Informed Building Design through Energy Modeling

PEDCO High Performance Buildings Seminar

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Introduction

Jason M. Park, P.E.

Senior Mechanical Engineer

High Performance Building Discipline Leader

Contact Information:

jpark@pedcoea.com

(513)-782-4920

www.pedcoea.com

Learning Objectives

- How to use energy modeling to help define and refine a project's energy goals.

- Understand the different types and uses of building energy models.

- Understand how energy modeling can optimize a building's design.

Introduction

- Who's in the room?
  - Architects
  - Owners/Facility Managers
  - Construction/Project Managers
  - Engineers
  - Energy Modelers

Energy Modeling?

Month	Day Type	Day	Hour	OA Dry Bulb deg F	Alt 1 Reheat Mbh	Alt 1 Fin Tube Aux Htg Mbh	Alt 1 Main Clg Airflow cfm	Alt 1 ClgPlant Ld tons	Alt 1 ArSd Econ on/off	Alt 1 QCond Heat Avail Mbh	Alt 1 QCond To Htg Coils Mbh	Alt 1 QCond Reject to Twr tons	Alt 1 QCond Reject to Twr Mbh	Alt 1 Boiler kW	Alt 1 Boiler Mbh
Mar	Wkdy	15	9	64	-91.40	-285.13	259,150.47	497.78	Econ Off	1,863.96	285.12	535.76	6,429.12	0.00	0.00
Mar	Wkdy	15	10	65	-36.54	-237.61	309,227.62	637.17	Econ Off	2,369.88	237.60	701.26	8,415.12	0.00	0.00
Mar	Wkdy	15	11	64	-13.63	-285.13	327,788.41	683.43	Econ Off	1,476.12	285.12	737.27	8,847.24	0.00	0.00
Mar	Wkdy	15	12	63	-6.97	-332.65	330,266.31	691.91	Econ Off	1,494.12	332.64	744.05	8,928.60	0.00	0.00
Mar	Wkdy	15	13	64	-28.10	-285.13	331,157.59	703.06	Econ Off	1,517.88	285.12	763.21	9,158.52	0.00	0.00
Mar	Wkdy	15	14	64	-30.76	-285.13	332,096.69	706.01	Econ Off	1,524.24	285.12	766.52	9,198.24	0.00	0.00
Mar	Wkdy	15	15	64	-30.77	-285.13	332,442.09	712.81	Econ Off	1,538.64	285.12	775.57	9,306.84	0.00	0.00
Mar	Wkdy	15	16	63	-34.28	-332.65	332,345.47	709.38	Econ Off	1,531.32	332.64	766.32	9,195.84	0.00	0.00
Mar	Wkdy	15	17	63	-35.28	-332.65	332,862.75	710.46	Econ Off	1,533.60	332.64	767.54	9,210.48	0.00	0.00
Mar	Wkdy	15	18	62	-49.23	-380.17	282,244.16	580.52	Econ Off	2,165.52	380.16	626.42	7,517.04	0.00	0.00
Mar	Wkdy	15	19	61	-67.08	-427.69	213,349.78	426.53	Econ Off	1,601.64	427.68	446.61	5,359.32	0.00	0.00
Mar	Wkdy	15	20	62	-100.31	-380.17	214,260.00	419.93	Econ Off	1,577.28	380.16	443.86	5,326.32	0.00	0.00
Mar	Wkdy	15	21	55	0.00	-475.21	71,561.79	144.06	Econ On	2,075.28	475.20	133.34	1,600.08	0.00	0.00
Mar	Wkdy	15	22	53	0.00	-570.26	71,507.55	143.91	Econ On	2,073.12	570.24	125.24	1,502.88	0.00	0.00
Mar	Wkdy	15	23	49	0.00	-760.34	71,492.95	143.85	Econ On	2,072.28	760.32	109.33	1,311.96	0.00	0.00
Mar	Wkdy	15	24	48	0.00	-807.86	71,485.42	143.80	Econ On	2,071.56	807.84	105.30	1,263.60	0.00	0.00
Mar	Wkdy	16	1	47	0.00	-855.38	71,375.66	142.47	Econ On	2,052.84	855.36	99.79	1,197.48	0.00	0.00
Mar	Wkdy	16	2	47	0.00	-855.38	71,373.46	142.44	Econ On	2,052.48	855.36	99.76	1,197.12	0.00	0.00
Mar	Wkdy	16	3	47	0.00	-855.38	71,372.21	142.43	Econ On	2,052.24	855.36	99.74	1,196.88	0.00	0.00
Mar	Wkdy	16	4	44	0.00	-997.95	71,371.80	142.42	Econ On	2,052.24	997.92	87.86	1,054.32	0.00	0.00
Mar	Wkdy	16	5	43	0.00	-1,045.47	71,371.97	142.42	Econ On	2,052.24	1,045.44	83.90	1,006.80	0.00	0.00
Mar	Wkdy	16	6	42	-202.06	-1,330.60	220,153.97	142.57	Econ On	2,054.28	1,330.56	60.30	723.60	0.00	0.00
Mar	Wkdy	16	7	41	-187.33	-1,378.12	220,256.33	142.88	Econ On	2,058.72	1,378.08	56.71	680.52	0.00	0.00
Mar	Wkdy	16	8	41	-241.79	-1,378.12	229,884.81	149.49	Econ On	2,151.24	1,378.08	64.43	773.16	0.00	0.00

Energy Modeling

- Let us dispel some myths.

  – Energy modeling does not have to be an overly complex and expensive endeavor for a project.

  – There is no "one size fits all" energy modeling type for a project.

- Energy modeling tools and resources are advancing rapidly.

  – New tools and resources are constantly being developed.

Energy Modeling

- Design phase energy models are excellent tools for indicating relative changes in energy use between design options.

- What they do not Predict
  - Design phase energy models do not predict absolute energy use during occupancy.
  - Design phase energy models do not have the ability to accurately predict fluctuations in occupant behavior and weather.
  - Atypical weather and changes to scheduled usage are often the two largest drivers to a building's performance.

Energy is a Design Problem

- " Energy is a design topic, not a technology topic." —Donald Watson, FAIA
- There is no new technology in HVAC or lighting systems that can make up for a bad design.
- Architectural Design and Energy Design are iterative processes.
  - Rounds and rounds of analysis.
- The Integrated Design Process is key.

Energy is a Design Problem

- Energy modeling and a focus on energy performance is not meant to replace the importance of design.

- Occupant comfort and productivity are the most important factors in the design of a building.

Human Productivity Improvements Linked to Daylighting*

A 1% productivity savings can nearly offset a company's entire annual energy cost.

Rent 14%

Maintenance 1%
Energy 1%

Salaries 84%

COMMERCIAL BUILDINGS COST / S.F.
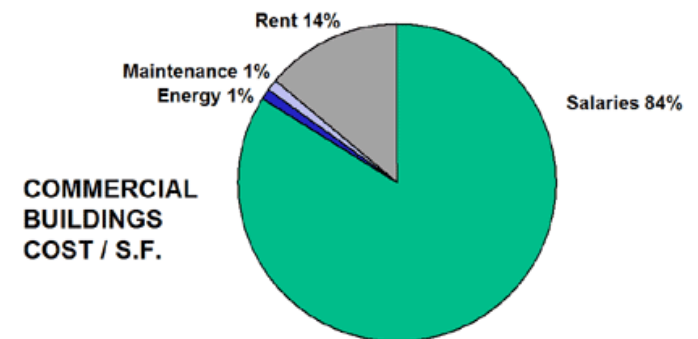
*Based on two field studies – one in schools and one in retail. H.M.G. 1999

Energy is a Design Problem

- Using energy modeling rather than prescriptive code requirements can enhance a project's design.

- Energy modeling can provide flexibility to the design.

Energy Modeling

- There are many early design decisions that the design team makes about a building's design that has an impact on energy performance.
  - Location
  - Orientation
  - Size & Shape (Massing)
  - Envelope Type
- Energy modeling can provide <u>information</u> to the team to help them make these important decisions.

