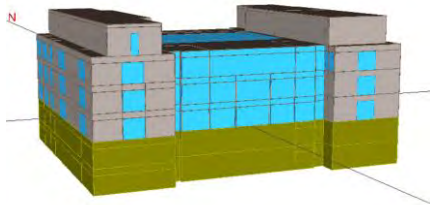
The Role of Energy Modeling in Building Design and Construction

Peter Levy, MS, BEMP, LEED AP, CPHC

Todays Objectives

- What is energy modeling?
- What information goes into a model?
- What information comes out a model?
- How are models used to inform designs?
- What other purposes do models serve?
- How is Daylight Modeling used?

What is Energy Modeling?

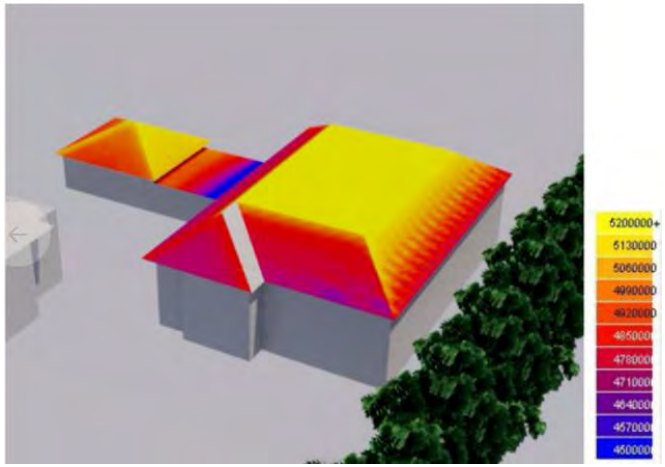


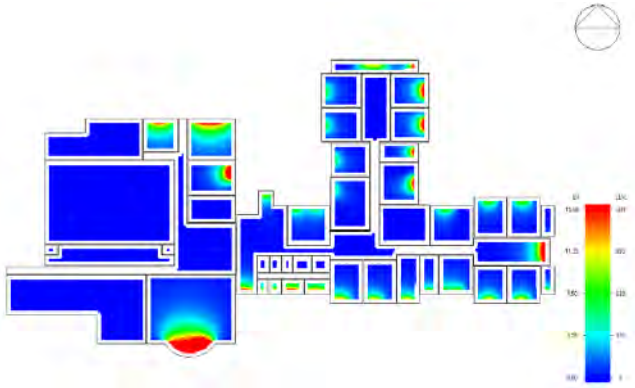
-Whole building energy simulation

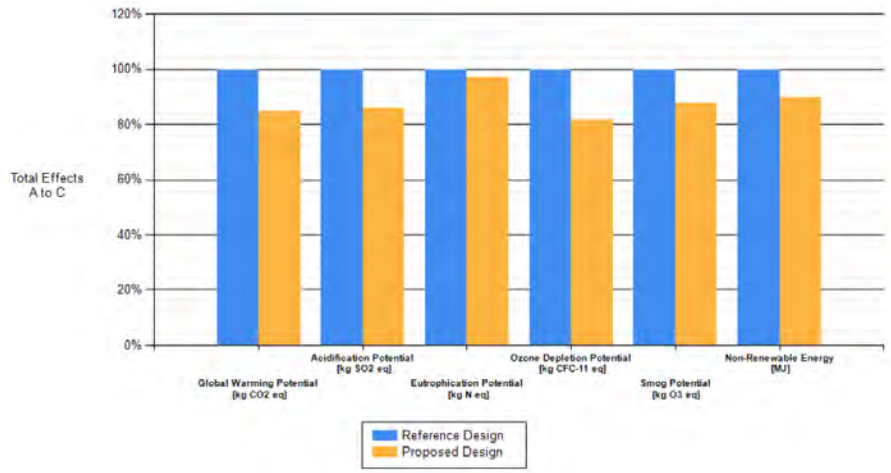
-Daylight analysis

-Solar PV analysis

-Life cycle analysis (LCA)





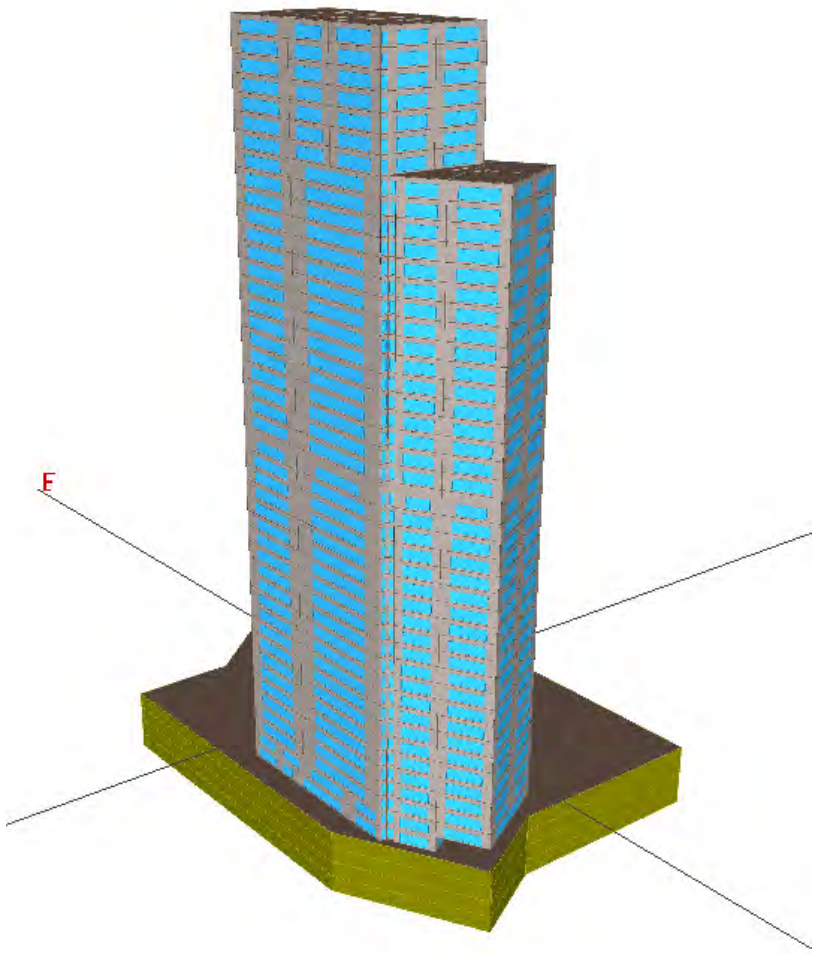


Whole Building Energy Simulation

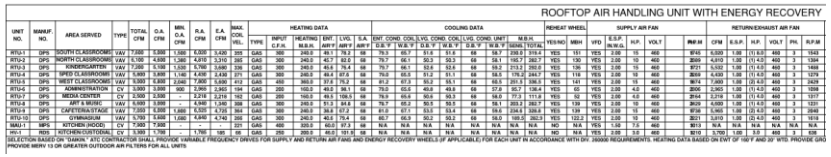
A computational model, which includes the:

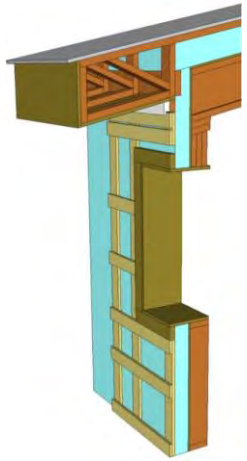
- Envelope
- Mechanical systems
- Internal loads
- Occupancy patterns
- Local annual weather

In order to predict the annual operational energy use of a building



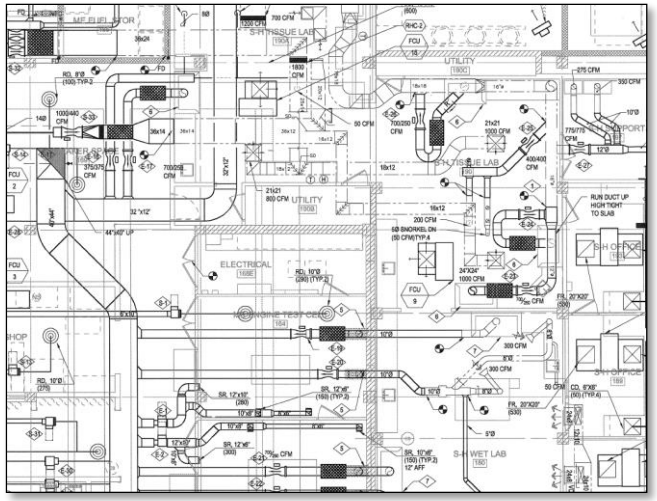
What Goes into a Model?





National Solar Radiation Data Base

1991- 2005 Update: Typical Meteorological Year 3



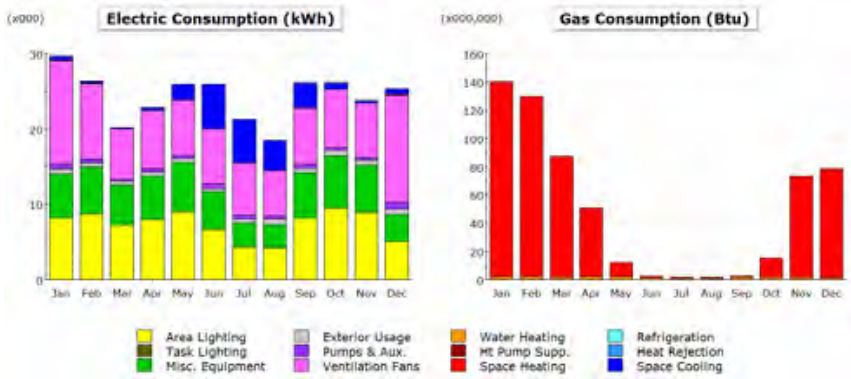
eQUEST

DesignBuilder

OpenStudio

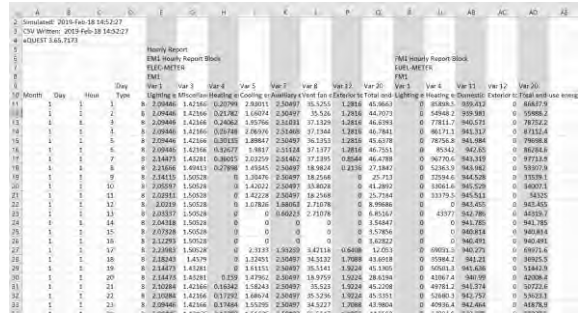
What Comes out of a Model?

Annual operational energy use



REPORT- BEPU Building Utility Performance — WEATHER FILE- Boston MA TMY2

	LIGHTS	TASK LIGHTS	MISC EQUIP	SPACE HEATING	SPACE COOLING	HEAT REJECT	PUMPS & AUX	VENT FANS	REFRIG DISPLAY	HT PUMP SUPPLEM	DOMEST HOT WTR	EXT USAGE	TOTAL
EM1 ELECTRICITY													
KWH	88256.	0.	63931.	206.	24189.	0.	6286.	102579.	0.	0.	0.	6812.	292259.
FM1 NATURAL-GAS													
THERM	0.	0.	0.	5753.	0.	0.	0.	0.	0.	0.	208.	0.	5961.



What is the Model Used For?

