

# Measurement & Verification (M&V) : Procedures and Methods



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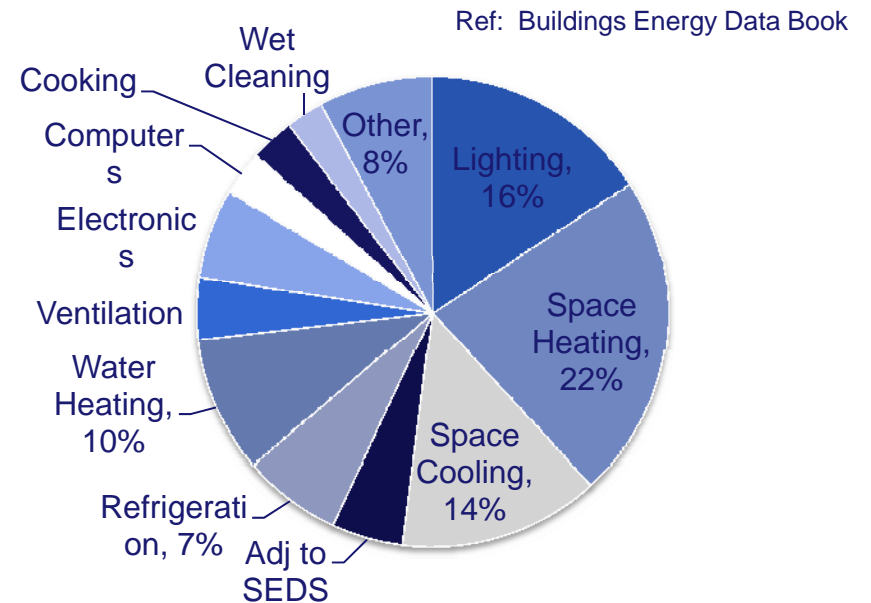
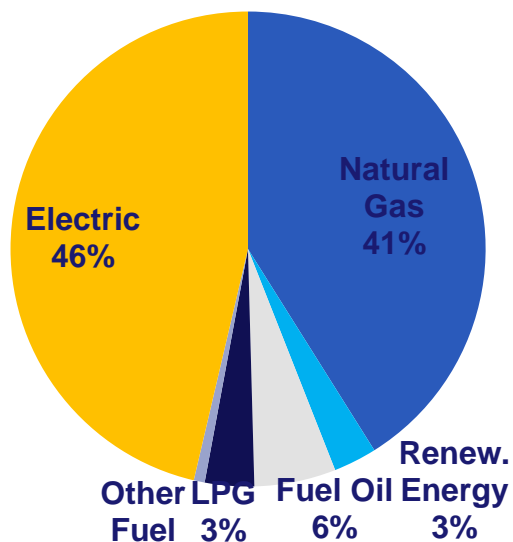
# Agenda

- ❖ Building Energy
- ❖ M&V Concepts and Guidelines
- ❖ M&V Approach
- ❖ LEED M&V
- ❖ M&V Plan
- ❖ Calibrated Simulation

# Building Energy Consumption

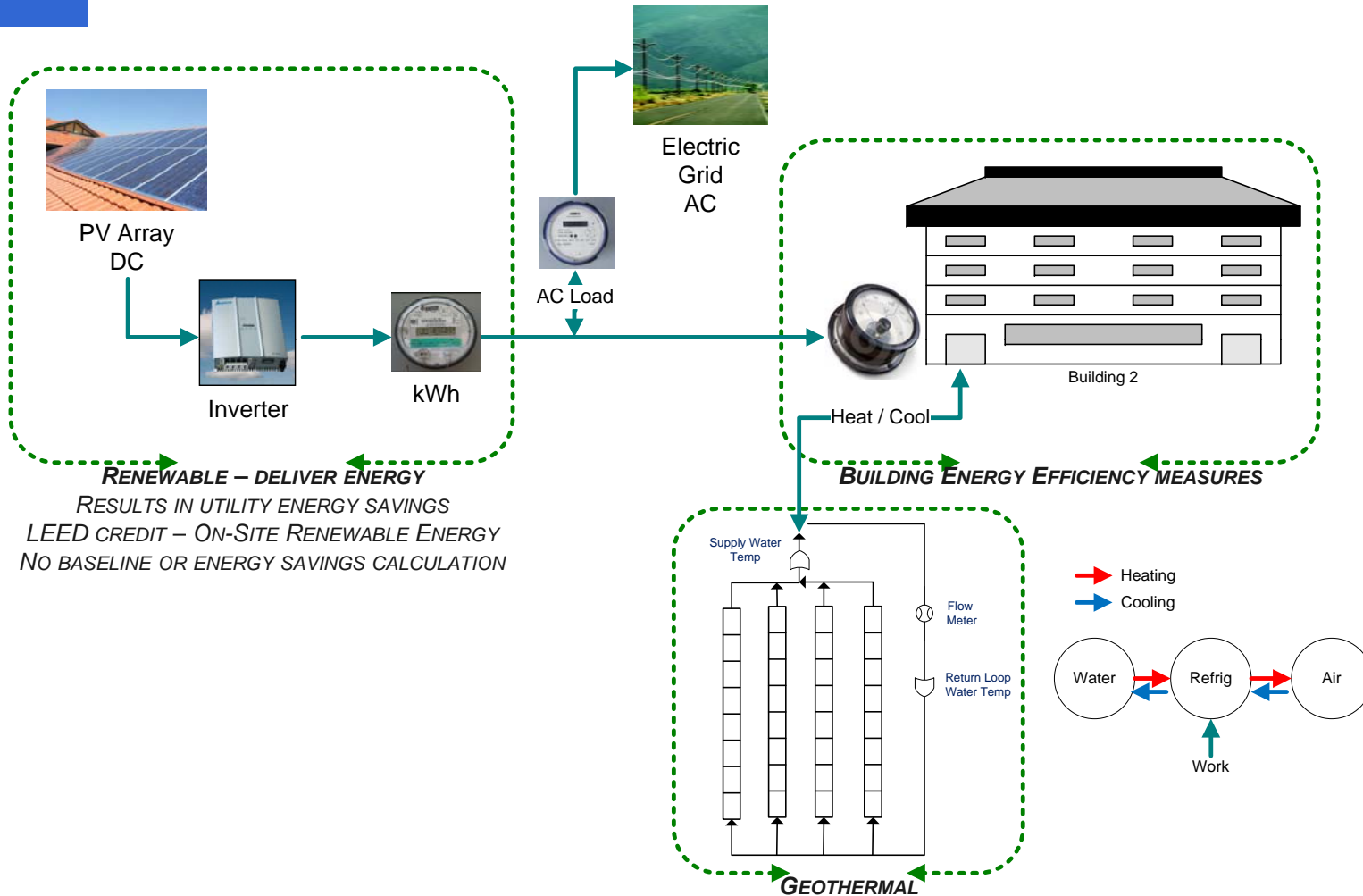
In the U.S. Buildings consume:

- ❖ 39% of all energy
- ❖ 74% of electricity produced
- ❖ 38% of carbon emissions



