SIMBUILD 2008

Closing the Gap:

The Role of Energy Modeling in

Measurement & Verification

SIMBUILD 2008

SimBuild 2008

3rd National Conference of IBPSA-USA

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- International Building Performance Simulation Association

U.S. Department of Energy

ASHRAE

Outline

- Part I:
  - Are LEED buildings more energy efficient than other buildings?
- Part II:
  - Energy modeling for Measurement & Verification
  - Closing the gap between design energy savings and actual energy savings

PART I

- Energy Efficiency of LEED-NC Buildings

Introduction

- To date, LEED certification does not required verification of energy savings
- USGBC commissioned New Buildings Institute of Vancouver, WA, to conduct a study to investigate the energy efficiency of LEED buildings

New Building Institute - NBI

- Comprehensive report
- Energy performance of 121 LEED NC Buildings (22%)
- Published March 4, 2008

NBI Study

- LEED Buildings
- CBECS Buildings
  - Commercial Building Energy Consumption Survey
  - DOE's database of 5000 existing commercial buildings
  - Survey is conducted every four years

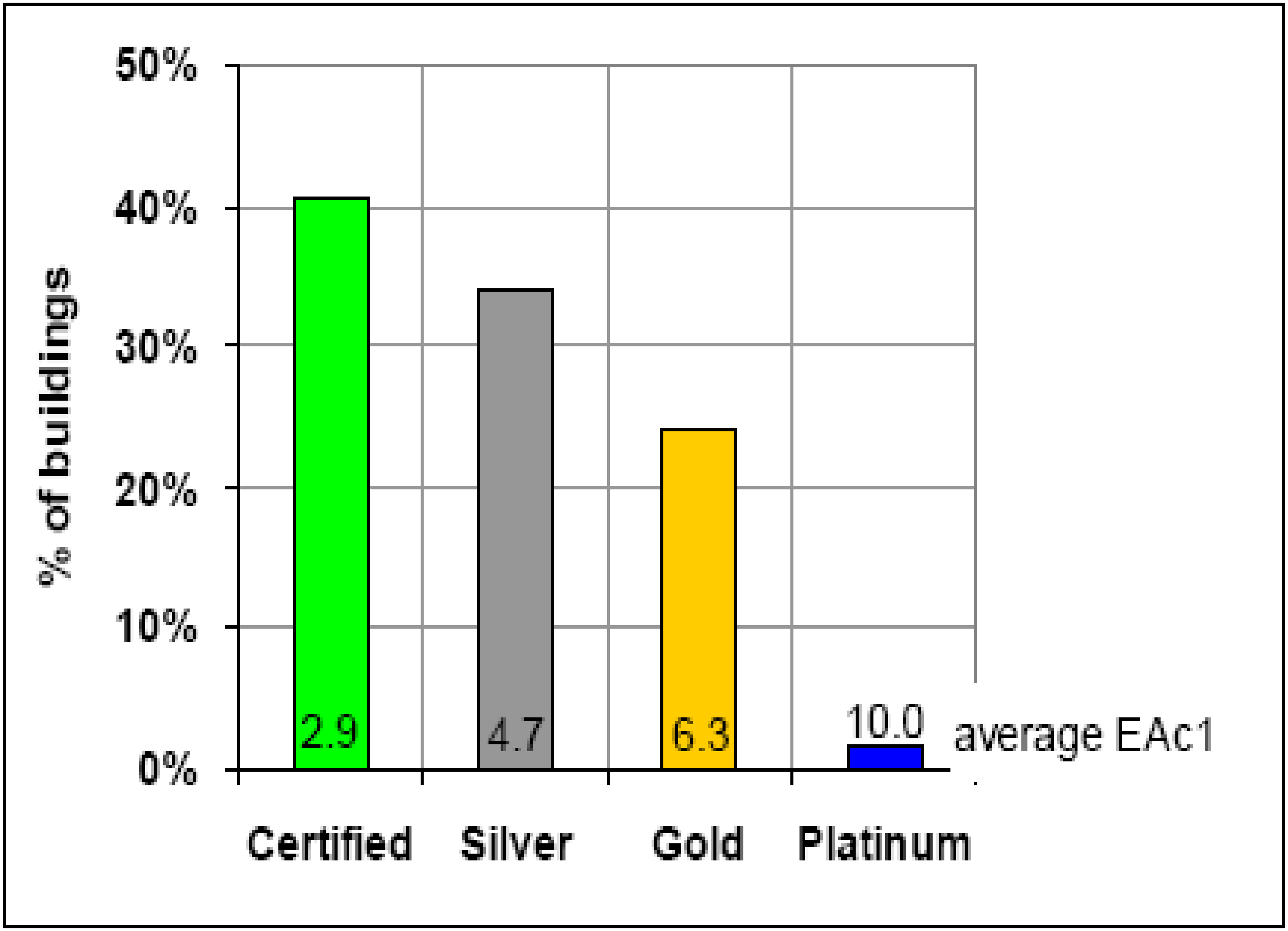


Figure 6: Certification Level Distribution with EAc1 Averages

NBI Study

Three metrics:

1) Energy Use Intensity (EUI) vs. CBECS

2) Energy Star Rating vs. CBECS

3) Measured versus Modeled Energy Consumption

A. Energy Use Intensity

(EUI)