Inform the design

Model various energy conservation measures early in the design

-Assess potential energy savings and incremental cost to determine payback period

-Make informed selection of ECMs to achieve greatest amount of energy savings with available capital

Validate the design

Required validation

-MEPA compliance

-Code compliance

-MSBA Compliance

-Municipality Compliance

-LEED (Certified/Certifiable)

Elective validation

Certification Programs

-LEED Certification

-CHPS

-Passive House

Utility Incentive Programs

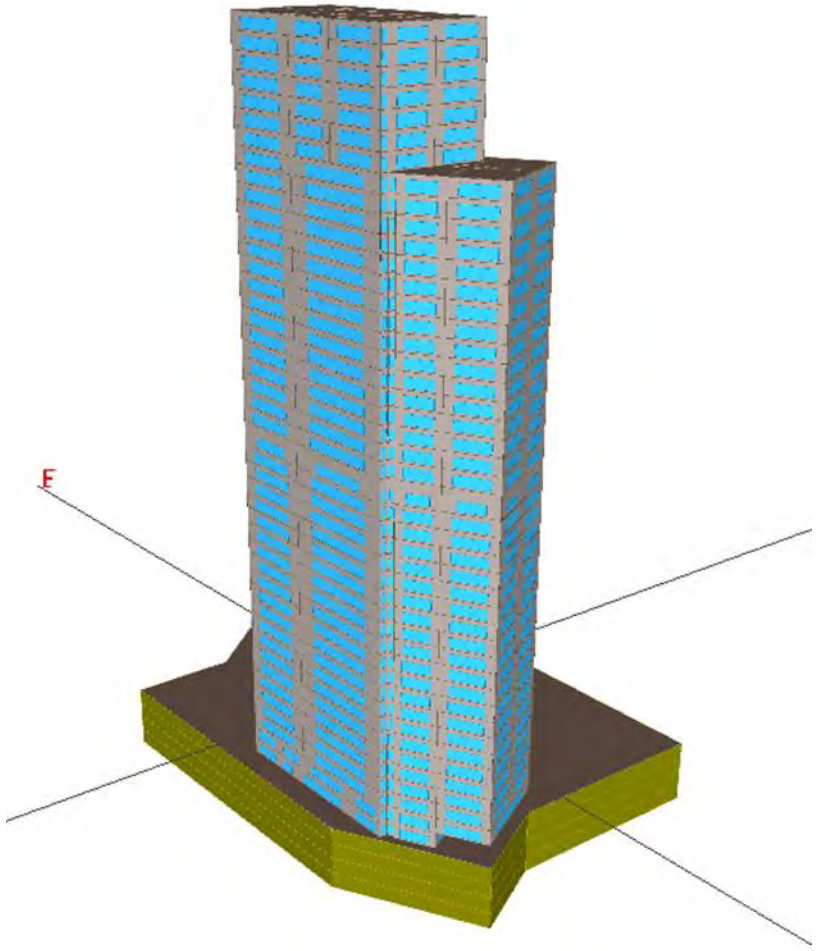
-Mass Save

-P4P

-NYSERDA

Often, a Project Requires all of Those
Residential Tower in Boston

- Started Model in Jan 2014
- Design Assistance Modeling in SD-DD
- Utility Incentive Model in DD-CD
- Code Compliance Model at 100% CD
- LEED Model at 100% CD



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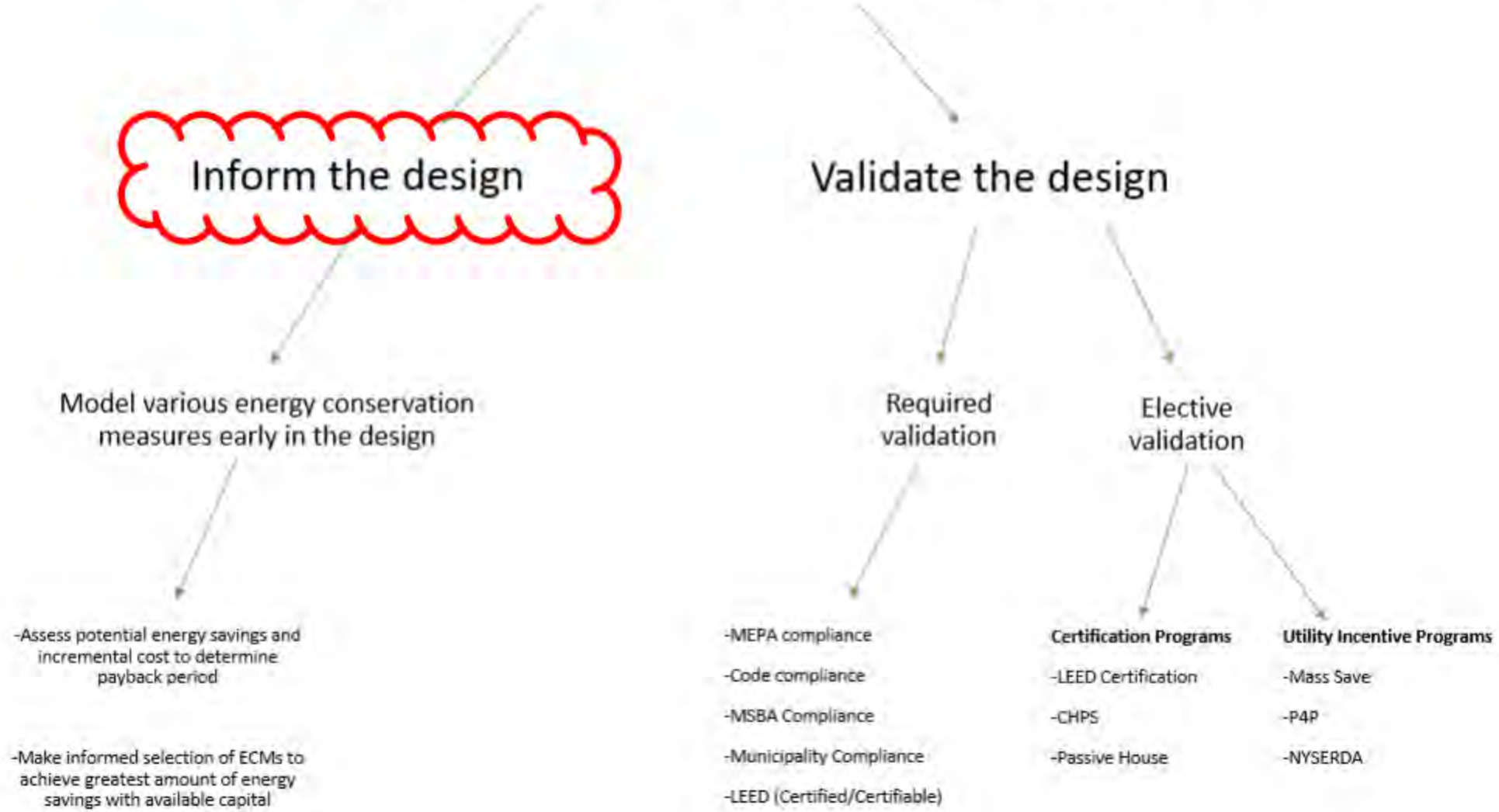


Modeling to Inform the Design

- Model various Energy Conservation Measures (ECMs) to assess how different design alternatives can reduce energy use.

  Typical ECMs:

  - Envelope (walls/roof/floor assemblies, windows, infiltration)
  - HVAC equipment (system types, unit efficiencies, energy recovery ventilation, DCV, fuel switching)
  - Internal Loads (Lighting Power Density, daylighting/occupancy controls)
  - Occupancy patterns, setpoint controls

Informing the Design (Envelope ECMs)

Glazing U-value and SHGC

Table 1: ASHRAE 90.1 2007 Baseline and As Designed Energy by End-Use (CW U-0.053)

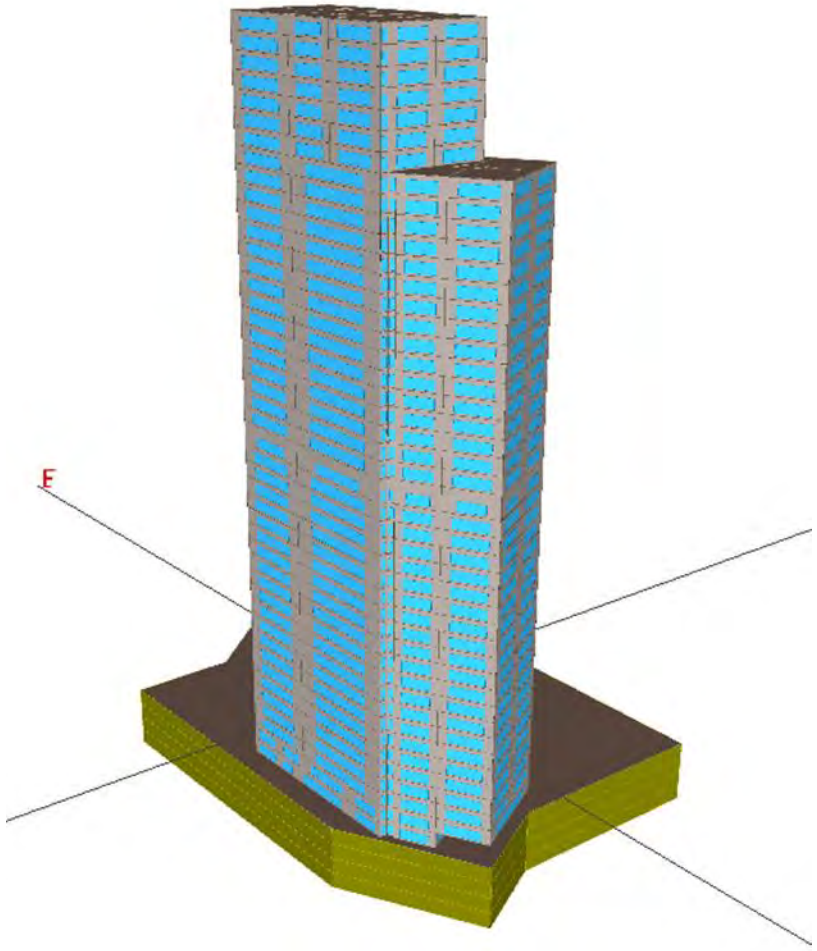
	Lights (MBTU)	Plug (MBTU)	Heating (MBTU)	Cooling (MBTU)	Ht Reject (MBTU)	Pumps (MBTU)	Fans (MBTU)	DHW (MBTU)	Ext Light (MBTU)	Total (MBTU)	Energy Savings (%)	Cost ($)	$ Savings over Base
2007 Baseline	4,630	5,035	12,890	2,281	0	24	4,008	5,249	112	34,229	NA	919,558	NA
Proposed	2,048	5,035	3,803	2,501	14	1,454	5,030	3,299	112	23,297	31.9%	815,200	11.3%
Low SHGC on SE and SW	2,048	5,035	4,056	2,156	12	1,365	5,014	3,299	112	23,097	32.5%	796,891	13.3%
Low SHGC on all Facades	2,048	5,035	4,239	1,955	10	1,310	5,008	3,299	112	23,017	32.8%	786,571	14.5%
Argon Windows ECM	2,048	5,035	3,706	2,053	10	1,358	5,008	3,299	112	22,630	33.9%	788,029	14.3%

