility

Need both baseline and reporting period data

D – Calibrated Simulation

When there is no meter (or facility) in the baseline, baseline data can be 'manufactured' under controlled circumstances.

Option C - Example

- Baseline period electricity bill

July 1999 (29 days)	=	800,000 kWh

- Reporting period electricity bill

July 2001 (31 days)	=	600,000 kWh
Raw difference	=	200,000 kWh

- Adjustment of baseline for meter reading period length & weather = +100,000 kWh

Avoided Energy	=	300,000 kWh

Option D - Example

Consider the case of a new building, designed to be more efficient than some Standard.

To prove how much better **actual** energy performance is than the standard:

1. After full occupancy begins, gather actual utility metered data (= “calibration data”).
2. Prepare a computer simulation of the energy use of the same *as built* conditions.
3. Compare simulated and actual energy use.

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Option D - Example

4. "Calibrate" (or adjust) the simulation until the differences are acceptable.
5. The "CALIBRATED SIMULATION" now shows actual energy use of: 5,000,000 kWh
6. Modify this Calibrated Simulation to remove the energy efficiency enhancements (to reflect a building built to the Standard). Simulated "Standard" energy use is: 7,000,000 kWh
7. Avoided Energy = 2,000,000 kWh

Summary of IPMVP Options

- The IPMVP has four M&V Options:

  A, B, C, and D
- The Options are generic M&V approaches for energy and water saving projects.
- Four Options provide a range of approaches for determining energy savings, to suit the characteristics of the ECMs being implemented and the desired balance between reporting accuracy and cost.

Common M&V Issues:

- M&V Cost
- Performance Contracts

M&V Cost

Key factors affecting M&V Cost:

- Meter quality
- Number of independent variables to be monitored
- Frequency of measurement and reporting
- Length of the baseline and reporting periods
- Sample size, if all equipment is not measured
- Other uses for meter information, to share costs

How Much M&V Is Enough?

- Total annual cost to determine savings should normally be less than 10% of the annual savings. (Ref: IPMVP Vol I, 2007 Chapter 8.5) (This maximum might be exceeded for special situations.)
- 3-5% is a more common expenditure (for ESCO projects)
- 0% is often chosen (= “deemed savings”). No measurement means uncertain savings. This is NOT an IPMVP method

The cost/accuracy tradeoff is made for each project

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Performance Contracts

- M&V plays a critical role in performance contracts:
  - maximizes the savings and the persistence of savings over the contract term
  - documents what savings were achieved and acts as the cash register for the exchange of value
- Performance contracts allocate the costs and benefits of M&V accuracy between the ESCO and Owner.
- Carefully consider contract motivations of all parties before designing the M&V. Append the M&V Plan to the contract.

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Short Examples

Short Examples - Program

- Multiple ECM Building Retrofit (Option C)
- Lighting Efficiency Improvement (Option A)

Sample M&V Project

Commercial Building in Canada

Energy Conservation Measures	Simple Payback (years)
Lighting retrofit	4.5
Energy efficient motors	5.6
HVAC modifications	5.4
Control system	3.4
Building leakage reduction	2.1
Training and awareness	0.5

Option C - Whole Facility

Selected Option C to assess total performance

- Use data from utility meters (gas and electric).
- Analyze baseline gas meter data relative to weather, to determine the correct weather *adjustments*. Weather will be expressed in heating degree days (HDD).

You will compute savings for two months.

