U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

CREEA-WB Whole Building Baseline Webinar

May 20, 2011

Objective

The objective of this presentation is to help you understand:

- What a commercial building energy baseline is
- When and why it is important
- The inputs needed to create one, and
- Where to find resources to help

What is an energy baseline?

- Building owners, managers, operators, etc. want to reduce their building's energy consumption, energy costs, and/or carbon footprint.
- Many questions follow:
  - Which of the many possible energy efficiency measures (EEMs) should be implemented?
  - How to financially or operationally justify the EEMs selected?
  - How to verify that the EEMs actually saved energy?
- A key component in addressing all of these questions is an energy baseline
- An energy baseline commonly refers to a representation of the energy consumption of a building and can be in the form of either:
  - A calibrated model of the building's current configuration and operation
  - A set of energy end use measurements that characterize the energy use of the building

An energy baseline represents the energy use of a building in its current state, using either a calibrated energy simulation model or measured energy data

Where does an energy baseline fit?

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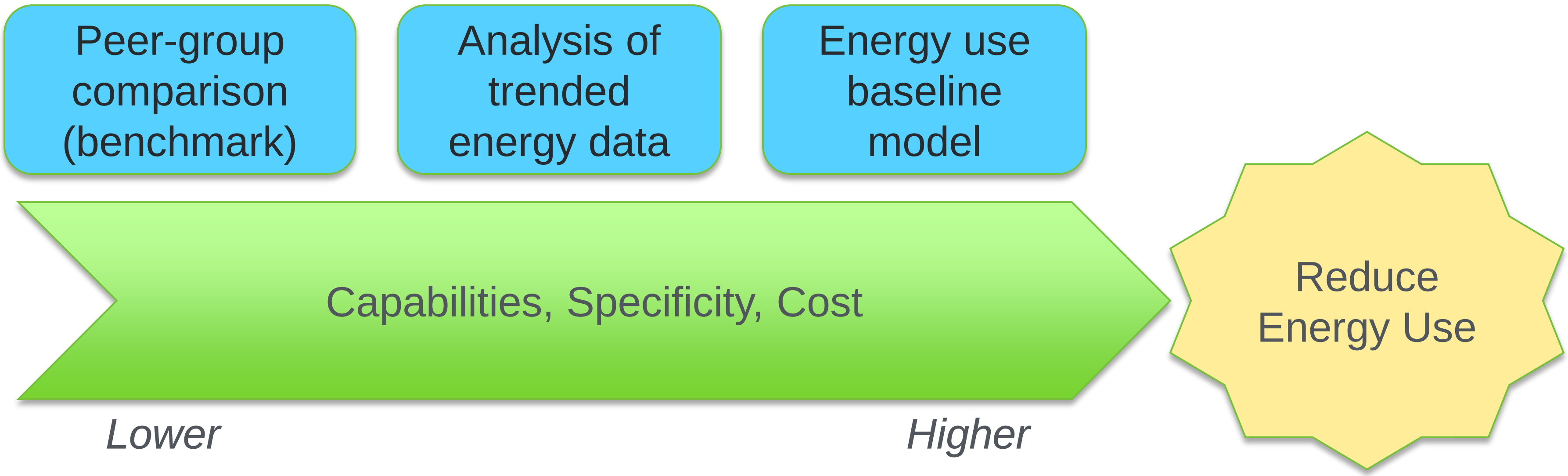

- Benchmarking (e.g. Energy Star Portfolio Manager) and use of an energy baseline model are ways to identify and assess savings of potential EEMs
- The key distinctions are:
  - Benchmarking often uses coarser metrics, relies on comparisons to peer groups, and provides broader guidance on approaches to reducing energy use of a building. EEMs identified are typically less complex measures, which have less system interdependence
  - Baseline energy models are specific to the building and can provide detailed guidance on EEMs, including capturing effects of interactions of measures on different systems, but at a greater cost than benchmarking

Why create an energy baseline?

