



Whole-Building Energy Analysis and Energy Modeling



**ASHRAE
Arkansas Chapter
Presentation**

Nicholas Long

December 1-2, 2010

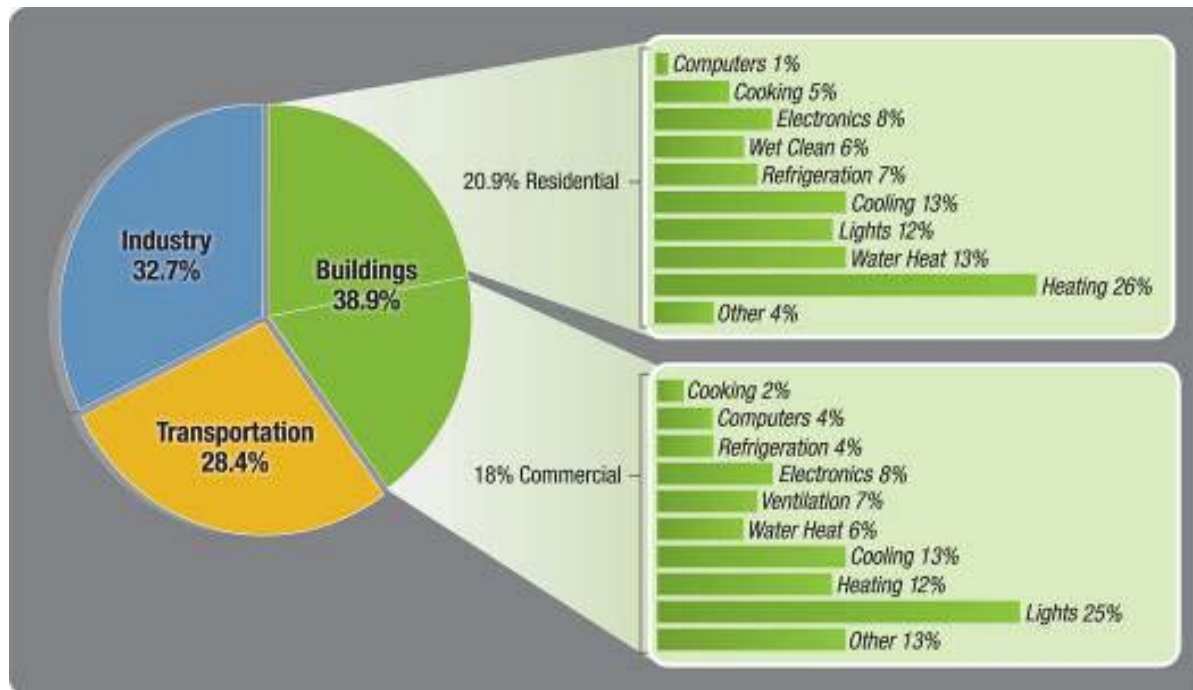
Outline

- U.S. Building Energy Use
- Energy Modeling in the Design Process
 - Building Model Progressions
- Energy Modeling Results in Real Projects
- ASHRAE Standards and Advanced Energy Design Guide Modeling
- Performance Based Design Build Procurement
- Modeling for Retrofits
- Other Barriers
- ASHRAE Energy Modeling Conference

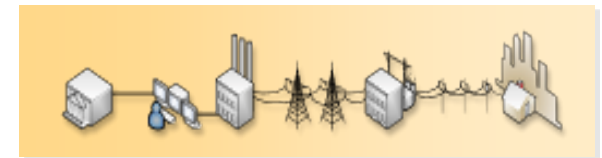
Building's are the Largest Energy Consumer in U.S.

Combined residential and commercial buildings sector account for:

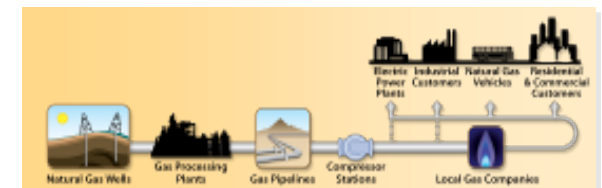
40% of U.S. Primary Energy Consumption



73% of U.S. Electricity



34% of direct U.S. Natural Gas

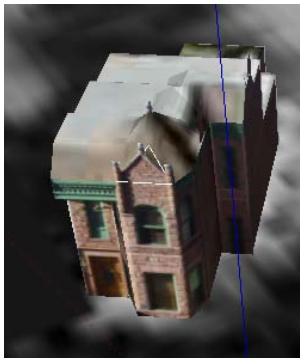


What does the commercial building stock look like?