LEED v. CBECS

- Good news…
  - Median EUI for LEED buildings = 69 kBtu/sf
  - CBECS EUI = 91 kBtu/sf
  - LEED buildings v. CBECS national average
    - 24% better
  - Office buildings only
    - 33% better

LEED v. CBECS (EUI)

Certified – 26% better than CBECS

Silver – 32% better than CBECS

Gold-Platinum – 44% better than CBECS

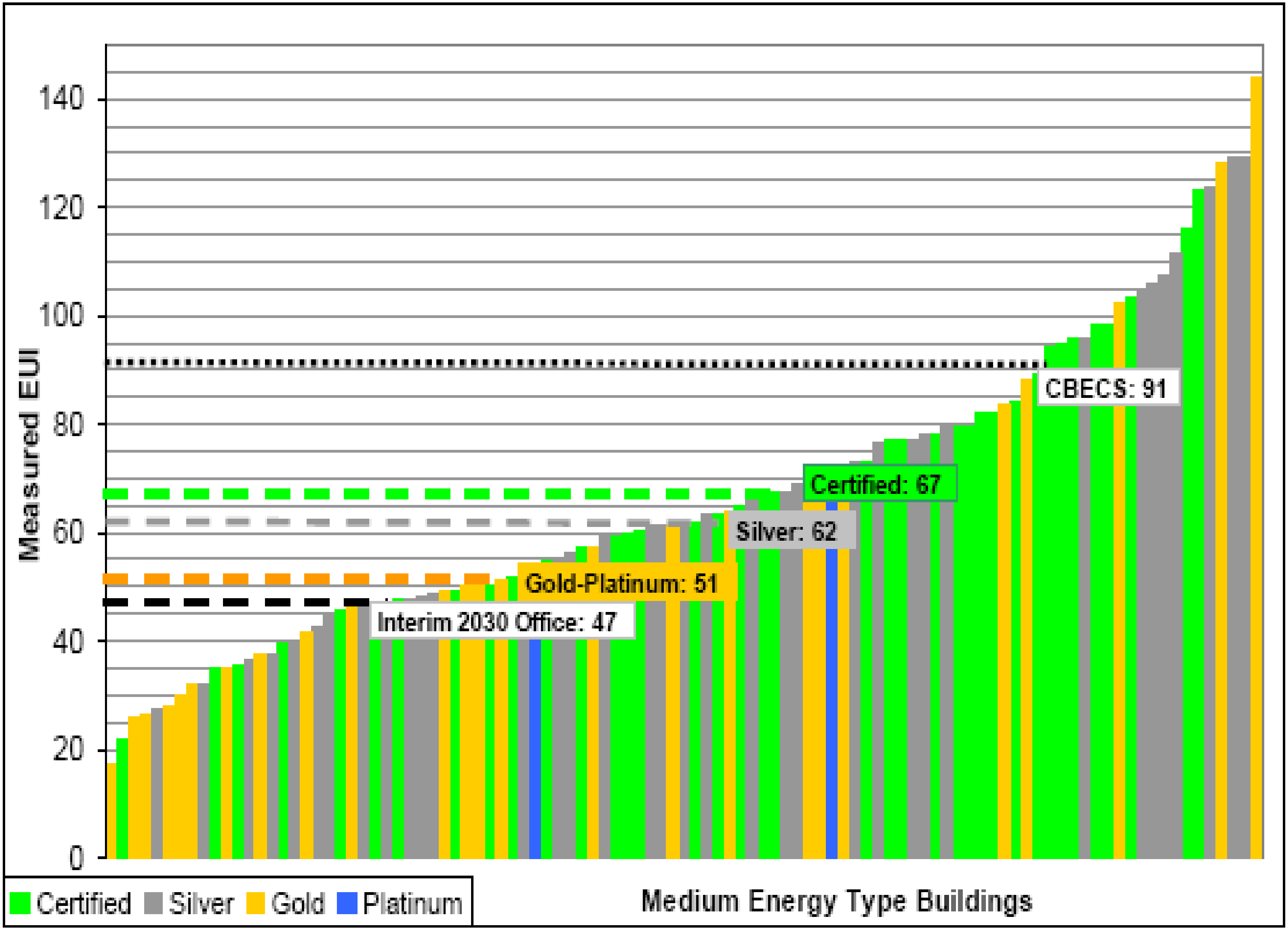


Figure ES- 2: EUI (kBtu/sf) Distribution

LEED v. CBECS (EUI)

- The bad news …
  - Significant scatter within each certification level
  - Scatter could not be explained by occupancy