Reduced gas use by 533 MBTU

Increased electricity use by 98 MBTU

Net energy savings of 387 MBTU (4.2%)

Net cost increase of $1,458 (0.2%)



- Used lowest viable SHGC
- Did not pursue lower U-value windows
  - If shades/overhangs were viable, results would have been different

Informing the Design (HVAC ECMs)

- Water Source Heat Pumps
- Hybrid Heat Pumps (Hydronic Heating)

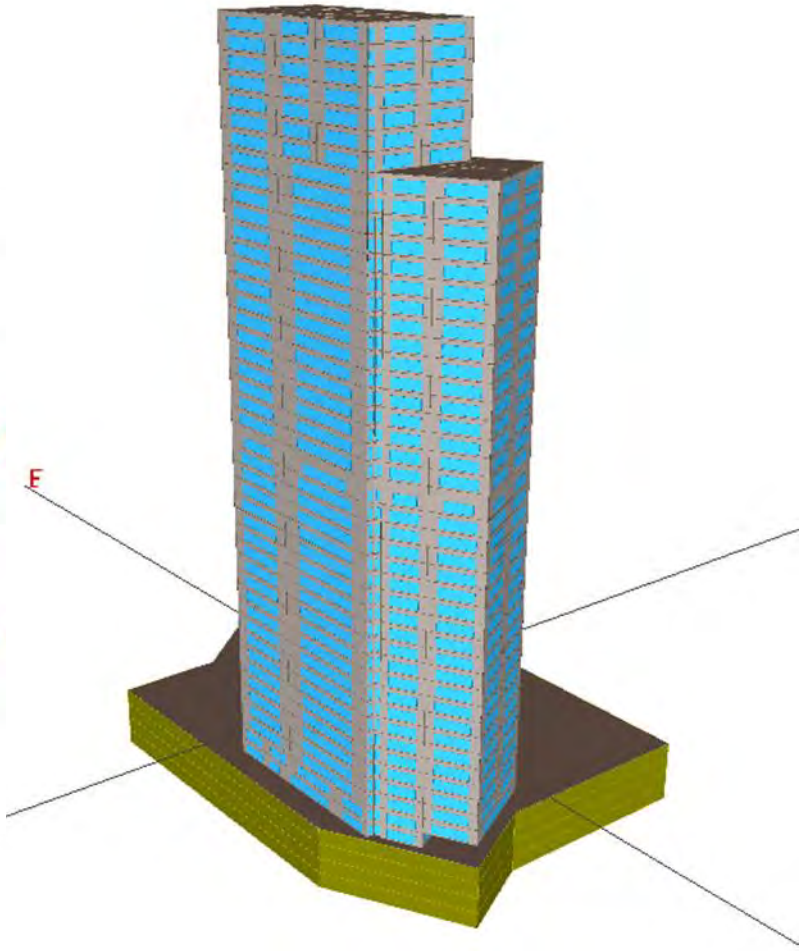
Table 2: Energy Savings

Original Selection

	Total Site (MBTU)	Cost ($)	Source (MBTU)	Site Energy (%)	Cost (%)	Source Energy (%)
Baseline	37,437	$1,032,321	74,103	NA	NA	NA
Whalen Hybrid 2 GPM/Ton	27,330	$943,935	64,639	27.0%	8.6%	12.8%
Whalen Hybrid 2.5 GPM/Ton	27,332	$944,035	64,645	27.0%	8.6%	12.8%
Whalen WSHP 2 GPM	26,487	$955,447	64,896	29.2%	7.4%	12.4%
Whalen WSHP 2.5 GPM	26,557	$959,891	65,173	29.1%	7.0%	12.1%
Climatemaster WSHP 2 GPM	26,448	$952,062	64,690	29.4%	7.8%	12.7%
Climatemaster WSHP 2.5 GPM	26,380	$948,939	64,487	29.5%	8.1%	13.0%

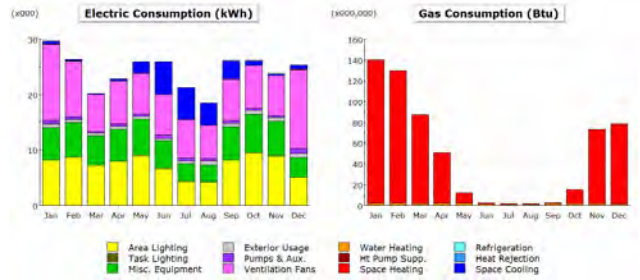
-Highest site & source energy savings
-2nd highest cost savings
-Didn't require running hydronic piping throughout building

- Used Climatemaster WSHP 2.5 GMP/Ton



Modeling to Inform the Design

Assess the potential operational energy savings and incremental cost of design alternatives.



In order to select ECMs that achieve greatest amount of energy savings with available capital.

$$$

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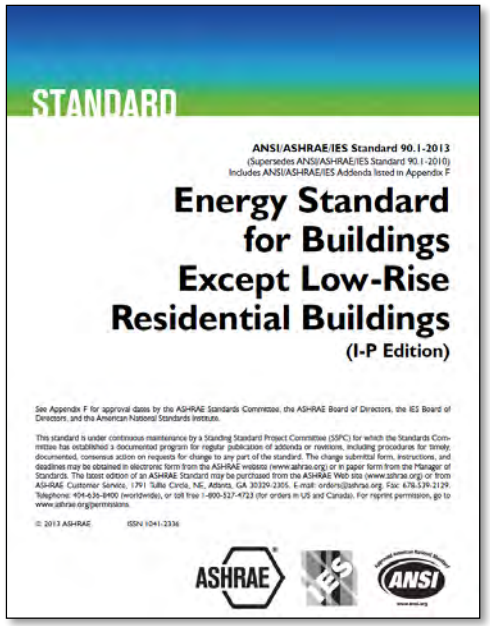
Validation Modeling

Baseline Case vs Proposed Case

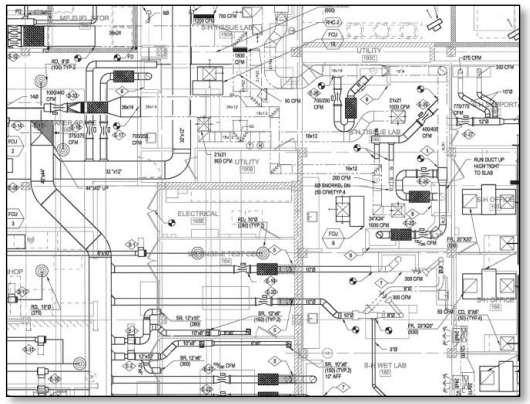
Per Code, based on:
-ASHRAE 90.1 (2007,2010,2013)
-IECC (2012, 2015)
-Stretch Code (10% better than code)
-Mass Save Baseline Document



-As Designed, based on:
-Architectural drawings
-MEP drawings
-Landscape drawings
-HVAC Narratives

ROOFTOP AIR HANDLING UNIT

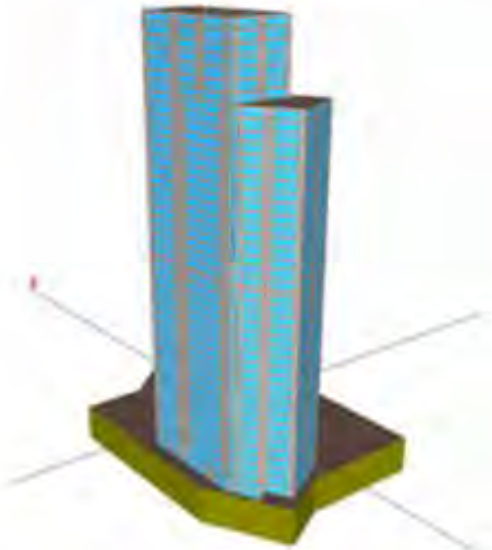
DESIGNATION	MANUF. MODEL NUMBER	LOCATION	SUPPLY FANS																RETURN FANS								CHILLED WATER COOLING COIL									
			TOTAL CFM	OUTSIDE AIR CFM	CAPACITY CONTROL		STATIC PRESS (IN.W.G.)		MODEL	CLASS	OUT. VEL (FPM)	FAN QTY	WHEEL		RPM	BHP	MOTOR H.P.	STATIC PRESS (IN.W.G.)		TOTAL CFM	FAN QTY	MOTOR H.P.	MODEL	WHEEL		RPM	TOTAL MBH	SENS. MBH	FACE VELOC. (FPM)	AIR SIDE			CHILLED WATER SIDE			
					TYPE	RANGE(%)	TOTAL W.P. (INLET)	TO UNIT EXTERNAL					DIA. (IN.)	TYPE				TOTAL	TO UNIT EXTERNAL					DIA. (IN.)	TYPE					UNIT EAT	UNIT LAT	P.D. (IN. W.G.)	ENT (°F)	LVT (°F)	GPM	P.D. (FT. H2O)
																													DB(°F)	WB(°F)	DB(°F)	WB(°F)				
AHU-1	VENTROL	ROOF	21,000	21,000	FW	-	6,75	3	-	-	520,7	4	14	-	3,866	(42,7	(43	3,8	2,5	6,000	2	(23	-	14	-	2,999	1,266,4	723,8	428,71	83,4	71	52,2	51,3	0,62	42	56	180,3	11,7
AHU-2	VENTROL	ROOF	21,000	21,000	FW	-	6,75	3	-		520,7	4	14	-	3,866	(42,7	(43	3,8	2,5	6,000	2	(23	-	14	-	2,999	1,266,4	723,8	428,71	83,4	71	52,2	51,3	0,62	42	56	180,3	11,7



Validation Modeling

Baseline Case Model

Identical Geometry, but all components built according to relevant code.