Project Energy Goals

- Information from the energy model can help:
  - Define and refine a project's energy goals.
  - Define and refine the energy goals for the different systems.
    - HVAC
    - Lighting
    - Plug Loads
    - Service Water Heating

Project Energy Goals

- Certification
  - LEED Platinum
  - Energy Star Cert
  - ASHRAE Building Energy Quotient
  - Green Globes

- Comparative
  - 50% better than ASHRAE 90.1
  - 40% energy reduction from current usage
  - Architecture 2030 Challenge

- End-Use Specific
  - Reduce energy usage by 50% better than ASHRAE 90.1 with a life-cycle cost payback of 10 years or less

Project Energy Goals

- ## Starting Point
  - Baseline Energy Model
    - The **WORST** building that can be designed from an energy perspective.
  - Energy Star Target Finder
    - Target Finder is EPA's online calculator that helps project teams assess the energy performance data of commercial building designs and existing buildings.
  - Compares it to similar buildings in a database
    - About 15 building types.
  - The data is from Commercial Building Energy Use Survey (CBECS) 2003

EUI - Energy Use Intensity

- Energy Use Intensity (EUI) is a measurement of a building's annual energy consumption relative to the building's gross square footage.

- Reported in kBTU/SF/YR

- Site EUI vs. Source EUI
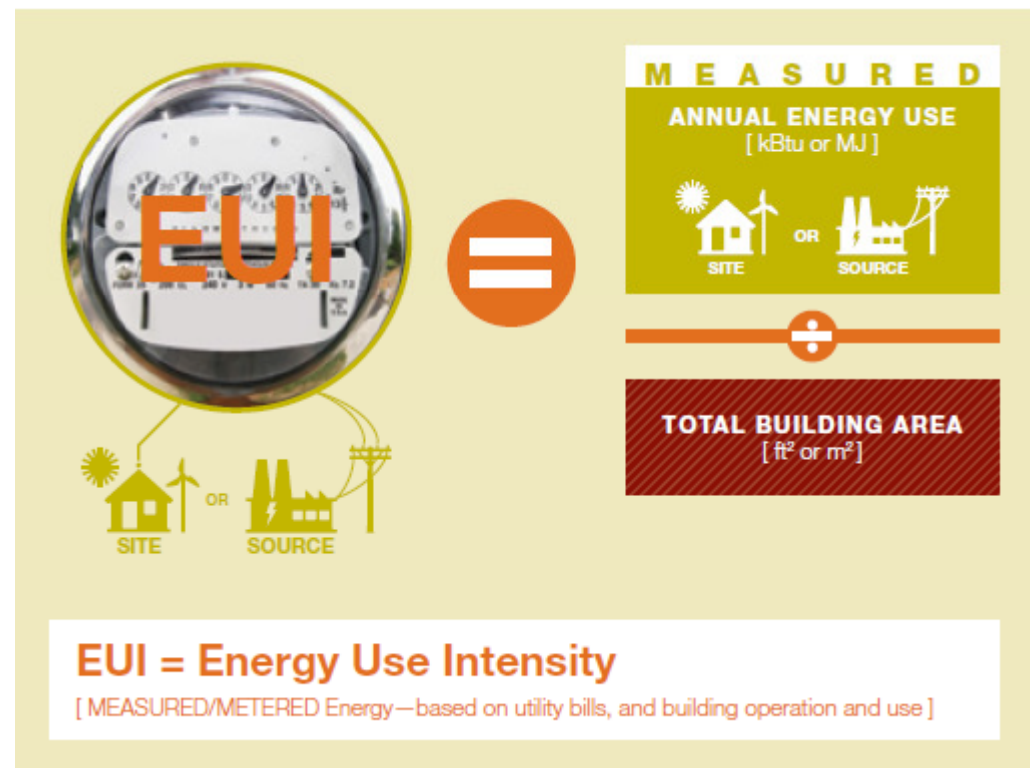
Image Source:AIA

Project Energy Goal Example

- Project Energy Goals: Options to Review
  - Energy Star Certification – Score 75 or greater.
  - Architecture 2030 Challenge - 70% Better than the Median Building Type Site EUI.
  - LEED Certification Discussion.

Project Energy Goal Example

- Office Building
  - Gross Area 54,000 sq ft
  - Occupancy 268 people
  - 1 computer per person + 4 servers – 272 computers
  - Building is 100% heated and cooled
  - Cincinnati, Ohio

Energy Star Target Finder

Source: Energy Star Portfolio Manager

Energy Star Target Finder

Metrics Comparison for Your Design and/or Target		
Metric	**Design Target***	**Median Property***
ENERGY STAR score (1-100)	75	50
Source EUI (kBtu/ft²)	200.8	271.4
Site EUI (kBtu/ft²)	90.7	122.7
Source Energy Use (kBtu)	10,840,671.40	14,656,920.00
Site Energy Use (kBtu)	4,898,821.00	6,623,356.00
Energy Cost ($)	91,351.96	123,510.64
Total GHG Emissions (Metric Tons CO2e)	663.1	896.5

* To perform calculations for your design target, we use the fuel mix that you've entered for your design energy estimates. If you have not entered estimated design energy, we'll use the average for your state. To perform calculations for the national median, we will assume the fuel mix and operational details of your property measurement in use, if available. Otherwise, we will use your design estimates.

Our project needs a site EUI of 90.7 or lower.

Baseline Building

- Build a preliminary baseline energy model per the energy code.

- Energy Code: ASHRAE 90.1-2007
  - Minimum Envelope Insulation (Roof, Walls, Floors, etc.)
  - Minimum Glazing Performance (U-Values, SHGC)
  - Maximum WWR
  - Minimum Lighting Power Density (W/sqft)
  - Minimum HVAC equipment Efficiencies
  - Minimum HVAC Controls
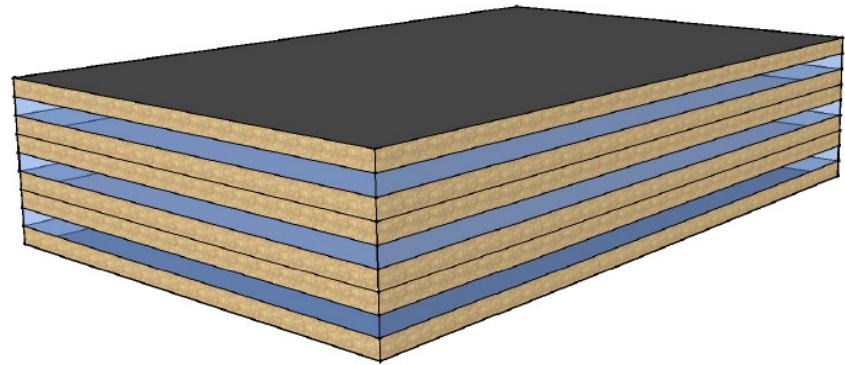
Most energy modeling software will construct an ASHRAE Standard 90.1 compliant model with just a few inputs.

Baseline Building
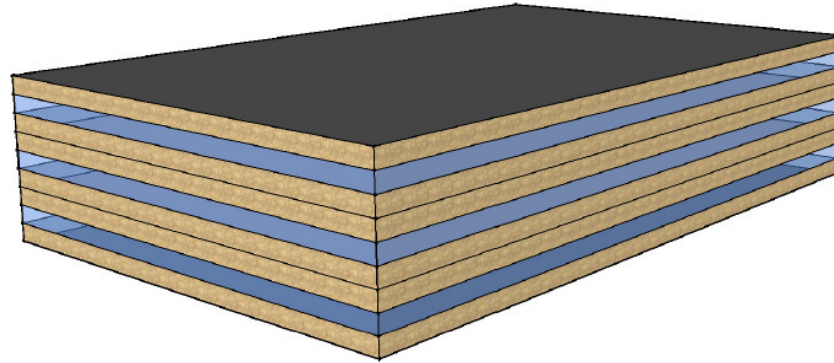
- Baseline Energy Model
  - Site EUI = 60.5 kbtu/sqft
  - Total Site Energy = 3,242,526 kbtu

Energy Star Results

Metrics Comparison for Your Design and/or Target			
Metric	Design Project	Design Target*	Median Property*
ENERGY STAR score (1-100)	78	75	50
Source EUI (kBtu/ft²)	190	200.8	271.4
Site EUI (kBtu/ft²)	60.5	90.7	122.7
Source Energy Use (kBtu)	10,181,531.80	10,840,671.40	14,656,920.00
Site Energy Use (kBtu)	3,242,526.00	4,898,821.00	6,623,356.00
Energy Cost ($)	91,893.20	91,351.96	123,510.64
Total GHG Emissions (Metric Tons CO2e)	651.5	663.1	896.5

* To perform calculations for your design target, we use the fuel mix that you've entered for your design energy estimates. If you have not entered estimated design energy, we'll use the average for your state. To perform calculations for the national median, we will assume the fuel mix and operational details of your property measurement in use, if available. Otherwise, we will use your design estimates.

