

Understanding Energy Modeling

USGBC-NCC Sacramento Branch

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SMUD

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Learning Objectives

After the presentation, attendees will be able to:

- Identify appropriate uses for energy modeling
- Specify energy modeling for a wide variety of project types
- Integrate energy modeling milestones into their projects
- Choose design options based on client goals and energy modeling results

Topics

- Definition of energy modeling
- Using energy modeling
 - Appropriate uses
 - Timing
 - Who does it
- New construction applications
- Existing building applications
- Demonstration (time and interest permitting)

What is Building Energy Modeling?

Building energy estimation using
a computer model of energy flow and processes

Loads

- Determine cooling and heating loads by mathematically simulating the thermal performance of the building
- Typically hour-by-hour for a full year

Energy

- Determine energy use over the course of a year by mathematically simulating the performance of HVAC equipment in response to these loads

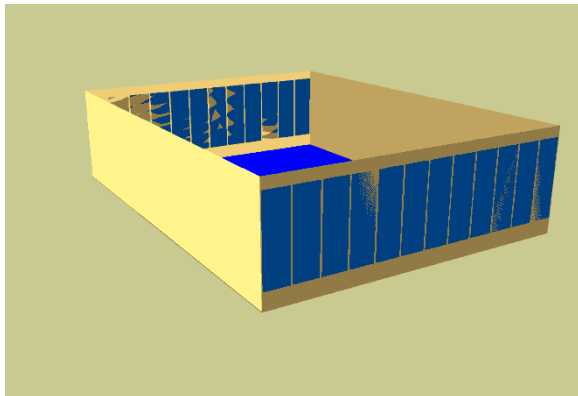
Cost

- Calculate operating costs using the energy data

Airport Terminal Example Conceptual Design Study

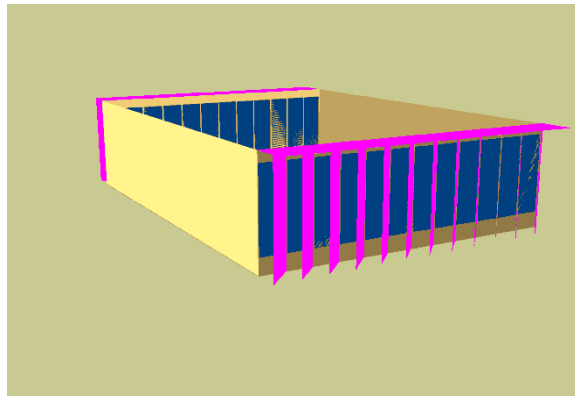
Baseline Design

- Double-loaded boarding area (60 ft slice)
- East/west facing glass
- Title 24-2005 compliant



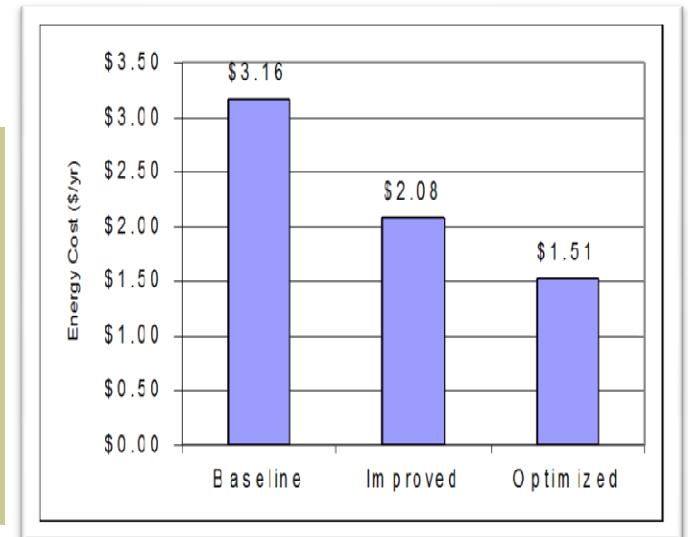
Improved Design

- Efficient lighting design
- High performance glazing
- Exterior shading – overhangs and fins



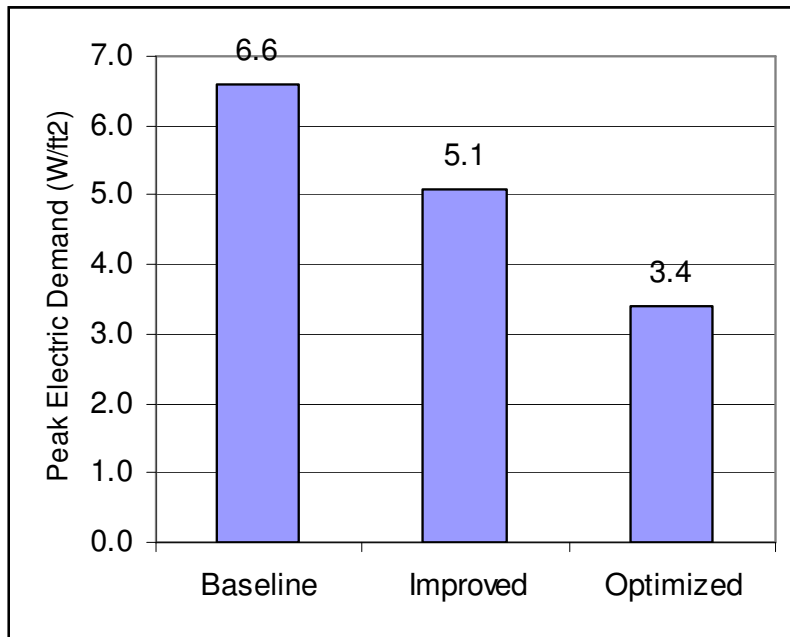
Optimized Design

- Daylighting controls
- Displacement ventilation
- Demand control ventilation

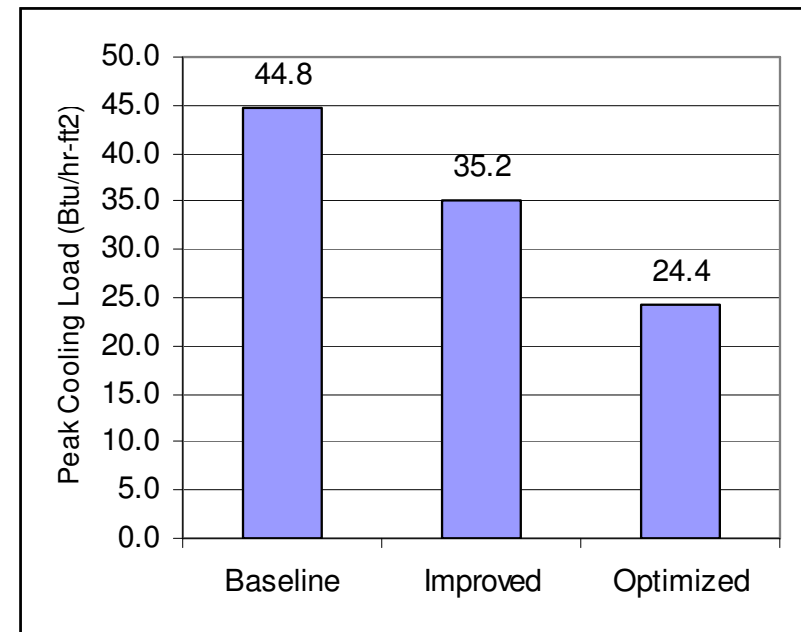


Airport Terminal Example (continued)

Peak Electric Demand (watts/ft²)



Peak Cooling Load (Btu/hr/ft²)



High-Rise Office Example Design Development Study

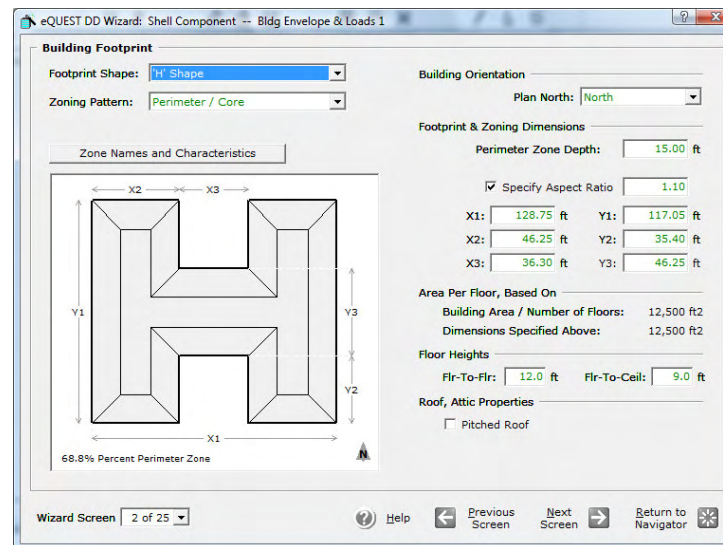
- 18 stories; 400,000 ft²
- LEED silver goal
- Constrained construction budget

Table 1. Energy Efficiency Measures and Approximate LEED Energy Credit Impact

No.	Efficiency Measure	Energy Cost Savings (\$/yr)	Percent Savings vs. Baseline	Approx. Additional LEED Points
1	Four-foot overhang	\$13,500	2.7%	0.54
2	Lighting power reduction, 1.3 to 1.0 W/ft ² in offices	\$30,600	6.1%	1.22
3	Lighting power reduction, 1.0 to 0.9 W/ft ² in offices	\$11,400	2.3%	0.46
4	Lighting occupancy sensors, private offices	\$6,200	1.2%	0.25
5	Lighting occupancy sensors, open offices	\$7,100	1.4%	0.28
6	Lighting occupancy sensors, support areas	\$1,700	0.3%	0.07
7	Lighting daylight dimming controls, open office	\$10,700	2.1%	0.43
8	Lighting daylight dimming controls, private office	\$9,700	1.9%	0.39
9	Hot water reheat	\$25,000	5.0%	1.00
10	Premium efficiency motors for fans and pumps	\$2,100	0.4%	0.08
11	Higher efficiency chiller (0.50 kW/ton at 44/85)	\$8,300	1.7%	0.33
12	Low face velocity air filters and coils (0.5 in w.c. reduction)	\$4,800	1.0%	0.19
	Totals	\$131,100	26%	5.24
	Subtotal of 2 - 12 (no overhang)	\$117,600	24%	4.70
	Subtotal of 2-6 & 9-12 (no overhang, no daylighting)	\$97,200	19%	3.89