- Without it, you can't:
  - quantitatively evaluate an array of potential EEMs
  - quantitatively evaluate the interactions of multiple EEMs (e.g. building shell and cooling load)
  - measure performance of EEMs that have been implemented
- Greenhouse gas and energy reporting is increasingly required of energy managers
  - Voluntary commitments
  - Recognition programs
    - Energy star challenge (benchmarking), Better buildings challenge
  - Mandatory reporting (potentially)
    - EO 13514 for federal buildings, California AB 1103 (benchmarking)
- Integral part of comprehensive energy management plan

Examples of EEMs Suitable for Benchmarking Analysis

- Benchmarking analysis can be better suited to evaluate EEMs where the ROI on the EEM is generally well documented in industry, and the energy use impacts are not significantly complex or involve interaction of multiple systems
  - Outside air economizers
  - Installing VFDs on pumps or fans
  - More efficient light fixtures
  - Lighting occupancy sensors
  - Daylight dimming controls
  - Plug load reduction strategies (e.g. plug load strips, occupancy sensors, power management software, etc.)

Examples of EEMs Suitable for Energy Baseline Model Analysis

- Baseline energy models are better suited technically to evaluate EEMs where the measures are more complex, and where it is important to capture the effects of the measures on multiple systems
  - Large building tenant improvement retrofits or expansions
  - Aggressive energy reduction goals requiring system re-definition and re-design
    - For example, identifying internal load and envelope measures needed to eliminate or greatly reduce compressor-based cooling (using natural ventilation, pre-cooling, etc.)
  - Evaluation of new heating and cooling systems
  - Combined envelope/shading strategies coupled with dimmable lighting, maximizing daylighting (impacts lighting, heating and cooling)

Example of energy baseline

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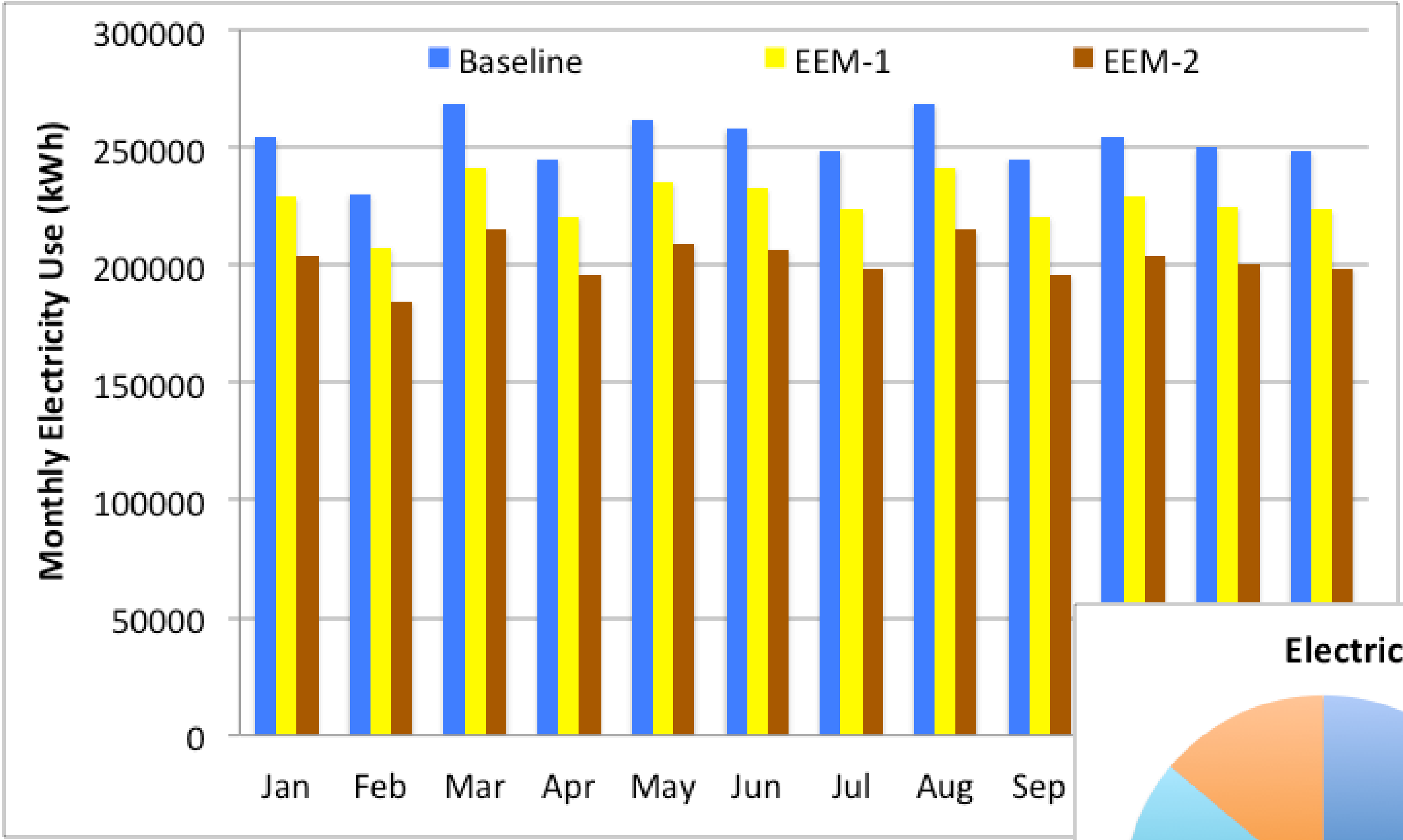