Project could earn Energy Star with a score of 78.

Architecture 2030 Challenge

All new buildings, developments, and major renovations shall be carbon-neutral by 2030.

Energy Savings Target for New Buildings

CBECS 2003 median building

Site EUI, relative to median building

60 %   70 %   80 %   90 %   100 %

Savings

100%   80%   60%   40%   20%   0%

2010   2015   2020   2025   2030

Architecture 2030 Challenge

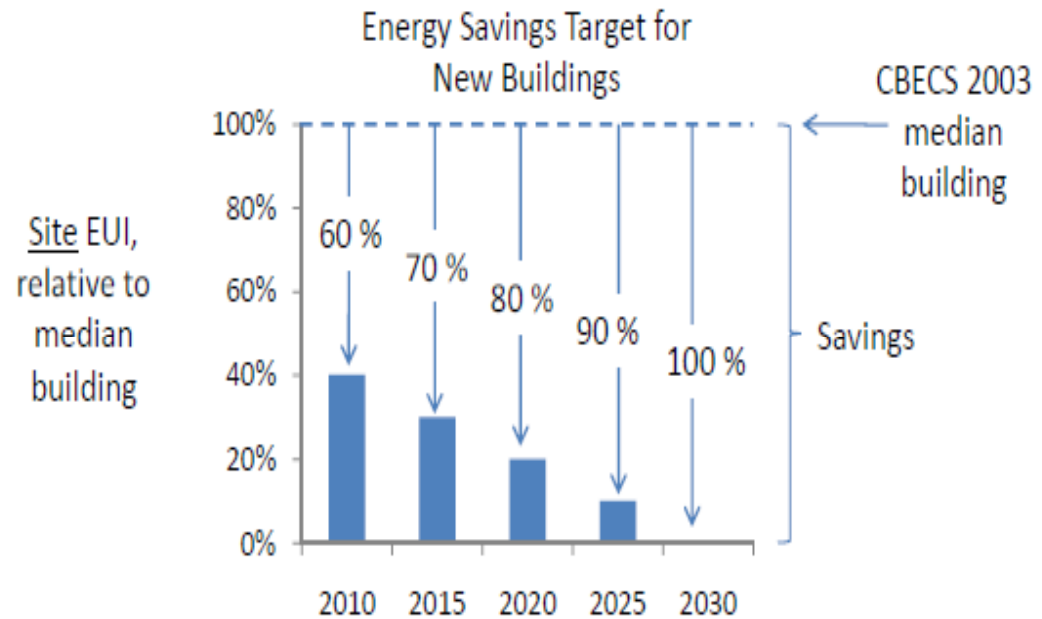| Metrics Comparison for Your Design and/or Target			
Metric	**Design Project**	**Design Target***	**Median Property***
ENERGY STAR score (1-100)	78	99	50
Source EUI (kBtu/ft²)	190	81.4	270.7
Site EUI (kBtu/ft²)	60.5	36.8	86.2
Source Energy Use (kBtu)	10,181,531.80	4,897,076.00	14,509,712.90
Site Energy Use (kBtu)	3,242,526.00	1,987,006.80	4,620,927.10
Energy Cost ($)	91,893.20	37,053.19	130,957.10
Total GHG Emissions (Metric Tons CO2e)	651.5	269	928.4

* To perform calculations for your design target, we use the fuel mix that you've entered for your design energy estimates. If you have not entered estimated design energy, we'll use the average for your state. To perform calculations for the national median, we will assume the fuel mix and operational details of your property measurement in use, if available. Otherwise, we will use your design estimates.

Architecture 2030 Challenge – Site EUI 70% better than Median Property.

Architecture 2030 Challenge

- To meet this project energy goal we will have to look at a number of ECMs
  - Reducing the loads
    - Building design to improve daylighting opportunities.
    - Improved Envelope (Wall & Roof Insulation).
    - HP Glazing and WWR on different exposures.
    - South, West, and East shading on glazing.
  - HP HVAC Systems – Radiant Systems
  - Reducing Lighting Power Density with Daylighting
  - Reduce Plug Loads
  - Onsite Renewable Energy

LEED Certification

LEED v4 - EA Credit: Optimize Energy Performance

New Construction	Points	Site Energy Use (kBtu)	Site EUI (kBtu/ft²)
5%	PREREQ	2,741,556	51.1
6%	1	2,712,697	50.6
8%	2	2,654,980	49.5
10%	3	2,597,263	48.5
12%	4	2,539,546	47.4
14%	5	2,481,829	46.3
16%	6	2,424,112	45.2
18%	7	2,366,395	44.1
20%	8	2,308,679	43.1
22%	9	2,250,962	42.0
24%	10	2,193,245	40.9
26%	11	2,135,528	39.8
29%	12	2,048,952	38.2
32%	13	1,962,377	36.6
35%	14	1,875,801	35.0
38%	15	1,789,226	33.4
42%	16	1,673,792	31.2
46%	17	1,558,358	29.1
50%	18	1,442,924	26.9
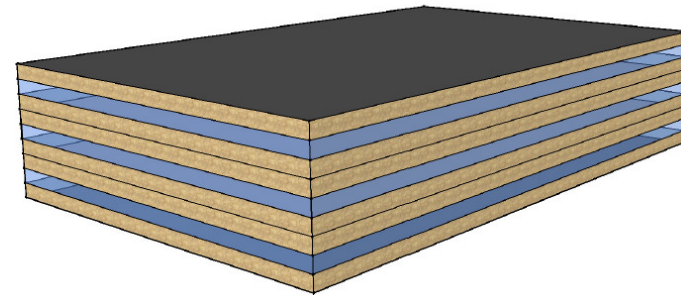
- Baseline Building (90.1-2010)
  - EUI = 53.8 kBtu/ft^2
  - Total Site Energy = 2,883,680 kBtu
- This information allows us to see how many points are possible and what our EUI target is for the project.

Individual System Energy Goals

- Information can be extracted from the energy model to see how the individual systems will need to reduce their energy usage.

- These individual system energy goals influence the schematic design, design development and contract document phases of the project.