Typical Energy Model Inputs

- Weather data
- Building geometry
- Thermal zones
- Construction types
 - Walls, roof, windows, floors
- Internal heat gains
 - Number of occupants
 - Lights
 - Equipment
 - Usage schedules
- Air infiltration rate
- HVAC type / usage
 - System type
 - Component performance
 - Ventilation rate
 - Controls, thermostat schedules
- Utility Rates



Typical Energy Model Outputs

- **Outputs**

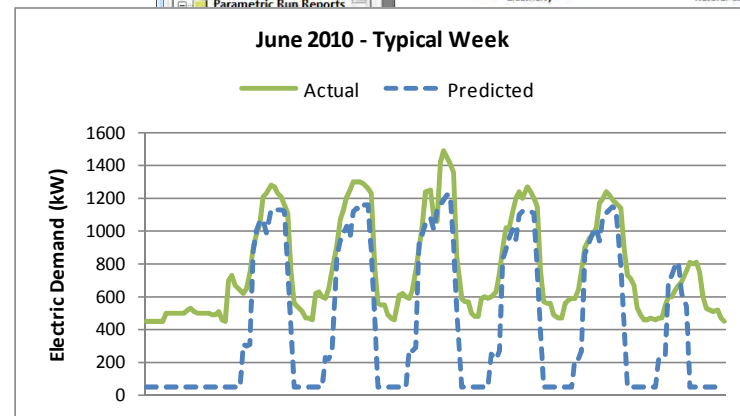
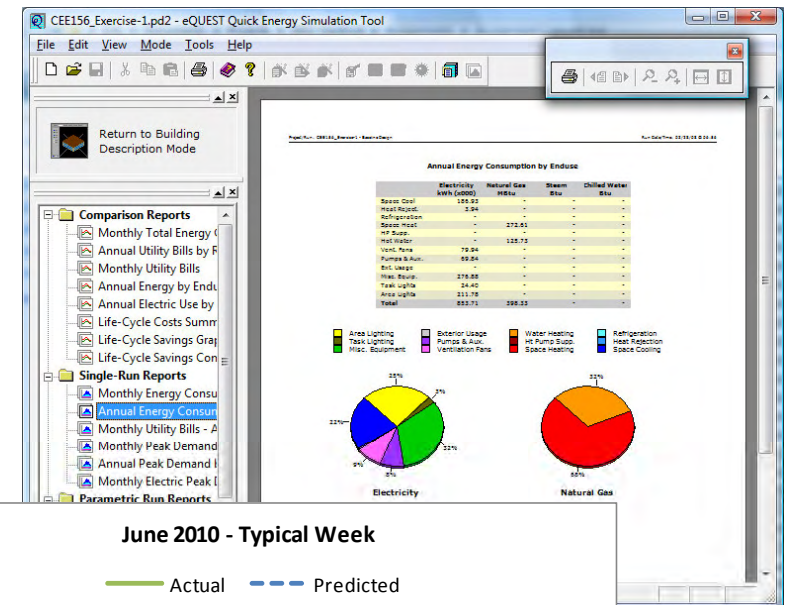
- Heating and cooling loads
- Airflows
- HVAC equipment sizing
- Energy consumption
- Energy costs

- **Format**

- Annual
- Monthly
- Hourly

- **Generally text-based**

- **Interfaces may provide summaries, graphs...**



DOE2.2 Output File

Assignment 3-3-skinny

DOE-2.2-47h2 4/13/2011 11:36:16 BDL RUN 12

REPORT- LS-B Space Peak Load Components EL1 South Perim Spc (G.S1) DESIGN DAY WEATHER FILE- CZ04RV2 WYEC2

SPACE EL1 South Perim Spc (G.S1)
SPACE TEMPERATURE USED FOR THE LOADS CALCULATION IS 70 F / 21 C

MULTIPLIER 1.0 FLOOR MULTIPLIER 1.0
FLOOR AREA 7275 SQFT 676 M2
VOLUME 72750 CUFT 2060 M3

TIME	COOLING LOAD		HEATING LOAD	
	NOV 17 2PM		DEC 21 6AM	
DRY-BULB TEMP	92 F	34 C	26 F	-3 C
WET-BULB TEMP	66 F	19 C	22 F	-6 C
TOT HORIZONTAL SOLAR RAD	152 BTU/H.SQFT	477 W/M2	0 BTU/H.SQFT	0 W/M2
WINDSPEED AT SPACE	4.4 KTS	2.2 M/S	8.7 KTS	4.5 M/S
CLOUD AMOUNT 0 (CLEAR) -10	0		10	

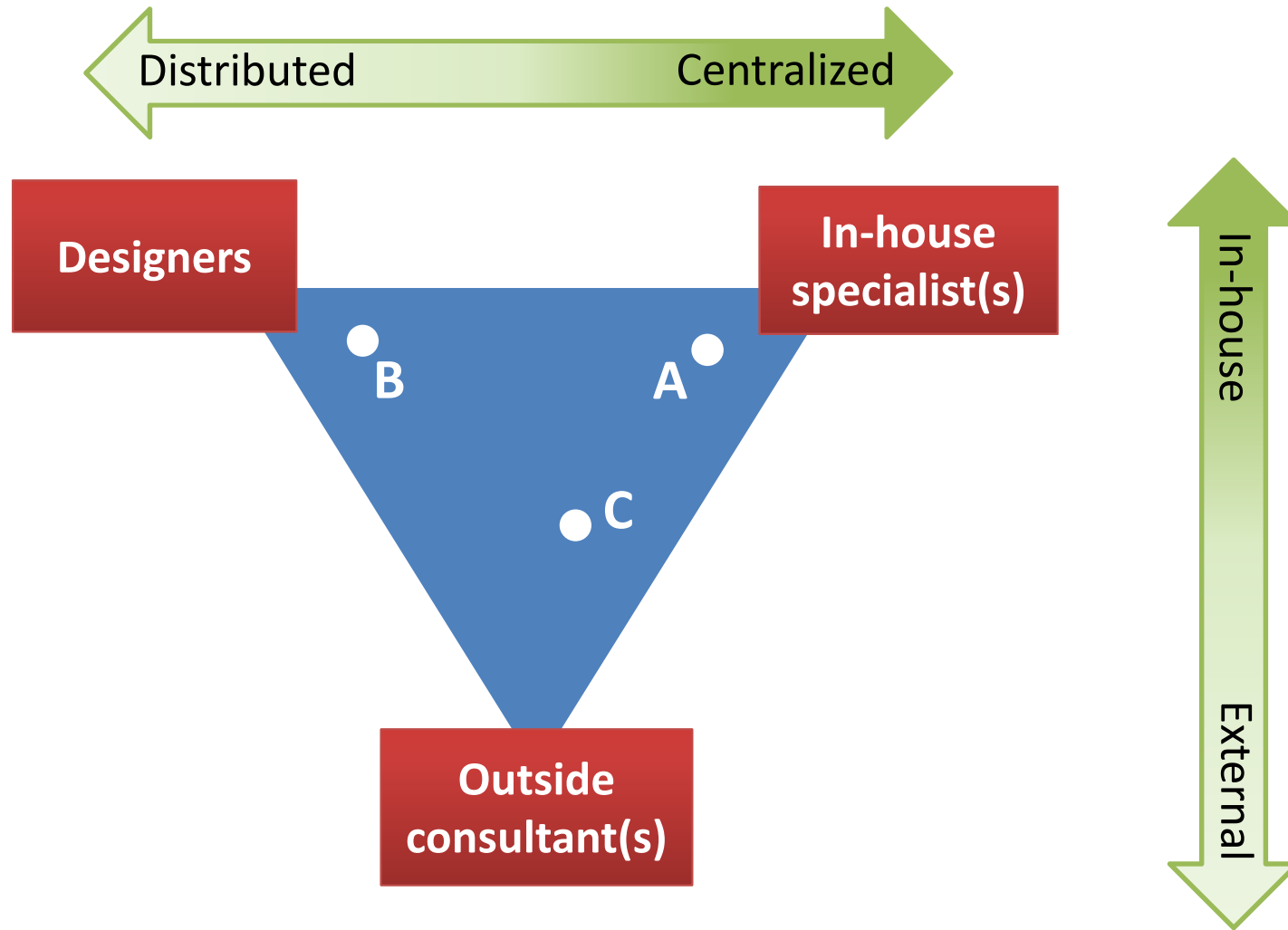
	SENSIBLE		LATENT		SENSIBLE			
	(KBTU/H)	(KW)	(KBTU/H)	(KW)	(KBTU/H)	(KW)		
WALL CONDUCTION	9.377	2.748	0.000	0.000	-6.331	-1.855		
ROOF CONDUCTION	0.000	0.000	0.000	0.000	0.000	0.000		
WINDOW GLASS+FRM COND	23.176	6.791	0.000	0.000	-61.733	-18.088		
WINDOW GLASS SOLAR	142.520	41.758	0.000	0.000	2.072	0.607		
DOOR CONDUCTION	0.000	0.000	0.000	0.000	0.000	0.000		
INTERNAL SURFACE COND	0.000	0.000	0.000	0.000	0.000	0.000		
UNDERGROUND SURF COND	-3.705	-1.086	0.000	0.000	-6.033	-1.768		
OCCUPANTS TO SPACE	6.164	1.806	7.101	2.081	0.000	0.000		
LIGHT TO SPACE	5.892	1.726	0.000	0.000	0.000	0.000		
EQUIPMENT TO SPACE	13.596	3.983	0.000	0.000	0.000	0.000		
PROCESS TO SPACE	0.000	0.000	0.000	0.000	0.000	0.000		
INFILTRATION	5.634	1.651	0.000	0.000	-8.817	-2.583		
TOTAL	202.652	59.377	7.101	2.081	-80.841	-23.686		
TOTAL / AREA	0.028	0.088	0.001	0.003	-0.011	-0.035		
TOTAL LOAD	209.753	KBTU/H	61.458	KW	-80.841	KBTU/H	-23.686	KW
TOTAL LOAD / AREA	28.83	BTU/H.SQFT	90.931	W/M2	11.112	BTU/H.SQFT	35.046	W/M2

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*****
* NOTE 1) THE ABOVE LOADS EXCLUDE OUTSIDE VENTILATION AIR *
* ---- LOADS *
* 2) TIMES GIVEN IN STANDARD TIME FOR THE LOCATION *
* IN CONSIDERATION *
* 3) THE ABOVE LOADS ARE CALCULATED ASSUMING A *
* CONSTANT INDOOR SPACE TEMPERATURE *
*****

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Who Does Energy Modeling?