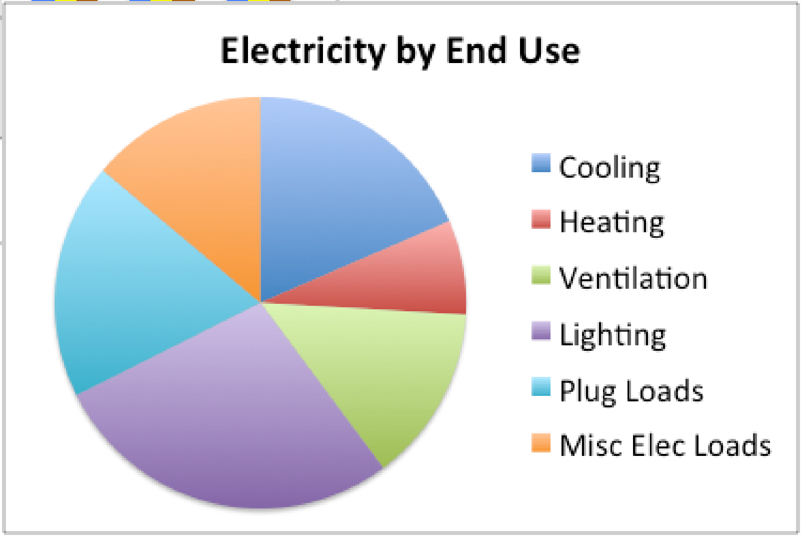

Steps to creating an energy baseline

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- Set goal or objective
  - 1. Evaluate and prioritize many potential EEMs and the interactions of multiple EEMs
  - 2. Evaluate the performance of an EEM or retrofit to be implemented
  - 3. Continuous energy performance improvement or maintenance
  - The first objective listed above requires a detailed energy simulation model and building energy use data (for model calibration)
  - The other objectives can be accomplished with either a model or building energy use data and relatively simple analysis (e.g. ratios, regression, and normalization)
- Collect building, system, and component specifications/operations
  - Building construction and materials
  - System specifications
  - Control sequences
  - Operation schedules and set points
  - Weather (outdoor temperature and RH)
- Collect whole building and system-level energy use and operations data
  - Whole building utility meter data
  - Building management system data
  - Sub-meter energy data
- Depending on goal, create detailed model or use simpler analysis tools

Building energy modeling

- Sophisticated software programs that allow users to predict a building's energy performance (e.g. Energy Plus, eQUEST, DOE-2)
- Models can be very powerful tools for predicting the performance of single or multiple EEMs and identifying the best bang for the buck options
- Models can also be used to evaluate and optimize energy saving control strategies
- To increase confidence in their predictions, energy models need to be calibrated with actual building energy data (the more the better)
- Some cautions about energy models:
  - Calibrated model may predict for one set of conditions very well, but not for others
  - Models are only as good as their inputs and expertise of the modelers
  - Can be expensive, especially for large detailed models