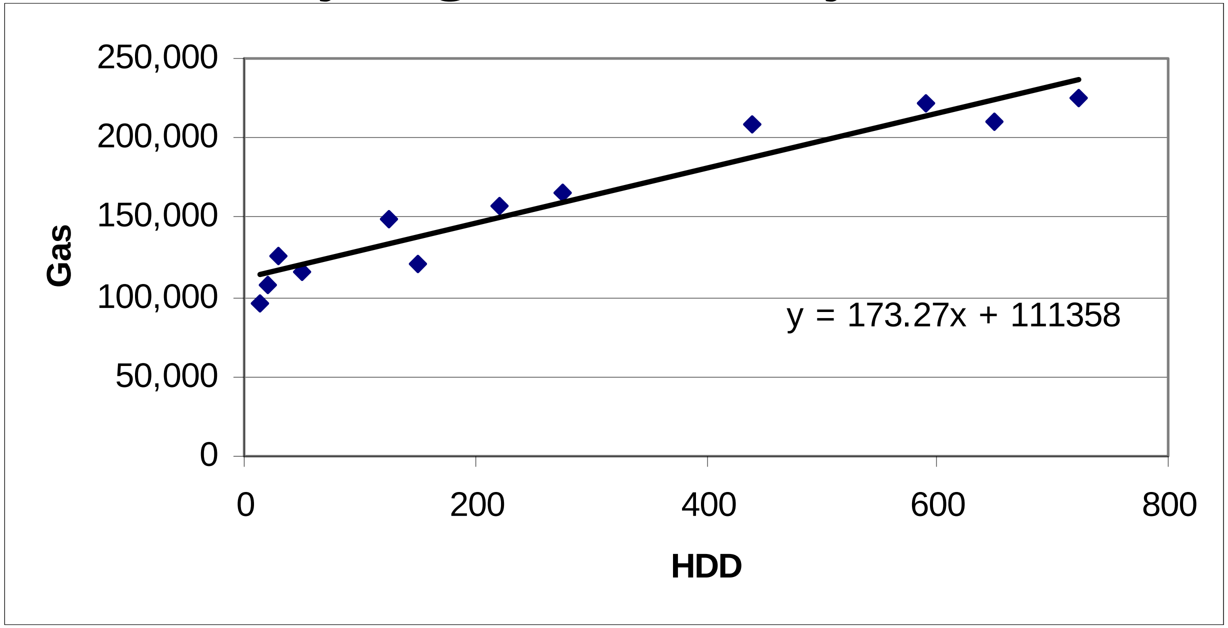
Sample Option C

Baseline Data

Meter Reading Date	Gas Consumption units	Heating Degree Days
February 5, 2004		
March 5, 2004	210,692	650
April 7, 2004	208,664	440
May 6, 2004	157,886	220
June 5, 2004	120,793	150
July 7, 2004	116,508	50
August 7, 2004	107,272	20
September 5, 2004	95,411	14
October 6, 2004	126,423	29
November 6, 2004	149,253	125
December 4, 2004	166,202	275
January 6, 2005	221,600	590
February 5, 2005	224,958	723
Total	**1,905,662**	**3,286**

Sample Option C
Baseline Model

The Gas vs Heating Degree Day relationship was found by regression analysis to be:



Gas = 173.27 * HDD + 111,358

(Regression analysis techniques are not part of this course.)

Sample Option C
Method

1. Record the current weather (HDD)
2. For each month after retrofit, compute what the baseline gas use *would have been* for those HDD by plugging HDD into the baseline model:

$$Gas = 173.27 * HDD + 111,358$$

3. Compare the computed baseline gas with actual reporting period gas, to determine 'avoided gas.'
4. Apply the current utility price to both baseline and actual to calculate cost avoidance.