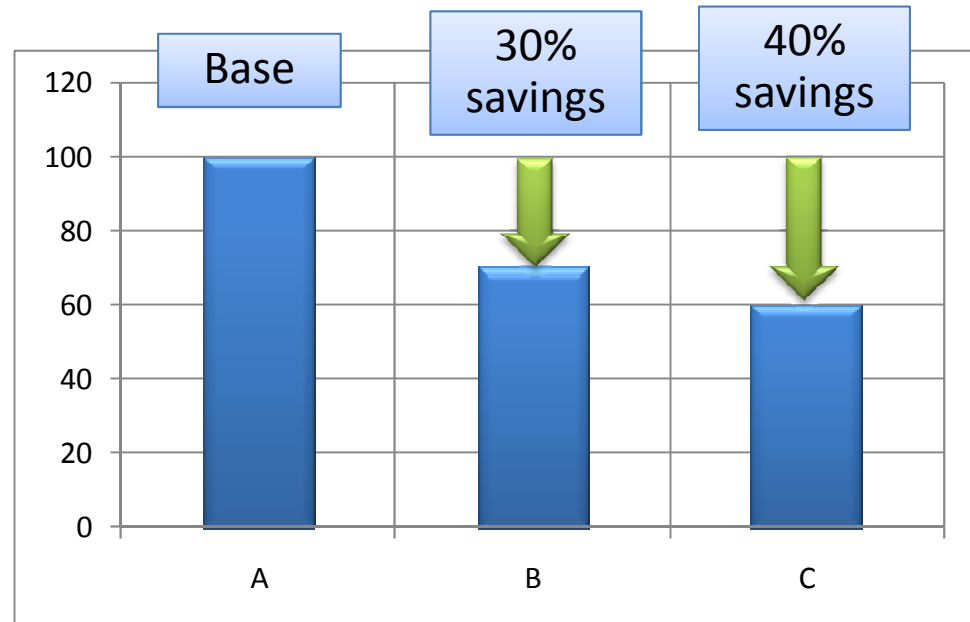
Appropriate Uses for Energy Modeling

Relative performance of design alternatives

Design Studies

Compliance analysis

Retrofit alternatives



With caution:

- Predicting actual energy consumption

Appropriate Uses for Energy Modeling

Design Studies

- Envelope design
 - Form, orientation, glazing, shading, insulation, daylighting
- System types
 - VAV vs. chilled beam
 - GSHP
 - Evaporative cooling
 - Etc...
- Control optimization
- Insights!

Compliance Analysis

- Energy code compliance
- LEED™ credit EAc1
- Utility incentives
- Policy compliance

Benchmark/Prediction

- Designed to meet EnergyStar
- Net zero design targets

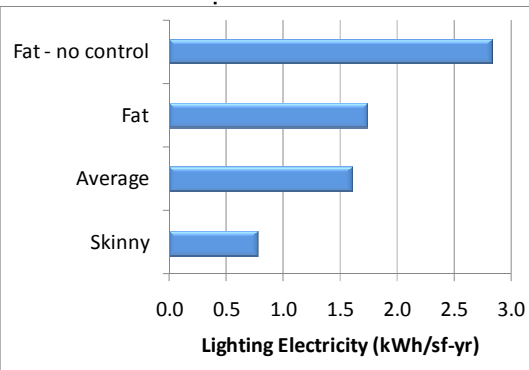
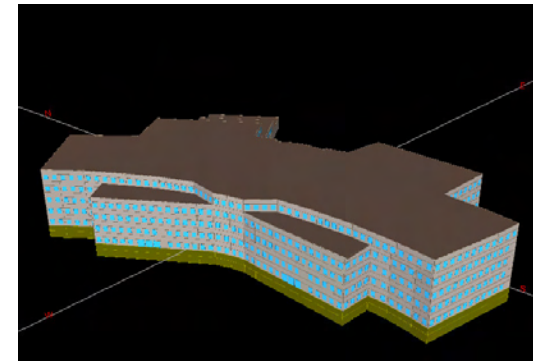
Appropriate Timing For Energy Modeling New Construction