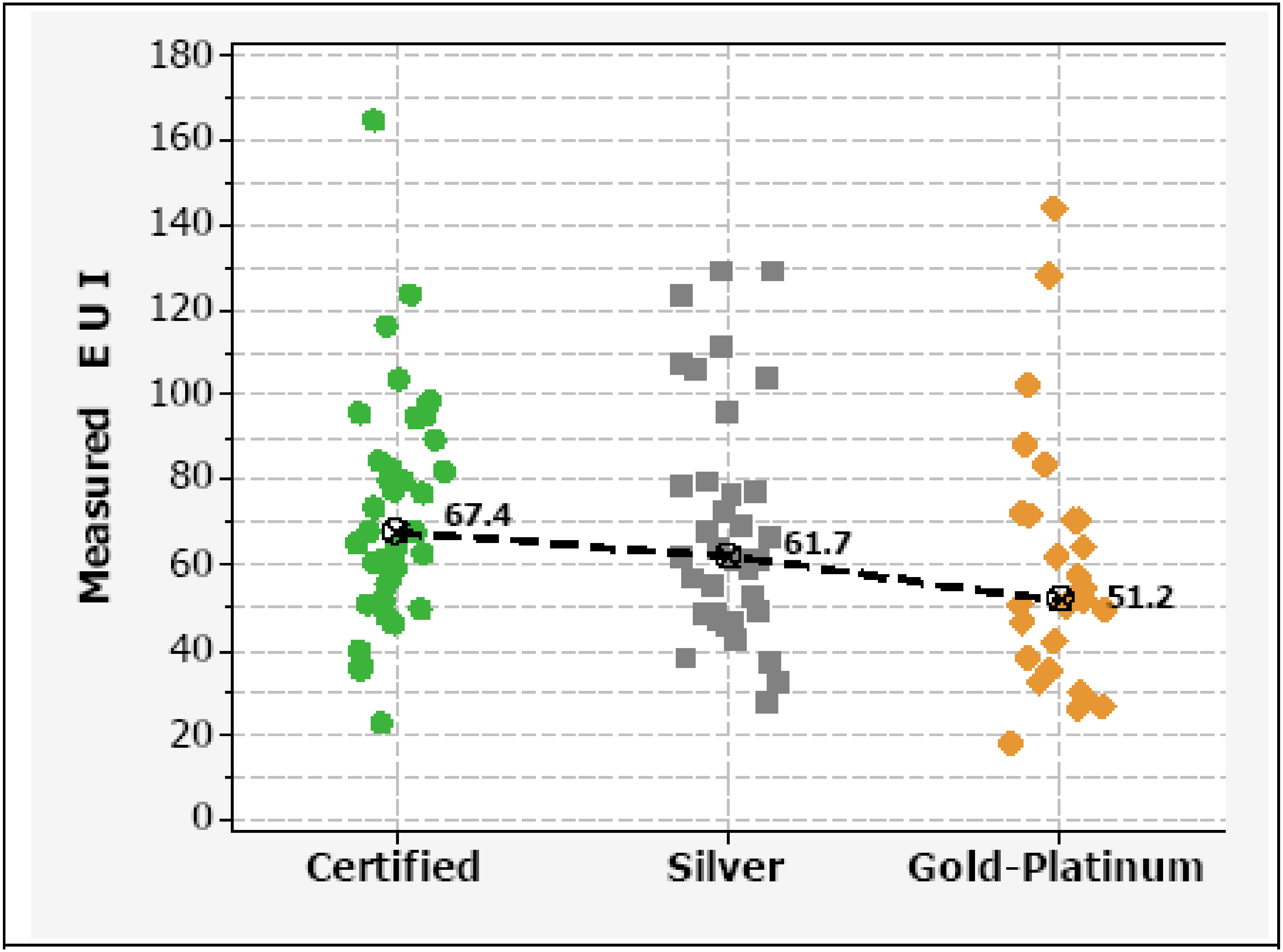


Figure 11: Measured EUIs (kBtu/sf) by LEED-NC Rating Level

LEED vs. CBECS

ENERGY STAR RATING

Energy Star

- Normalized for:
  - Temperature
  - Schedules
  - Occupancy
  - Building classification
  - Equipment

Energy Star

- The Good News…
  - Average LEED Energy Star – 68
  - Average CBECS – 50

Energy Star

- The Bad News…
  - 25% of LEED Energy Star < 50 !!

