Metering, Monitoring, and Verification – Part 2

APPA Institute for Facilities Management
Indianapolis, IND
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Purpose of Today's Presentation

- To provide a broad understanding of:
  - Various energy analysis methodologies
  - Ways to create energy information
  - Use of information to verify energy performance

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WORDS OF WISDOM

You can manage what you don't measure, but

if you do, you're just guessing

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Agenda

- Overview
  - Definitions
  - Basic Options
- Description of M & V Options
- Examples

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IPMVP*

*International Performance Measurement and Verification Protocol

- Purpose: The IPMVP provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects.
- This document can help in the selection of the M&V approach that best matches:
  - i) project costs and savings magnitude
  - ii) technology-specific requirements
  - iii) risk allocation between buyer and seller (i.e., which party is responsible for installed equipment performance and which party is responsible for achieving long term energy savings).

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Option A	Option B	Option C	Option D

IPMVP M&V Options

M&V Option	How savings are calculated
Option A: "Retrofit Isolation, Key Parameter" – Based on *measured* equipment performance, measured or *estimated* operational factors, and annual verification of "*potential to perform.*"	Engineering calculations using measured and estimated data
Option B: "Retrofit Isolation, All Parameters" – Based on *measurements* (usually *periodic or continuous*) taken of all relevant parameters.	Engineering calculations using measured data
Option C: Based on *whole-building* or facility-level utility meter data adjusted for weather and/or other factors.	Analysis of utility meter data
Option D: Based on *computer simulation* of building or process; simulation is calibrated with measured data.	Comparing different models

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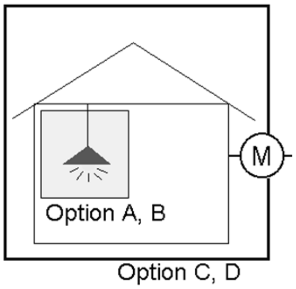
Options A and B vs. Options C and D



Options A&B are retrofit-isolation methods.

Options C&D are whole-facility methods.

The difference is where the boundary lines are drawn.

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Option A | Option B | Option C | Option D

Option A

- Simple approach (and low cost)
- Performance parameter(s) measured (before and after); usage parameters may be measured or *estimated.*
- Used where the "*potential to perform*" needs to be verified but highly accurate savings estimation is simple or not necessary.
- ***Option A is NOT "stipulated savings" !***

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Option A | Option B | Option C | Option D

Stipulate

- To stipulate is to agree to a term or condition.
- Under IPMVP, to stipulate means to *estimate without measurement*.
- Measured values may also be stipulated.

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Option A	Option B	Option C	Option D

Appropriate Use of Stipulations

- Parameter is well understood
- Willingness to accept risk
- Previous experience
- Probable success of ECM
- Small savings and/or small uncertainty
- Greater M&V costs not justified
- Stipulations don't add to uncertainty
- Monitoring serves no other purpose

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Option A	Option B	Option C	Option D

Inappropriate Use of Stipulations

- Unwillingness to assume risk
- Parameters not known with reasonable certainty
- Potential for technical problems
- Monitoring provides valuable information
- Stipulation significantly contributes to overall uncertainty

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Option A	Option B	Option C	Option D

Sources of Stipulations

Acceptable	Unacceptable
Measurements	Undocumented assumptions
Engineering Analysis	Proprietary algorithms
Measurement-based models	Unsupported handshake agreements
Manufacturer's data	Guesses at parameters
Standard tables	Models based on questionable data
TMY weather	Other buildings
ANSI/ARI/ASHRAE	
Facility logs	

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Option A | **Option B** | Option C | Option D

Option B

- Under Option B, all relevant parameters are measured, usually periodically or continuously.
- Measurement frequency is consistent with expected variations.
- Applicable where accurate savings estimation is necessary and where long-term performance needs to be tracked.
- Reduces uncertainty, but requires more effort.