Energy model input interfaces: eQUEST construction material inputs

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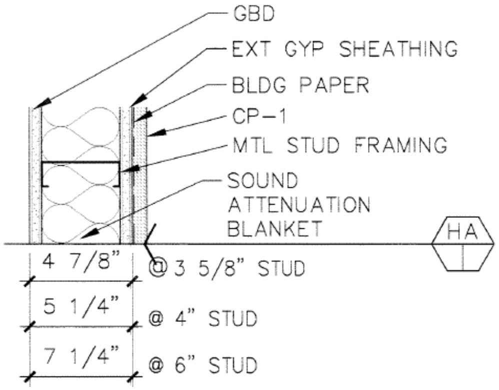
	Layers Name	Inside Film Resistance (R-val) (h-ft2-°F/Btu)	Material 1	Thickness 1 (ft)	Material 2	Thickness 2 (ft)	Material 3
1	Tilt-Up Layers	0.685	Conc HW 12in (HF-(	1.000	Batt/Steel Studs - 6	0.511	GypBd 1/2in (GP
2	Curtain Wall Layers	0.685	Steel Siding (HF-A3	0.005	Batt/Steel Studs - 6	0.511	GypBd 1/2in (GP
3	Slab On Grade Layers	0.680	Insul Bd 1in (HF-B2	0.083	2-Ft Ground Materi	2.000	Conc HW 6in (HF
4	Floor Layers	0.680	Conc HW 10in	0.830		n/a	
5	Roof Layers	0.685	Blt-Up Roof 3/8in (B	0.031	Rigid Insulation (6in	0.500	Conc HW 6in (HF
6	ACT layers	0.680	AcousTile 1/2in (AC	0.042		n/a	

- Provide the wall construction and materials



	Material Name	Specification Method	Thickness (ft)	Conductivity (Btu/h-ft-°F)	Density (lb/ft3)	Specific Heat (Btu/lb-°F)
1	Conc HW 10in	Properties	0.830	1.0000	140.00	0.200
2	Rigid Insulation (6in)	Properties	0.500	0.0200	1.80	0.290
3	2-Ft Ground Material	Properties	2.000	0.5000	100.00	0.250
4	Batt/Steel Studs - 6in	Properties	0.511	0.0500	0.60	0.200
5	Conc HW 12in (HF-C11)	Properties	1.000	1.0000	140.00	0.200
6	GypBd 1/2in (GP01)	Properties	0.042	0.0926	50.00	0.200
7	Steel Siding (HF-A3)	Properties	0.005	26.0000	480.00	0.100
8	Insul Bd 1in (HF-B2)	Properties	0.083	0.0250	2.00	0.200
9	Conc HW 6in (HF-C13)	Properties	0.500	1.0000	140.00	0.200
10	Linoleum Tile (LT01)	Resistance	n/a	n/a	n/a	n/a
11	Blt-Up Roof 3/8in (BR01)	Properties	0.031	0.0939	70.00	0.350
12	AcousTile 1/2in (AC02)	Properties	0.042	0.0330	18.00	0.320