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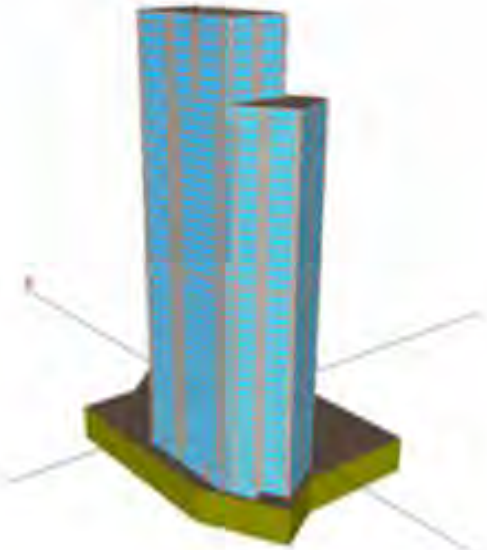
Proposed Case Model

Built to reflect all components of the design



=Savings (%)

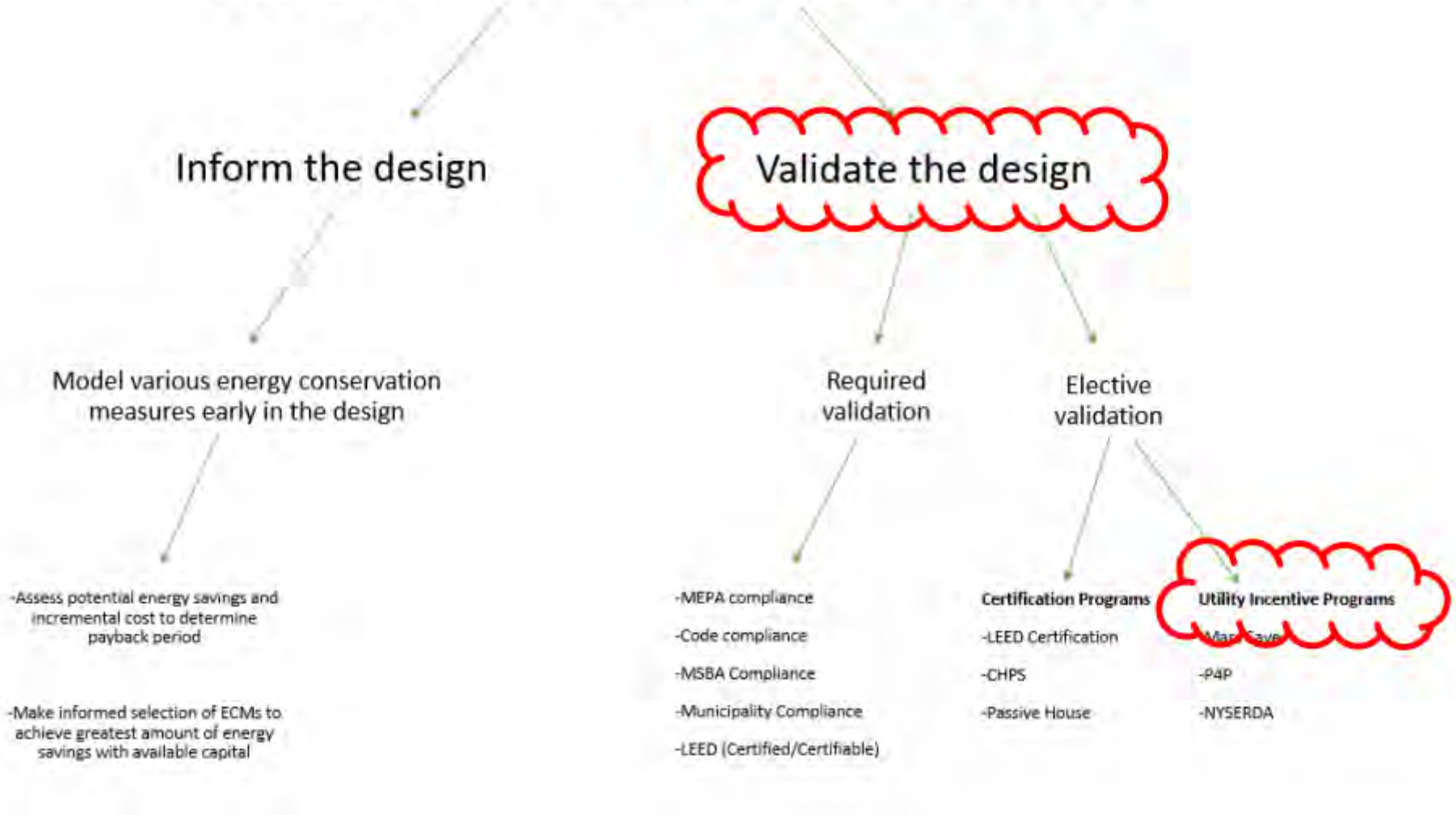
Validation Modeling

Metric to measure savings:

- Site Energy
- EUI (site energy kBTU/SF)
- Source Energy
- Energy Cost
- Green House Gas Emissions

Unfortunately, no standard metric, which confuses clients to no end.

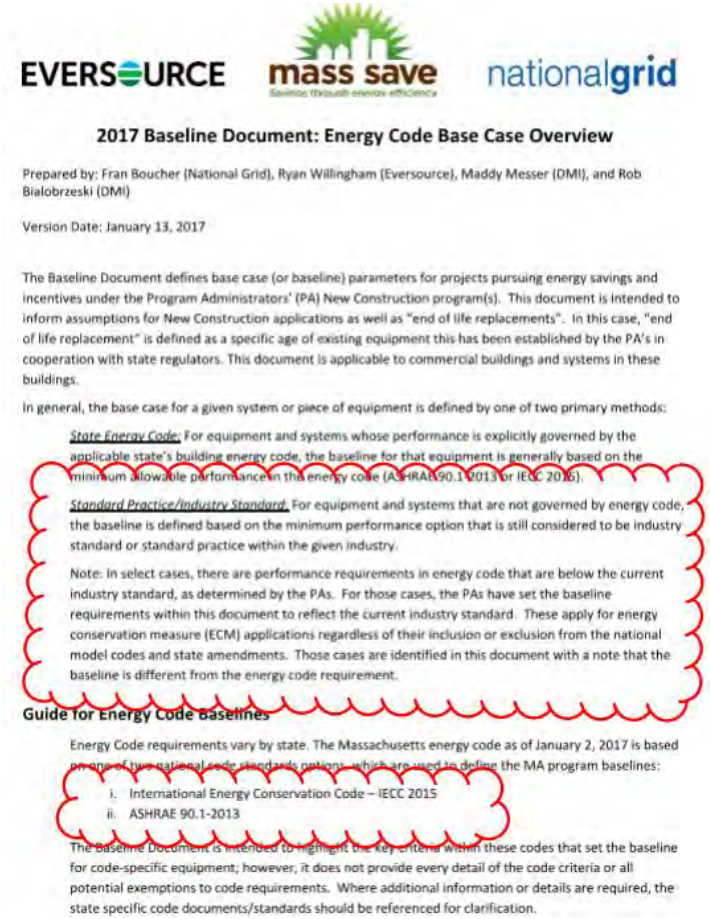
What is the Model Used For?



Utility Incentives

Commercial version of Mass Save program

- Baseline code: Altered version of ASHRAE 90.1 2013/IECC 2015)
- Energy Metric: Site energy
- Pays $/kWh saved
- Pays $/Therms saved



EVERSOURCE mass save nationalgrid

2017 Baseline Document: Energy Code Base Case Overview

Prepared by: Fran Boucher (National Grid), Ryan Willingham (Eversource), Maddy Messer (DMI), and Rob Bialobrzeski (DMI)

Version Date: January 13, 2017

The Baseline Document defines base case (or baseline) parameters for projects pursuing energy savings and incentives under the Program Administrators' (PA) New Construction program(s). This document is intended to inform assumptions for New Construction applications as well as "end of life replacements". In this case, "end of life replacement" is defined as a specific age of existing equipment this has been established by the PA's in cooperation with state regulators. This document is applicable to commercial buildings and systems in these buildings.

In general, the base case for a given system or piece of equipment is defined by one of two primary methods:

State Energy Code: For equipment and systems whose performance is explicitly governed by the applicable state's building energy code, the baseline for that equipment is generally based on the minimum allowable performance in the energy code (ASHRAE 90.1 2013 or IECC 2015).

Standard Practice/Industry Standard. For equipment and systems that are not governed by energy code, the baseline is defined based on the minimum performance option that is still considered to be industry standard or standard practice within the given industry.

Note: In select cases, there are performance requirements in energy code that are below the current industry standard, as determined by the PAs. For those cases, the PAs have set the baseline requirements within this document to reflect the current industry standard. These apply for energy conservation measure (ECM) applications regardless of their inclusion or exclusion from the national model codes and state amendments. Those cases are identified in this document with a note that the baseline is different from the energy code requirement.

Guide for Energy Code Baselines

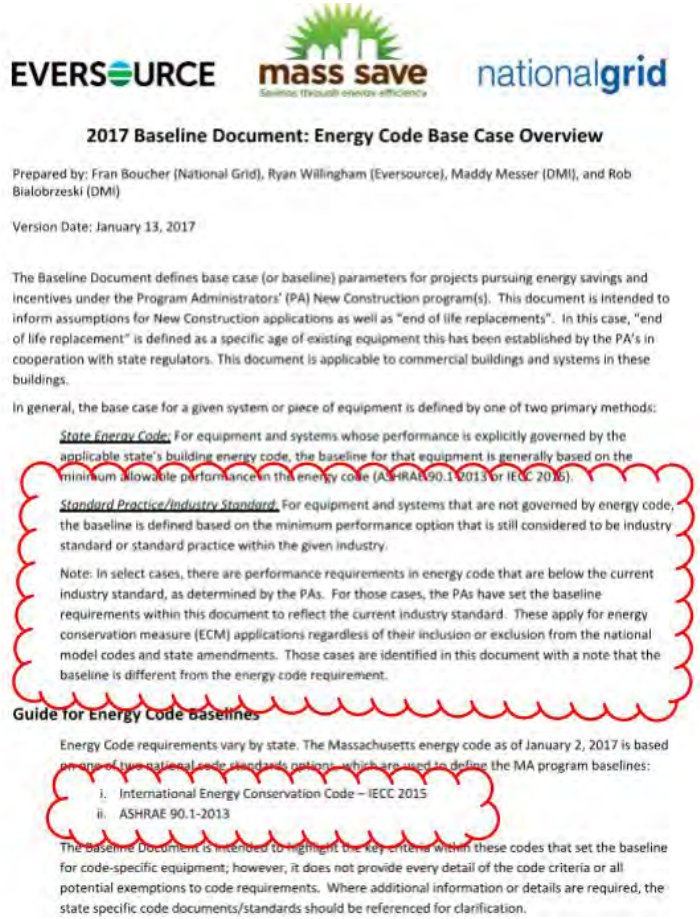
Energy Code requirements vary by state. The Massachusetts energy code as of January 2, 2017 is based on one of two national code standards options, which are used to define the MA program baselines:

i. International Energy Conservation Code – IECC 2015
ii. ASHRAE 90.1-2013

The Baseline Document is intended to highlight the key criteria within these codes that set the baseline for code-specific equipment; however, it does not provide every detail of the code criteria or all potential exemptions to code requirements. Where additional information or details are required, the state specific code documents/standards should be referenced for clarification.