***Energy is the single largest controllable operating expense for office buildings***

# Building Facility

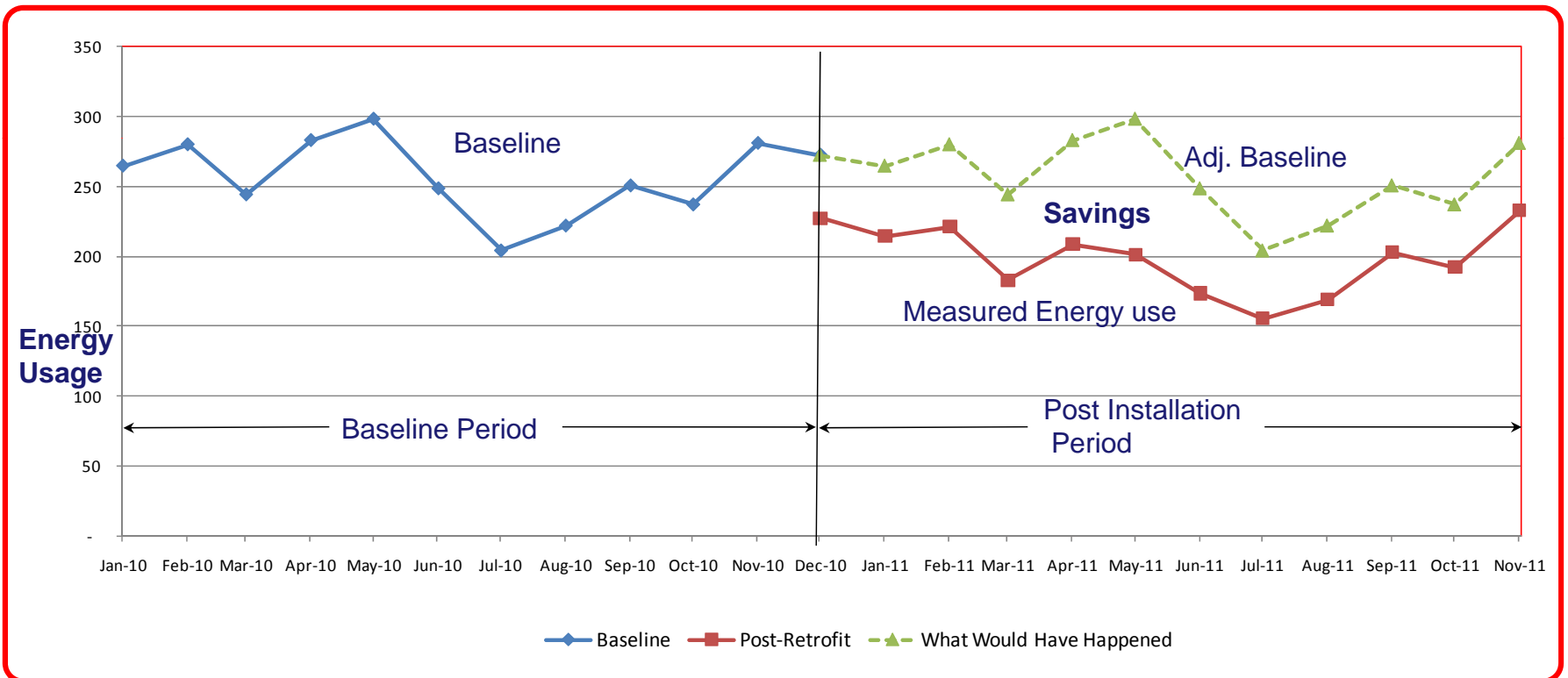


**Renewable energy technologies supply energy rather than simply reduce energy consumed**

# Measurement and Verification

M&V is the process of using measurement to reliably determine actual savings created within an individual facility.

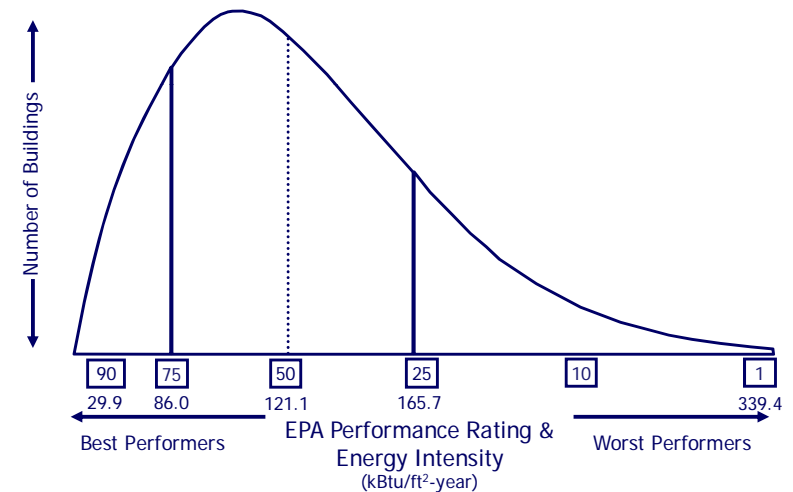
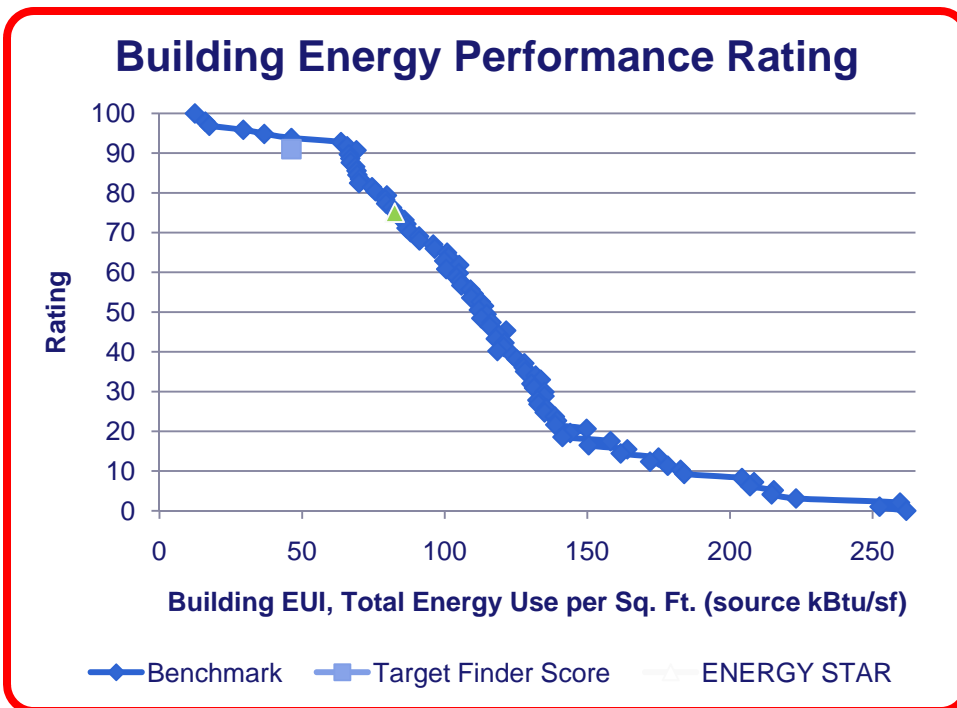
$$\text{Savings} = \text{Baseline Energy use} - \text{Post installation Energy use} \pm \text{Adjustments}$$



**Savings cannot be directly measured, since they represent the absence of energy use**

# M&V and Benchmarking

- ❖ Identify energy savings opportunities
- ❖ Meet sustainability rating requirements (LEED)
- ❖ To serve as a commissioning tool
- ❖ Support evaluation of efficiency programs
- ❖ Account for variance from the utility budget
- ❖ Enhance financing of efficiency projects
- ❖ Document financial transactions



- ❖ Benchmarking through ENERGY STAR Portfolio Manager
- ❖ Target Rating uses EPA energy performance rating of 1-100
- ❖ Compare one building against a national sample of similar buildings

# Guidelines

## Guidelines



FEMP M&V for Federal Energy Projects and Renewable Energy Guide

> Allocate Risk/Responsibility



ASHRAE Guideline 14-2002 Measurement of Energy and Demand Savings

## Protocol



IPMVP Vol 1 Concepts and Options for Determining Energy and Water Savings

IMPVP Vol 2 – Indoor Environmental Quality Issues

IPMVP Vol 3 Applications (New Construction, renewable Energy)

> Minimize Uncertainty

← LEED NC  
Renewable energy

## Executive Order

Energy Policy Act of 2005  
EO 13423 Strengthening Federal Environmental, Energy, and Transportation Management 2007

EO 13514 Federal Leadership in Environmental, Energy, and Economic Performance 2009