Baseline model, set performance goals, e.g. Energy Star score, LEED points

Fundamental design alternatives with simple models

Specific design alternatives with more detailed models

Update models, produce compliance documentation

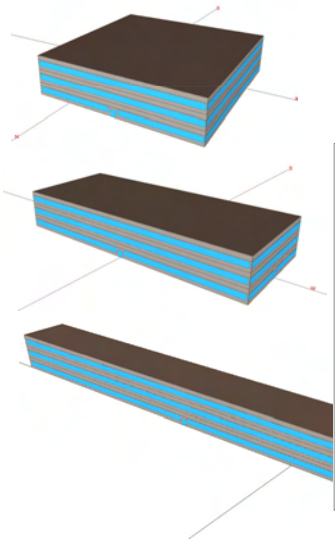


Pre-Design

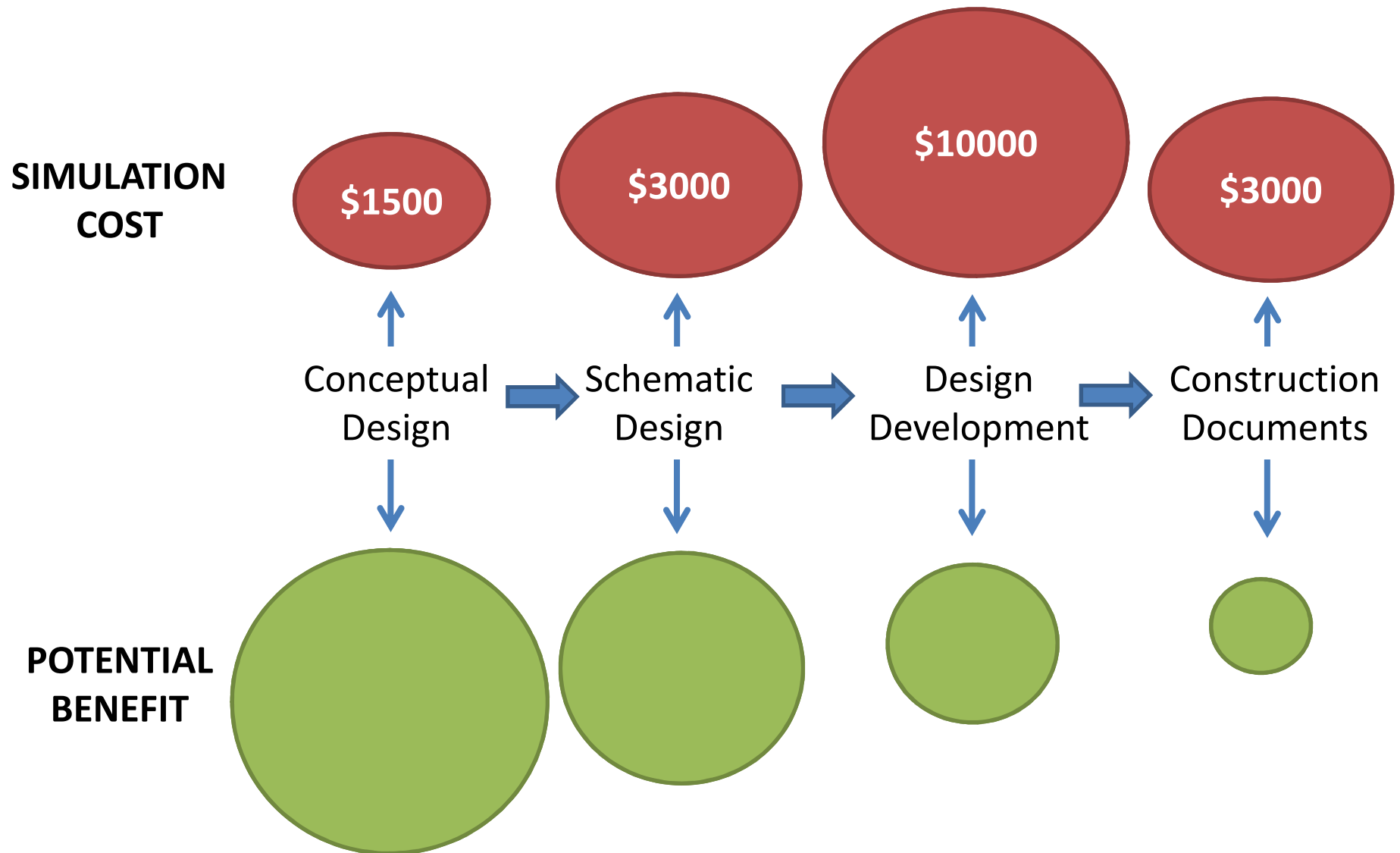
Schematic Design

Design Development

Construction Documents

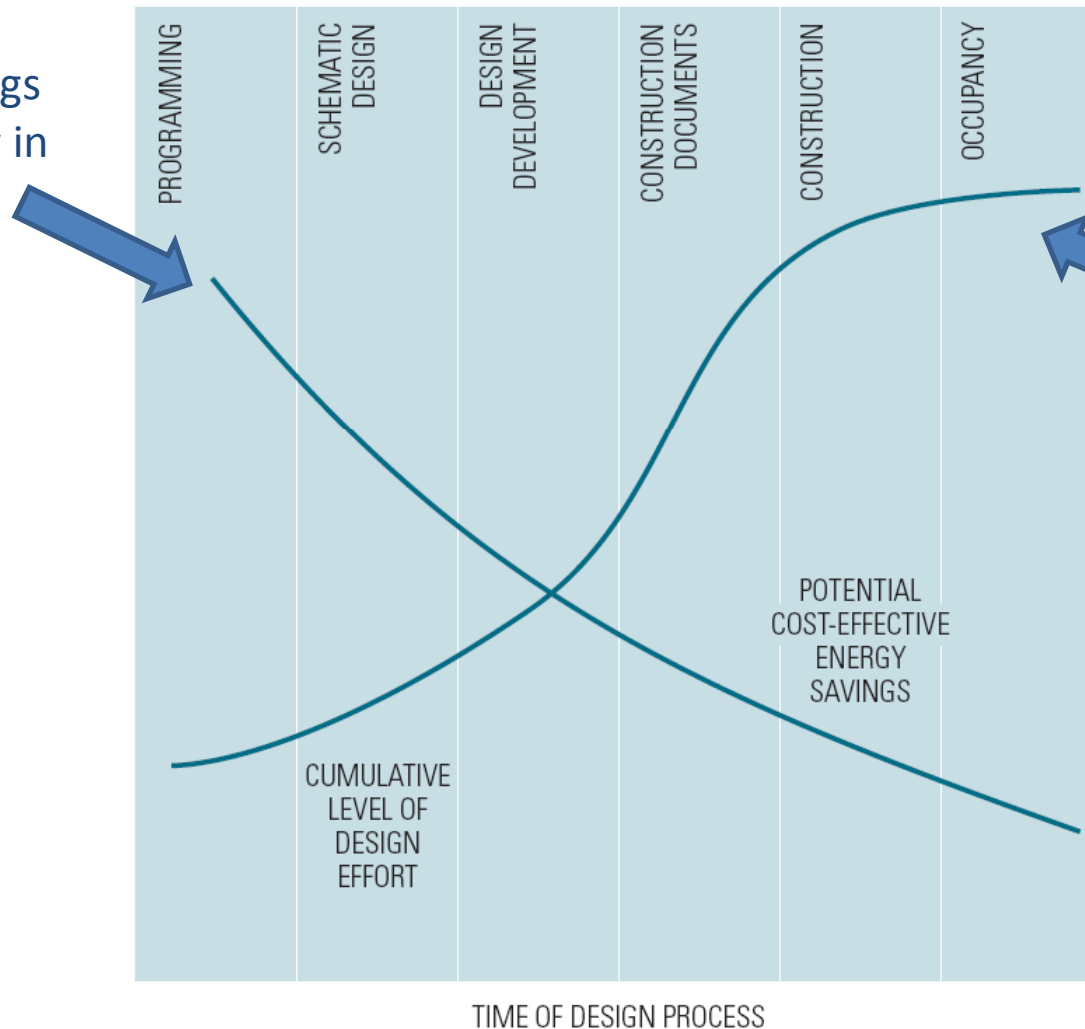


Modeling Timing & Cost/Benefit



Degree of Effort vs. Potential Energy Savings

Greatest savings available early in the design process

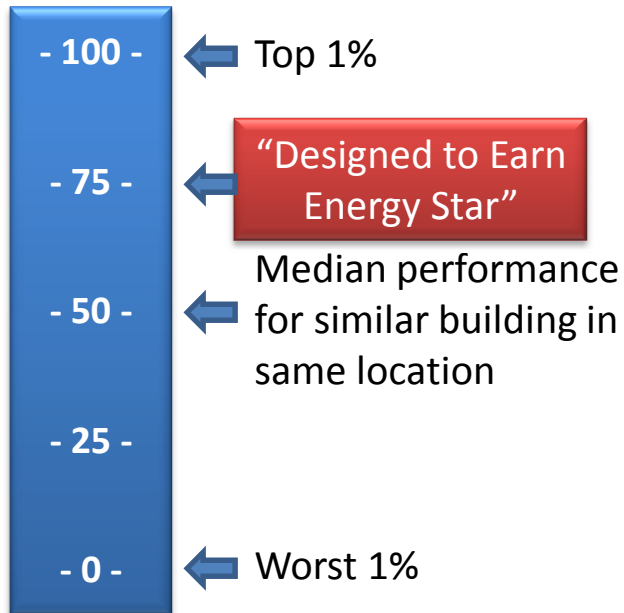


At later stages the opportunities are fewer and the cost of design changes is greater

Courtesy: Platts; data from ENSAR Group

Benchmark

Energy Star Target Finder



- For buildings under design
- Basis for score
 - Perform building energy simulation
 - Compare to similar buildings in database
 - About 15 building types
 - Source energy use intensity (EUI)
 - in kBtu/ft²-yr
 - Data from Commercial Building Energy Use Survey (CBECS) 2003

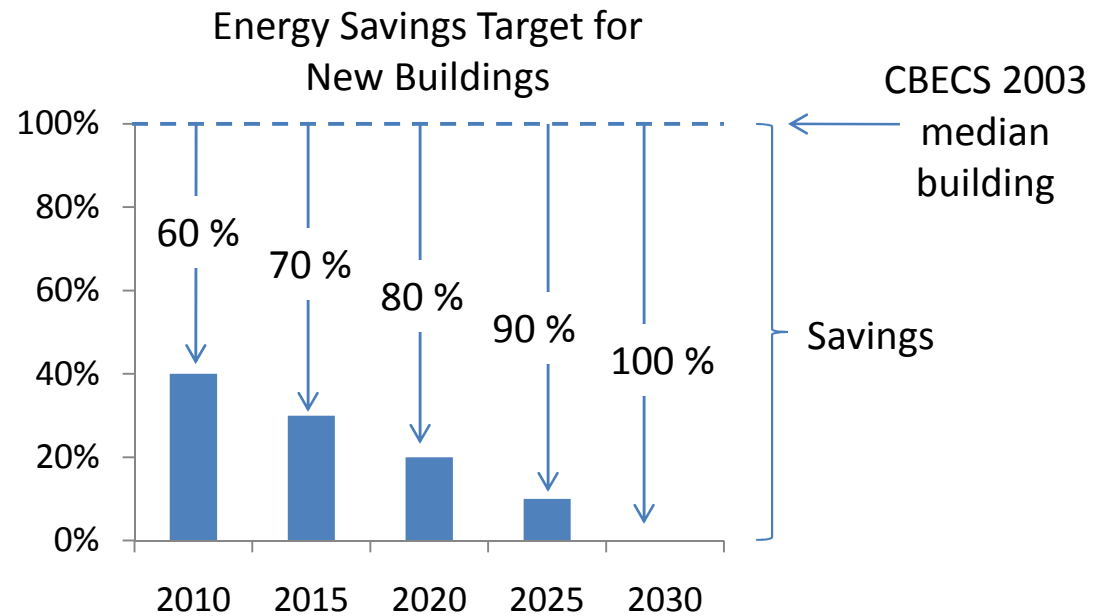




Performance Target 2030 Challenge from Architecture 2030



Site EUI,
relative to
median
building



LEED 2009 for New Construction

Optimize Energy Performance Credits

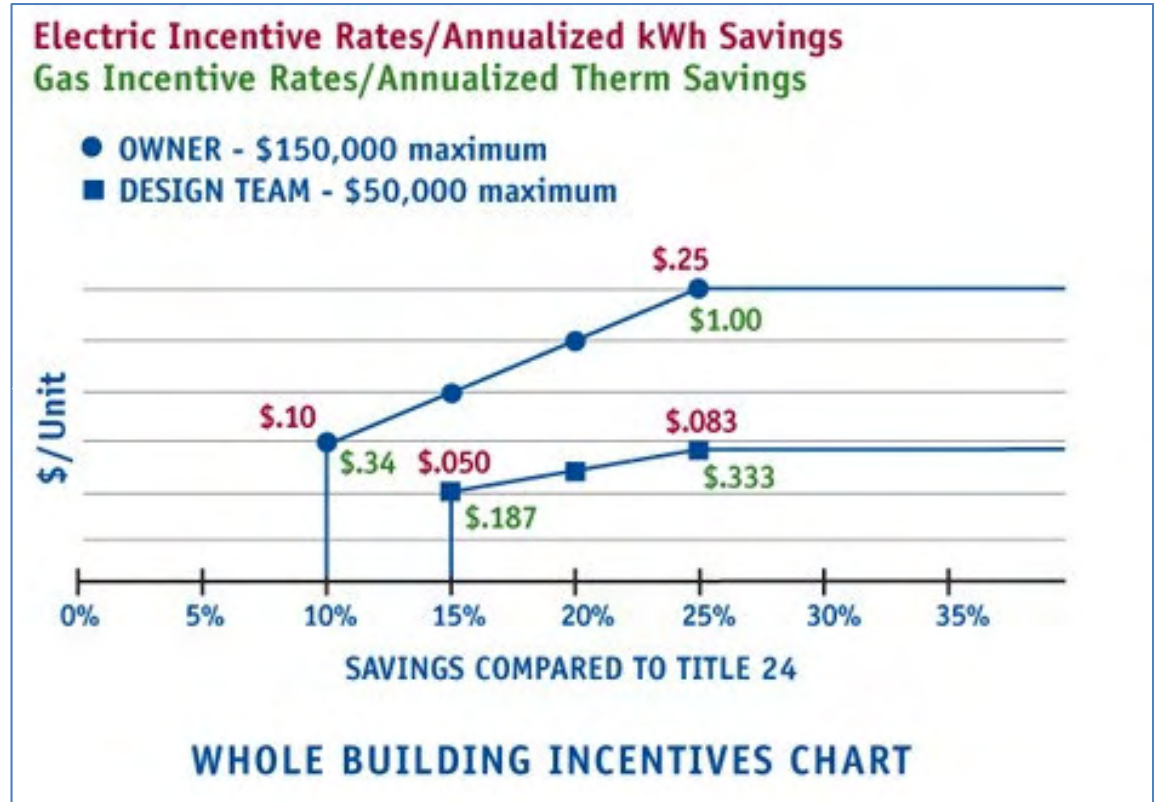


- Relative performance target
 - Perform two simulations
 - Baseline for comparison
 - ASHRAE Standard 90.1-2007
 - Energy cost basis
- Some states and local govts adopted as policy
- See also:
 - www.usgbc.org