Individual System Energy Goals
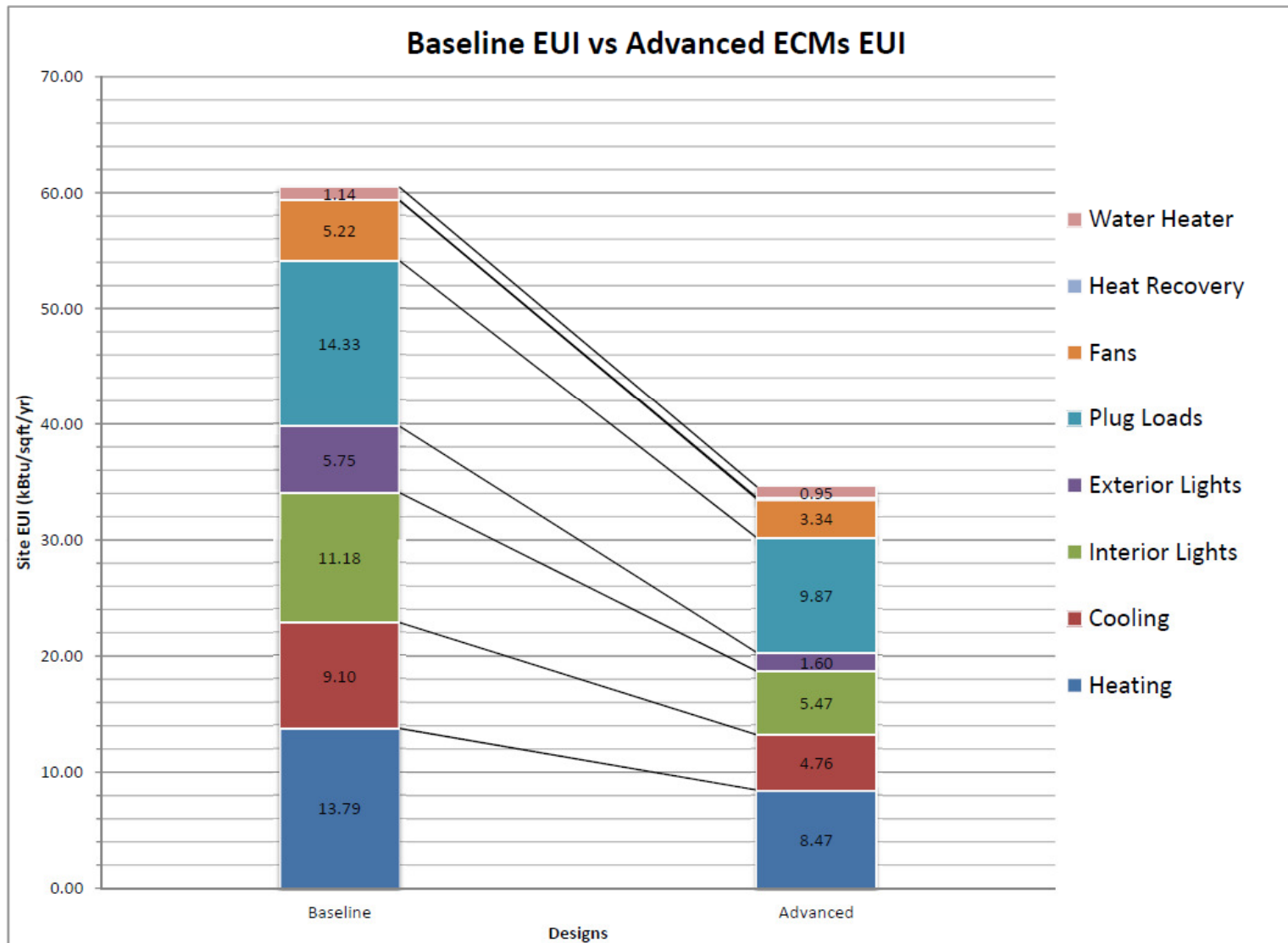
Types of Energy Modeling

Four Most Common Types:

- Design Performance Modeling (DPM)

- Building Energy Modeling (BEM)

- Building Operation Modeling (BOM)

- Project Resource Modeling (PRM)
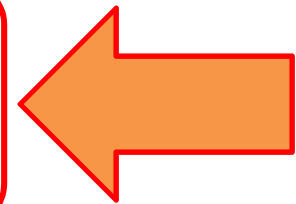
Design Performance Modeling

- Used early on or at the start of the project.
  - Concept and Schematic Design Phases.
- Used to provide information to building design decisions by predicting a building's energy performance.
- Allows for quick analysis of many design alternatives.

Design Performance Modeling

- Simple models – K.I.S.S.
  - Remove the details that have little or no impact on the energy performance.
  - Modeling the heat transfer surfaces.
  - Using standard or packaged inputs.
  - HVAC and Lighting system are treated like a "black box".

Design Performance Modeling

- Concept Design Phase
  - Used to set and qualify project energy goals.
  - Experiment with building massing and orientation alternatives.
  - Determine envelope construction alternatives.
  - Assess daylighting possibilities with the building design alternatives.

DPM – Massing Study
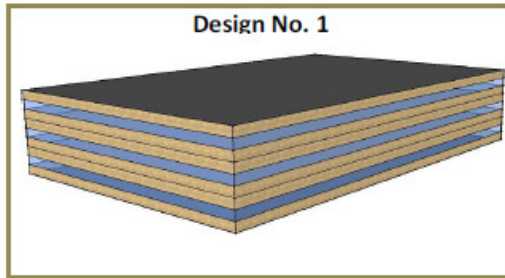
Design No. 1	
Site EUI (kBtu/ft²)	53
Site Energy Use (MMBtu)	2,841
Daylighting Potential	Bad

Basic Design
Large Core Space - Daylighting Issues
Large Core Space - Cooling Energy High
Smaller Wall Surface Area
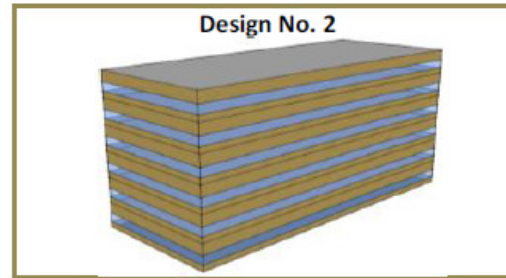Large Roof Area
Small Window Area
Orientation low impact

Design No. 2	
Site EUI (kBtu/ft²)	47
Site Energy Use (MMBtu)	2,519
Daylighting Potential	Maximum

Tall Skinny Design
Small Core Space - Maximum Daylighting
Small Core Space - Cooling energy lower
Large Wall Surface Area
Large Window Area
Small Roof Area
Orientation high impact
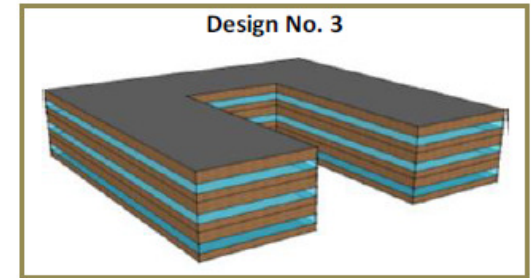
Design No. 3	
Site EUI (kBtu/ft²)	50
Site Energy Use (MMBtu)	2,680
Daylighting Potential	Good

Section Design
Small Core Space - Good Daylighting
Small Core Space - Cooling energy lower
Large Wall Surface Area
Large Window Area
Large Roof Area
Orientation some impact

Design Performance Modeling

Response Curves

Examples:

Wall Insulation

Glazing

Shading

DPM – Response Curves

Annual Energy Consumption (kBTU)
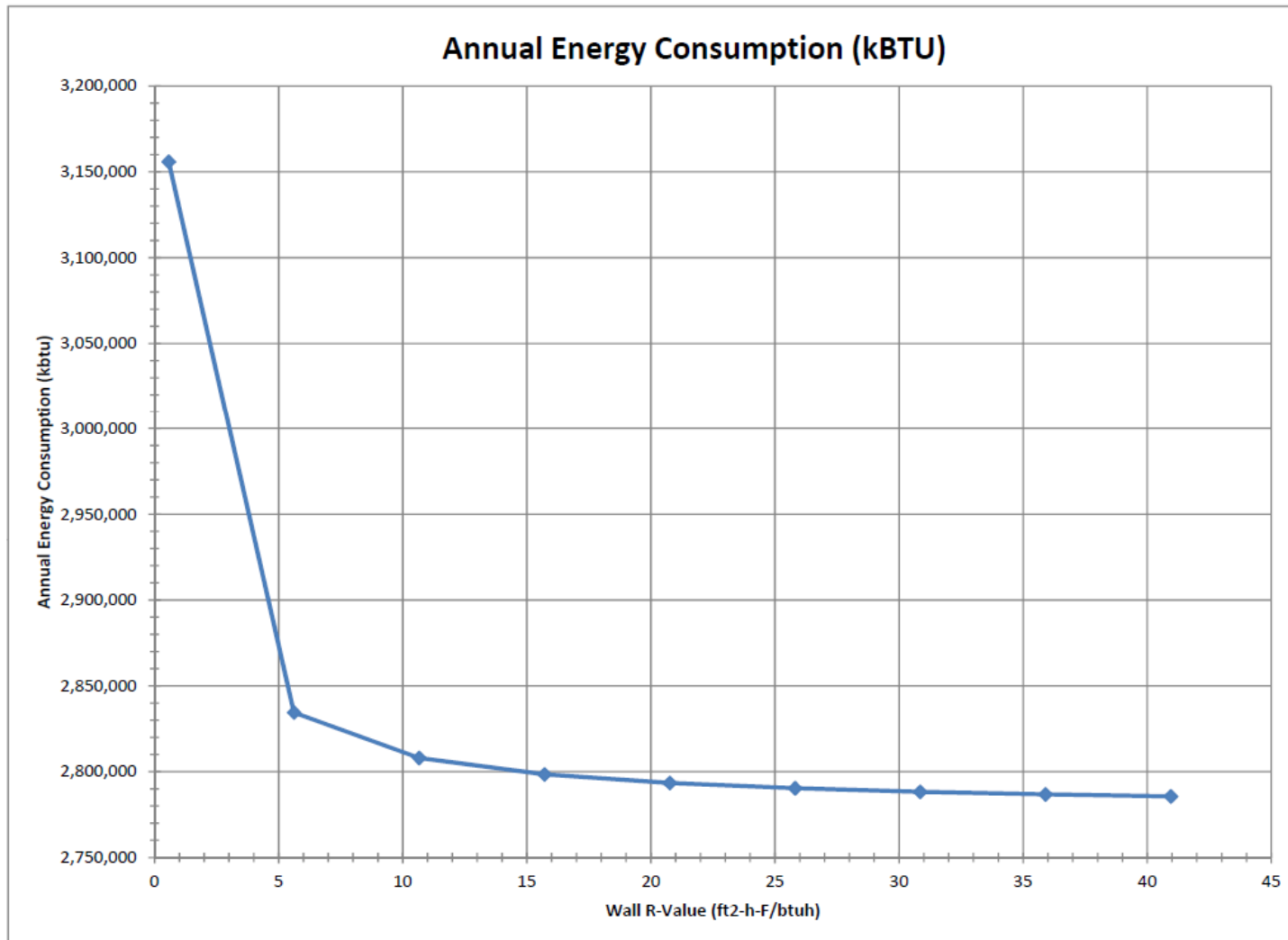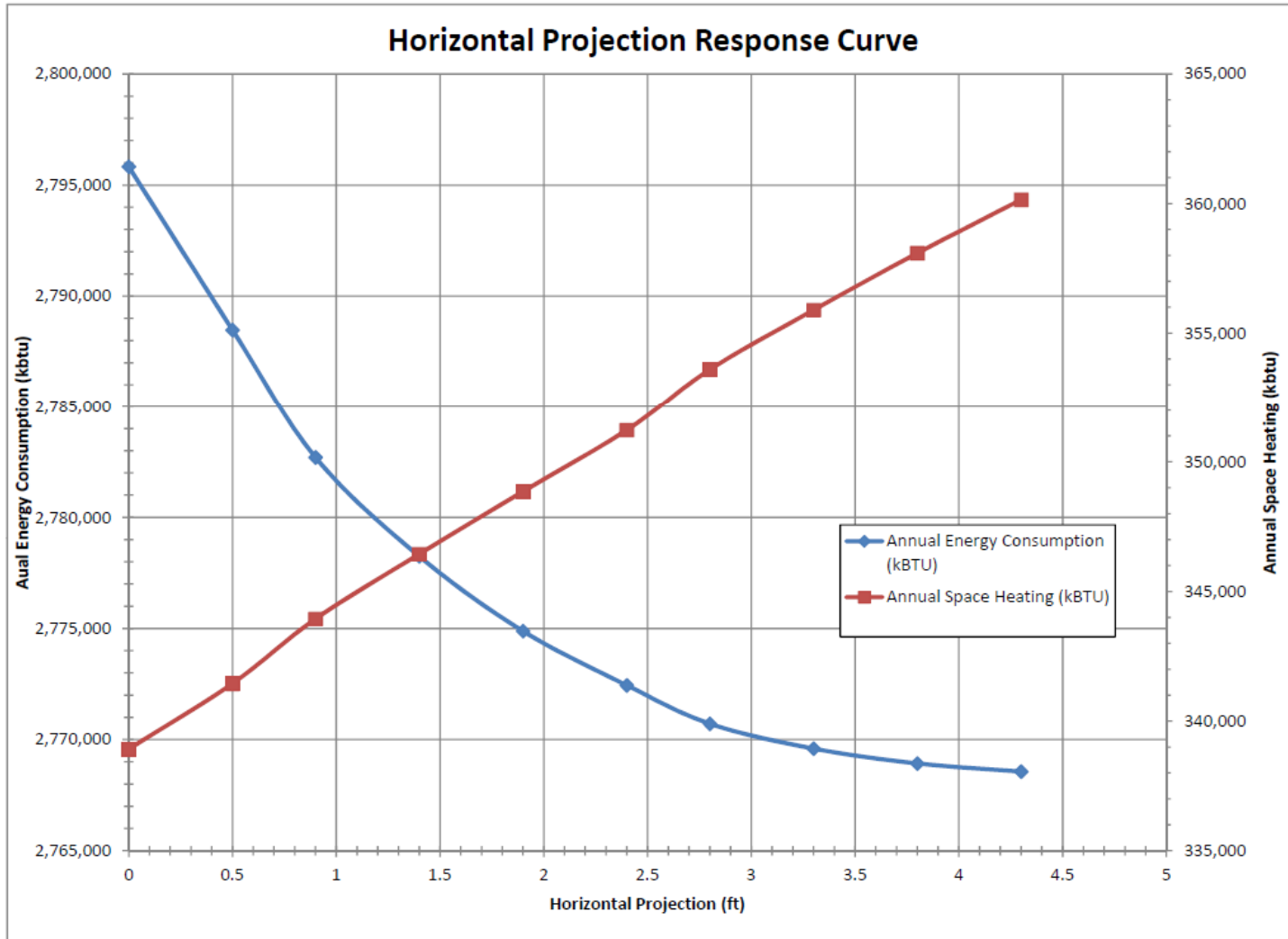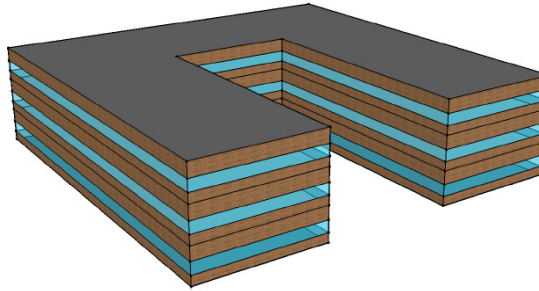
DPM – Response Curves
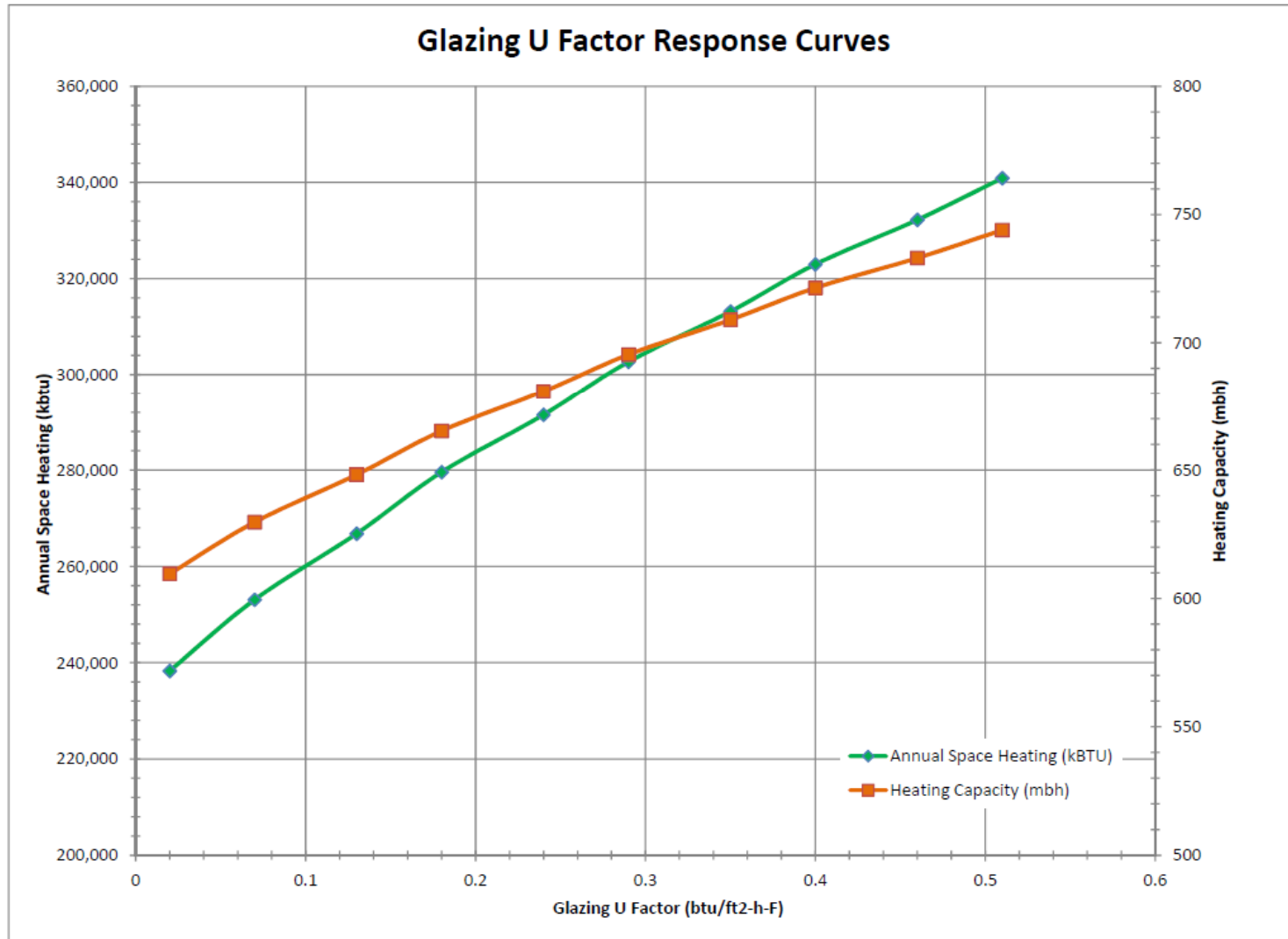
DPM – Response Curves