Utility Incentives

- Utility Incentive Process
  - SD/DD Design Charrette (Potential ECMs)
  - DD Model with projected ECMs
  - Mass Save projects potential incentive $
  - Owner decides which ECMs to pursue
  - 100% CD Model with final ECMs
  - Post Construction inspection of Installed ECMs
  - Incentives distributed



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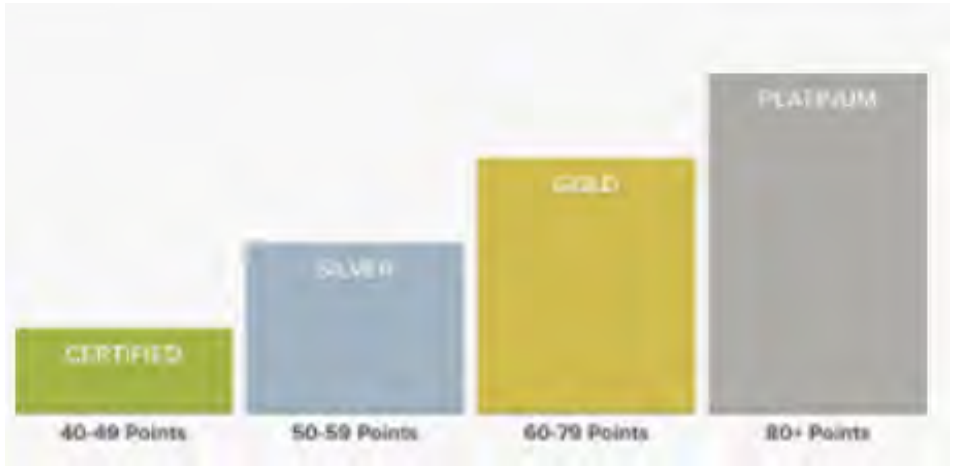
LEED Minimum Energy Prerequisite / Optimize Energy Performance



Optimize Energy Performance Credit

TABLE 1. Points for percentage improvement in energy performance

New Construction	Major Renovation	Core and Shell	Points (except Schools, Healthcare)	Points (Healthcare)	Points (Schools)
6%	4%	3%	1	3	1
8%	6%	5%	2	4	2
10%	8%	7%	3	5	3
12%	10%	9%	4	6	4
14%	12%	11%	5	7	5
16%	14%	13%	6	8	6
18%	16%	15%	7	9	7
20%	18%	17%	8	10	8
22%	20%	19%	9	11	9
24%	22%	21%	10	12	10
26%	24%	23%	11	13	11
29%	27%	26%	12	14	12
18%	16%	15%	7	9	7
20%	18%	17%	8	10	8
22%	20%	19%	9	11	9
24%	22%	21%	10	12	10
26%	24%	23%	11	13	11
29%	27%	26%	12	14	12
32%	30%	29%	13	15	13
35%	33%	32%	14	16	14
38%	36%	35%	15	17	15
42%	40%	39%	16	18	16
46%	44%	43%	17	19	-
50%	48%	47%	18	20	-

LEED Minimum Energy Performance / Optimize Energy Performance

- LEED V4
  - Baseline Code: ASHRAE 90.1 2010
  - Savings metric: % energy cost savings (typically)
  - Pre-requisite requires 5% energy cost savings (NC)
  - Optimize Energy Performance Credit 6%-50% (up to 18 points)

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18%	16%	15%	7	9	7
20%	18%	17%	8	10	8
22%	20%	19%	9	11	9
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38%	36%	35%	15	17	15
42%	40%	39%	16	18	16
46%	44%	43%	17	19	-
50%	48%	47%	18	20	-

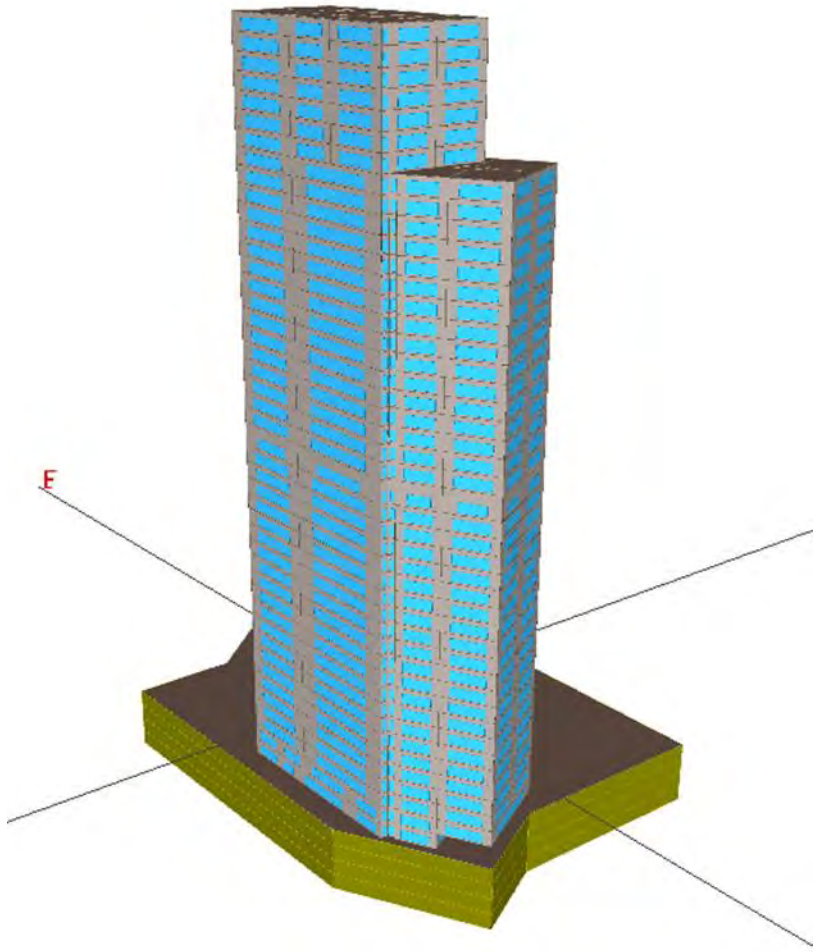
LEED Optimize Energy Performance Credit

Pursued Alternative Energy Performance Metric ACP

-Replaces Energy cost as the energy savings metric with:
- -Source energy savings
- -GHG emissions savings

-Provides a more meaningful environmental metric, in which relative cleanliness of the local grid is accounted for

-Beneficial for projects in New England, given how clean our grid is



LEED Optimize Energy Performance Credit

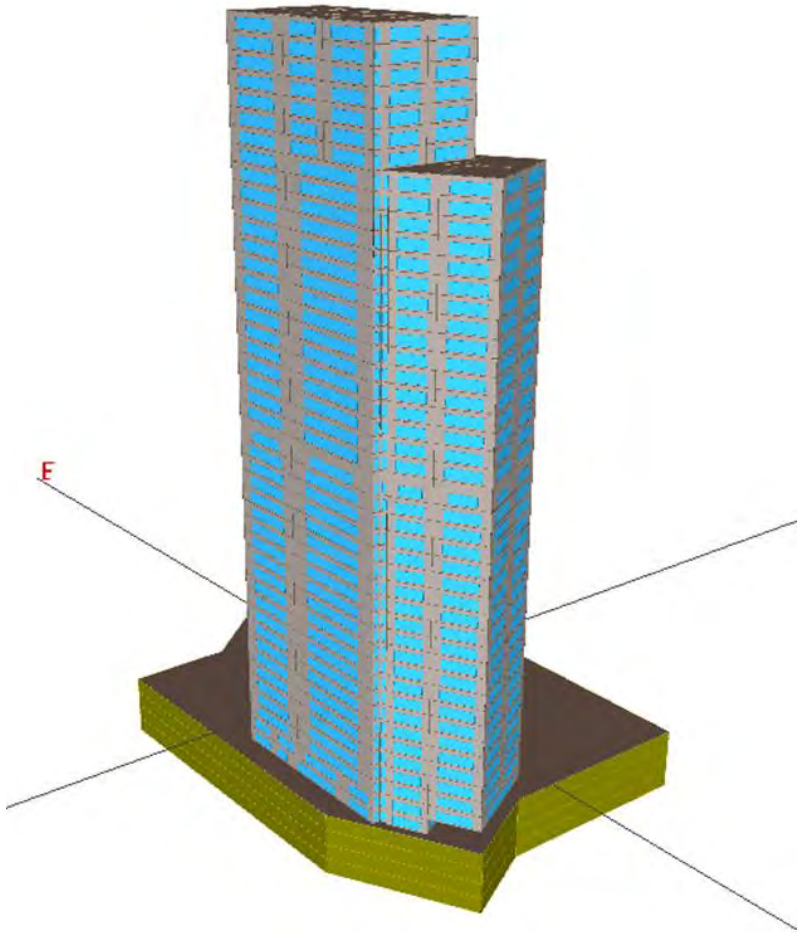
ACP: Greenhouse Gas Emissions

ENERGY STAR® PortfolioManager® Technical Reference

Figure 5 – Indirect Greenhouse Gas Emission Factors for Electricity in the U.S.

eGRID Regional Description	eGRID Acronym	CO_{2eq} Emissions (kg/MBtu)
South/Central Alaska	AKGD	143.21
Most of Alaska	AKMS	67.11
Southwest US	AZNM	139.45
Southwest Coast	CAMX	70.44
Most of TX	ERCT	134.81
Most of Florida	FRCC	135.11
HI excluding Oahu	HIMS	154.03
Oahu Island	HIOA	222.70
Eastern WI	MROE	223.24
Upper Midwest	MROW	[illegible]
New England	NEWE	74.94
Northwest US	NWPP	[illegible]
New York City	NYCW	84.69
Long Island, NY	NYLI	157.66
Upstate NY	NYUP	39.34
Mid Atlantic	RFCE	101.31
Most of Michigan	RFCM	170.01
Ohio Valley	RFCW	166.36
CO-Eastern WY	RMPA	183.02
KS-Western MO	SPNO	189.06
TX Panhandle-OK	SPSO	166.81
Lower Mississippi	SRMV	111.95
Middle Mississippi	SRMW	215.68
SE US, Gulf Coast	SRSO	145.58
Tennessee Valley	SRTV	158.54
Virginia/Carolina	SRVC	107.69
National Average		133.49

Energy Source	*GHG Emission Factor (kG/Btu x 10^6)*	*Baseline (kg CO2 Emissions)*	*Proposed (kg CO2 Emissions)*
Electricity	76.67	1,320,798.3	1,316,659.8
Natural Gas	53.11	1,131,715.7	611,094.3
		-	-
		-	-
		-	-
		-	-
Total		**2,452,514.0**	**1,927,754.1**
Savings			**21.40%**



LEED Optimize Energy Performance Credit

ACP: Source Energy

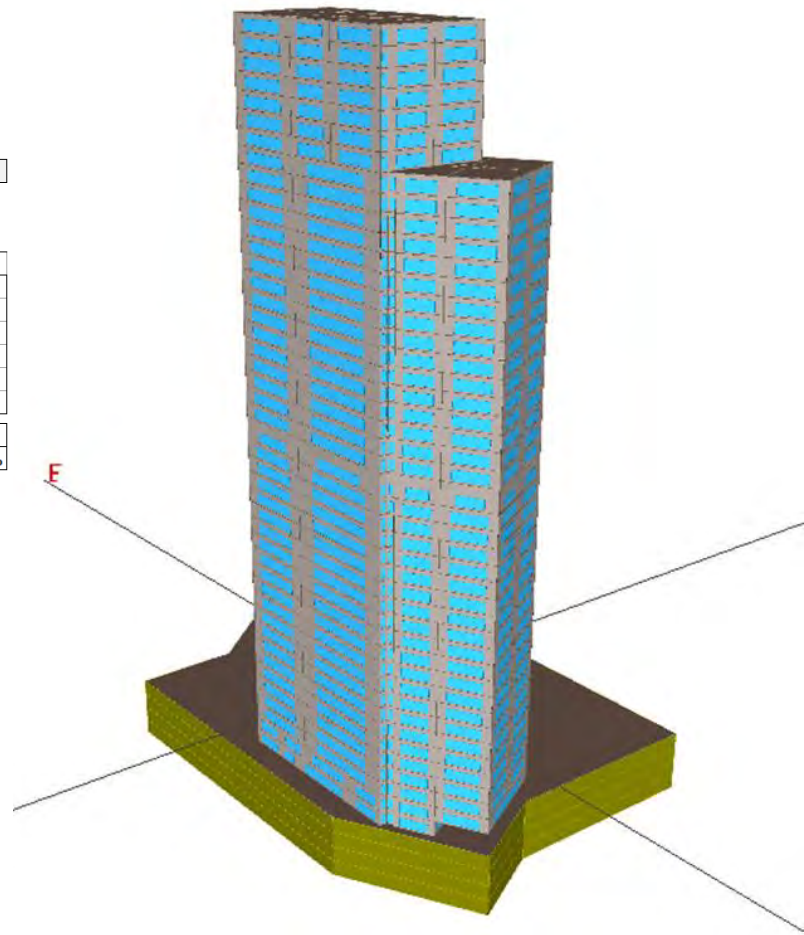
Figure 1 – Source-Site Ratios for all Portfolio Manager Energy Meter Types

Energy Type	U.S. Ratio	Canadian Ratio
Electricity (Grid Purchase)	2.80	1.96
Electricity (Onsite Solar or Wind, RECs Retained)	1.00	1.00
Electricity (Onsite Solar or Wind, RECs Sold/Arbitrage)	2.80	1.96
Natural Gas	1.05	1.01
Fuel Oil (No. 1,2,4,5,6, Diesel, Kerosene)	1.01	1.01
Propane & Liquid Propane	1.01	1.04
Steam	1.20	1.33
Hot Water	1.20	1.33
Chilled Water	0.91	0.57
Wood	1.00	1.00
Coal/Coke	1.00	1.00
Other	1.00	1.00

Source Energy (US) - ENERGY STAR Portfolio Manager

Indicate the source-to-site ratios or primary energy factors for each building energy source.