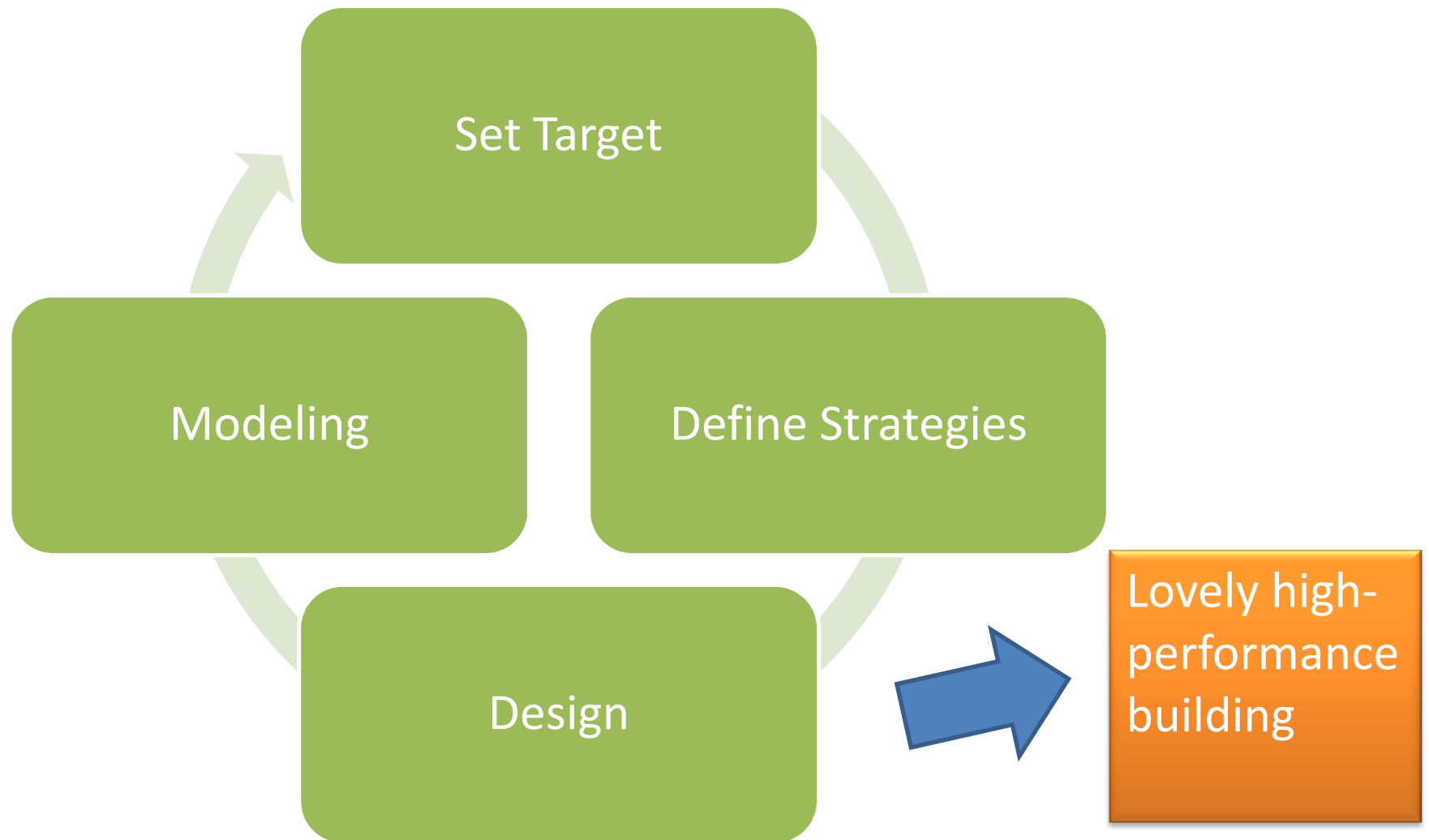
New Buildings	Existing Building Renovations	Points
12%	8%	1
14%	10%	2
16%	12%	3
18%	14%	4
20%	16%	5
22%	18%	6
24%	20%	7
26%	22%	8
28%	24%	9
30%	26%	10
32%	28%	11
34%	30%	12
36%	32%	13
38%	34%	14
40%	36%	15
42%	38%	16
44%	40%	17
46%	42%	18
48%	44%	19

Utility Incentive Program Savings By Design

Most California utilities.
“Whole Building” approach.
Building energy simulation.
www.savingsbydesign.com

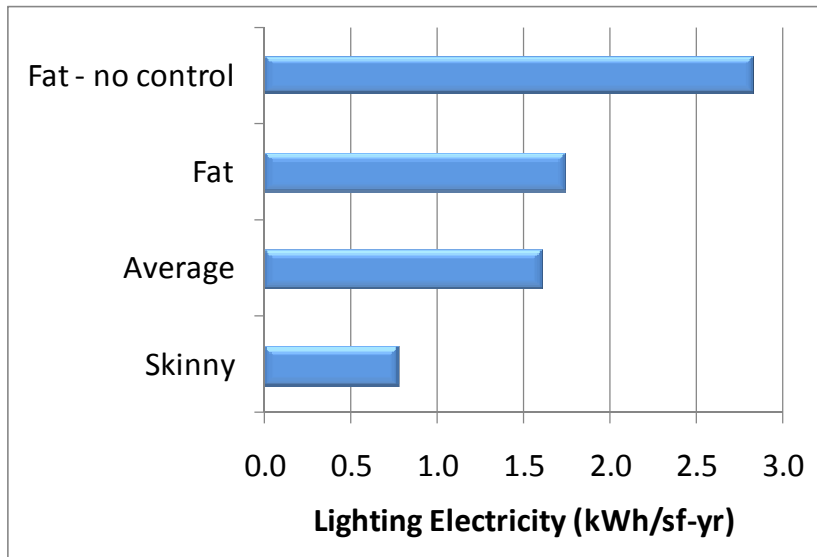
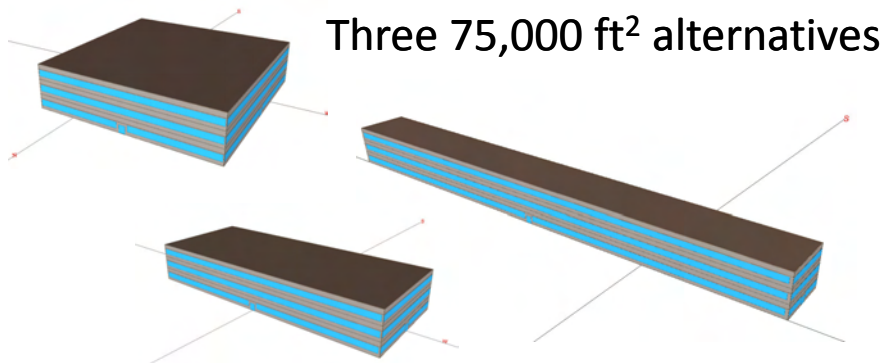


Modeling in an Iterative Design Process



Example Conceptual Design Study

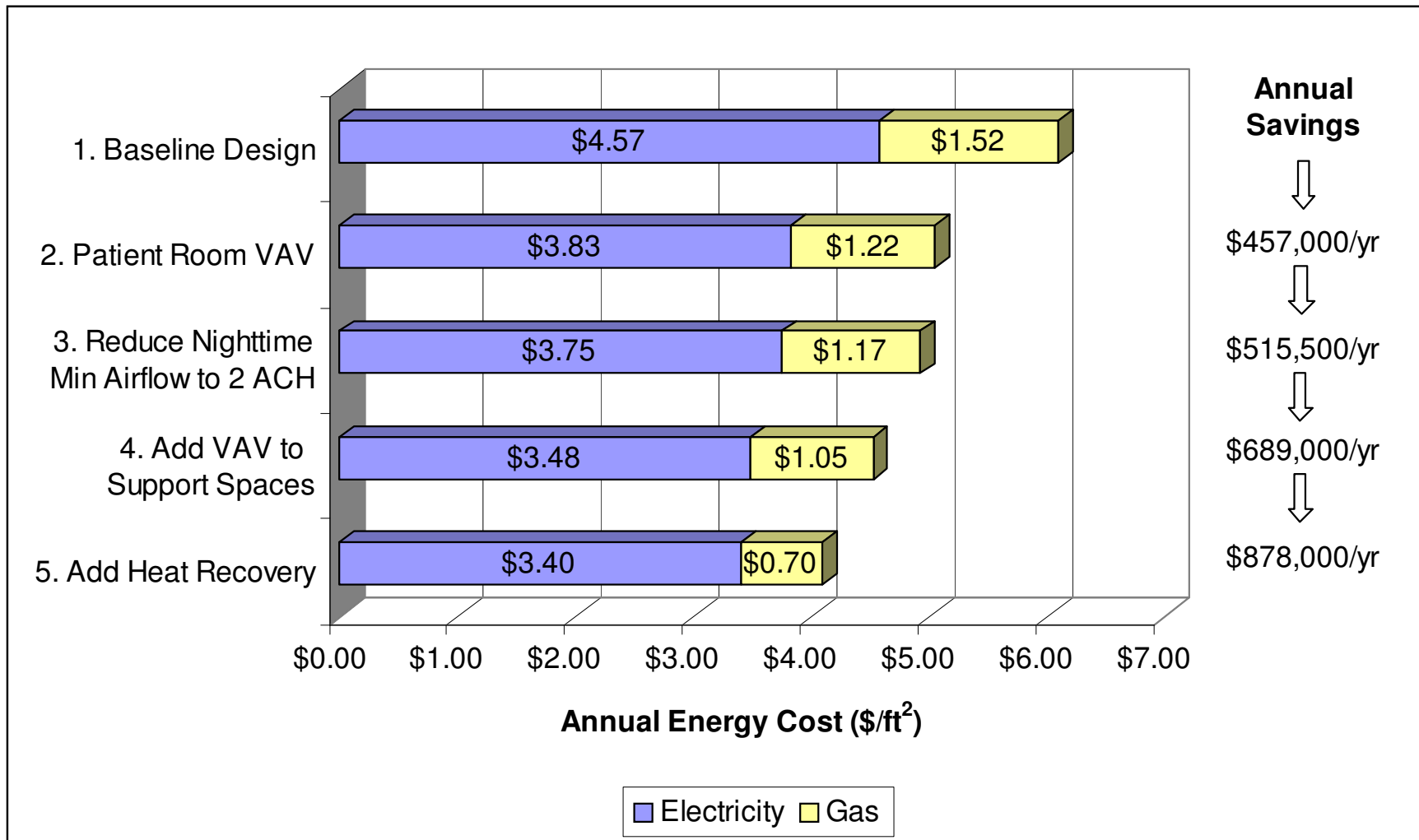
Daylighting Energy Savings & Building Form