## LEED Guideline

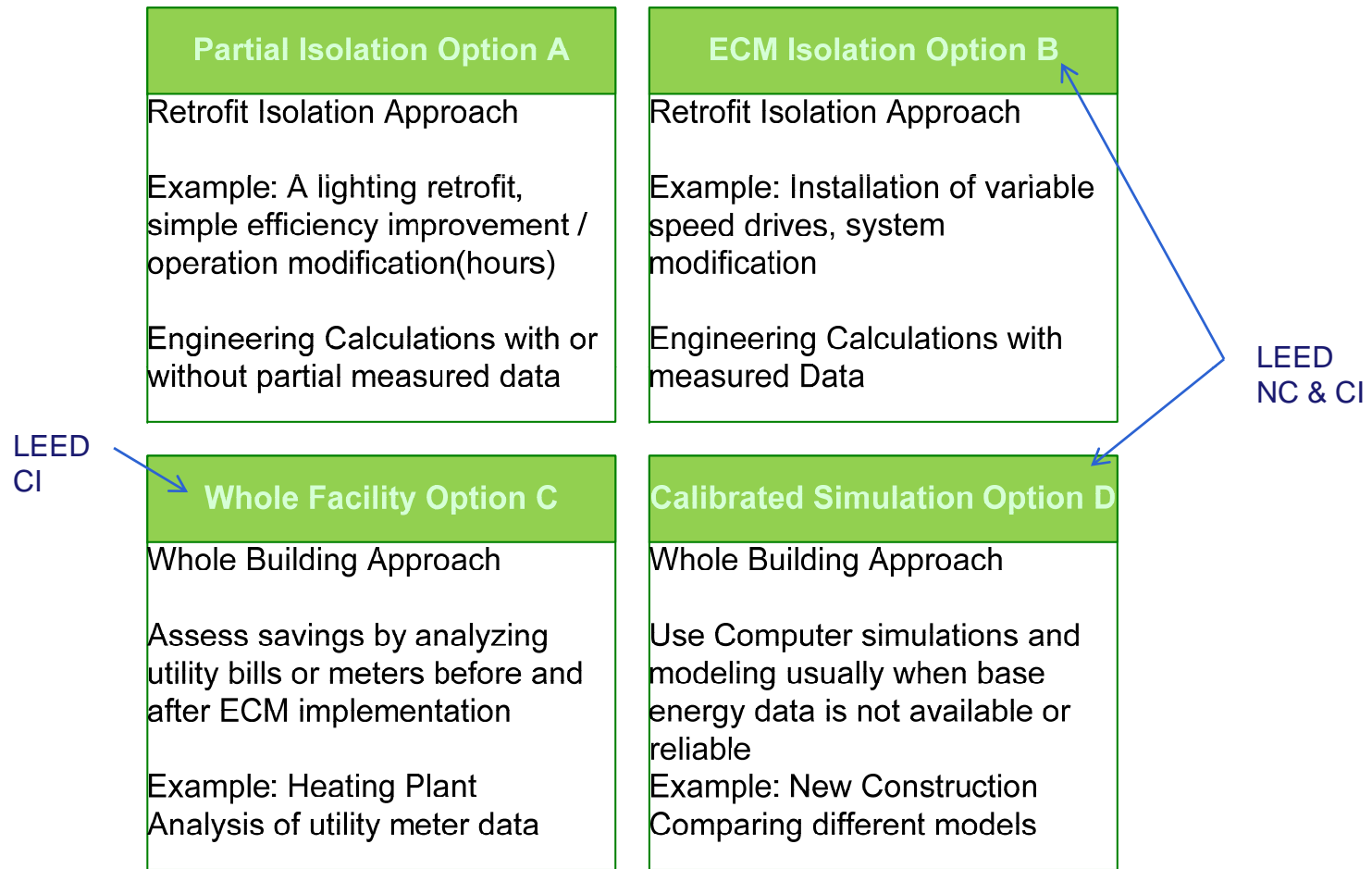


LEED BD+C EAc5 Measurement and Verification



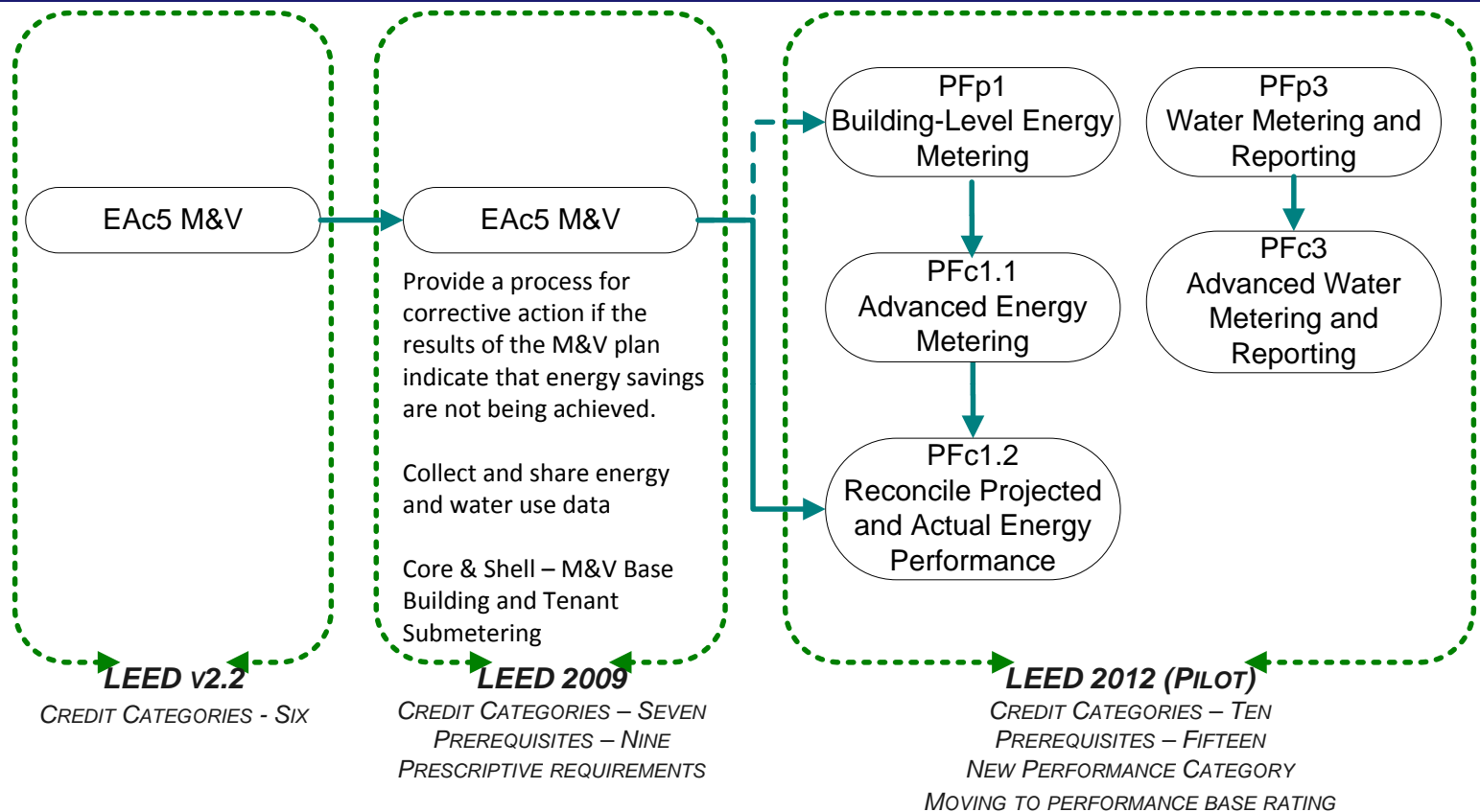
LEED BOM EAc3 Performance Measurement

# IPMVP – M&V Options



***Approach based on objective, constraints and cost to determine energy and water savings***

# LEED M&V



Option D, IPMVP Vol III, 2006

Final report - address variance, avoided tenant energy use, energy cost and GHG emissions to the EAc1 baseline