Design Performance Modeling

- Schematic Design Phase
  - Explore ways to reduce loads.
  - Test energy conservation measures (ECM) to determine the lowest possible energy use.
  - Review alternative HVAC systems for the project.
  - Develop lighting power densities and controls to support daylighting.

DPM – ECM Analysis

	Annual Energy Consumption [kbtu]		Annual Energy Use per Gross Internal Area [kbtu/sqft]		Annual Space Cooling [kbtu]		Annual Space Heating [kbtu]		Heating Capacity [mbh]		Cooling Capacity [tons]	
Baseline Concept	**2,591,861**		**48**		**537,028**		**765,295**		**1,200**		**133.3**	
Strategy Bundle	*1,841,337*	*29%*	*34*	*29%*	*369,225*	*31%*	*266,529*	*48%*	*624*	*48%*	*83.5*	*37%*
HVAC System Eff	2,094,099	19%	39	19%	458,392	15%	430,124	20%	966	20%	113.1	15%
East & West Shading	2,582,763	0%	48	0%	516,558	4%	776,667	0%	1,200	0%	130.8	2%
South Shading	2,591,491	0%	48	0%	536,526	0%	765,427	0%	1,200	0%	132.9	0%
North WWR 40%	2,562,238	1%	48	0%	519,489	3%	753,211	2%	1,179	2%	130.8	2%
North WWR 45%	2,565,567	1%	48	0%	521,466	3%	754,562	2%	1,181	2%	131.1	2%
Infiltration	2,431,144	6%	45	6%	533,987	1%	607,619	18%	984	18%	121.2	9%
Wall Insulation	2,547,294	2%	47	2%	542,661	-1%	715,096	3%	1,159	3%	132.0	1%
HP Glazing	2,523,460	3%	47	2%	446,400	17%	787,522	4%	1,148	4%	121.1	9%
Roof Insulation	2,570,158	1%	48	0%	538,390	0%	742,230	1%	1,182	1%	132.8	0%

DPM – HVAC Alternatives
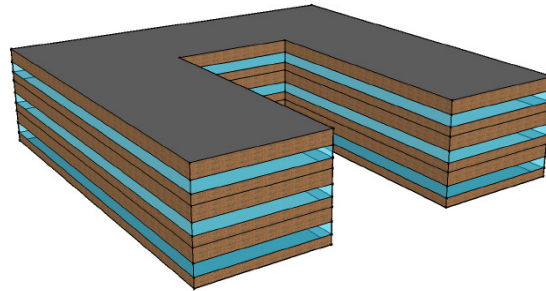
	HVAC System Type	Heating Equipment Capacity [mbh]		Cooling Equipment Capacity [tons]		EUI [kbtu/sqft]		Annual Energy Cost [$]	
Baseline Concept	Packaged Rooftop VAV w/ Reheat	1,488		98.6		39		61,045	
	Water Source Heat Pump	1,197	20%	86.9	12%	37	5%	46,941	23%
	VRF Fan Coil Units w/ Central Outside Air	640	57%	100.2	-2%	29	26%	44,675	27%
	Fan Coils w/ Central Outside Air	1,132	24%	85	14%	35	10%	45,329	26%

DPM – HVAC Alternatives

HVAC System Alternative Cooling Capacity

DPM – HVAC Alternatives

HVAC System Alternative Heating Capacity

Heating Equipment Capacity [mbh]