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Option A | Option B | **Option C** | Option D

Option C

- Option C looks at energy use and cost of entire facility, not at specific equipment.
- Considers weather, occupancy, etc. for *baseline adjustments*
- Applicable where total savings need to be quantified but component-level savings do not AND where savings are > 15% of current energy use
- Easily implemented; commercial and free software is available

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Option A | Option B | Option C | **Option D**

Option D

- Option D treats building as computer model
- Flexible, but requires significant effort
- Applications:
  - New construction
  - Energy management & control systems
  - Multiple interacting measures
  - Building use changes
  - Building modifications (e.g., windows)

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Option A	Option B	Option C	Option D

Examples

- Option A: Lighting
- Option B: Variable-Speed Drive
- Option C: Heating Plant
- Option D: New Construction

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Option A	Option B	Option C	Option D

Example Lighting Project

Consider the following lighting project:

What's measured?

What's estimated?

- Upgrade 5,000 fixtures
- Existing performance: 86 Watts
- New performance: 56 Watts
- Operating hours: 3,000/year
- Electricity: $0.10 / kWh + $10 / kWd/mo

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Option A	Option B	Option C	Option D

Option A

Performance:

- Baseline power consumption is 86 Watts.
- Proposed power consumption is 56 Watts.
- Difference is 30 Watts.

Usage:

- Baseline and New: 3,000 hours / year

Financial:

- Energy = $0.10/kWh + $10/kWd/mo

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Option A	Option B	Option C	Option D

Lighting Savings

- Energy Savings = QTY*(Before - After) * Hours
  - ES = (5,000) * (86 W - 56 W) * (3,000 hours) * (1 kW / 1000 W)
  - ES = 450,000 kWh / year

What's measured?

What's estimated?

- Demand Svgs = QTY * (Before - After) * DF
  - DS = (5,000)*(86 W - 56 W)*(1 kW/1000 W)*DF
  - DS = 150 kW * DF
- DF: Diversity Factor. % of lights operating when peak demand is set.

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Option A	Option B	Option C	Option D

Lighting Cost Savings

- Cost Savings = (Unit Cost)*(Energy Savings) + (Unit Cost)*(Demand Savings)

CS = (450,000 kWh) * ($0.10/kWh) + (150 kW) * (75%) * ($10/kW) * 12 mo.

- Cost Savings = $45,000 + $13,500 = $58,500 / year
- Assumes diversity factor of 75%.

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Option A	Option B	Option C	Option D

Example VSD Project

Variable-Speed Drive on HVAC Fan

- Baseline Fan: Operates continuously at a single speed and power no matter what the cooling load is.
- VSD Fan: Speed and power change with cooling load.

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Option A | **Option B** | Option C | Option D

Option B

What's measured?

What's estimated?

Fan Performance

- Baseline fan: Constant power (140 kW).
- VSD Fan: Power changes w/ weather.

Fan Usage

- Fan power changes hourly with cooling load (outside temperature and sunshine).

Financial

- Energy = \$0.10 / kWh + \$10 / kW-mo

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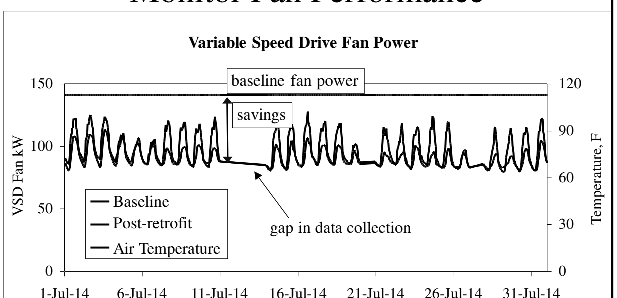
Option A | **Option B** | Option C | Option D

Monitor Fan Performance



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Option A | **Option B** | Option C | Option D

Calculate Monthly Energy Savings

E Savings =(kW_{Before} - kW_{After}) * (1 Hour) * hrs/mo.