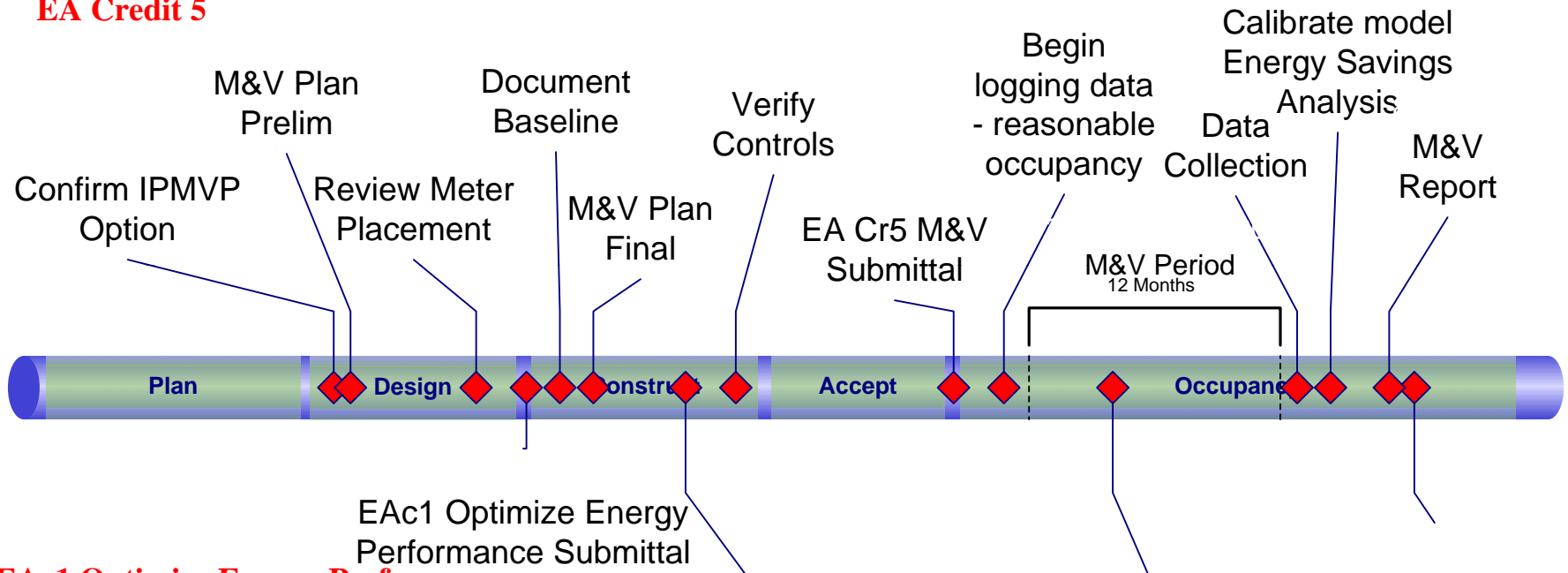
**Credit is being redeveloped to address building performance**

# LEED Related Credits

| Area            | Credit Name  | BD+C NC<br>2012<br>(Pilot) | BD+C NC<br>2009 | CI<br>2009 | CS<br>2009 | EBOM<br>2009 | EBOM<br>2011<br>(Pilot) |
|-----------------|--|----------------------------|-----------------|------------|------------|--------------|-------------------------|
| Optimize Energy | Minimum Energy Performance (EA Prerequisite) and Optimize Energy Performance (EA Credit 1) | ✓                          | ✓               | ✓          | ✓          | ✓            | ✓                       |
| Commissioning   | Fundamental Cx (and Verification) of Building Energy Systems (EAp1 / PFp_)                 | ✓                          | ✓               | ✓          | ✓          |              |                         |
|                 | Cx - Investigation & Analysis, Implementation and Ongoing Cx                               |                            |                 |            |            | ✓            | ✓                       |
| Energy Metering | Building-Level Energy Metering   | PFp_                       |                 |            |            |              | PFp_                    |
|                 | Advanced Energy Metering   | PFc1.1                     |                 |            |            |              | PFc_                    |
|                 | System-Level Metering  |                            |                 |            |            | EAc3.2       | PFc_                    |
| Water Metering  | Water Metering and Reporting (PF credit)   | PFp_                       |                 |            |            |              | PFc_                    |
|                 | Water Performance Measurement  |                            |                 |            |            | WEc1         | PFc_                    |
| BAS             | Performance Measurement - Building Automation  |                            |                 |            |            | EAc3.1       | EAc3.1                  |
| M & V           | Measurement and Verification   |                            | EAc5            | EAc3       |            |              |                         |
|                 | Reconcile Design and Actual Energy Performance   | PFc1.2                     |                 |            |            |              |                         |
|                 | M&V - Base Building  |                            |                 |            | EAc5.1     |              |                         |
|                 | M&V - Tenant Submetering   |                            |                 |            | EAc5.2     |              |                         |
|                 | Emissions Reduction Reporting  |                            |                 |            |            | EAc6         |                         |
| Survey          | Occupant Experience Survey   | PFc4                       |                 |            |            |              | PFp_                    |

# Measurement & Verification

## EA Credit 5



### EAc1 Optimize Energy Performance

EPAct (2005)

Executive Order 13423 (2007)

Federal Sustainable Buildings MOU

LEED High Performance and Sustainable Buildings Guidance

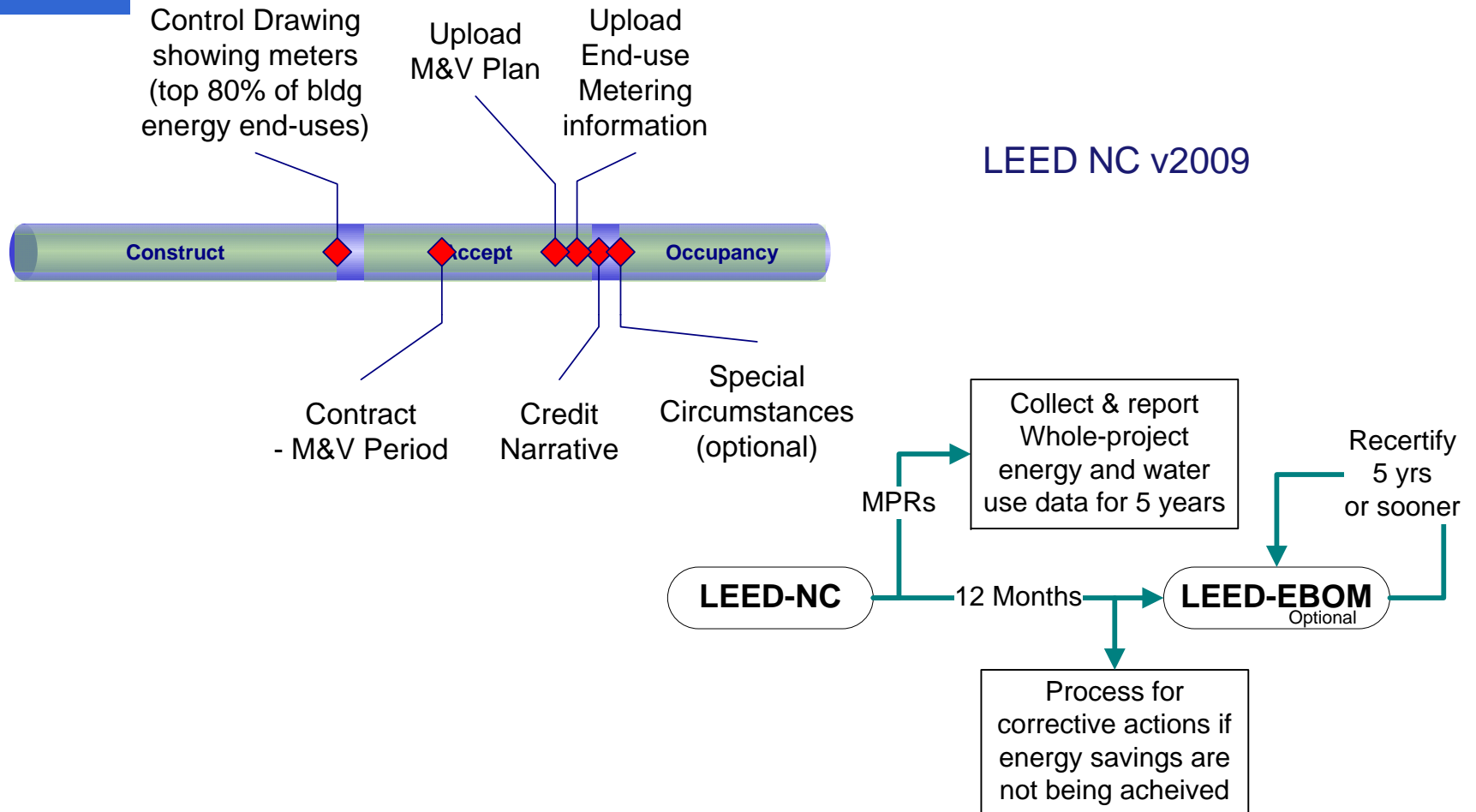
EAc1 Optimize Energy Performance Submittal