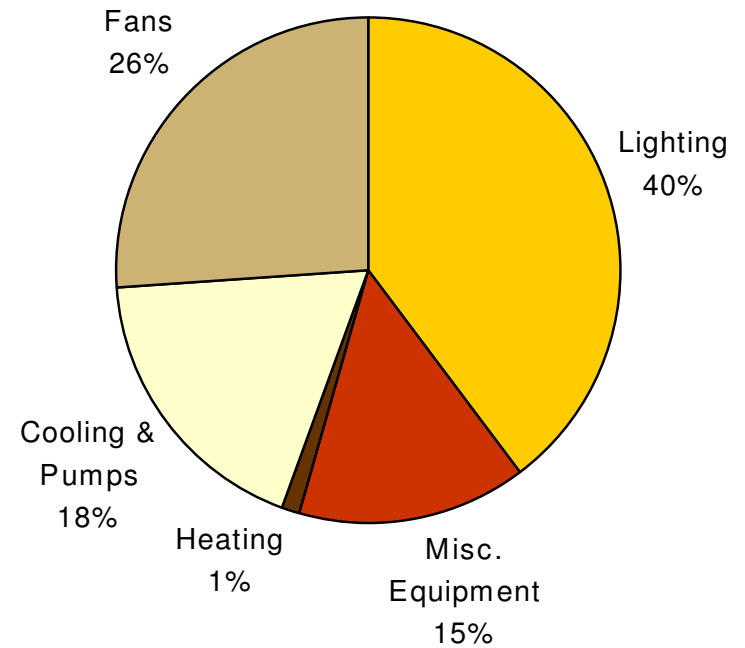
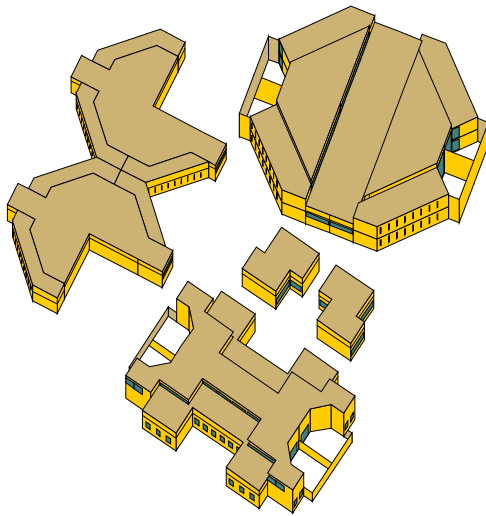
Building footprint	Auto Daylight Control	Lighting Electricity (kWh/yr)	Total Energy Cost (\$/yr)
158' x 158'	No	211,408	\$137,055
158' x 158'	Yes	129,912 (39% savings)	\$119,551 (13% savings)
250' x 100'	Yes	119,696 (44% savings)	\$118,011 (14% savings)
500' x 50'	Yes	57,335 (73% savings)	\$115,715 (16% savings)
500' x 50' with 2' overhang on south	Yes	57,912 (73% savings)	\$111,107 (19% savings)

Energy simulation results
Sacramento, CA

Hospital HVAC Analysis – New Construction



Institutional Facility New Construction

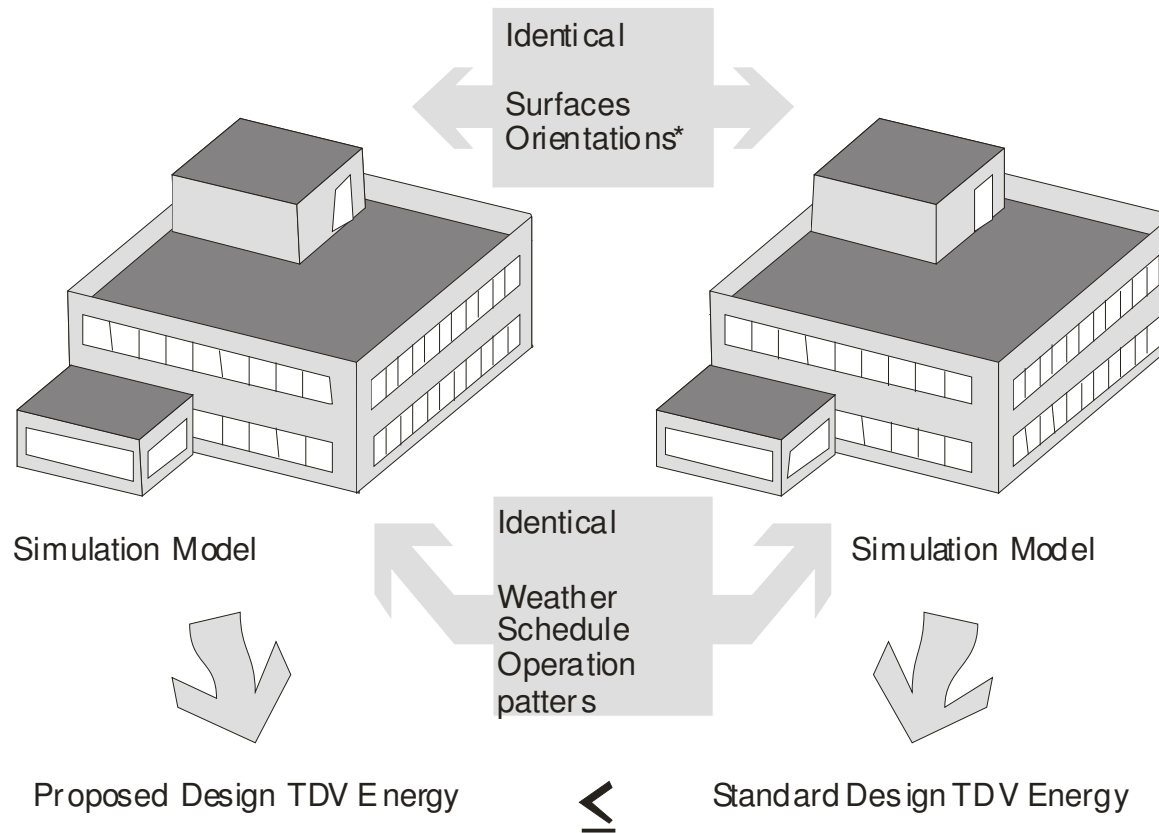


Measure	Incremental Initial Cost (\$)	Annual Energy Savings (\$/yr)	Change in Life-Cycle Cost (\$)	Simple Payback Period (years)
As-designed	0	-1,796	35,195	0.0
Efficient lighting	0	32,887	-641,514	0.0
VAV for living areas	174,400	29,927	-414,832	5.8
Efficient cooling tower	30,000	5,116	-70,266	5.9
Tower VFD fan	9,000	584	-2,437	15.4
Skylights in dayrooms	0	2,800	-54,881	0.0
Hybrid gas/electric cooling	112,500	3,116	65,142	36.1
Thermal energy storage	540,000	10,000	343,996	54.0

Modeling for Energy Code Compliance

Proposed Design
Meets mandatory requirements
Building envelope, interior lighting,
HVAC and water heating modeled as
shown on the plans and specifications

Standard Design
Meets mandatory requirements
Meets prescriptive requirements for
envelope, lighting, HVAC and water
heating



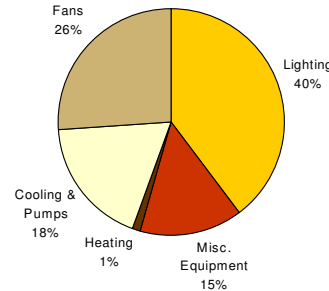
*Unless glazing area in budget design
requires adjustment

Existing Building Energy Modeling

Appropriate Timing For Energy Modeling Existing Buildings

Calibrate model for measurement and verification (M&V)

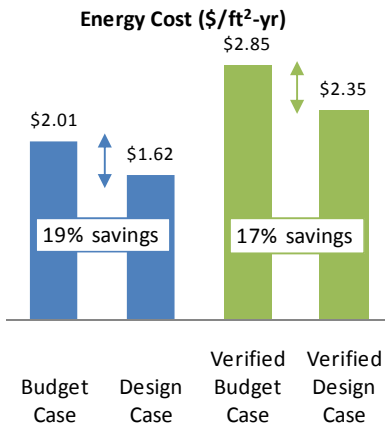
Use model to estimate end-use energy breakdown, identify savings opportunities