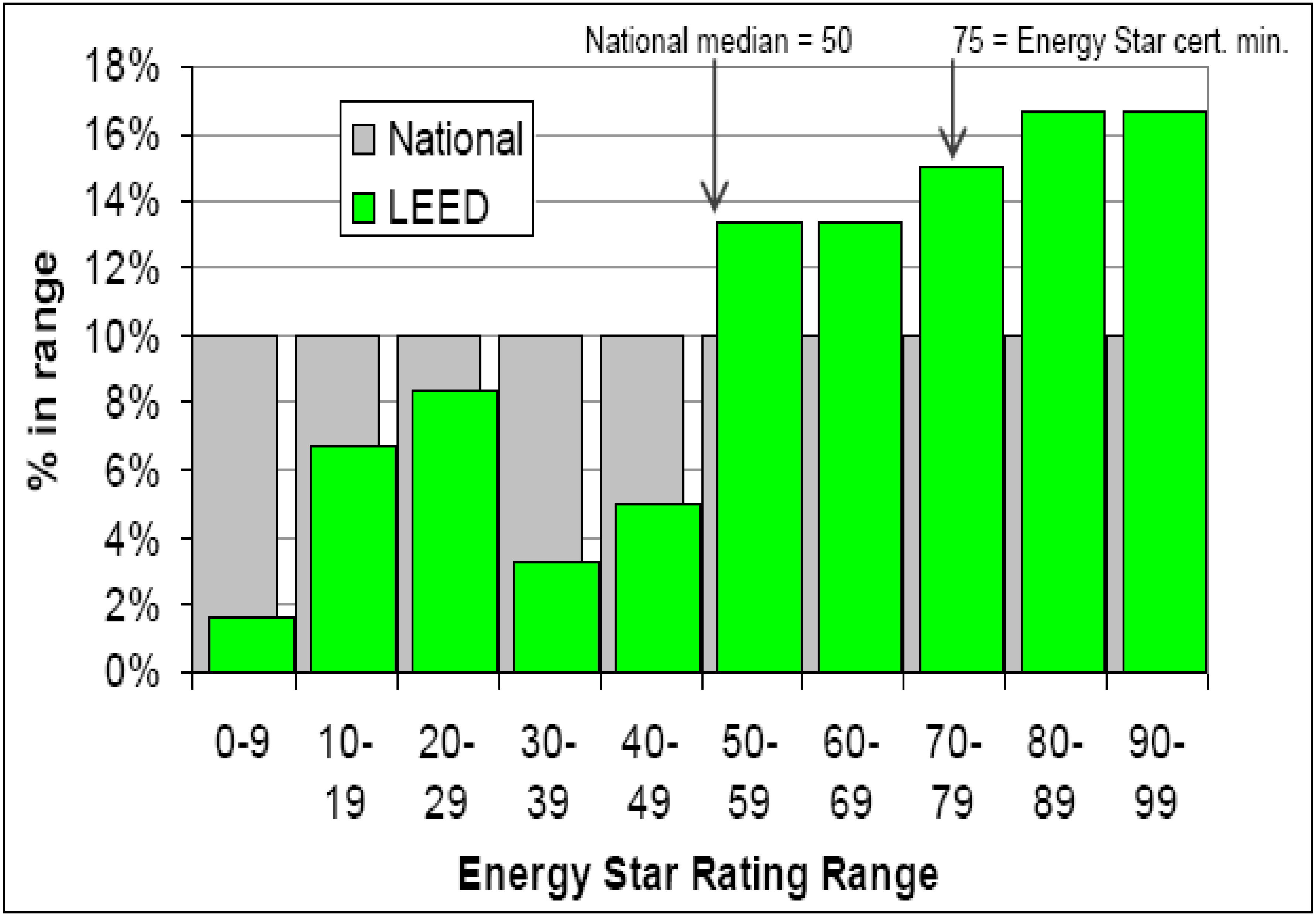


Figure ES- 3: Distribution of Energy Star Ratings

Modeled Energy Performance
versus
Measured Energy Performance

Measured vs. Modeled

- The Good News…
  - Average modeling accuracy = 92% !