Install Building Electric, Natural Gas and Steam meters to track and continuously optimize performance

Data update – High Performance Building Database

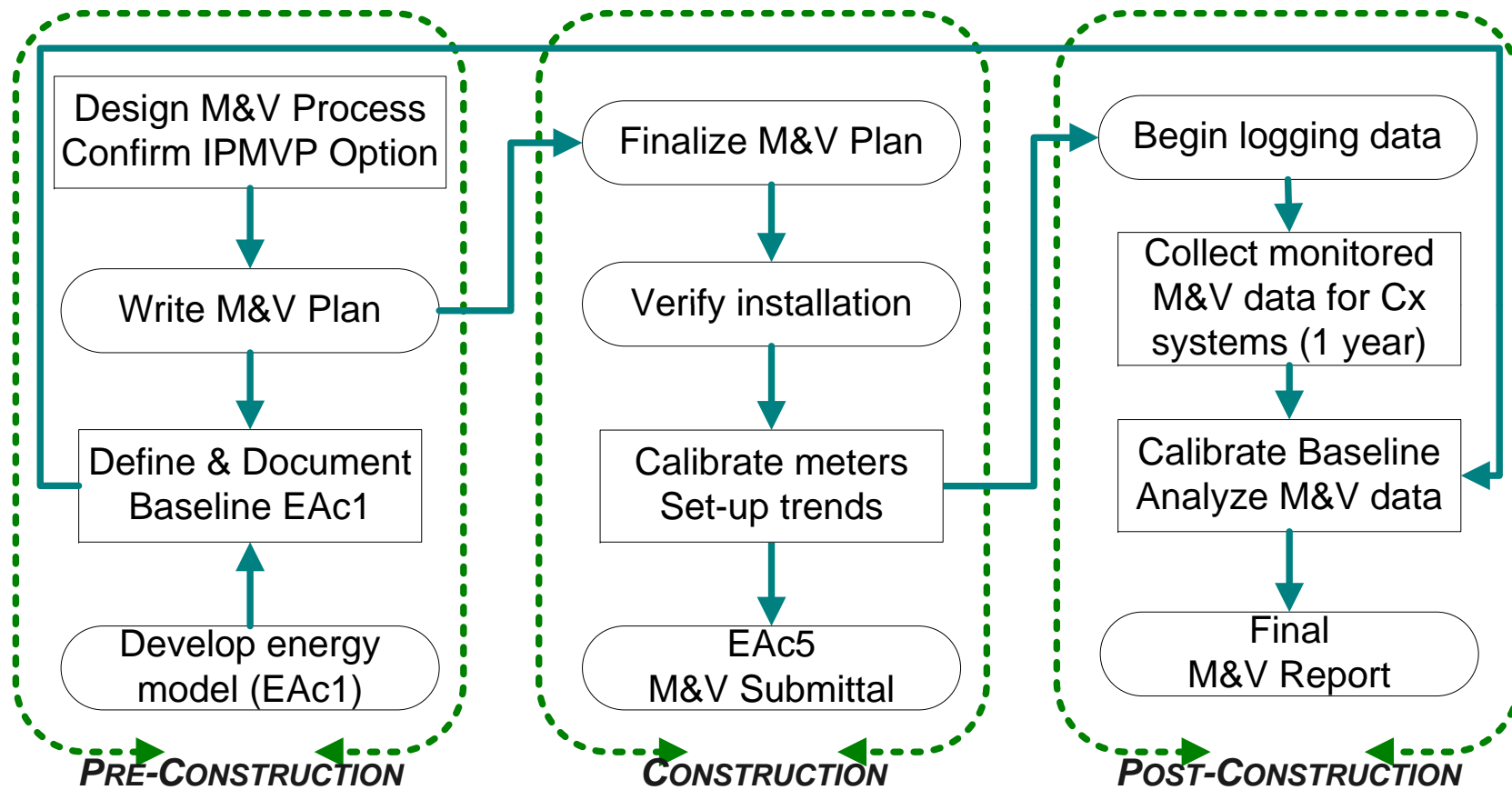
EnergyStar Benchmarking Energy use within 10% of design energy budget

# LEED Requirements



***Decreased energy and water use consumption is a major component of LEED certification***

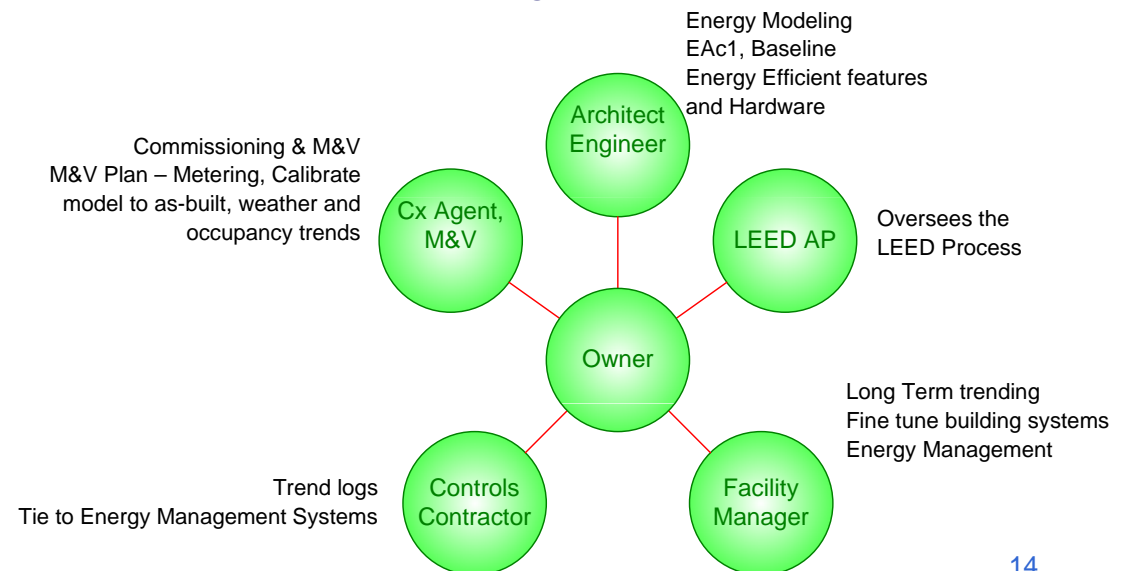
# LEED - M&V Process



***Provide for the ongoing accountability of building energy consumption over time***

## ❖ Project Specific M&V Plan

- Details of baseline conditions and data collected
- Document assumptions and sources of data
- What will be verified
- Who will conduct the M&V activities and when
- Details of engineering analysis performed
- How energy savings will be calculated
- Utility rates and how they will be used to calculate cost savings
- Detail any operations & maintenance (O&M) cost savings claimed