Energy Source	*Source-to-Site Ratio*	*Baseline (Btu x 10^6)*	*Proposed (Btu x 10^6)*
Electricity	3.14	54,093.0	53,923.5
Natural Gas	1.05	22,374.3	12,081.5
		-	-
		-	-
		-	-
		-	-
Total		**76,467.3**	**66,005.0**
Savings			**13.68%**



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		-	-
		-	-
		-	-
		-	-
Total		**76,467.3**	**66,005.0**
Savings			**13.68%**

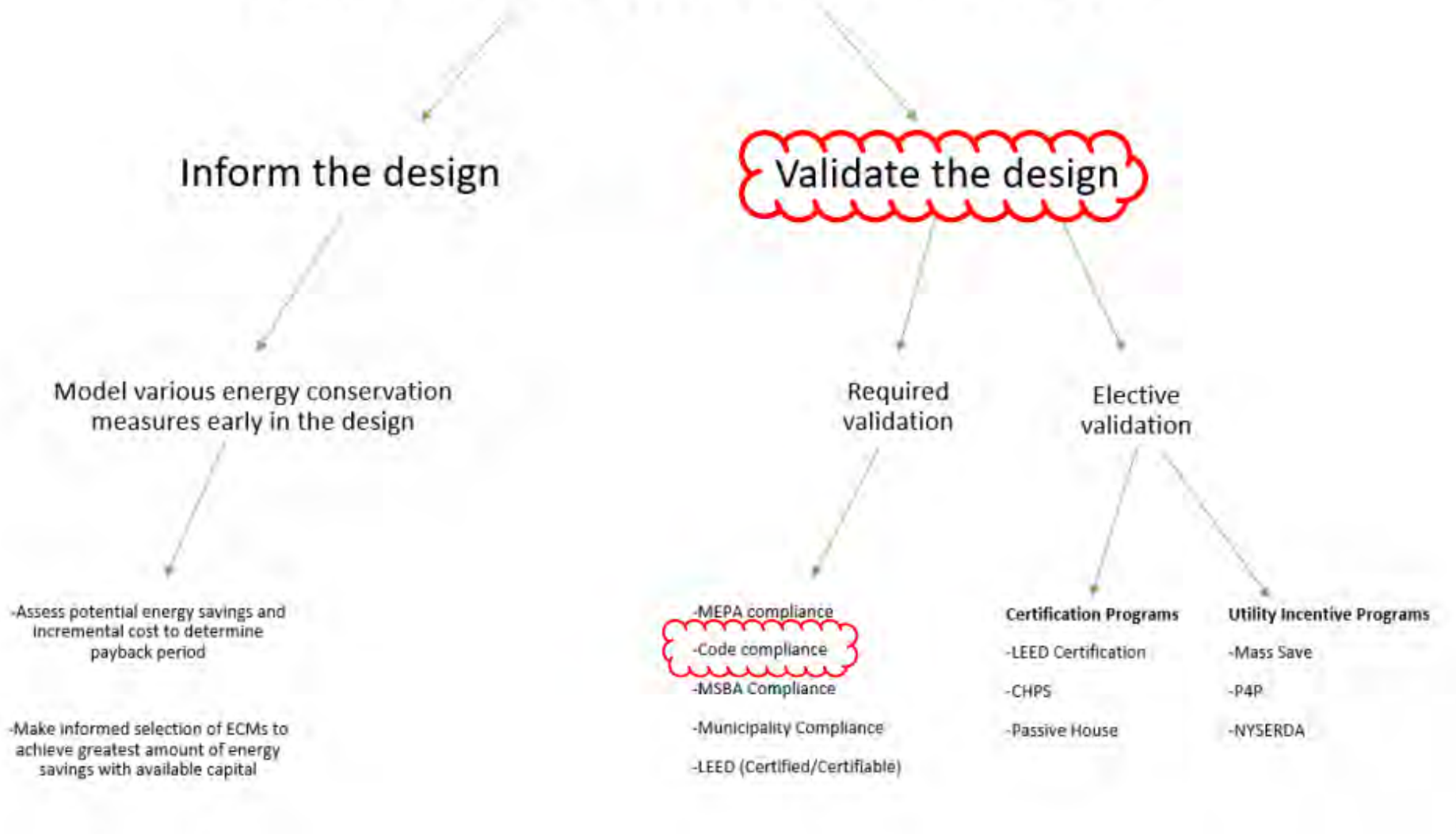
Percentage Improvement Used to Determine Minimum Energy Performance Prerequisite Compliance and Optimize Energy Performance Points:

Savings	**17.54%**

TABLE 1. Points for percentage improvement in energy performance

New Construction	Major Renovation	Core and Shell	Points (except Schools, Healthcare)	Points (Healthcare)	Points (Schools)
6%	4%	3%	1	3	1
8%	6%	5%	2	4	2
10%	8%	7%	3	5	3
12%	10%	9%	4	6	4
14%	12%	11%	5	7	5
16%	14%	13%	6	8	6
18%	16%	15%	7	9	7
20%	18%	17%	8	10	8
22%	20%	19%	9	11	9
24%	22%	21%	10	12	10
26%	24%	23%	11	13	11
29%	27%	26%	12	14	12
18%	16%	15%	7	9	7
20%	18%	17%	8	10	8
22%	20%	19%	9	11	9
24%	22%	21%	10	12	10
26%	24%	23%	11	13	11
29%	27%	26%	12	14	12
32%	30%	29%	13	15	13
35%	33%	32%	14	16	14
38%	36%	35%	15	17	15
42%	40%	39%	16	18	16
46%	44%	43%	17	19	-
50%	48%	47%	18	20	-

What is the Model Used For?



Code Compliance

Code Compliance in Massachusetts

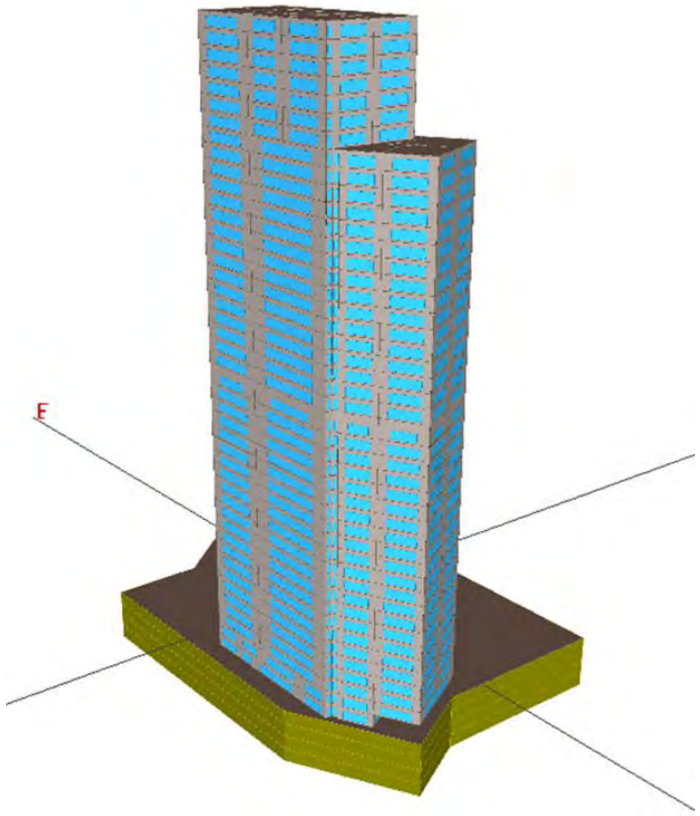
- Energy modeling is used when a project can't use prescriptive compliance path
- Baseline Code: IECC 2015 / ASHRAE 90.1 2013 (with MA amendments)
- Energy metric: Site energy
- Projects must use meet, or use less energy than the Baseline
- Massachusetts Stretch Code: Buildings >100,000 SF must use 10% less site energy than Baseline (if in a stretch code community)

Code Compliance

Table 2: Energy Savings

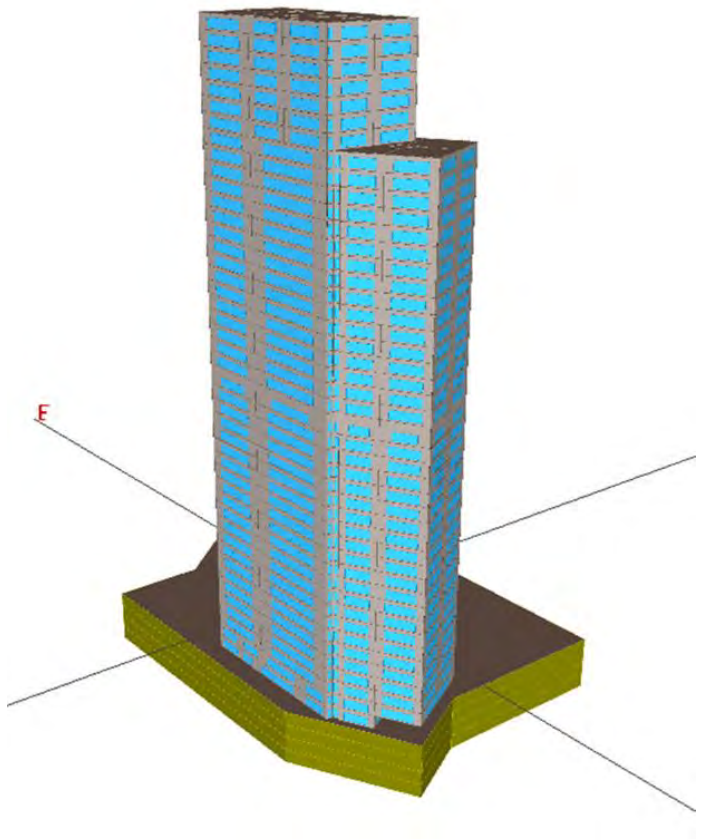
	Total Site (MBTU)	Site Energy (%)
Baseline	34,686	NA
Proposed	27,796	19.8%