4.8 Million Buildings

72 Billion Square Feet

Average Commercial Building
is 15,000 Square Foot



53% are Small Buildings
(1,000 to 5,000 ft²)
consume 11% of energy

Credit: DOE EIA CBECS, 2003, Google Earth



0.2% are Large Buildings
(> 500,000ft²)
consume 14% of energy

**“Every building is a forecast.
Every forecast is wrong.”**

Stewart Brand

Simulation vs. Operating Energy

In DOE's low-energy building research, simulation has been critical for designing and operating buildings to support decision-making.

Focus on Energy Efficiency, then Renewable Energy

BUT, compared to simulations, real buildings:

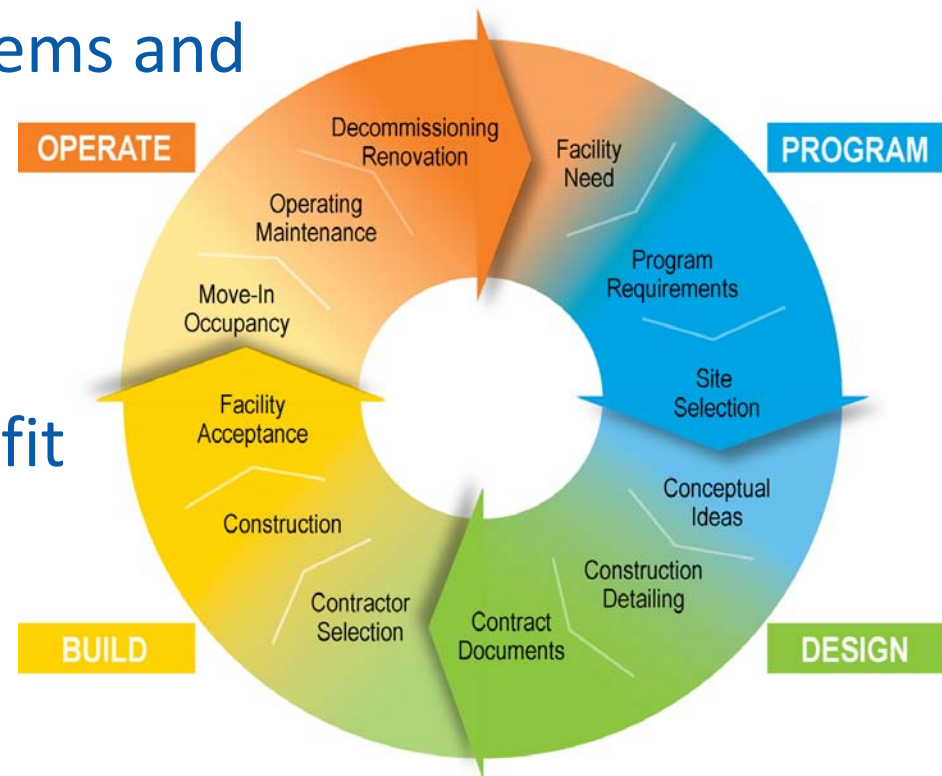
- Use more energy
- Produce less power
- Have worse controls
- Have more varied schedules
- Have more occupant complaints
- GIGO