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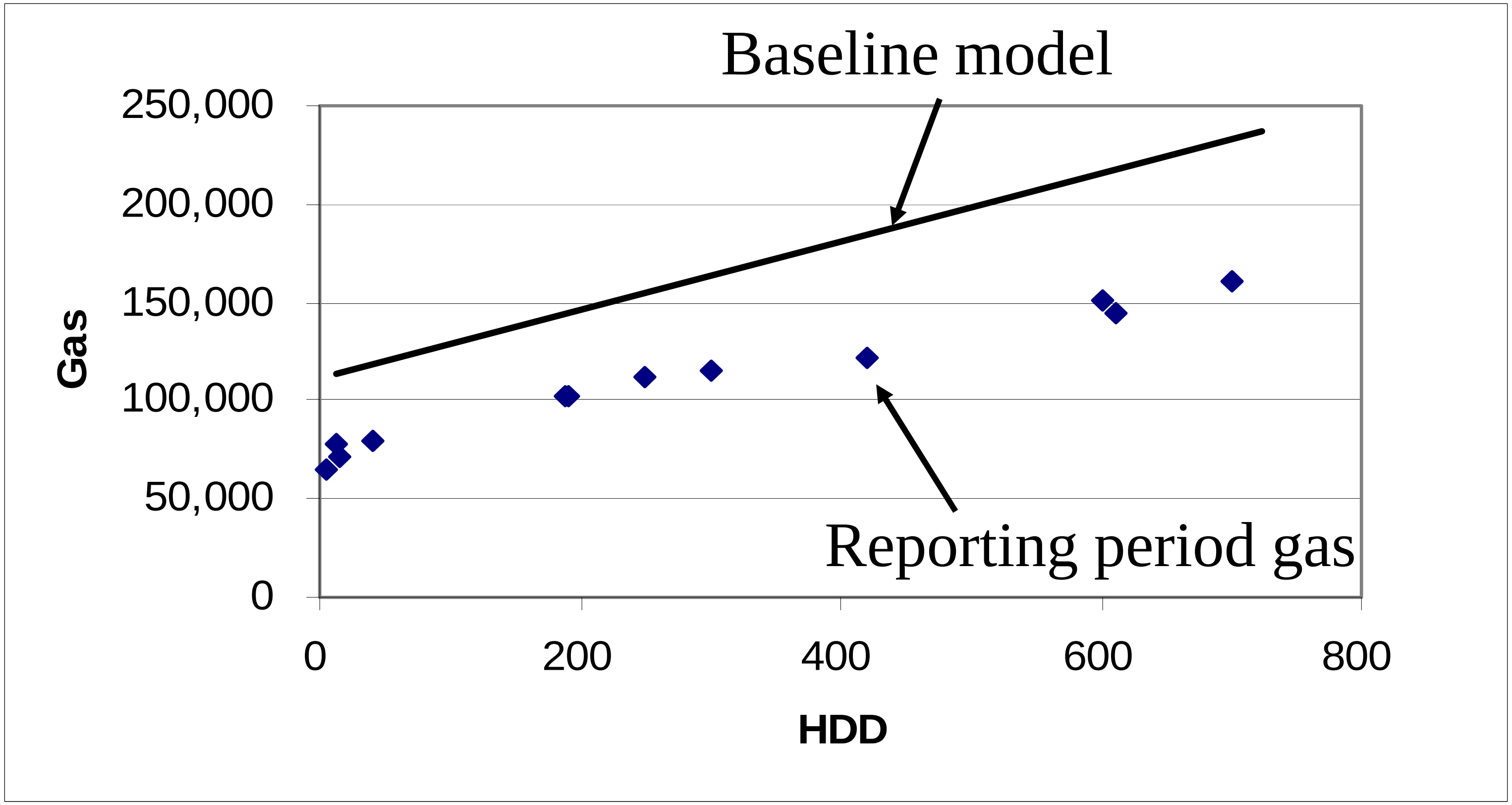
Sample Option C
Graphical View Of Savings



Sample Option C
Computations

Meter Reading Date	Actual Post-Retrofit Data		Projected Baseline			Savings	
			Baseload	Weather Sensitive	Total	Gas (units)	Value
	Consumption	HDD	Factors				Price =
	Units		111,358	173.27			$ 6.232
March 6, 2006	151,008	601	111,358	104,135	215,493	64,485	$ 401,871
April 4, 2006	122,111	420	?	?	?	?	?
May 6, 2006	102,694	188	111,358	32,575	143,933	41,239	$ 257,001
June 5, 2006	111,211	250	111,358	43,318	154,676	43,465	$ 270,874
July 5, 2006	80,222	41	111,358	7,104	118,462	38,240	$ 238,312
August 6, 2006	71,023	15	111,358	2,599	113,957	42,934	$ 267,565
September 8, 2006	65,534	5	111,358	866	112,224	46,690	$ 290,972
October 9, 2006	77,354	12	?	?	?	?	?
November 4, 2006	103,000	190	111,358	32,921	144,279	41,279	$ 257,251
December 10, 2006	115,112	300	111,358	51,981	163,339	48,227	$ 300,551
January 7, 2007	160,002	700	111,358	121,289	232,647	72,645	$ 452,724
February 4, 2007	145,111	612	111,358	106,041	217,399	72,288	$ 450,499

Option C - Best Applications

- Significant energy saving (10% or more of consumption measured by the utility meter)
- All parameters which significantly affect energy usage can be clearly identified (during baseline and after implementation)
- Adjustments factors are simple
- Individual ECM measurement is not required
- Multiple ECMs
- Complex ECMs
- Soft savings ECMs (eg. building leakage reduction, operator training, occupant/user awareness)

Option C
Advantages & Disadvantages

Advantages:

- Evaluates performance of the entire facility
- Includes interactive effects amongst ECMs, and between ECMs and the rest of the facility

Disadvantages:

- No separation of the impact of different ECMs
- Not a saving control method, since normal unexplained total facility energy variations may obscure individual months' savings. However the method provides annual reconciliation.