Compare design alternatives

Evaluate savings for retrofit measures

Compliance documentation



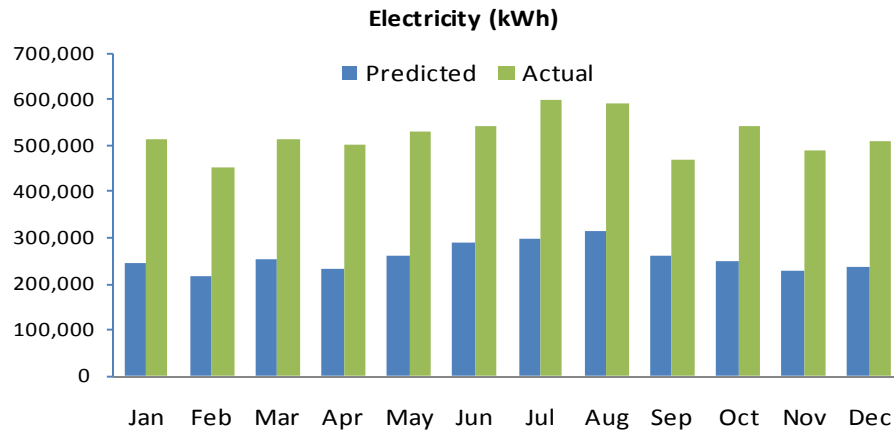
Operation

Retrofit

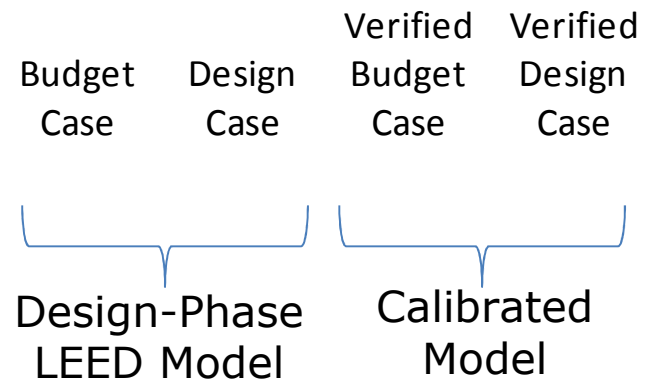
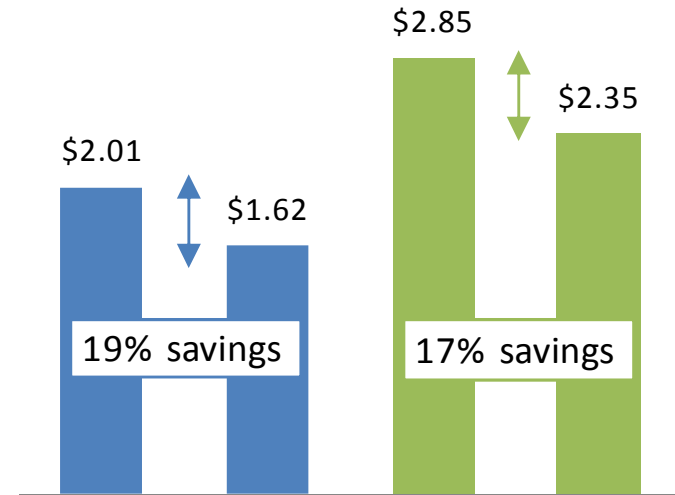
Renovation

Measurement & Verification - High-rise Office

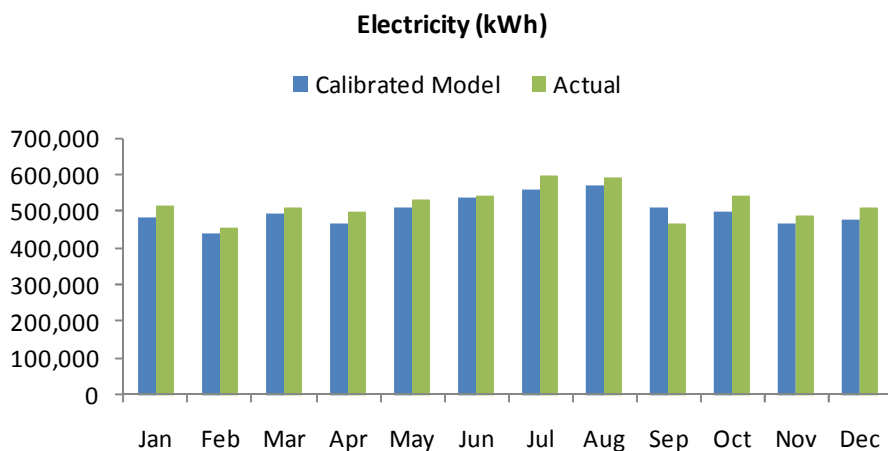
Before Calibration



Energy Cost (\$/ft²-yr)



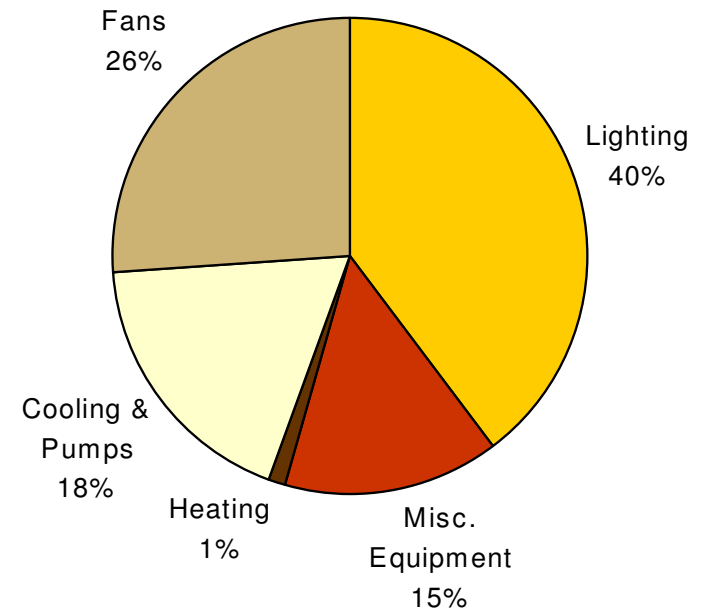
After Calibration



Existing Building Retrofit Modeling

- What is it good for?

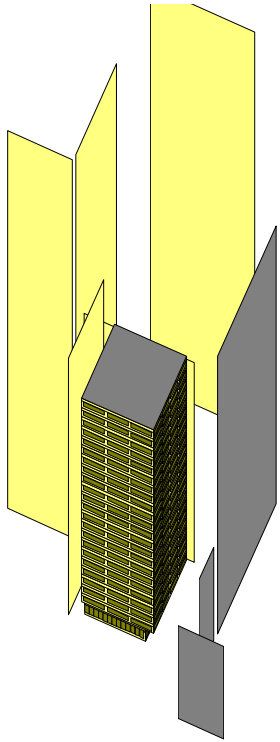
- Estimate end-use energy breakdown
- Insights into savings opportunities
- Savings estimates for some measures
 - Other calculation methods appropriate for other measures



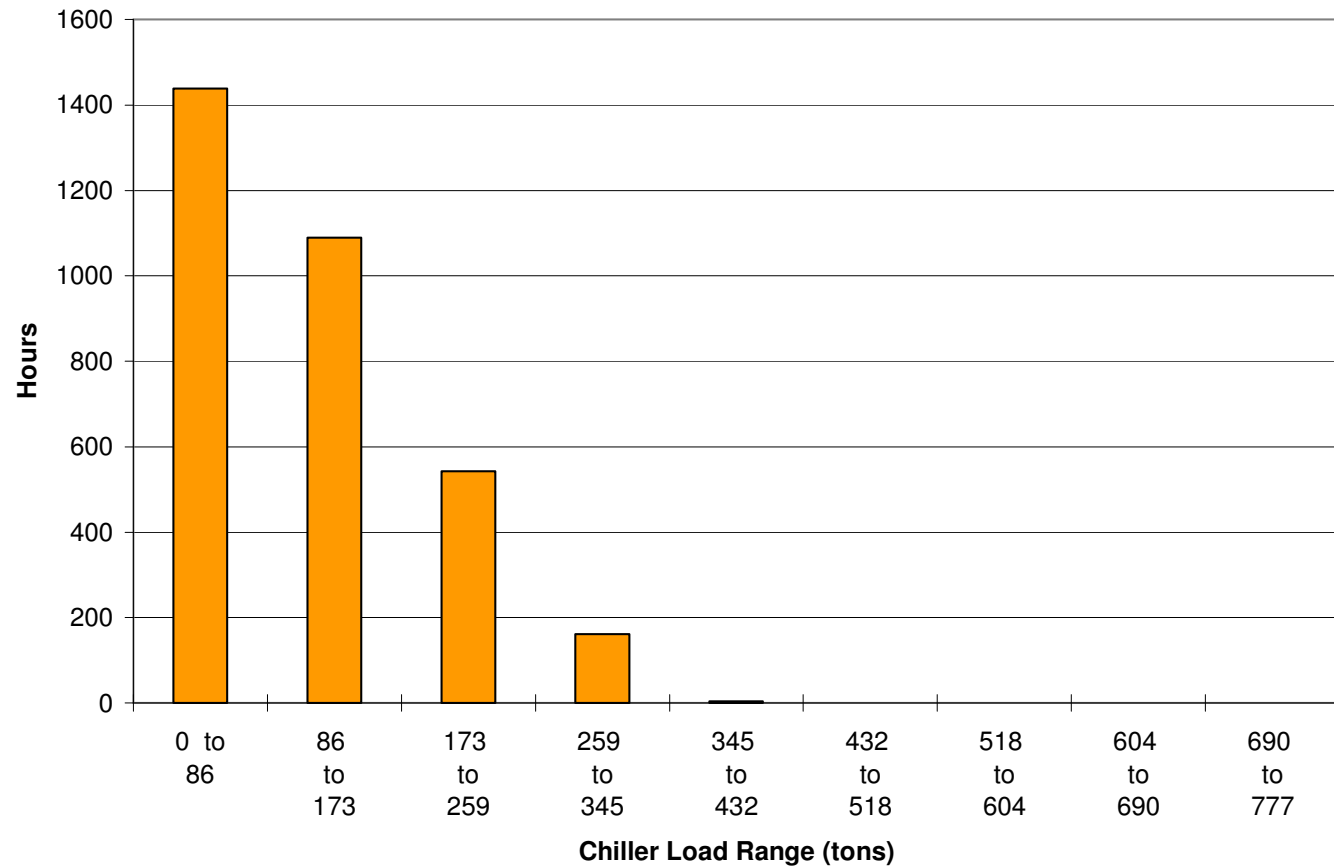
Existing Building Retrofit Modeling

- **Appropriate Measures**
 - Building enclosure upgrades
 - window replacement
 - retrofit window films
 - window shading devices
 - roof insulation
 - wall insulation
 - Some HVAC system replacements
 - Air-side economizers
 - Demand controlled ventilation
 - Supply air temperature reset controls
- **Potentially Appropriate**
 - Chiller retrofit
 - Packaged HVAC system retrofit
 - Supply air pressure reset controls
 - Refrigeration retrofits
- **Less Appropriate**
 - Lighting retrofit
 - Motor efficiency
 - Some HVAC retrofits
 - Process efficiency measures

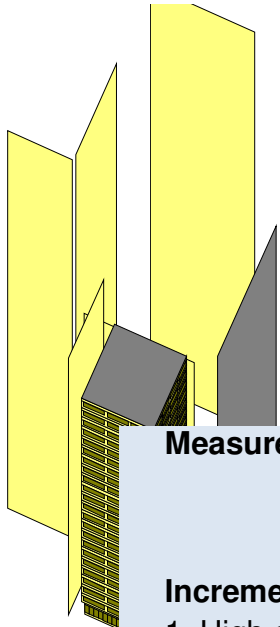
High-Rise Office Chilled Water Plant Retrofit Analysis