- Packaged Rooftop VAV w/ Reheat: 1,488
- Water Source Heat Pump: 1,197
- VRF Fan Coil Units w/ Central Outside Air: 640
- Fan Coils w/ Central Outside Air: 1,132
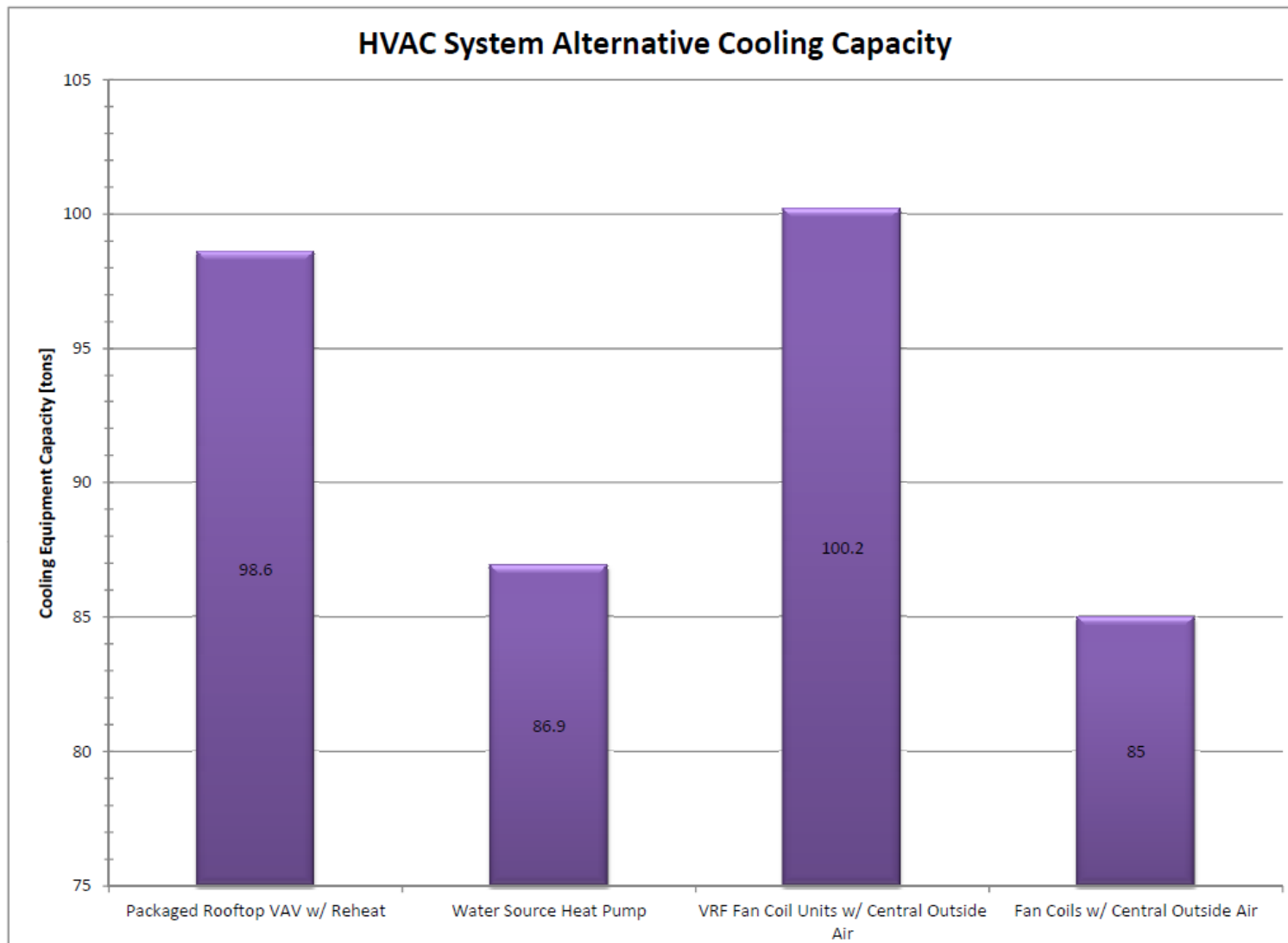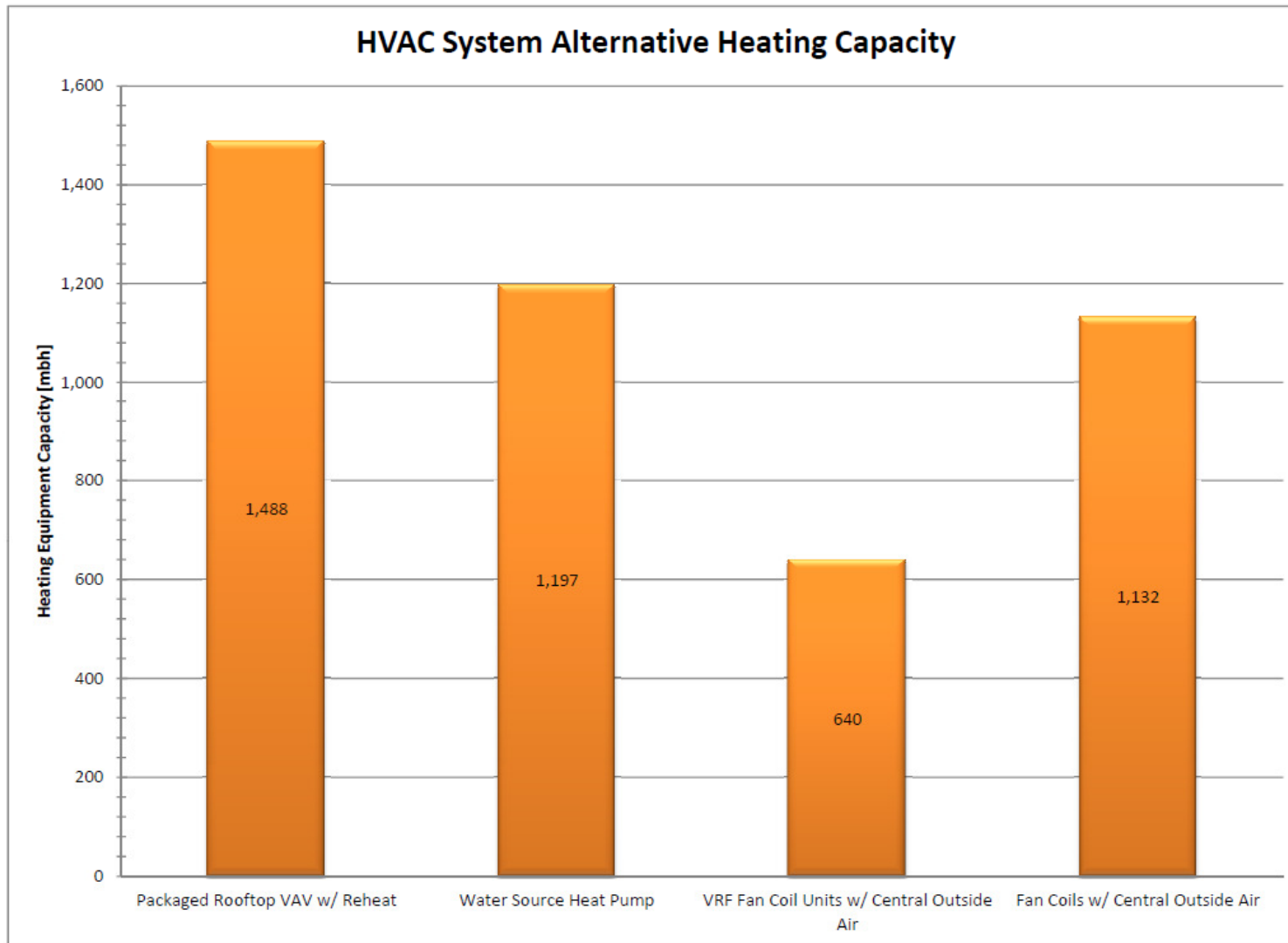
Design Performance Modeling

- End of Schematic Design
  - Identified possible ECM.
  - Develop a matrix with preliminary energy cost for each ECM.
  - Financial Analysis – Life-Cycle Cost Analysis
    - Additional first-cost investment
    - Anticipated annual energy cost savings
    - Simple payback periods
    - Return on investment (ROI)

Building Energy Modeling

- Used during the Design Development and Construction Document Phases.

  - Detailed models
    - Modeling each space in the building
      - Actual people count
      - Actual plug loads
      - Actual lighting loads
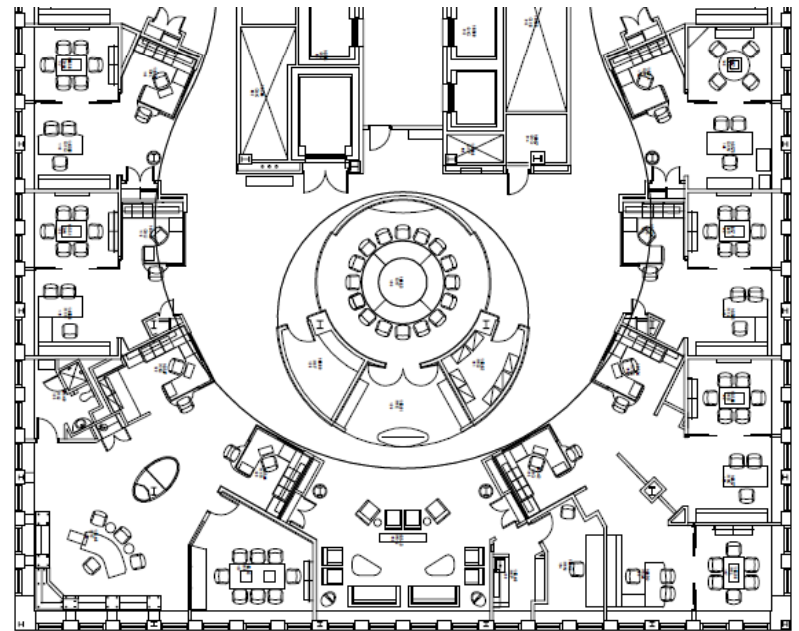
Building Energy Modeling

- **Design Development Phase**
  - Applying the final package of ECM into the project.
  - Right sizing equipment.
    - HVAC
    - Lighting
  - Financial investment/life-cycle cost analysis.
  - Analyzing VE options.

Zone Cooling

	Calculated Design Load [Btu/h]	User Design Load [Btu/h]	User Design Load per Area [Btu/h–ft2]	Calculated Design Air Flow [ft3/min]	User Design Air Flow [ft3/min]
L001_C01	49062.27	49062.27	7.48	2519.583	2519.583
L001_P02	54661.77	54661.77	15.51	2815.462	2815.462
L001_P01	23847.10	23847.10	11.12	1228.351	1228.351
L001_P03	36644.12	36644.12	17.08	1887.670	1887.670

Building Energy Modeling

- Contract Document Phase
  - Adding the final details for all of the building systems.
  - Finishing the energy model for:
    - Project compliance with the energy code.
    - Project compliance with green building certification.
    - Utility company rebates.