Credit: NREL PIX

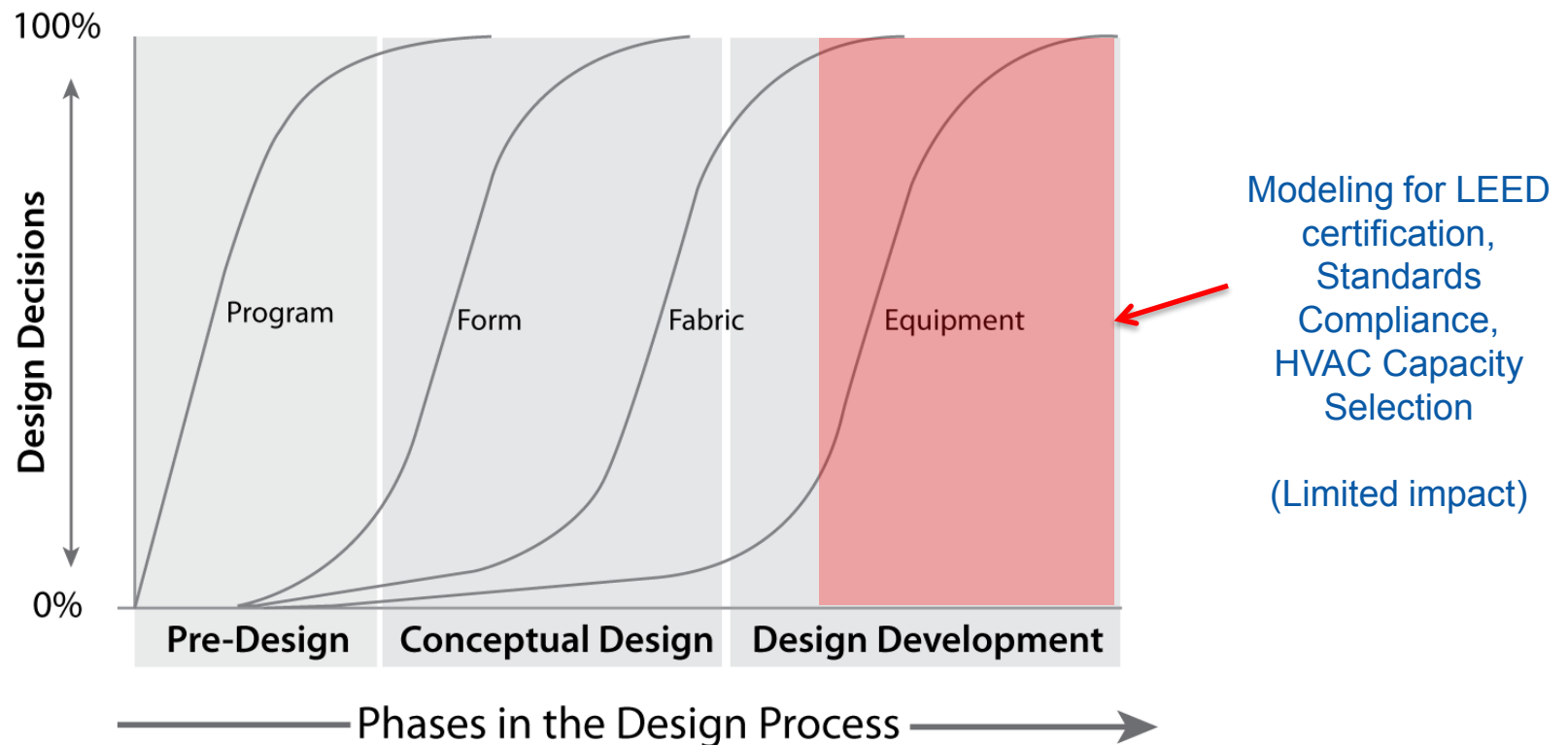
Why Use Energy Simulation?

- Inform energy decisions from the earliest phases
- Help the design team and owner focus energy-use reduction
- Assess predicted performance with project goals
- Size renewable energy systems and determine contribution
- Evaluate alternatives throughout programming, design, construction, operation—as well as retrofit
- Simulation is cheaper than constructing the wrong building!