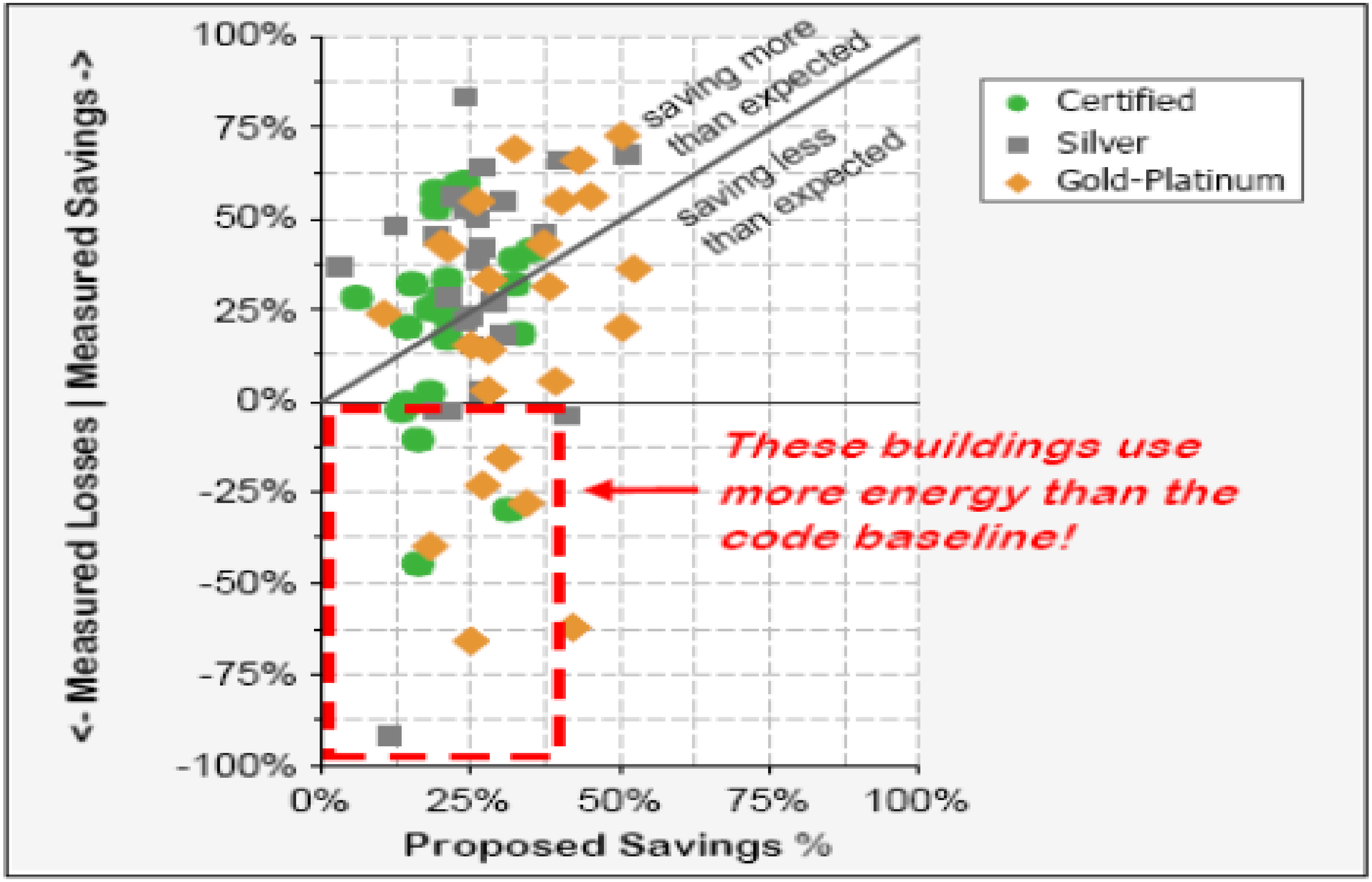
Measured v. Modeled

- Bad News..
  - Over <u>one-half</u> deviated by more than 25%

- Adverse impact on decision making

- Is energy modeling a poor predictor of project-specific energy performance??

Measured versus Proposed Savings Percentages
(NBI, Turner, Frankel, 2008)



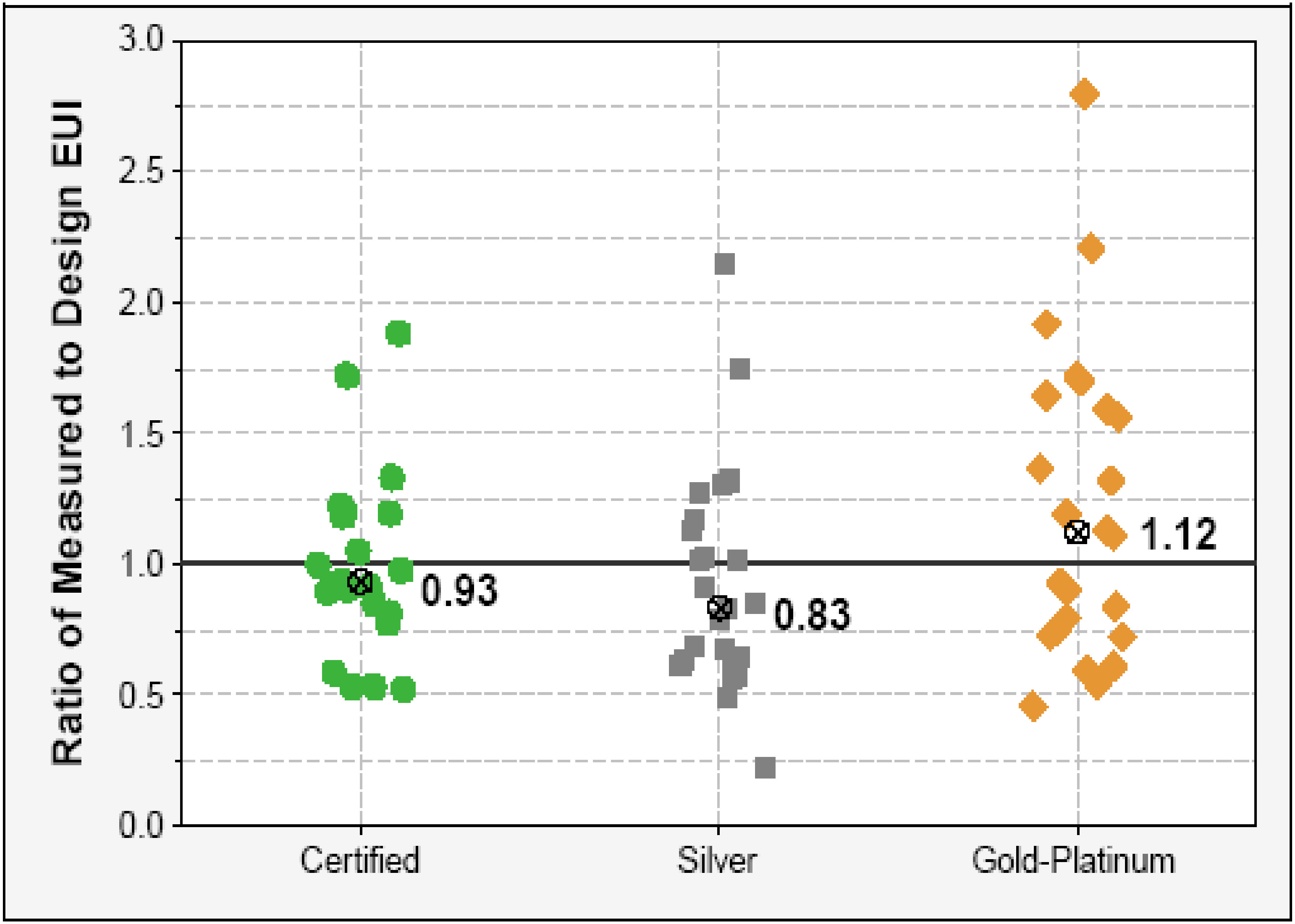


Figure 17: Measured/Design EUI by LEED rating level, with Medians

Measured vs. Modeled

- Need to improve technique of predicting actual building energy use
- Current predictions may be erratic in certain cases