Propose design used 19.8% less site energy than ASHRAE 90.1 2013 Baseline



Models Completed for Project

- Design Assistance Model (~15 sets of ECMs)
- Final 100% CD Proposed Case model
- LEED Baseline (ASHRAE 90.1 2010)
- Utility incentive Baseline (Altered ASHRAE 90.1 2013)
- Code Compliance Baseline (ASHRAE 90.1 2013)



Daylighting Analysis

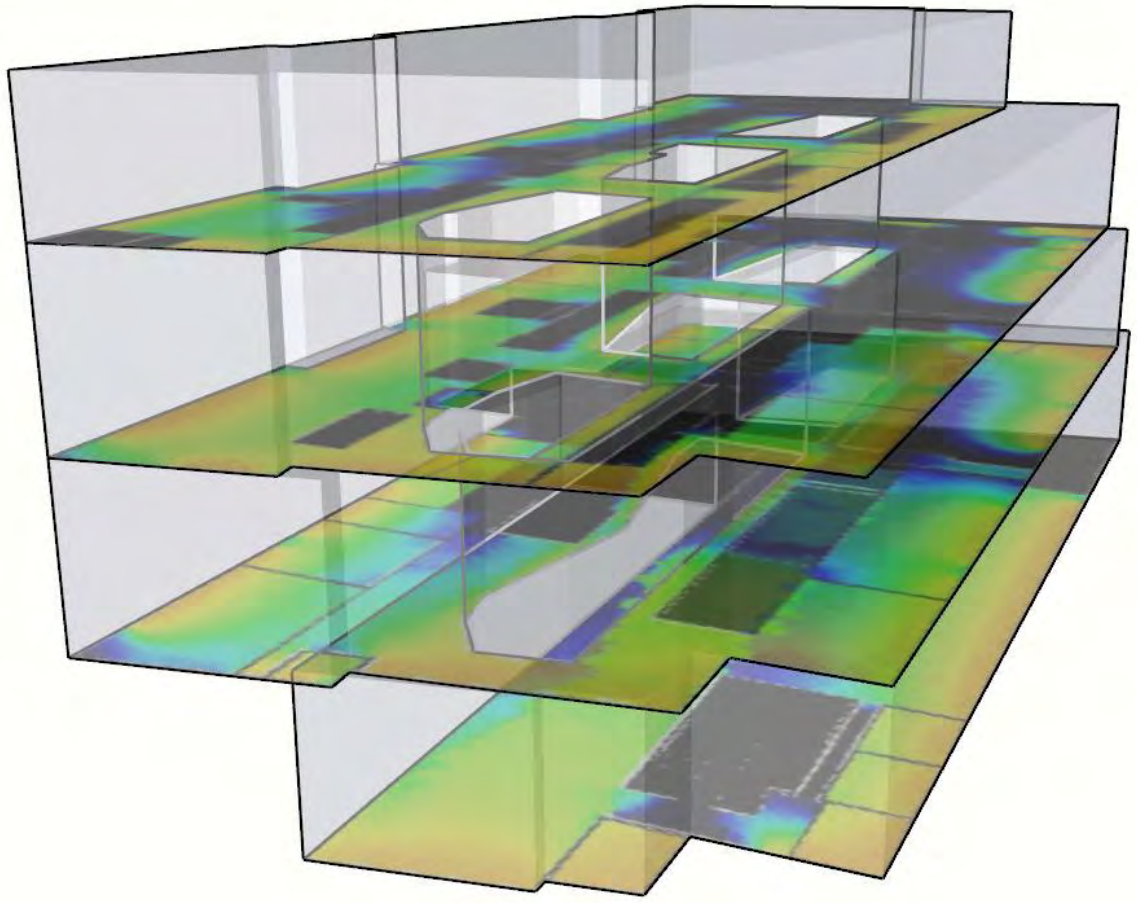
- Types of Daylighting Analysis

- Illuminance study
  - Point in time analysis (typically 9am, 12pm, 3pm on the Solstices and equinox

- Spatial Daylight autonomy
  - Runs daylight analysis of every hour of the year, based on TMY weather file

  - Percent of occupied hours that there is adequate daylight (300 lux) such that artificial light is not needed.

  - ASE: Percent of occupied hours that there is greater than 1,000 lux, creating glare issues



What Are Daylight Models Used For

Inform the design

-Study daylight opportunities

- Mitigate glare issues

Validate the design

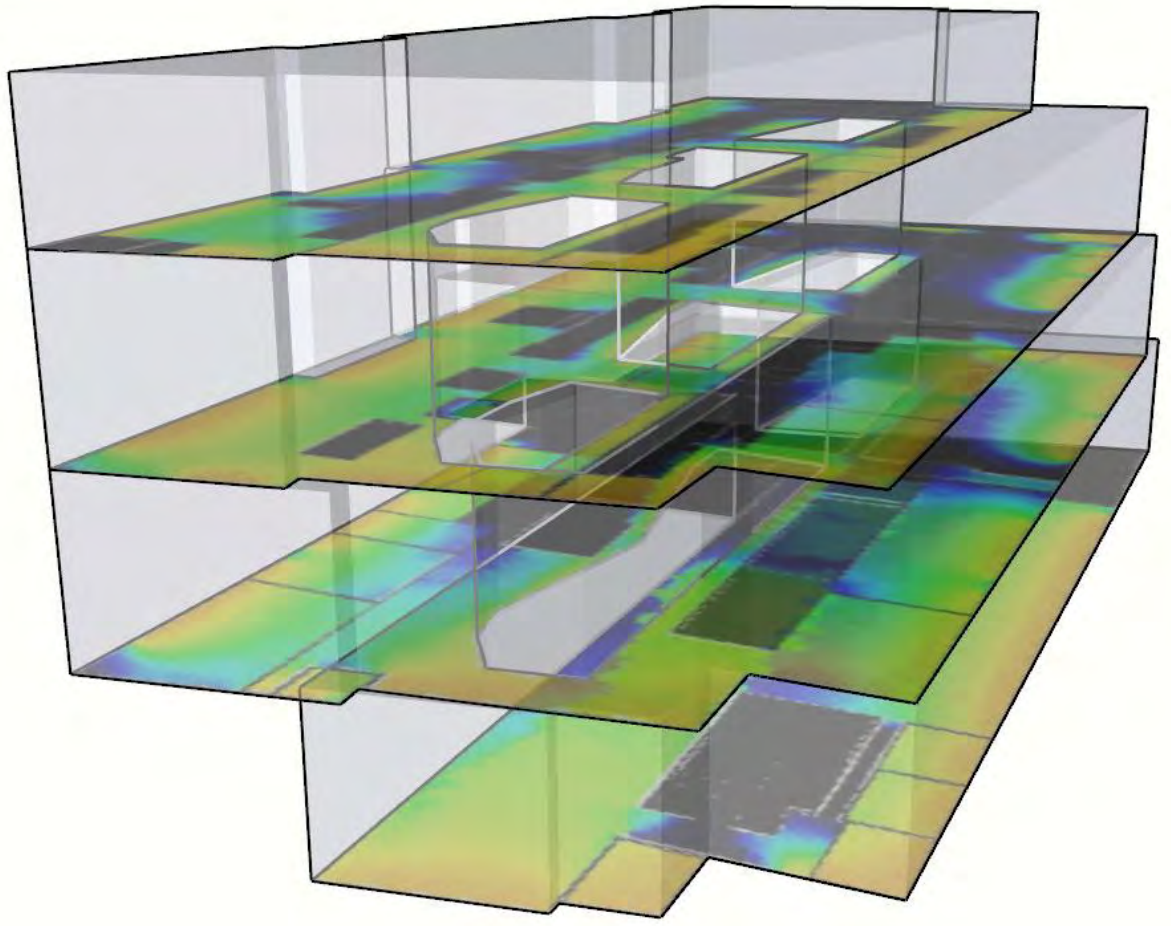
-LEED Daylighting Credit

Daylight to Inform the Design

Large Office Building in Boston

- First floor Lobby/Café adjacent to a heavily glazed wall

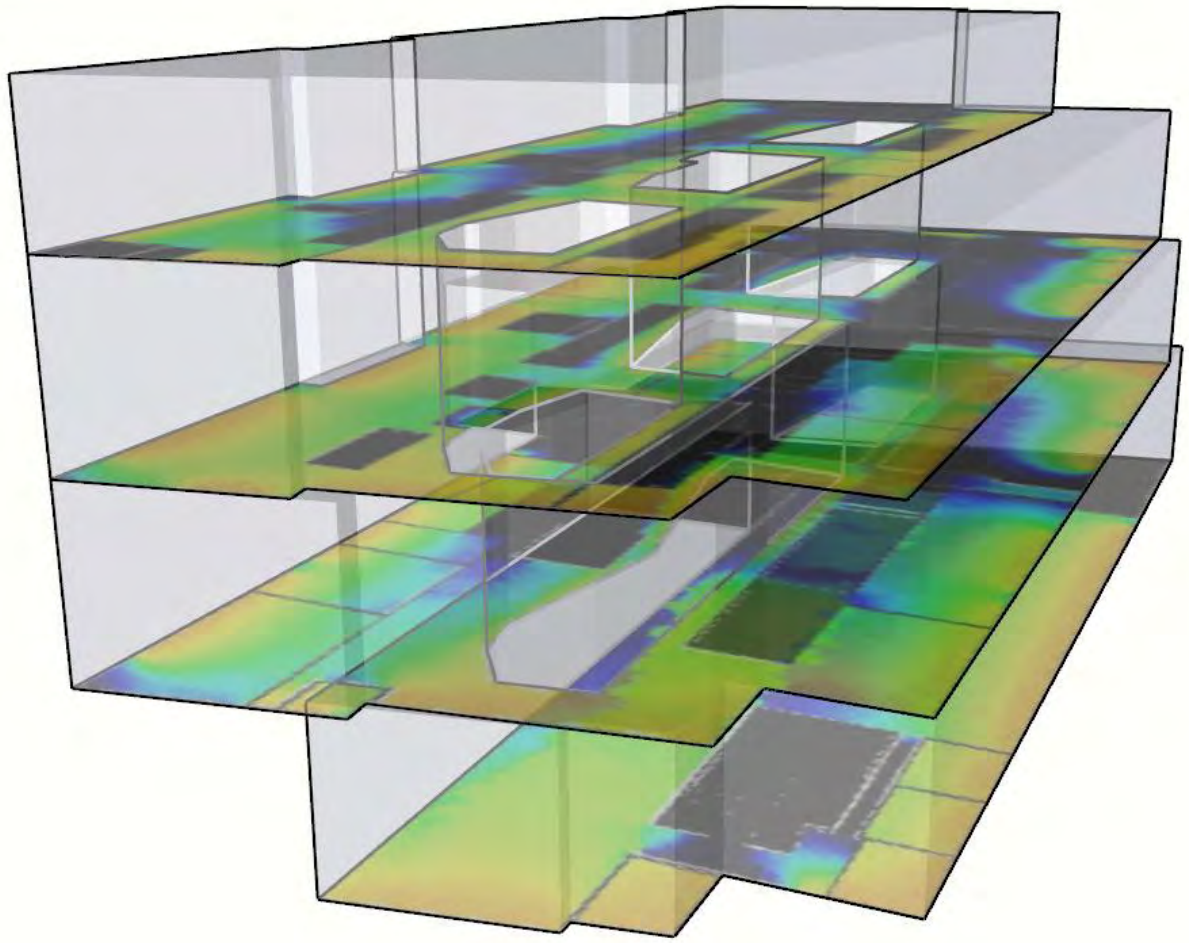
- Primary concern was controlling glare in Lobby/Café without reducing daylight too much