Simulated Chiller Load Profile
(3235 total operating hours, 443 tons peak load)

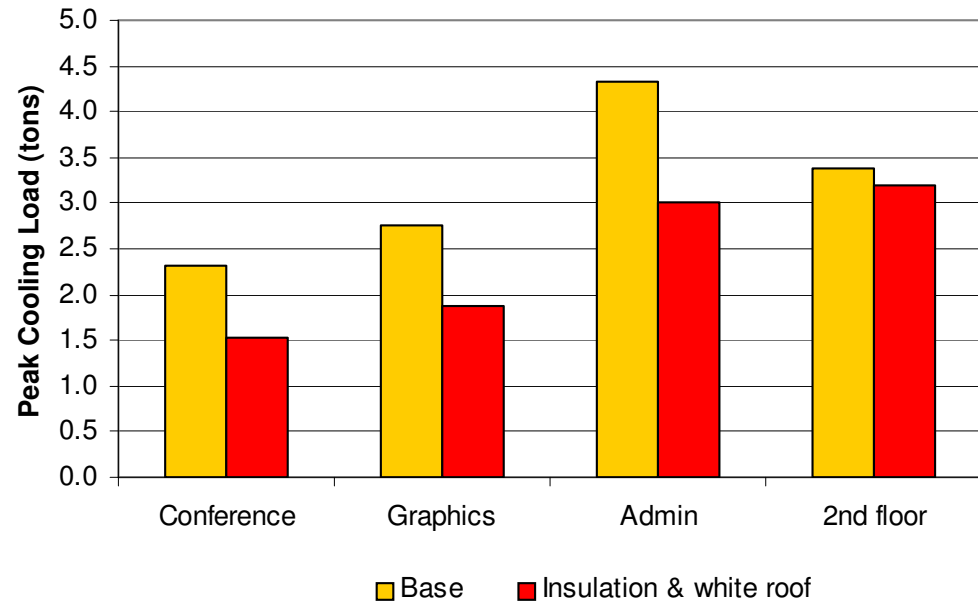
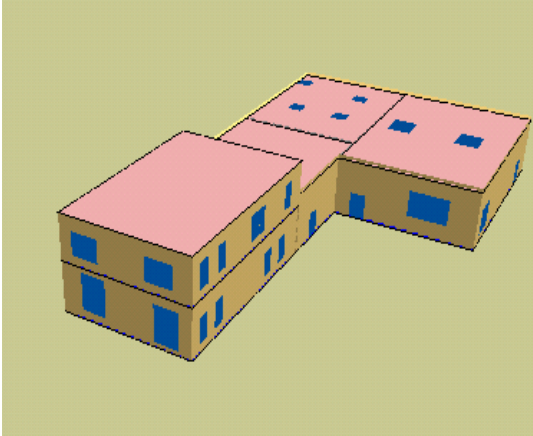


High-Rise Office Chilled Water Plant Retrofit Analysis



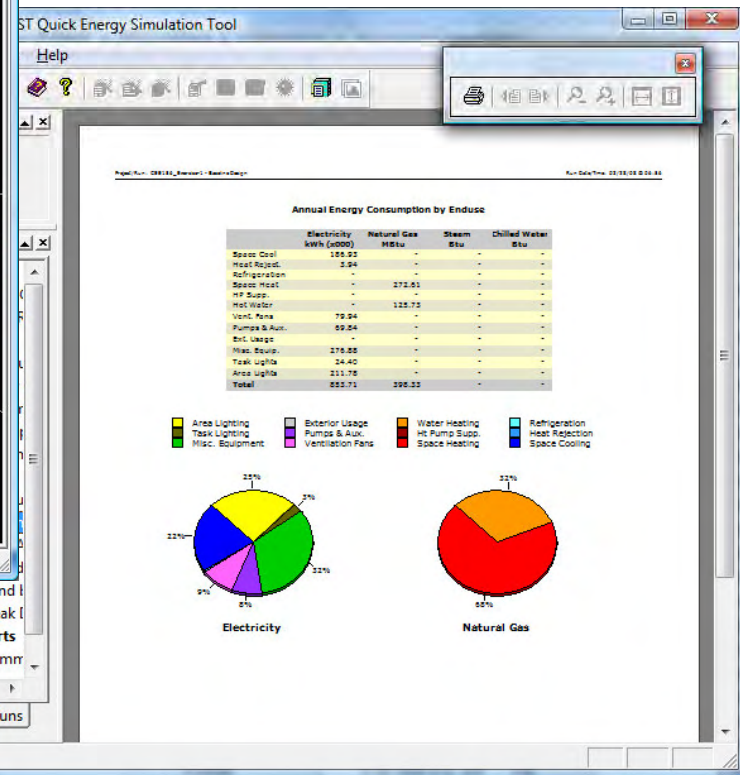
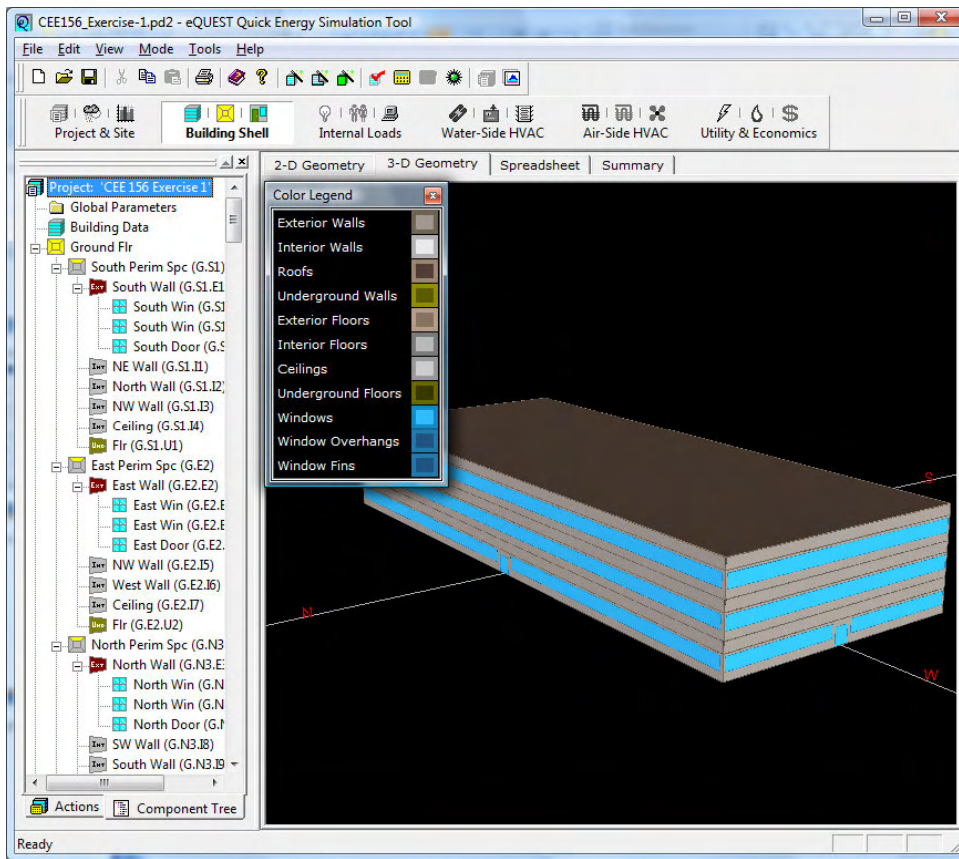
Measure	Estimated Demand Savings (kW)	Estimated Electricity Savings (kWh/yr)	Estimated Energy Cost Savings (\$/yr)	Estimated Installed Cost (\$)	Estimated Incentive (approx) (\$)	Simple Payback Period (yrs)
Incremental Results						
1. High eff chiller	239	414,908	\$58,354	\$350,000	\$36,513	5.4
2. Var. speed chiller control	37	127,897	\$15,174	\$50,000	\$8,199	2.8
3. Primary/secondary pumping	0	77,282	\$6,574	\$90,000	\$3,091	13.2
4. EMS	-9	44,960	\$8,139	\$160,000	\$1,048	19.5
Cumulative Results						
1. High eff chiller	239	414,908	\$58,354	\$350,000	\$36,513	5.4
2. Var speed chiller	276	542,805	\$73,528	\$400,000	\$44,712	4.8
3. 2 + prim/sec pumping	276	620,087	\$80,102	\$490,000	\$47,803	5.5
4. 3 + EMS	267	665,047	\$88,241	\$650,000	\$48,852	6.8

Small Office Renovation

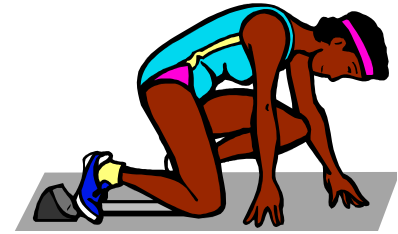


Energy Efficiency Measure	Energy Savings (\$/yr)	Energy Savings (%)	Initial Cost (\$)	Simple Payback Period (years)
+ Efficient lighting	\$1,237	12%	\$0	0
+ Roof insulation and white roof	\$605	6%	\$10,500	17
+ Efficient air conditioner	\$84	1%	\$540	6
+ Economizer	\$120	1%	\$800	7
+ Natural Ventilation	\$186	2%	\$0	0
+ Daylighting	\$348	3%	\$500	1
TOTAL	\$2,580	25%	\$12,340	5

Demonstration



Some Resources for Getting Started



- Building Energy Software Tools Directory
 - www.eere.energy.gov/buildings/tools_directory/
- BLDG-SIM and associated email lists
 - www.onebuilding.org
- Energy Design Resources
 - Simulation Design Brief and Simulation Guidelines
 - www.energydesignresources.com
- Article “Simulation Literacy 101”
 - http://www.buildinggreen.com/features/mr/sim_lit_101.cfm
- International Building Performance Simulation Association (IBPSA)
 - Conference papers online
 - Local chapters forming... NY, SF, ...
 - www.ibpsa.org
 - www.ibpsa.us

Questions?

Erik Kolderup

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