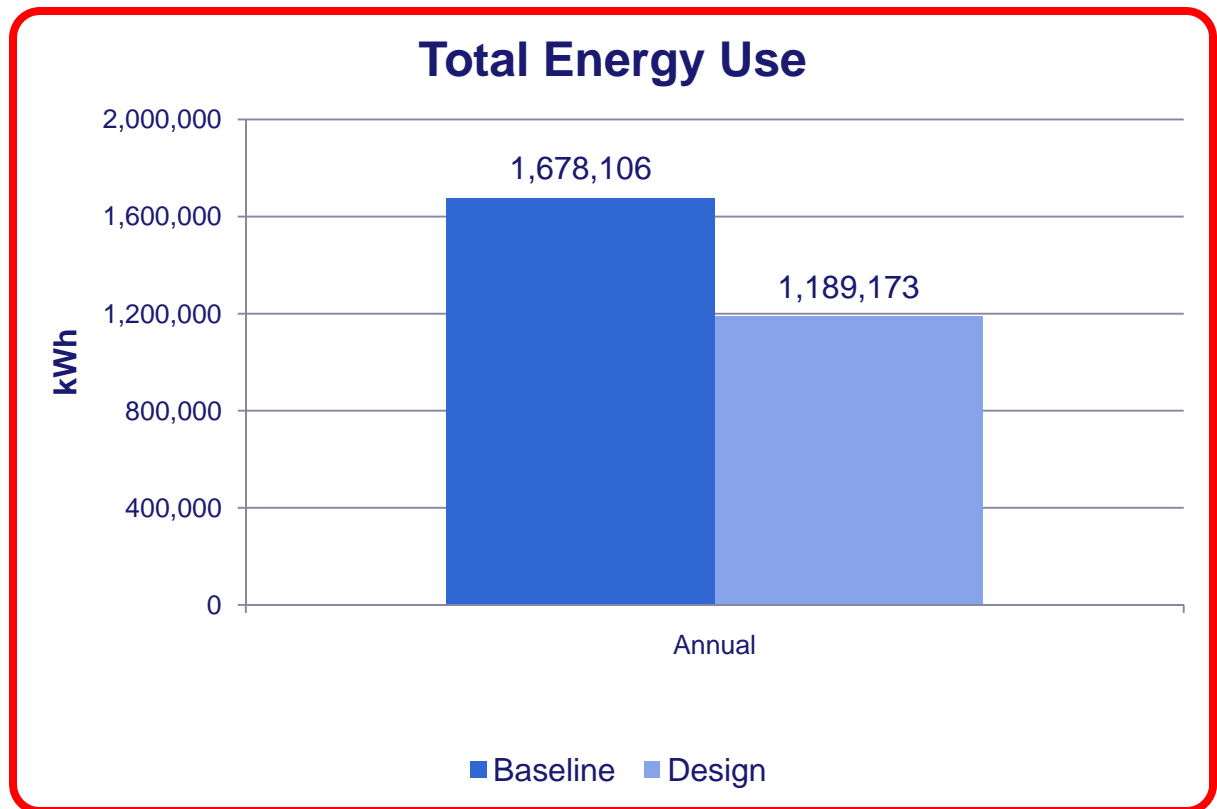
# Baseline

- ❖ Baseline physical conditions
  - Equipment inventory and conditions
  - Occupancy
  - Nameplate data
  - Energy consumption rate
  - Control strategies
  - Other
- ❖ Factors
  - Items Monitored
  - How long
  - Complexity
  - Stability of baseline
  - Other variables

***It is important to properly define and document the baseline conditions***

# Building Energy Use

- ❖ Software Tool
- ❖ Model Proposed Building
- ❖ Model Baseline Building
- ❖ Elements
  - Envelope
  - Lighting
  - HVAC Systems
  - Receptacle
  - Schedules
  - Energy Prices



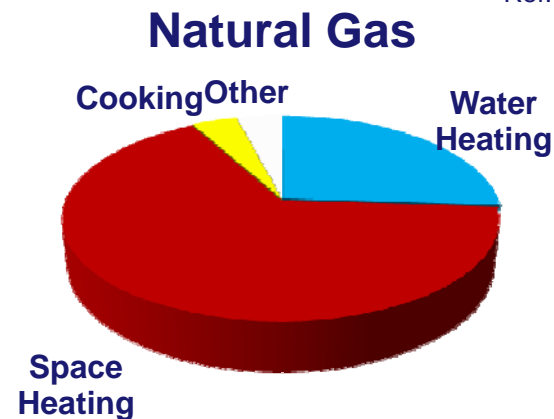
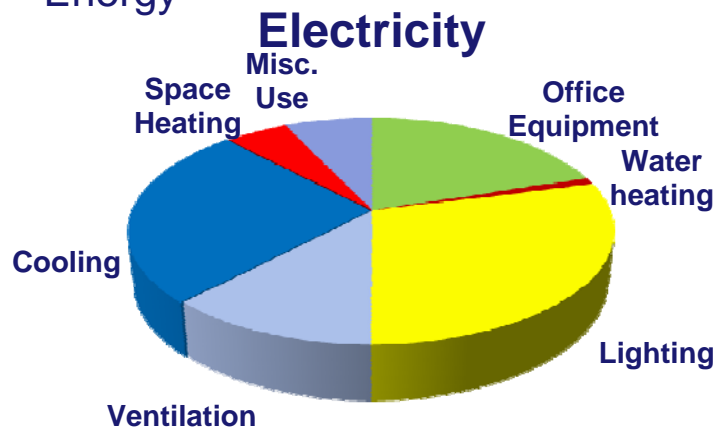
***LEED design submittal EAc1***

## ❖ Whole Building

- Electric: kW, kWh
- Natural Gas: Cubic Feet
- Water: Gallons
- Steam: Pounds
- Chilled Water: Gallons, deg F, kW, variable speed, status
- Propane
- Photovoltaic – DC and AC output
- Geothermal or Ground Source Energy

## ❖ Energy end-uses

- Primary HVAC equipment
- Secondary HVAC equipment
- Lighting
- Vertical Transportation
- Other (plug loads, processes etc.)