Summary: Part I

- On average, LEED designed buildings save energy
- On average, energy modeling captures aggregate building performance
- Tremendous variability in energy performance within each group
- Some LEED buildings consumed more energy than code baseline buildings

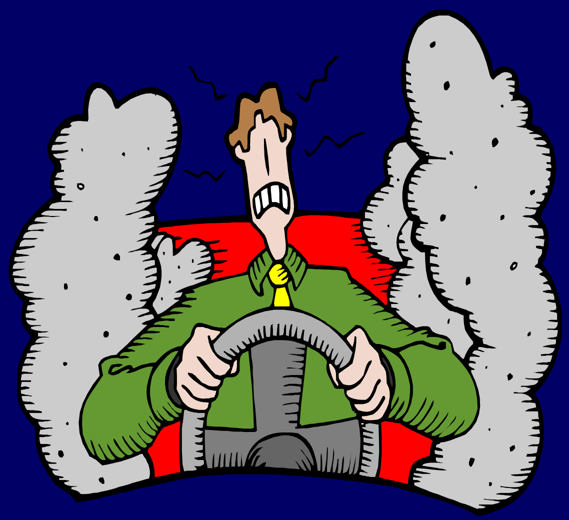
Conclusion…

- Calibrate energy models
- Provide meaningful feedback to the design community
- Measurement & verification provides a link between LEED EAc1 energy model and actual building performance

PART II

MEASUREMENT
AND
VERIFICATION

Introduction



- Buildings use
  - 71% of electricity
  - 40% of all energy in the US
- Entire transportation sector: 29%
- What has the public's attention???
  - filling a gas tank is a direct measurement of performance
  - M & V issue

What is M & V ?

- LEED – NC 2.2:
  - Compare actual building performance versus predicted building performance
  - Provide an ongoing accounting of building energy consumption over time

History of M & V

- IPMVP = International Performance Measurement & Verification Protocol
- Non-profit organization
- Dedicated to efficient use of resources
- Established in 1997

Why Engage in M & V?

- Integrate design with finished product
  - Demonstrate performance of new technology
- Quantify energy savings
  - Show compliance with energy reduction legislation
- Improve operations and maintenance
- Educate tenants regarding energy conservation

Reference Materials M & V

- IPMVP Volume III
  - LEED Version 3.0
  - Best practices for M & V
- ASHRAE Guideline 14
  - Detailed procedures
  - Specific instrumentation

LEED – M & V

- EA Credit 5
  - Two options for M & V from the IPMVP
  - Option B – ECM isolation
    - Simple equipment replacement
    - Minimal interactive effects with other ECMS
  - Option D – Building Energy Simulation
    - New construction
    - Building design is integrated and holistic
    - Numerous ECMs

IPMVP - Option D

- Use calibrated computer simulation models to analyze the energy performance of:
  - Retrofit projects
  - New construction
  - Savings risk outweigh the M & V costs
- Performance is determined by a comparison of:
  - Baseline Model
  - Performance Model

Software

- BES:
  - Flexible & accurate
  - Well supported & tested
  - Whole building
  - Hourly weather data
  - Public domain
    - Equest
    - EnergyPlus

M & V Development

- Development of M & V is ongoing
- Begin in early design phase
- Analysis used for design decisions become key factors in M & V study
- Whole team approach
- Energy analysis → M & V

What not to do…

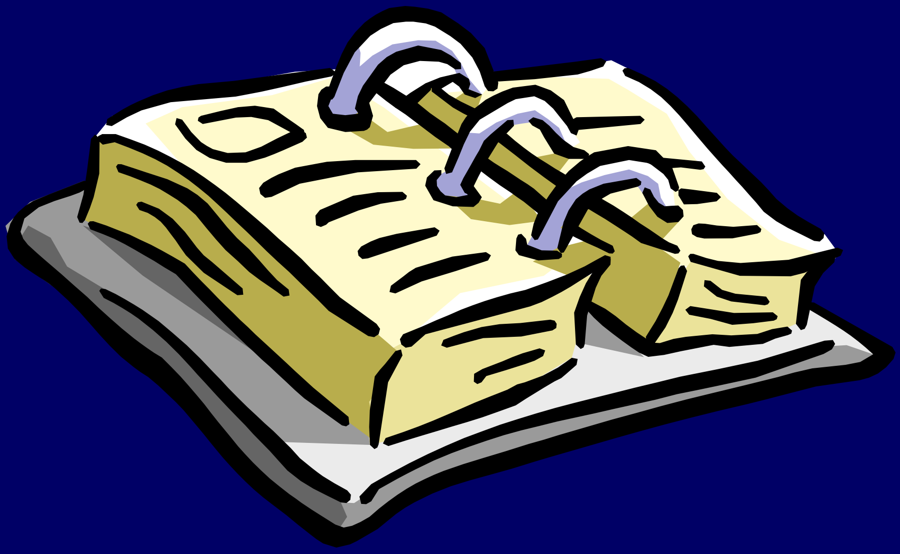
- LEED Core & Shell
- Initial energy model: core & shell
- Energy model changed to include tenant space
  - LEED requires full tenant compliance
- Only part of the team knew of the change
  - Metering was added after the fact
  - $$$

M & V Steps

- 1) Data collection
- 2) Model development and testing
- 3) Calibration of the performance model
- 4) Calibration of the baseline model
- 5) Energy savings calculation

Step 1: Data Collection

- Envelope
- Occupancy
- Systems
- Plant
- Weather
- Etc.