Cost Savings = (Unit Cost) (Energy Savings)

Month	kWh Saved	Cost Savings
July	27,592	\$2,759
August	24,316	\$2,432
September	26,870	\$2,687
October	34,724	\$3,472
November	40,858	\$4,086

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Option A | **Option B** | Option C | Option D

Calculate Monthly Demand Savings

DM Savings = kW_{Before} - Max(kW_{After})

Why no DF?

Cost Savings = (Unit Cost) (Demand Savings)

Month	kW Saved	Cost Savings
July	59	$587
August	71	$712
September	64	$645
October	74	$737
November	85	$849

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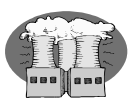
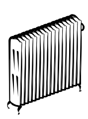
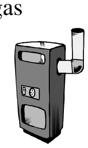
Option A | Option B | **Option C** | Option D

Example Heating Project

Heating system upgrade

- Baseline: Oil-fired boilers with central steam plant provide heat to buildings.
- New System: Shut down steam plant. Install gas furnaces in all buildings.

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Option A | Option B | **Option C** | Option D

Heating System Characteristics

<u>Baseline Performance:</u>
- Oil-fired, low-efficiency, distribution losses (70% system efficiency)

<u>New Performance:</u>
- Gas-fired, high efficiency, no distribution losses (91% system efficiency)

<u>Usage:</u>
- Driven by weather

<u>Financial:</u>
- Oil is $ 1.50 / gallon (1.4 therms / gal)
- Gas is $0.75 / therm

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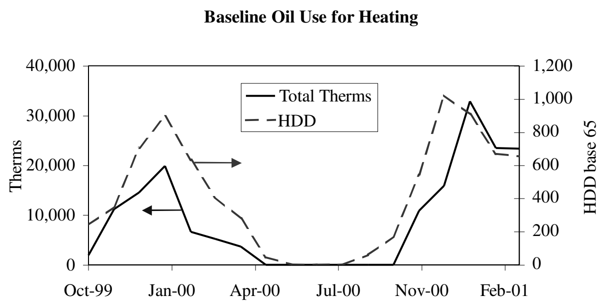
Option A | Option B | **Option C** | Option D

Compare Oil Use to Temperature



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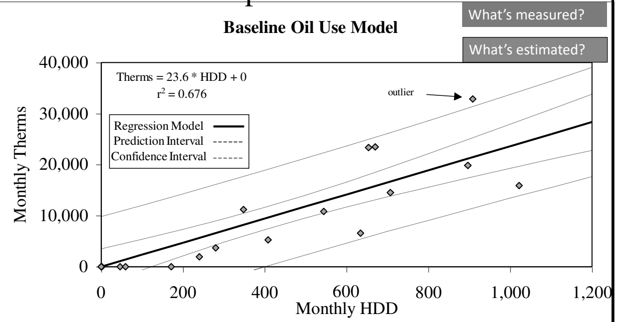
Option A | Option B | **Option C** | Option D

Develop Baseline Model

What's measured?

What's estimated?



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Option A | Option B | **Option C** | Option D

Calculate Monthly Energy Savings

Baseline Therms = 23.6 * HDD   New Therms = Baseline*.70

Month	HDD	Baseline Therms	New Therms	Energy Savings, Therms
January	915	22,046	15,432	6,614
February	742	17,617	12,332	5,285
March	520	11,934	8,354	3,580
April	348	7,531	5,272	2,259
May	91	952	666	285
June	9	0	0	0
July	0	0	0	0
August	1	0	0	0
September	112	1,489	1,042	447
October	364	7,940	5,558	2,382
November	442	9,937	6,956	2,981
December	823	19,691	13,784	5,907
Total	**4,367**	**99,137**	**69,396**	**29,741**

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Option A	Option B	Option C	Option D

Calculate Monthly Cost Savings

Oil = ($1.5/gal) / (1.4 therms/gal) = $1.07 / therm — Gas = $0.75 / therm

Month	Baseline Cost	New Cost	Cost Savings
January	$23,621	$11,574	$12,047
February	$18,876	$9,249	$9,627
March	$12,786	$6,265	$6,521
April	$8,069	$3,954	$4,115
May	$1,020	$500	$520
June	$0	$0	$0
July	$0	$0	$0
August	$0	$0	$0
September	$1,596	$782	$814
October	$8,508	$4,169	$4,339
November	$10,647	$5,217	$5,430
December	$21,097	$10,338	$10,760
Total	**$106,218**	**$52,047**	**$54,171**

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Option A	Option B	Option C	Option D

Example New Construction

- Proposed building incorporates energy-efficient design features selected and implemented by ESCO.
- Baseline building is existing design before ESCO modifications.