SECTION 1.6 - PERFORMANCE RATING METHOD COMPLIANCE REPORT

Table EAp2-4. Baseline Performance - Performance Rating Method Compliance

In the table below, list each energy end use for the project (including all end uses reflected in the baseline and proposed designs). Then check whether the end-use is a process load, select the energy type, and list the energy consumption and peak demand for each end-use for all four baseline design orientations.
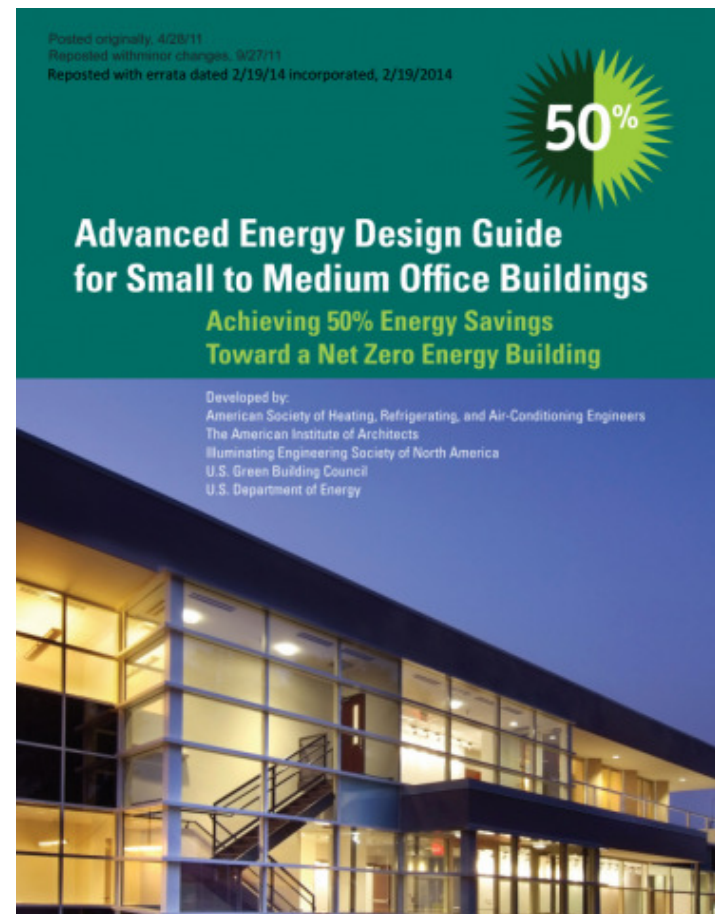
End Use	Process	Baseline Design Energy Type	Units of Annual Energy & Peak Demand		Baseline (0° rotation)	Baseline (90° rotation)	Baseline (180° rotation)	Baseline (270° rotation)	Baseline Building Results
Interior Lighting	☐	Electricity	Energy Use	kWh	28,767	28,767	28,767	28,767	28,767
			Demand	kW	9.5	9.5	9.5	9.5	9.5
Exterior Lighting	☐	Electricity	Energy Use	kWh	6,066	6,066	6,066	6,066	6,066
			Demand	kW	1.5	1.5	1.5	1.5	1.5
Space Heating	☐	Natural Gas	Energy Use	therms	2,603.8	2,608.5	2,620.5	2,612.2	2,611.25
			Demand	therms/h	228.2	228.2	228.2	228.2	228.2
Space Cooling	☐	Electricity	Energy Use	kWh	7,300	7,317	7,326	7,249	7,298
			Demand	kW	48.5	48.5	49.1	48.4	48.63
Pumps	☐		Energy Use						
			Demand						
Heat Rejection	☐	Electricity	Energy Use	kWh	734	734	735	727	732.5
			Demand	kW	6.5	6.5	6.5	6.5	6.5

The End

- Design Performance Modeling and Building Energy Modeling are tools that can be used throughout the design to optimize the performance of all the building systems.
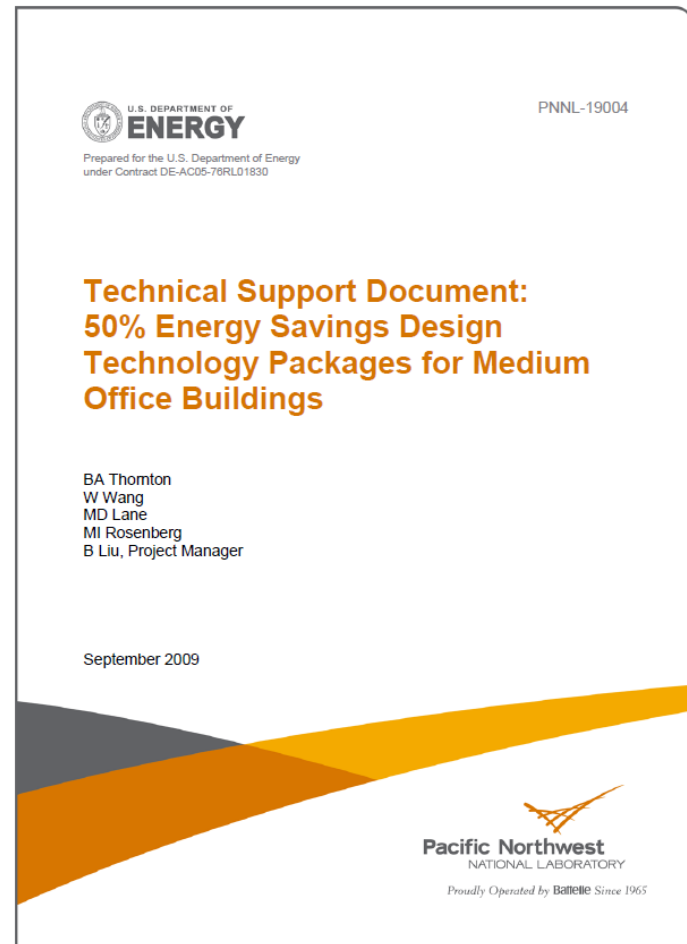
Advanced Energy Design Guides

- Provides design guidance and prescriptive solutions to get significant energy savings over minimum building energy codes.

- Partnership between the U.S. Department of Energy (DOE), ASHRAE, AIA, USGBC, and IES

- 50% AEDG
  - Small to Medium Office Buildings
  - K-12 School Buildings
  - Medium to Big Box Retail Buildings
  - Large Hospitals
  - Grocery Stores

- 30% AEDG
  - Small Office Buildings
  - Small Retail Buildings
  - Small Warehouses and Self-Storage Buildings
  - Highway Lodging
  - Hospitals/Healthcare Buildings
  - K-12 School Buildings

- 50% AEDGs can be used to meet LEED v4 EA CREDIT: Optimize Energy Performance Option 2.

- FREE download at ASHRAE. www.ashrae.org/aedg

Posted originally, 4/28/11
Reposted with minor changes, 9/27/11
Reposted with errata dated 2/19/14 incorporated, 2/19/2014

50%

Advanced Energy Design Guide for Small to Medium Office Buildings

Achieving 50% Energy Savings
Toward a Net Zero Energy Building

Developed by:
American Society of Heating, Refrigerating, and Air-Conditioning Engineers
The American Institute of Architects
Illuminating Engineering Society of North America
U.S. Green Building Council
U.S. Department of Energy

Technical Support Document:

- The Technical Support Document describes the process and methodology for the development of the *Advanced Energy Design Guides.*

- There are reports for each of the AEDGs.

- And yes they are free!!

U.S. DEPARTMENT OF **ENERGY**

PNNL-19004

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**Technical Support Document:
50% Energy Savings Design
Technology Packages for Medium
Office Buildings**

BA Thornton
W Wang
MD Lane
MI Rosenberg
B Liu, Project Manager

September 2009

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NATIONAL LABORATORY

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Thank You

- Remember to Sign-in for the Breakout Sessions.
- Questions?

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Jason M. Park, P.E.

Contact Information:

jpark@pedcoea.com

(513)-782-4920

www.pedcoea.com