Daylight to Inform the Design

Options Studied

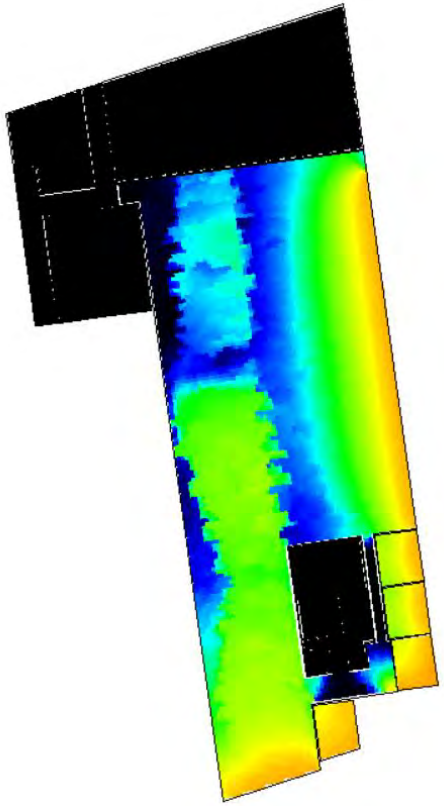
- Original Design
- Reduced VLT
- Shading fins



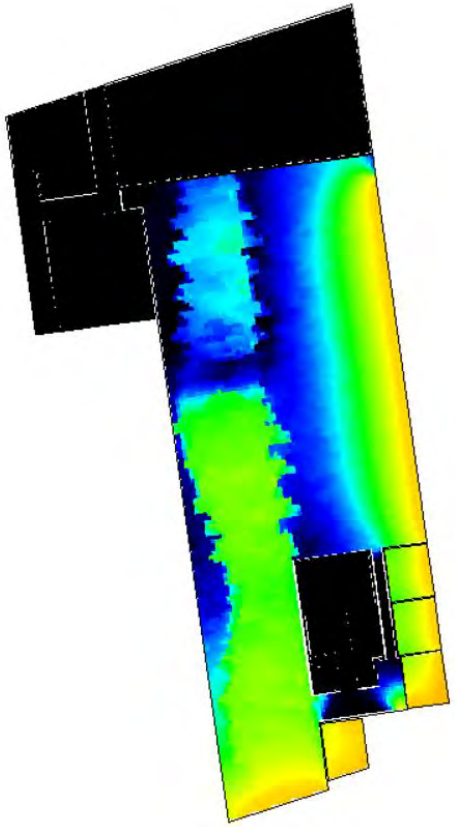
Daylighting to Inform the Design

SDA Analysis (% of occupied hours above 300 lux)

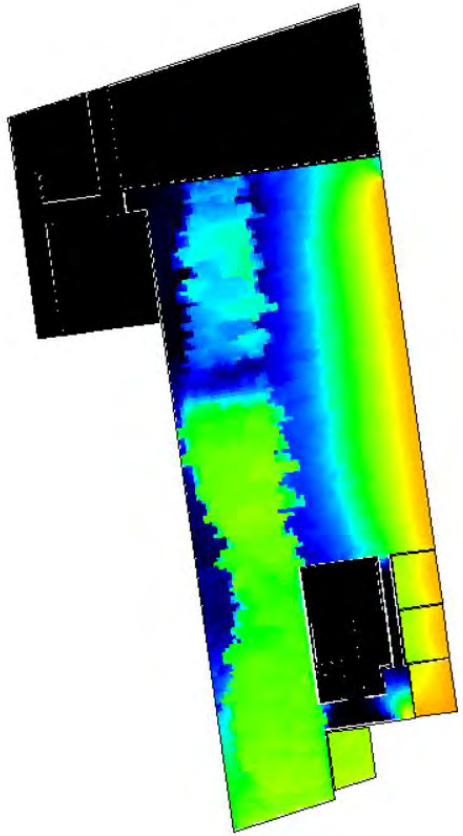
Original Design

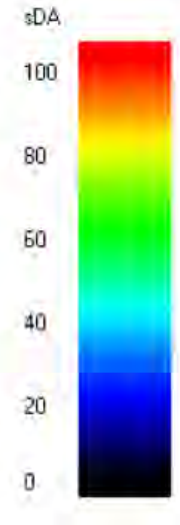


Low VLT



Shading Fins

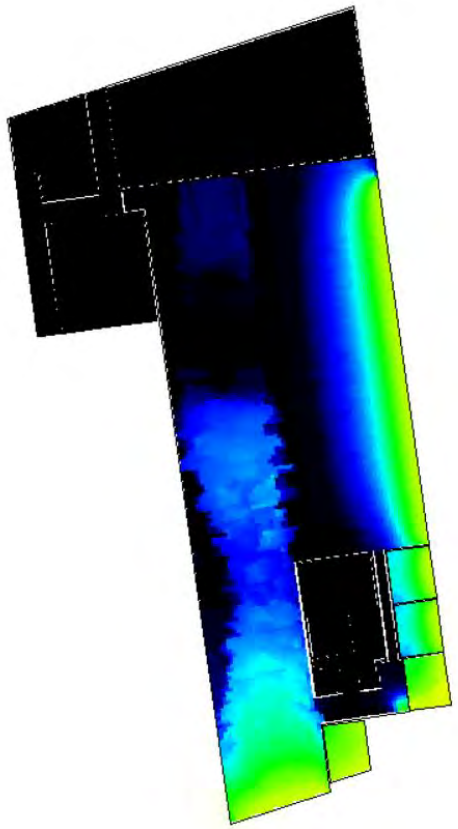




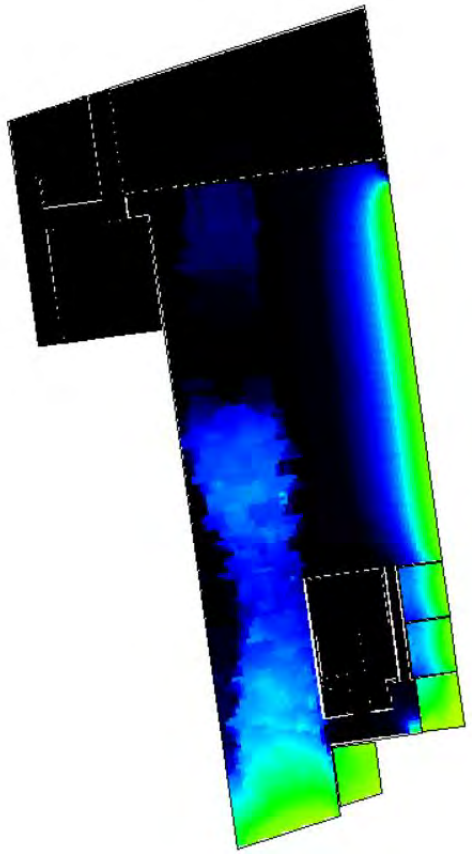
Daylighting to Inform the Design

Glare Analysis (% of occupied hours above 1,000 lux)

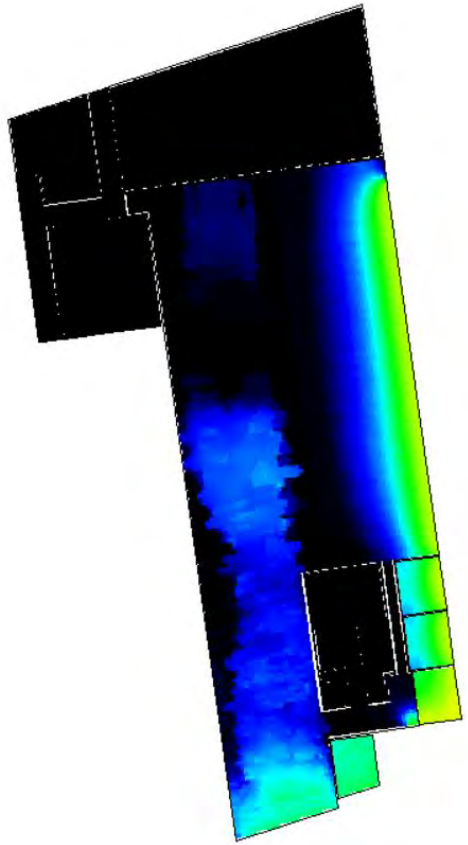
Original Design

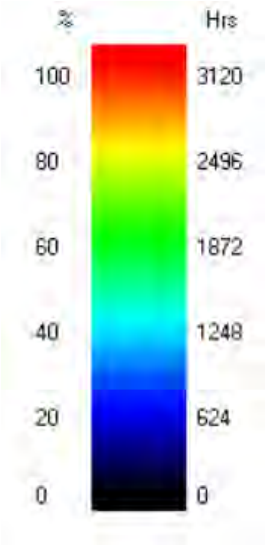


Low VLT



Shading Fins





Daylighting for LEED

- 3 ways to achieve daylight credit
  - SDA 300/50 (300 lux for 50% of occupied hours)
  - Illuminance
  - On site measurement options

- Only counts “Regularly occupied spaces”

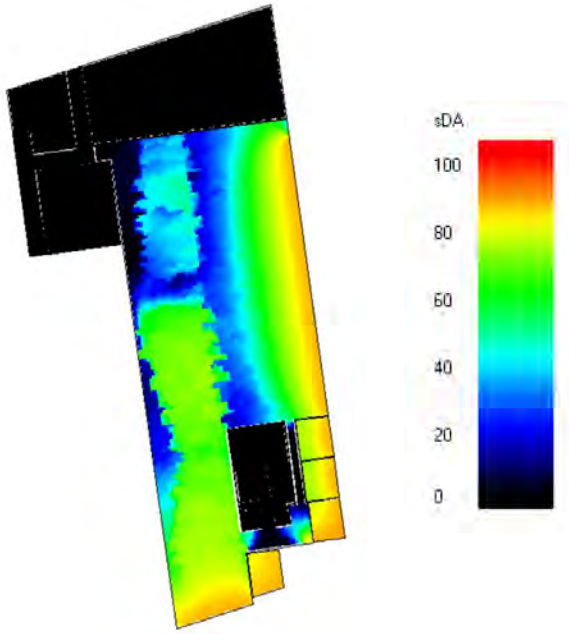
- Daylighting credit was very difficult in LEED V4, but has been updated to be more achievable in LEED V4.1.

Daylighting for LEED

SDA analysis for LEED V4.1

Table 1. Points for Option 1

	New Construction, Core and Shell, Schools, Retail, Data Centers, Warehouses and Distribution Centers, Hospitality	Healthcare
The average $sDA_{300/50\%}$ value for the regularly occupied floor area is at least **40%**	1 point	1 point
The average $sDA_{300/50\%}$ value for the regularly occupied floor area is at least **55%**	2 points	2 points
The average $sDA_{300/50\%}$ value for the regularly occupied floor area is at least **75%**	3 points	Exemplary performance



- If over 10% of regularly occupied spaces with over 1,000 Lux for 250 hours/year identify how the glare will be addressed.