Step 2a: Proposed Model Creation

- Input data from Step 1 -> Energy Model
- Debug the model
- Examine design day calculations
  - Are loads met?
- Examine annual/seasonal energy information
  - Is energy consumption logical?

Step 2b: Baseline Model Creation

- Derive the baseline from the proposed design (in New Construction)
- "Back-engineer" the baseline by modifying the proposed design
- Project energy performance of the baseline

Step 3: Calibration of Proposed Model

- After one year of occupancy
- Model is adjusted to account for operating conditions during the M & V period
  - Weather
    - Actual weather data calibration
  - Occupancy
  - System set points

Step 3: Calibration of Proposed Model

- Energy Use
  - Utility bills
  - Meter
  - Sub-meter
- Other Data Sources
  - Building controls
  - Surveys
  - Security
  - Data loggers to follow trends

Step 3: Calibration of Proposed Model

- Investigate significant deviations between
  - Proposed Model
  - Building's energy information
- Calibration may uncover
  - Performance curve differences
  - Deterioration in operations
- Correct the Proposed Model to achieve calibration

Calibration Example

- Partially filled 10-story office tower
- Determine energy consumption of:
  - Tenant Occupied Space
  - Vacant Space
  - Common Area
- Utility Bills
  - Heat Pumps
  - Lights/Plug Loads
  - Gas Bill

Calibration Example

- Metering?
  - Limited knowledge
- Total Building Energy Simulation?
  - Ongoing application for future tenants, etc.

Calibration Example

- Series building energy simulations
  - Annual data
- Calibrated gas usage
- Calibrated light and plug loads
- Simulation matched utility bills
  - Within 5% - gas
  - Within 10% - electricity

Step 4: Calibration of Baseline Model

- New Construction Baseline
  - Hypothetical: minimally code-compliant building
- Retrofit Baseline
  - Building before ECMs
    - Based on utility bills, etc.

Step 4: Calibration of Baseline Model

- Baseline matches the Proposed Model except for ECMs
- May need to make secondary changes
  - Dramatically increase heating/cooling loads
  - Plant size
  - System operation

Step 5: Energy Saving Calculation

- Method 1
  - Baseline Model – Proposed Model = Energy Savings
    - Reduces systemic errors
    - Assumes perfect equipment operation

Step 5: Energy Savings Calculation

- Method 2:
  - Baseline Model – Utility Bills = Energy Savings
    - Captures equipment performance degradation
    - Need a highly accurate Baseline Model

Table 4-4 Example Calculations to Determine Monthly Model Calibration

Month	2,006 Measured kWh (M)	eQUEST Simulated kWh (S)	S-M	MBE	Squared Error
Jan	839,040	842,236	3,196	0%	10,212,435
Feb	814,080	774,882	(39,198)	5%	1,536,448,710
Mar	766,080	827,555	61,475	-8%	3,779,175,625
Apr	874,555	928,017	53,462	-6%	2,858,226,075
May	984,960	1,077,269	92,309	-9%	8,520,951,481
Jun	960,000	1,005,105	45,105	-5%	2,034,461,025
Jul	1,079,040	1,184,382	105,342	-10%	11,096,884,293
Aug	956,160	1,034,555	78,395	-8%	6,145,776,025
Sep	908,160	1,009,812	101,652	-11%	10,333,192,128
Oct	888,960	999,842	110,882	-12%	12,294,831,230
Nov	952,320	840,194	(112,126)	12%	12,572,295,939
Dec	871,680	822,511	(49,169)	6%	2,417,626,946
Total	**10,895,035**	**11,346,360**	**451,325**	**-4%**	**73,600,081,912**
	Overall Results:				
	MBE_{month}	**-4%**			
	Cv(RMSE):	**9%**			

M & V Expense

- Initial Fee: already incurred
  - Develop a model for LEED - EA c1
- Additional Fee:
  - Tune EAc1 model during the performance period
- Building sub-system metering

M & V Expense

- The more rigorous – the more expensive
  - Level of detail in surveys
  - Duration of metering
  - Amount of analysis required