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Sample M&V Project

Hospital

Energy Conservation Measures	Simple Payback (years)
Lighting power reduction	**2.7**
Water conservation	2.2
Steam system management	1.3
Power factor correction	2.3
Sterilizers and DHW	6.5
Chiller Plant	9.7

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Sample M&V Project

Retrofit Isolation

ECM	Item Measured	Level Measured	Item Assumed
Lighting power reduction	**Fixture kW demand**	**Random sample**	**Hours of Use (based on lighting logger data taken before retrofit)**
Water	Water flow	Sample toilets & showers	Toilets: # Flushes Showers: # & Time
Steam Traps	Steam Loss	Sample	Extrapolate to all
Power Factor	Utility Bill	100%	Annual avoided utility bill cost penalty
Sterilizer	Steam Use	100%	Annual usage
Chiller Plant	Efficiency kW/Ton	100%	Ton Hours

Sample M&V Project

Retrofit Isolation

As an example, consider the M&V design for the **Lighting ECM**, using Option A, Retrofit Isolation: Key Parameter Measurement.

- Before and after sample load measurements
- Assumed operating hours of lights.

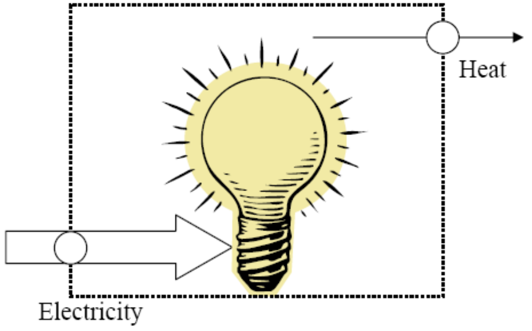
Sample Option A

Lighting - Measurement Boundary

To set the measurement boundary, consider:

What affects energy use *inside* ?

- lamp efficiency improvement
- operating hours
- fraction of lamps burned out



What energy effects happen *outside* the boundary?

- less cooling
- more heating
- task lights added to un-measured circuits

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Sample Option A
Design

Measurement:

- measure at randomly selected light switches
- use clamp-on true RMS wattmeter, calibrated
- measure for 1 second before and 1 second after retrofit

Assumptions:

- 100 hrs/month of operation in the savings reporting period, based on a measurement in the baseline.
- assume mechanical cooling adds 20% to savings
- ignore heating energy change and added task lights
- 5% of lamps/ballasts are burned out at any time

Sample Option A

Observations

	Pre-retrofit	Post-retrofit
# Samples	73	30
Measured average watts per operating fixture	193.1	102.1
Number of fixtures	2,000	1,950

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Sample Option A

Computations

	Pre-retrofit	Post-retrofit
Total kW (95% of fixtures operating)		
Lighting load reduction		kW
Reduction adjusted for cooling savings		kW
Monthly energy savings		kWh/month

Sample Option A

Notes

- Option A is known as "**Retrofit Isolation: Key Parameter Measurement.**" The key parameter in this example is power change in the fixtures, so it is measured
- This sample was IPMVP 2007 "Option A" because we *Assumed* the operating hours, even though we logged operating hours in the baseline.
- Manufacturer supplied data is not field measured. IPMVP treats it as *assumed*. To adhere to IPMVP Option A the manufacturer data cannot be the **key parameter,** but it can be another (non-key) parameter.

Option A - Best Applications

- Operating conditions (eg occupancy) are regularly changing.
- A contractor is not responsible for all parameters affecting energy use.
- Able to Assume a parameter with a level of certainty acceptable to all parties.
- On-going measurement is not required. But to be sure savings are still happening in future, regularly verify that equipment remains in place and is operated properly.

Option A

Retrofit Isolation: Key Parameter Measurement

Advantages:

- Cost effective where numerous energy influencing factors cannot be tracked (such as in a hospital or in a complex industrial process)
- Easy to administer

Disadvantages:

- Assumed factor may introduce error
- Not reconciled to total facility utility usage
- Does not track on-going facility performance