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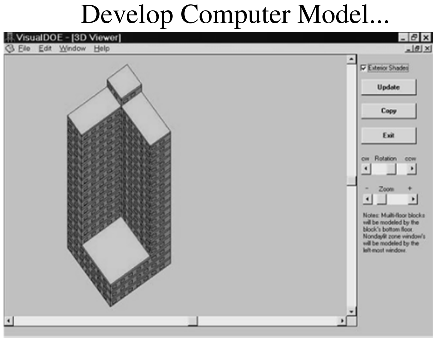
Option A	Option B	Option C	Option D

Develop Computer Model...



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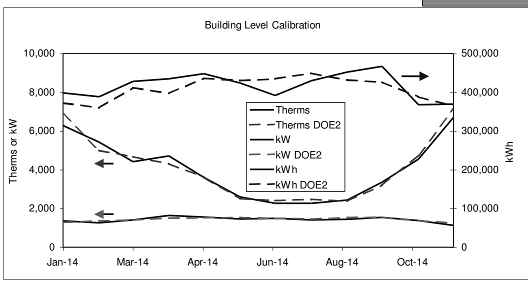
Option A	Option B	Option C	Option D

... Calibrate Model ...

What's measured?

What's estimated?



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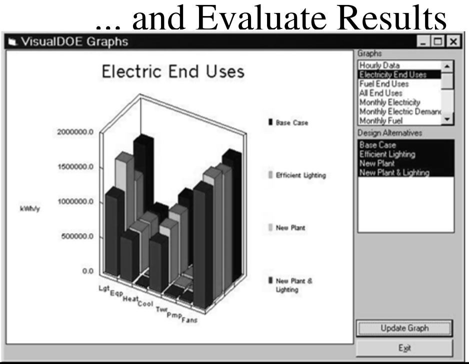
Option A	Option B	Option C	Option D

... and Evaluate Results



What's measured?

What's estimated?

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Option A	Option B	Option C	Option D

Calculate Savings

- Evaluate energy use for each scenario.
- Calculate savings for each scenario relative to base case.

	Energy Use, kWh				
Alternative	**Lights**	**Cooling**	**Other**	**Total**	**Savings**
Base Case	1,500,298	955,263	2,447,979	4,903,540	-
Efficient Lighting	1,125,240	860,062	2,365,638	4,350,940	**552,600**
Efficient Chiller	1,500,298	788,681	2,426,812	4,715,791	**187,749**
Chiller & Lighting	1,125,240	708,933	2,346,427	4,180,600	**722,940**

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Option A | Option B | Option C | **Option D**

Option D Risk Allocation

	Usage	Performance
Option D (savings based on TMY weather)	Owner	ESCO

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Review and Discussion

- Total energy use and savings are functions of both usage and performance.
- Options A and B are retrofit-isolation methods.
- Options C and D are whole-facility methods.
- Can mix and match methods.
- Selection of M&V method based on need to verify savings cost-effectively.

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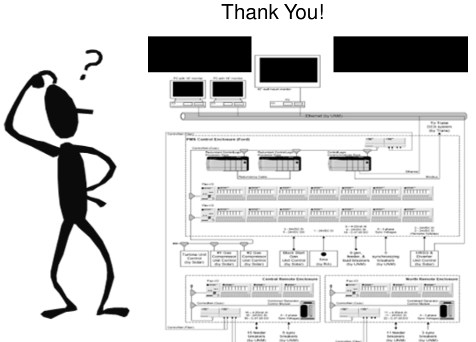
Questions & Answers

Thank You!



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