- Modeler will use that to find specific parameter inputs needed for the model

Energy model input interfaces: Energy Plus HVAC fan inputs

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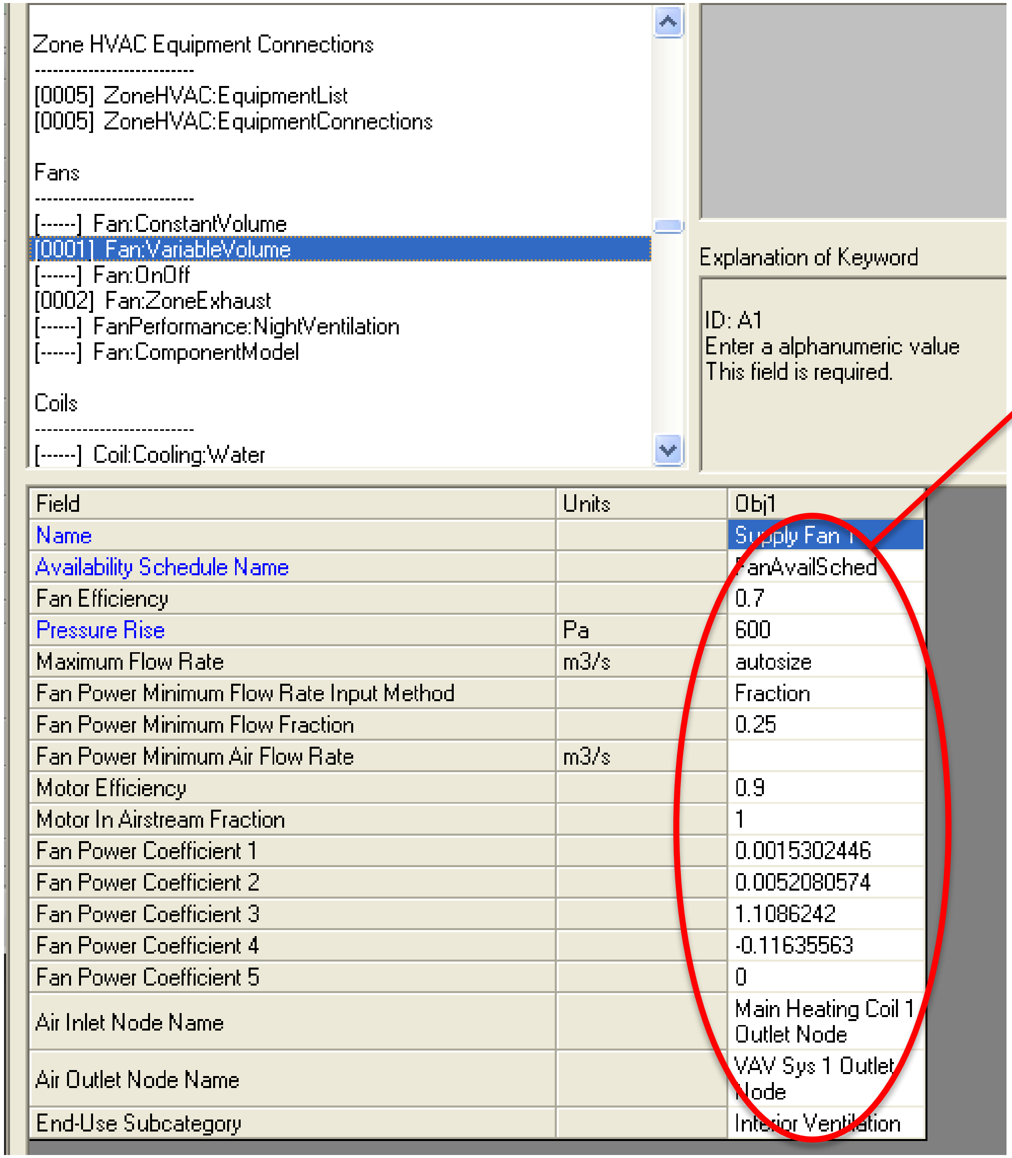

- Provide fan make and model
- Modeler will use that to find specific parameter inputs needed for the model

Building properties

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- Specific dimensions of floors and spaces/zones
- Function(s) of building; occupancy type by space
- Slab, floor, wall, ceiling, and roof constructions and materials
- Window sizes and/or window-to-wall-ratio
- Window type and makes and models
- Window covering types and makes and models
- Wall, floor, roof insulation U-values
- Installed lighting rated power by space; lighting control specifications
- Any significant plug loads (e.g. medical equipment, data centers)

Sources: As-built construction drawings and submittals

HVAC system properties

- Compile submittals for all HVAC components and the make and model information for all of the following:
  - Chillers and boilers
  - Fans and fan motors
  - Pumps and pump motors
  - Cooling towers
  - Heat exchangers
  - Terminal unit equipment
  - VAV boxes
- Compile control sequences for all AHUs, VAVs, economizers, etc.

Sources: As-built controls drawings, sequences, and submittals

Operation schedules and set points

- HVAC set points and schedules
  - Chilled and hot water supply temps
  - Supply air temperature
  - Economizer control temperature or enthalpy set points
- Zone temperature set points
- Lighting schedules
- Occupancy schedule (e.g. building opens at 6a and closes at 8p)

Source: building management system

Weather data

- Weather input files are available for US climate zones and cities
- BMS will often monitor outdoor air temperature, but may not trend
- BMS may monitor RH, but again may not trend
- Always preferable to have stored historical site weather data to capture site-specific meteorological variations
- Local weather data is also available from many sources (e.g. www.weatherunderground.com)
- If natural ventilation is a possible future retrofit, installing a good anemometer at the building and storing wind speed and direction data, as much as years ahead of time, is a worthwhile investment

Whole building utility meter data

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- Energy use and demand data available from utilities
- Time resolution may only be monthly, especially for gas
- For buildings in high demand rate categories, 15-minute interval data may be available for electricity
- For buildings with multiple meters identify which systems or areas of the building are on which meter
- District chilled or hot water measured at the building with Btu meter
- District steam measured in pounds delivered