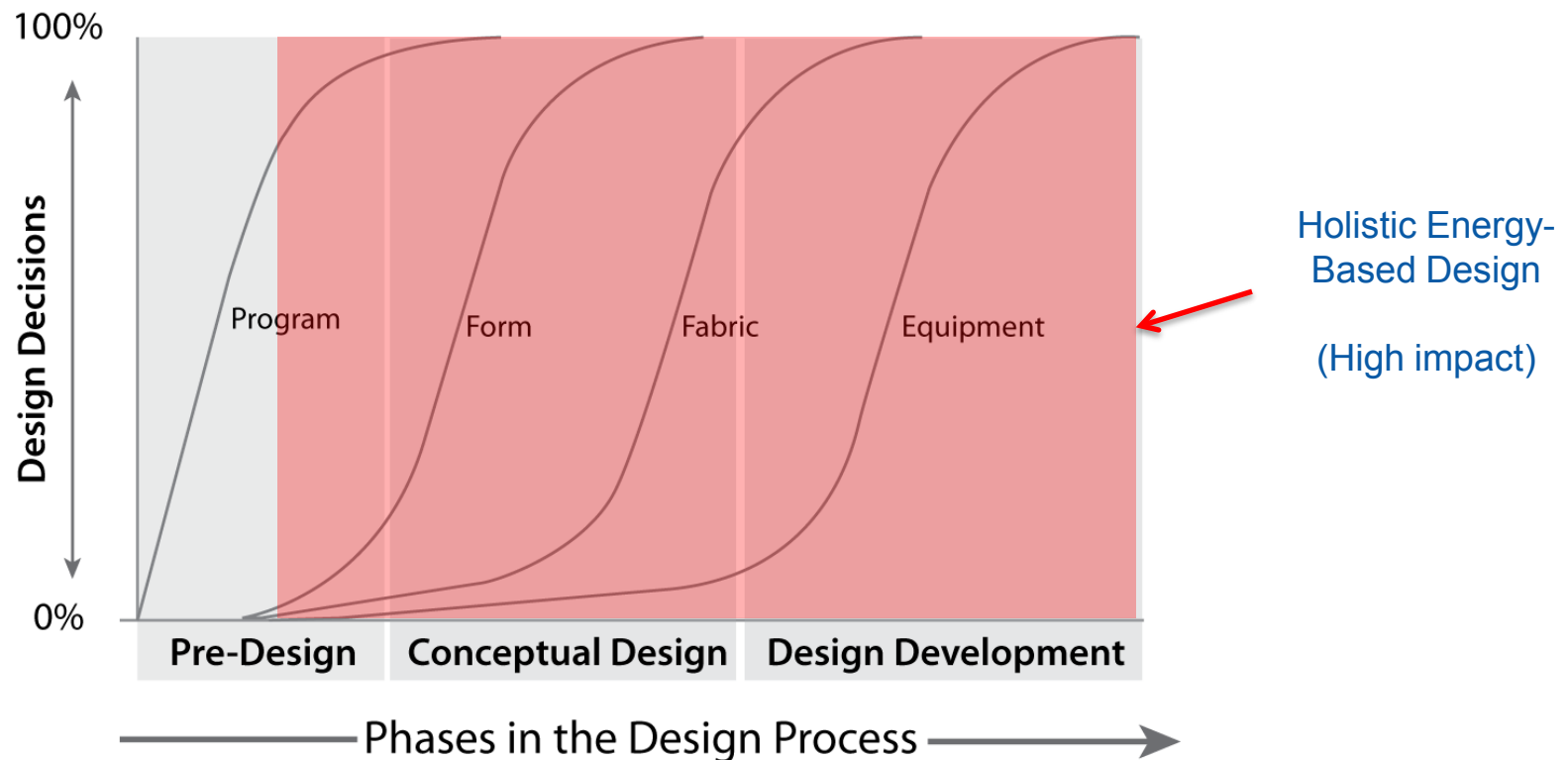
Typical Use of Energy Modeling

Energy efficiency is often not a primary consideration during the building design process, and evidence of modeling and energy simulation is often used only to get a LEED certification if it is used at all.



Typical Use of Energy Modeling

Energy modeling needs to be about more than getting a checkbox on a certification.



What Can Energy Simulation Do for My Buildings?

Typically used for studies of individual buildings. Simulation can help determine:

- Building overheating
- Heating, cooling equipment design
- Predict the dynamic response and performance of buildings
- Compare different design or retrofit options—load calculations, energy performance, peak demand, and cost-benefit implications
- Simulate complex and ‘green’ technologies:
 - Naturally ventilated, passive buildings
 - Thermal energy storage
 - Daylighting
 - Overheating in unconditioned spaces
 - Advanced controls operation
- Regulatory compliance
- Integrated views of performance
- Points for green building ratings

Other multiple building set uses include:

- Policy—set standards levels, support decision-making
- Technology R&D—market penetration, technology applicability

Visual History of Whole Building Energy Analysis Tools

GRAPHISOFT
ARCHICAD

Proprietary
(Web, GUI)