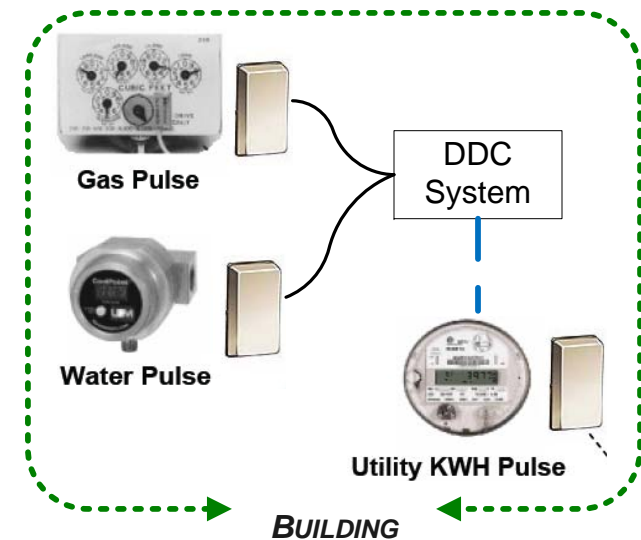
Ref: 2003 CBECS

# Data Collection

## ❖ Advanced Meters

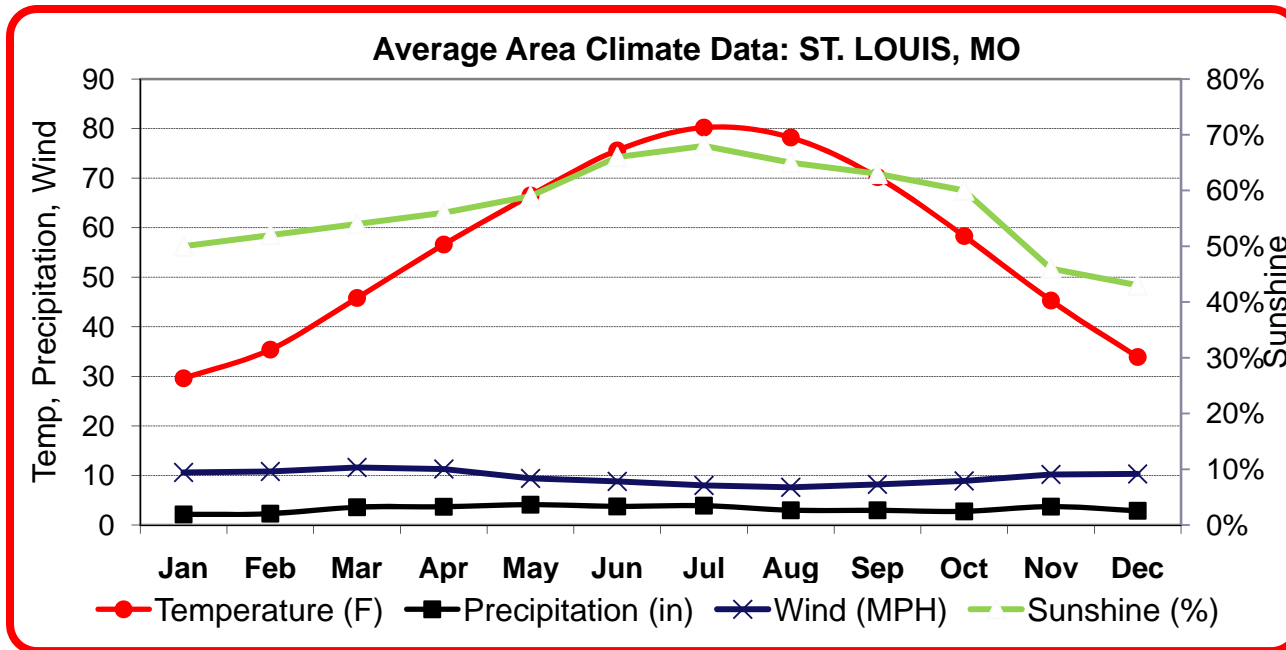
- Accuracy
- Digital Output - Pulse
- Frequency – one pulse per unit
- Quantities Measured
- Measurement Configuration
- Operating Temperature
- Humidity Range
- Type
- Code – ASME, AWWA, other
- Other
  - Capital and Installed Cost
  - Recalibration needs
  - Maintenance Cost

- ## ❖ Building Automation System (BAS) is a tool for collection, storage/retrieval, analysis and visualization of equipment and systems operating performance



***BAS can monitor energy consumption of specific end-uses***

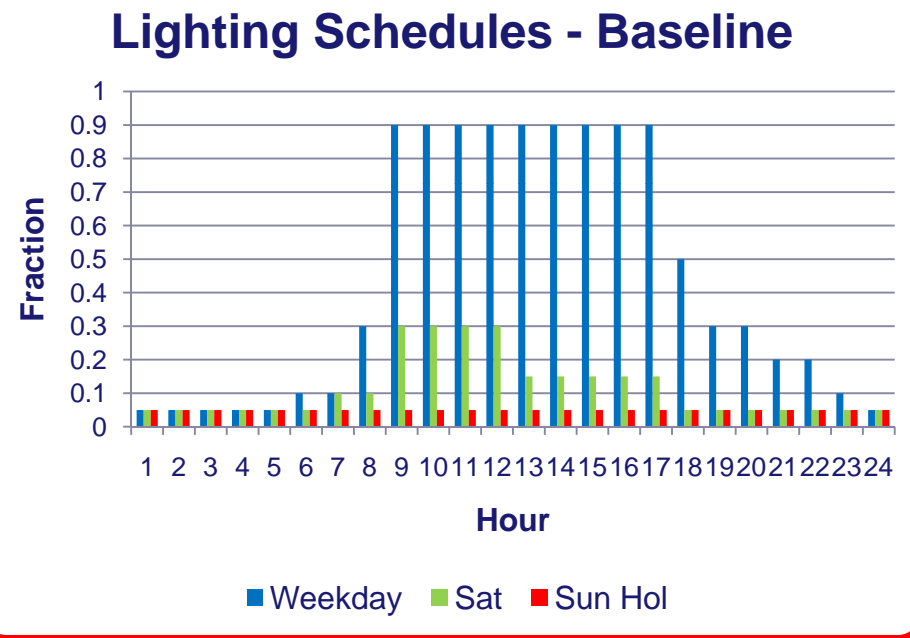
# Weather



## ❖ Weather data in a variety of formats

- [www.gard.com/weather/index.htm](http://www.gard.com/weather/index.htm)
- [http://www.eere.energy.gov/buildings/energyplus/weatherdata\\_sources.cfm](http://www.eere.energy.gov/buildings/energyplus/weatherdata_sources.cfm)
- [www.weatherunderground.com](http://www.weatherunderground.com)
- Other

- ❖ Buildings are dynamic systems
  - Collect post-retrofit energy data
  - Collect Weather data
  - Occupancy / usage
  - Operation patterns
  - System parameters
    - PV System
    - Geothermal system