Sub-meter energy data

- Measuring baselines for major system retrofit projects may require sub-metering of energy use by those system components (e.g. HVAC, lighting, plug loads)
- A datalogger can be used to record the energy use output of a motor controller when that point is not wired back to the BMS
  - Dataloggers are inexpensive (don't require pulling cable) and typically easy to operate, but they do require labor for downloading at regular intervals
- If energy use is not available from the controller a power meter may be installed in the panel serving the motor
- Btu meters to measure the energy of chilled or hot water
- Duration of sub-metering depends on system's energy performance with respect to weather or occupancy
  - For example, evaluation of a lighting-related EEM may require as little as 2-weeks of sampling while a chiller-related retrofit may require 6-months or more

Building management system data

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- Constant speed motors often report on/off status to BMS
- Variable speed motors often report speed (in Hz or %) to BMS
- Both status and speed can be converted to energy use with other information that relates status or speed to power
  - Power rating or power curve provided by the manufacturer
  - Spot measurements of power consumption
- BMS often monitors data that can be used to calculate energy use or loads
  - Chilled and hot water flow rates and supply and return temperatures
  - Supply, return, mixed, and outdoor air temperatures and damper positions

Data management

- Creating a baseline and tracking energy use can generate a significant amount of data
- Using a spreadsheet program and putting different related sets of data points on different sheets or tabs within the same sheet can help with organization
- If possible use same time interval for all points, which makes sorting and analysis much easier
- Missing or erroneous data is not uncommon and if only a few sample intervals are affected, values can be interpolated by averaging the before and after measurements
- If the missing or erroneous data gap is too long that time interval should be excluded from any analysis
- Universal Translator (utonline.org) is a very useful tool for “cleaning up” data before analysis (and even has some nice analysis tools)

The value of data

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- Computer memory – cheap
- Compiling building info and utility bills – pretty cheap
- Set up BMS to trend and store data – relatively cheap
- Historical record of high resolution energy use data and building operating conditions…PRICELESS!!!

Example of regression analysis

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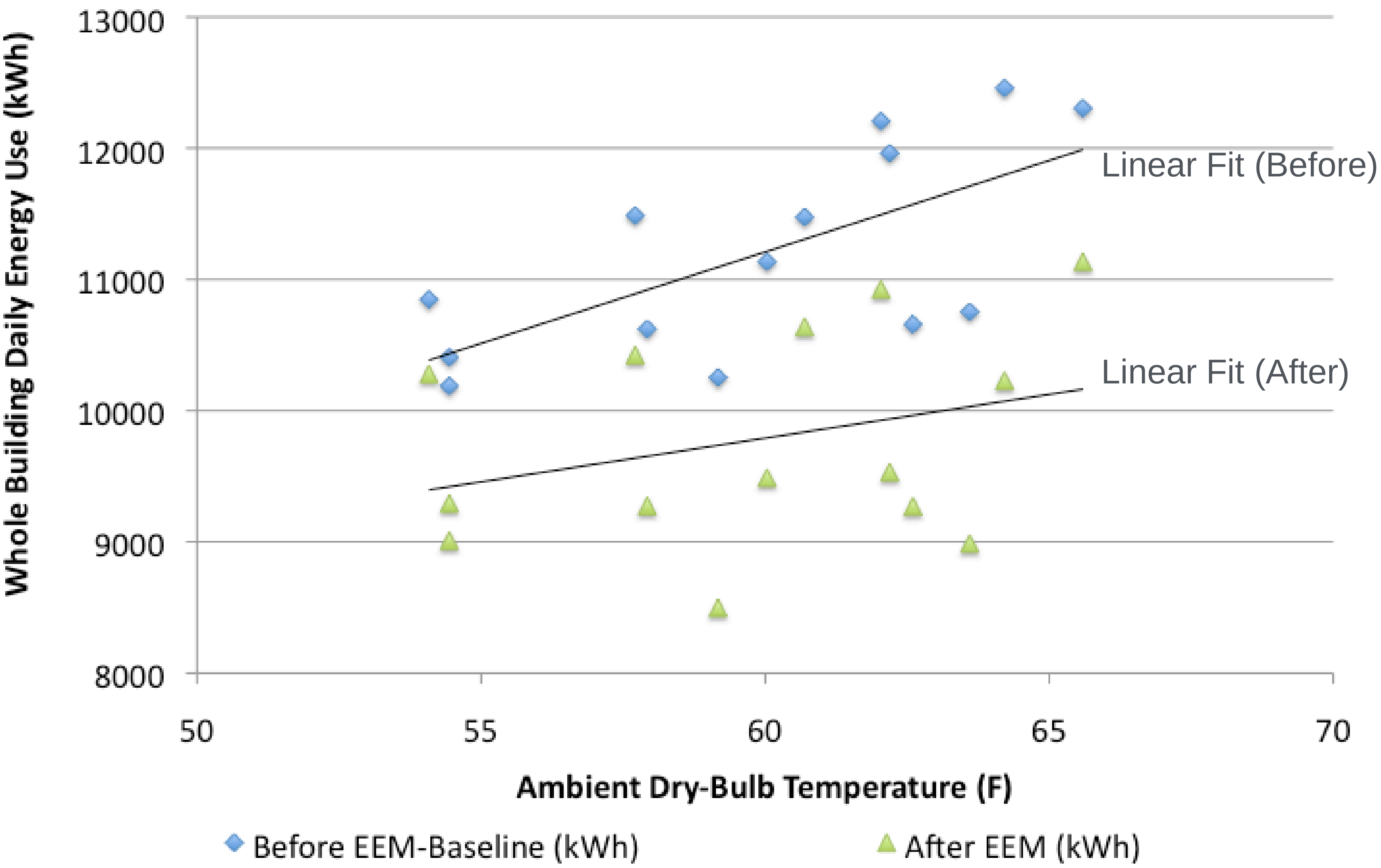