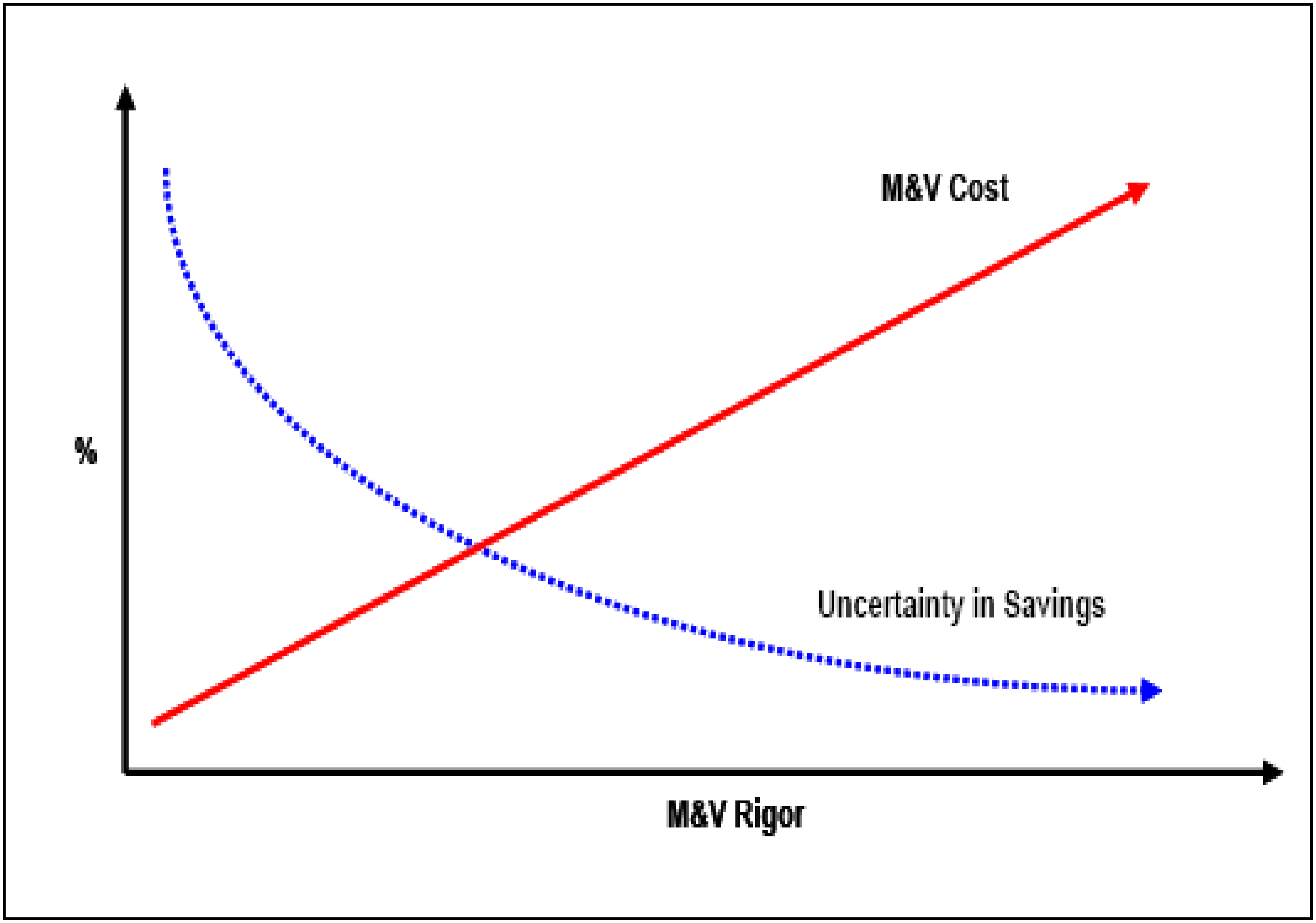
M & V Expense

- Value of the information provided is appropriate to the value of the project
- Overall M & V: 1 – 10% of energy savings costs

M & V Expense

- Average annual M & V costs are 3.3% of annual energy cost savings.
- Complex ECMs will warrant greater M & V costs
- Simple ECMS require minimal M & V costs

Figure 5-2 The Law of Diminishing Returns for M&V



Summary

- On average LEED buildings save energy
- Energy savings has wide variation
  - Overall Energy Use Intensity (EUI)
  - Energy Star Ratings
  - Modeled vs. Measured Energy Performance

Summary

- M & V provides a link between predicted and actual energy saving
- M & V costs are ~ 3% of anticipated energy savings associated with a project
  - Significant portion of these costs are already incurred during EAc1

Summary

- M & V benefits offset the cost of calibration and modeling
  - Quantify energy savings
  - Detect underperformance of equipment or systems
  - Raise awareness of energy conservation for tenants

References – Part I

- Turner, C., Frankel, M. "Energy Performance of LEED for New Construction Buildings: Final Report." Prepared for USGBC, Washington DC. March 2008.
- Morrison, L., Azerbegi, R., Walker, A. "Energy Modeling for Measurement and Verification." Third National Conference of IBPSA-USA, Berkeley, CA. July 2008.

References – LEED I

– McKinley, T., Alleyne, A., "Identification of Building Model Parameters and Loads Using On-Site Data Logs" Third National Conference of IBPSA-USA, Berkeley, CA. July 2008.

Reference – Part II

- M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 3.0.; US DOE, Federal Energy Management Program, April 2008.
- IPMVP: Concepts and Options for Determining Energy Savings in New Construction, Vol III; April, 2003.

General References

- LEED – NC Version 2.2

Thank you!

Questions???