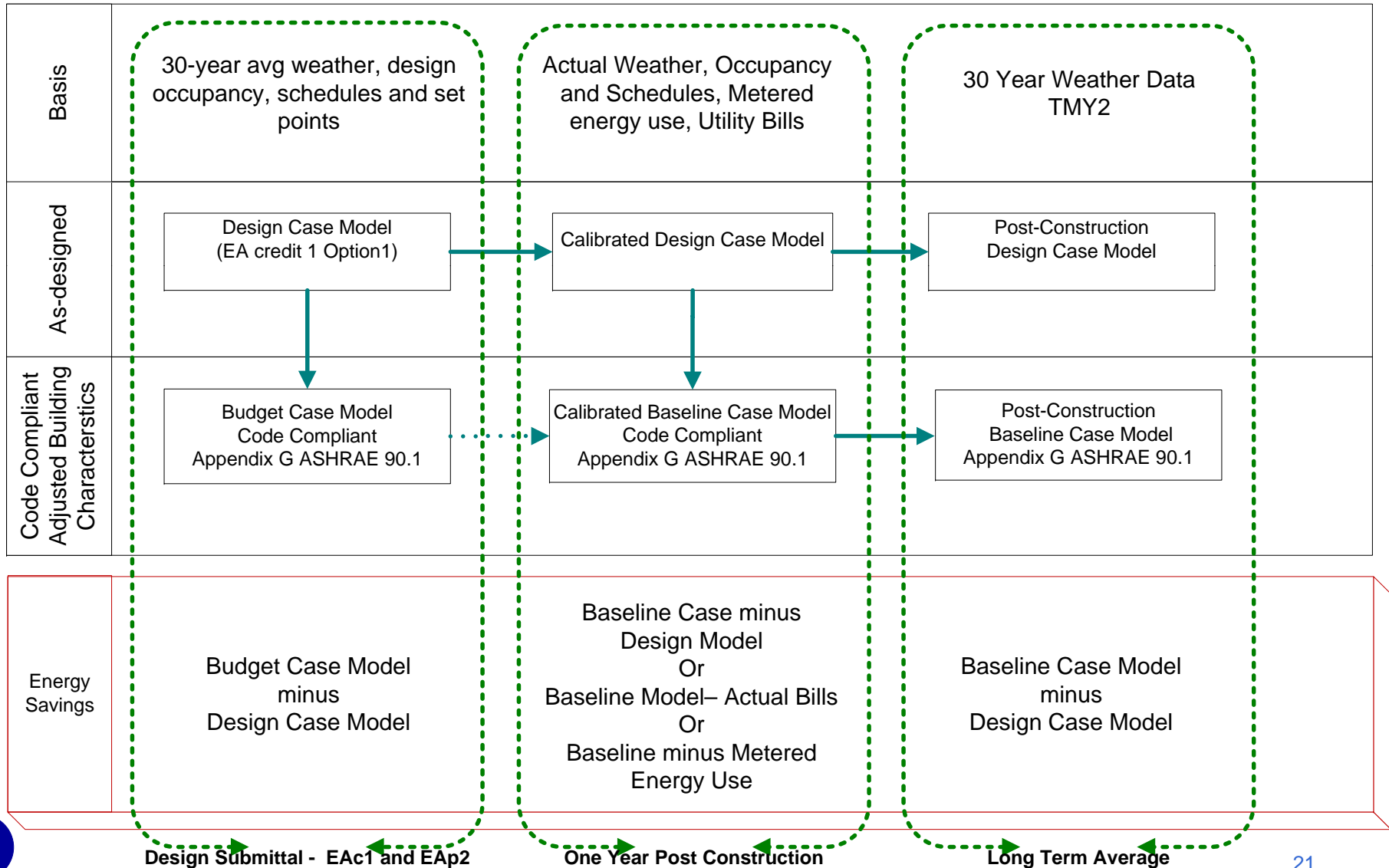


- ❖ Re-Run simulation
  - Verify model simulates actual conditions
  - Check predicted vs. actual for energy types

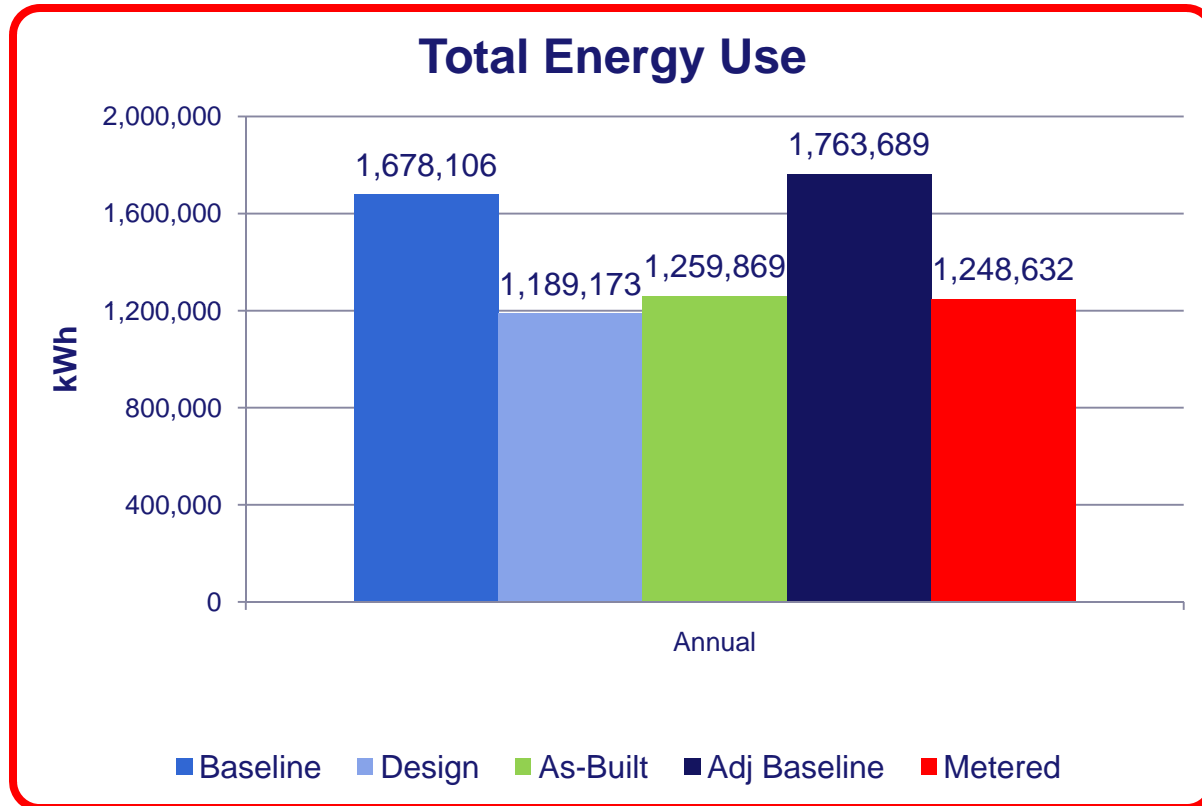
***When differences are acceptable, the simulation is called “calibrated simulation”***



# Calibrated Simulation



# Building Energy Use



# Energy - End Use



**LEED for New Construction: Construction**  
**EA CREDIT 5: MEASUREMENT AND VERIFICATION**

Project #

All fields and uploads are required unless otherwise noted.

**ALL OPTIONS**

Provide end-use metering information for each end-use. Elements from **Table. End-Use Metering** are linked to EAp2: Minimize Energy Performance and EA1: Optimize Energy Performance if the performance path is pursued. If or project teams not using the performance path, complete the table below using typical end-uses derived from the Commercial Buildings Energy Consumption Survey (CBECS).

Table. End Use Metering.

| End Use                              | Proposed Design Energy Type | Units of Annual Energy & Peak Demand | Proposed Energy Use                    | End-Use is Metered        | Metered Energy Use |
|--------------------------------------|-----------------------------|--------------------------------------|--|---------------------------|--------------------|
|                                      |                             | (select one)                         |  | (select one)              |                    |
| Proposed total energy use (kBtu/yr): |                             |                                      | 0                                      | Total metered energy use: | 0                  |
|                                      |                             |                                      | Percent metered end-use energy use (%) |                           |                    |

Add Row Delete Row

Select one of the following:

- Option 1:** The project team has developed & implemented a Measurement & Verification (M&V) plan consistent with Option D: Calibrated Simulation (Savings Estimation Method) in IPMVP Volume III.
- Option 2:** The project team has developed & implemented a Measurement & Verification (M&V) plan consistent with Option B: Energy Conservation Measure Isolation in IPMVP Volume III.

LEED for New Construction: Construction  
EA Credit 5: Measurement and Verification

**BETA**

Page 1 of 2

Save Form

Version 0.2.3

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| End Use                             | Proposed Design Energy Type | Units of Annual Energy & Peak demand | Proposed Energy Use | End-Use is Metered       | Metered Energy Use |
|-------------------------------------|-----------------------------|--------------------------------------|---------------------|--------------------------|--------------------|
| Air System                          | Electricity - Grid          | kWh                                  |                     |                          |                    |
| Cooling                             | Electricity - Grid          | kWh                                  |                     |                          |                    |
| Heating                             | Electricity - Grid          | kWh                                  |                     |                          |                    |
| Pumps                               | Electricity - Grid          | kWh                                  |                     |                          |                    |
| Cooling Tower                       | Electricity - Grid          | kWh                                  |                     |                          |                    |
| Lighting                            | Electricity - Grid          | kWh                                  |                     |                          |                    |
| Elec Equipment                      | Electricity - Grid          | kWh                                  |                     |                          |                    |
| Misc. Electric                      | Electricity - Grid          | kWh                                  |                     |                          |                    |
| Heating                             | Natural Gas                 | Therms                               |                     |                          |                    |
| Misc. Natural Gas                   | Natural Gas                 | Therms                               |                     |                          |                    |
|                                     |                             | ton hrs                              |                     |                          |                    |
| Proposed total energy use (kBtu/yr) |                             |                                      |                     | Total Metered energy use |                    |
| Percent metered end-use energy use: |                             |                                      |                     |                          |                    |

**Provide a process for corrective action if the results of the M&V plan indicate that energy savings are not being achieved**



## ❖ Option D Limitations

- Requires significant effort
- Use specialized software that requires significant experience to use
- Results vary with effort (and \$\$\$) expended
- Requires measurement for calibration

## ❖ Uncertainty

- Modeling assumptions and effort
- Meter data measurement uncertainty
- Uncertainty associated with the weather data
- Non-weather-dependent load is assumed to be proportional to number of scheduled hours

# Thank You!



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