Normalizing energy consumption

- Comparing energy use from one period to another is only useful if the data is normalized by factors that impact energy performance
  - Lower whole building electricity consumption in August compared to July may be due to implementation of an EEM or it may just be due to differences in outdoor temperatures or occupancy
- Energy data is typically normalized for weather using heating and cooling degree days (HDDs and CDDs).
- HDDs and CDDs for various locations and time periods are available from internet sites (e.g. degreedays.net)
- Can also normalize by number of occupants or building activities if those vary a lot and/or significantly impact the energy consumption of the building
- Simple example: implement EEM on Aug 1; whole building electricity use was 230 MWh in July and 250 MWh in August; number of CDDs was 320 in July and 400 in August.
  - Comparing only energy consumption, it actually increased 9% after implementing the EEM
  - Taking into account the greater cooling demand, energy use per CDD decreases 13% from 0.72 to 0.63 MWh/CDD

Summary

- An energy baseline characterizes the current state of a building's energy consumption
- A powerful tool for creating a baseline is a calibrated energy model, but a baseline can also be created with measured data
- Key to the creation of any energy baseline is gathering building and HVAC specifications and operations data and measured energy end use data

Combined with a good building energy modeler and/or energy analyst, the compiled data provides a powerful tool for identifying, prioritizing, and verifying a wide array of potential EEMs

A few final thoughts…

- Initial steps of creating an energy baseline can be a significant exercise in compiling and organizing large amounts of data
- Modeling is a powerful tool, particularly for quantifying the interaction of multiple EEMs with each other and with existing building components and systems
- Creating an energy baseline model is most valuable to large-scale, energy efficiency retrofit projects that involve multiple building systems

Building and HVAC model inputs

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Building Data
Building location
Utility providers
Floor area and dimensions
Occupancy type(s) and schedule(s)
Lighting power and schedules by space
Plug load power and schedules by space
Elevator power and schedule
Gas equipment power and schedule
Building slab, floor, wall, roof construction layers and materials
Window construction specs
Window shading device specs and schedules
Zone temperature set points and schedules
Exterior lighting power and schedules
Service water heating makes and models

HVAC Data
HVAC system type
Total cooling capacity
Cooling, heating, and AHU schedules
Cooling and heating supply air temperature set points and schedules
For each supply, return, relief and exhaust fan: make, model, and quantity (brake horse power, static pressure, fan and motor efficiencies, fan part-flow performance curve)*
Air economizer control type, design, max, and min outside air flow rates, lockout set points
Cooling, heating, and preheat coil capacities
Humidifier and desiccant types and settings
For each boiler type: make, model, quantity, fuel type and supply and return water temperature set points and schedules (heat loss, capacity, efficiency, part-load performance curve)*

*items in ()'s will be determined by modeler from make/model

HVAC model inputs (continued)

HVAC Data (con’t)
For each chiller type: make, model, quantity, fuel type, condenser type, supply and return water temperature set points and schedules (rated capacity, rated efficiency)*
For each cooling tower type: make, model, type, quantity, number of cells, total fan horsepower, design wet-bulb, design entering and return water temperature (capacity and power adjustment curves)*
Water-side economizer type, heat exchanger effectiveness, maximum dry-bulb temperature, availability schedule
For each pump type: service, quantity, , design flow rate and head (motor power-per-unit-flow, motor efficiency, impeller efficiency)*

*items in ()’s will be determined by modeler from make/model

Summary of energy data points

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System	Point Name	Units
Whole Building	Electric consumption	kW
	Gas consumption	ft^3 or therms
Mechanical Room	Electric consumption	kWh
	Gas consumption	ft^3 or therms
Cooling	Chiller electric power consumption	kW
	CHW supply temperature for each chiller or loop	F
	CHW return temperature for each chiller or loop	F
	CHW flow rate per chiller/loop (or CHW valve pos.)	gpm or % open
	CHW loop pump power consumption	kW
Heating	Heating boiler gas consumption	
	HHW supply temperature for each chiller or loop	F
	HHW return temperature for each chiller or loop	F
	HHW flow rate per chiller/loop (or CHW valve pos.)	gpm or % open
	HHW loop pump power consumption	kW

Resources

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COMNET Commercial Buildings Energy Modeling Guidelines and Procedures

http://www.comnet.org/mgp-manual

Guidance to building energy modelers, ensuring technically rigorous and credible assessment of energy performance of commercial and multifamily residential buildings. It provides a streamlined process that can be used with various existing modeling software and systems, across a range of programs.

Guidelines for Verifying Existing Building Commissioning Project Savings

http://resources.cacx.org/library/HoldingDetail.aspx?id=477

This guideline documents measurement and verification (M&V) procedures based on short time interval energy data collected from existing buildings and their systems that are undergoing a commissioning process. It describes procedures with which commissioning providers may demonstrate realized savings to building owners, program managers, and program evaluators.

ENERGY STAR Guidelines for Energy Management

http://www.energystar.gov/index.cfm?c=guidelines.download_guidelines

This guide helps organizations get started by applying a proven strategy to set performance goals, create and implement action plans, assess performance and progress, and recognize your organization’s achievements. See Chapter 2, “Assess Performance.”

Resources

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Best Practice Guide, Commercial Office Buildings. Planning an Energy Program, Assessing Energy Performance.

http://www.fypower.org/bpg/module.html?b=offices&m=Planning_an_Energy_Program&s=Assessing_Energy_Performance

Brief guidance on assessing building energy performance and methods of establishing baselines.

ASHRAE Standard 105-2007, Standard Methods of Measuring, Expressing and Comparing Building Energy Performance

http://www.techstreet.com/standards/ashrae/105_2007?product_id=1644048

This standard is intended to foster a commonality in reporting the energy performance of existing or proposed buildings to facilitate comparison, design and operation improvements, and development of building energy performance standards.

Empire State Building Case Study

http://www.esbnyc.com/documents/sustainability/ESBOverviewDeck.pdf

Case study of rigorous evaluation and implementation of energy efficiency measures and retrofits conducted for the Empire State Building.

Resources

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Universal Translator software

http://www.pge.com/mybusiness/edusafety/training/pec/toolbox/tll/software.shtml

The Universal Translator is used to manage and analyze data from loggers and building energy management systems. It synchronizes data sets with different recording rates and start times. It has a flexible graphing tool, data filtering mechanisms and built-in analysis routines for equipment run-time, zone temperature variation, air-side economizers, and lighting controls.

Metering Best Practices, A Guide to Achieving Utility Resource Efficiency

http://www1.eere.energy.gov/femp/pdfs/mbpg.pdf

The focus of this guide is to provide the Federal Energy/Facility manager and practitioner with information and actions aimed at understanding metering and working to achieve the potential savings and benefits.

An Introduction to Utility Bill Weather Normalization for Energy Contractors

www.abraxasenergy.com

Guidance for normalizing energy use data for variations in weather.