ENERGY-10



Free or Public Domain

Web
Interfaces



Open Source

GUI
Interfaces

Restricted Source



eQUEST

Text
Interfaces

BDL

IDF

Simulation
Engines

BLAST



C&E



1980

1990

2000

2010

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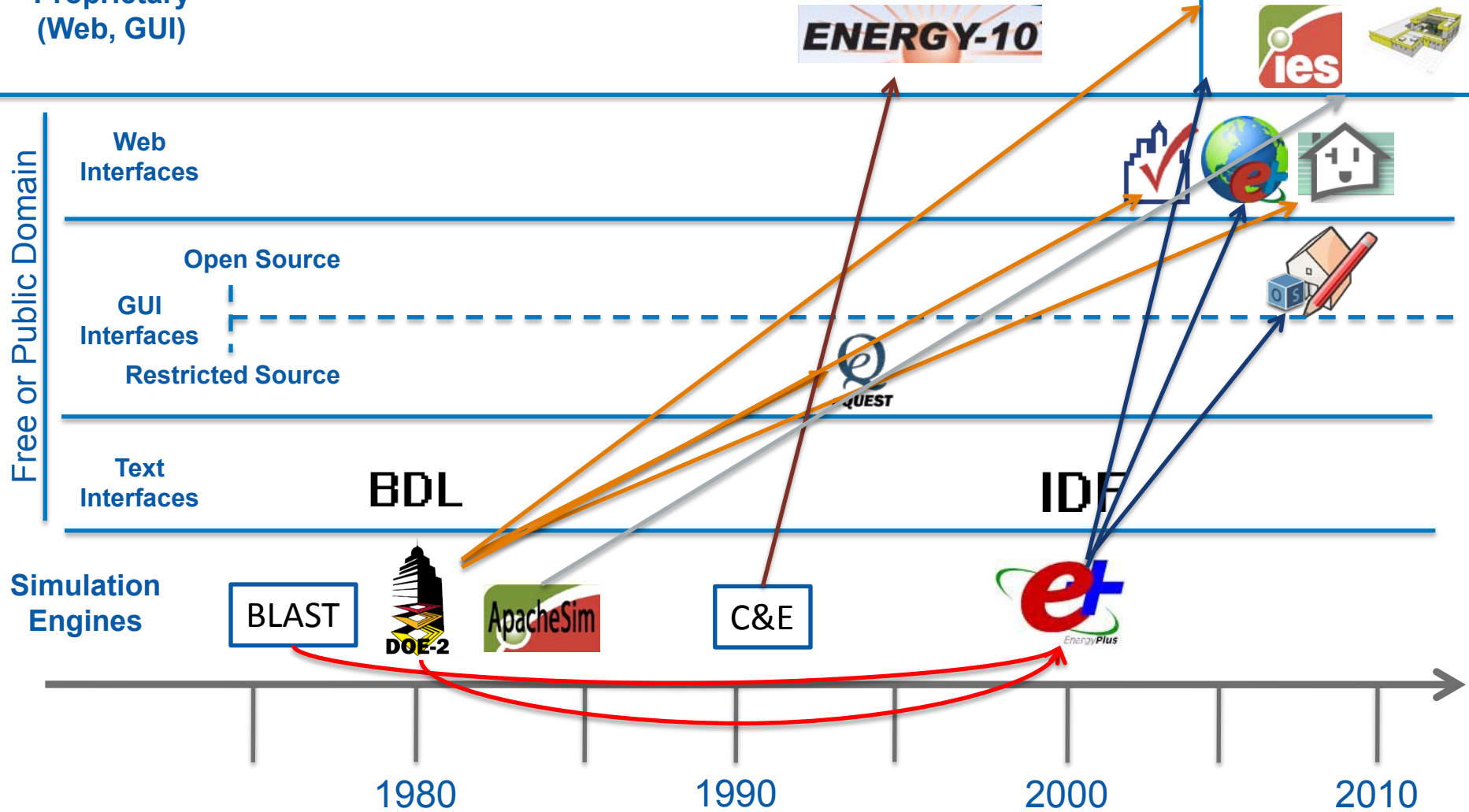
IDF



2000



2010



Inputs Needed for Whole-Building Simulation

- Weather Data
- Ground Temperatures
- Building Geometry
- Window Areas
- Constructions
- Ground Coupling
- Building Program / Thermal Zoning
- Plug Loads (Electric / Gas)
- Miscellaneous Electrical Loads
- People Activity
- Lighting Type
- Infiltration
- Daylighting Configuration
- Schedules
- HVAC Systems
 - Fans
 - Coils
 - Boilers
 - Chillers
 - ERV
 - PTHP/VAV/etc
- Ventilation Requirements
- Exhaust Requirements
- HVAC Performance Data
- Control Sequences
- Temperature Setpoints
- SWH / DHW
- Water Use
- Utility Rates

... and more

Building Model Progression

- Energy models have a natural progression that are similar to the design process
- Earlier phases of the design process require heavily defaulted data, but can be used to get order of magnitude results
- As one enters more detail, they “jumps fidelity levels”.
- Higher fidelity models will have changes in:

- temporality: deals with better accuracy in time.

Example: 10-minute data versus 1-hour data, or moving to a more complex level in order to catch control cycles of certain equipment

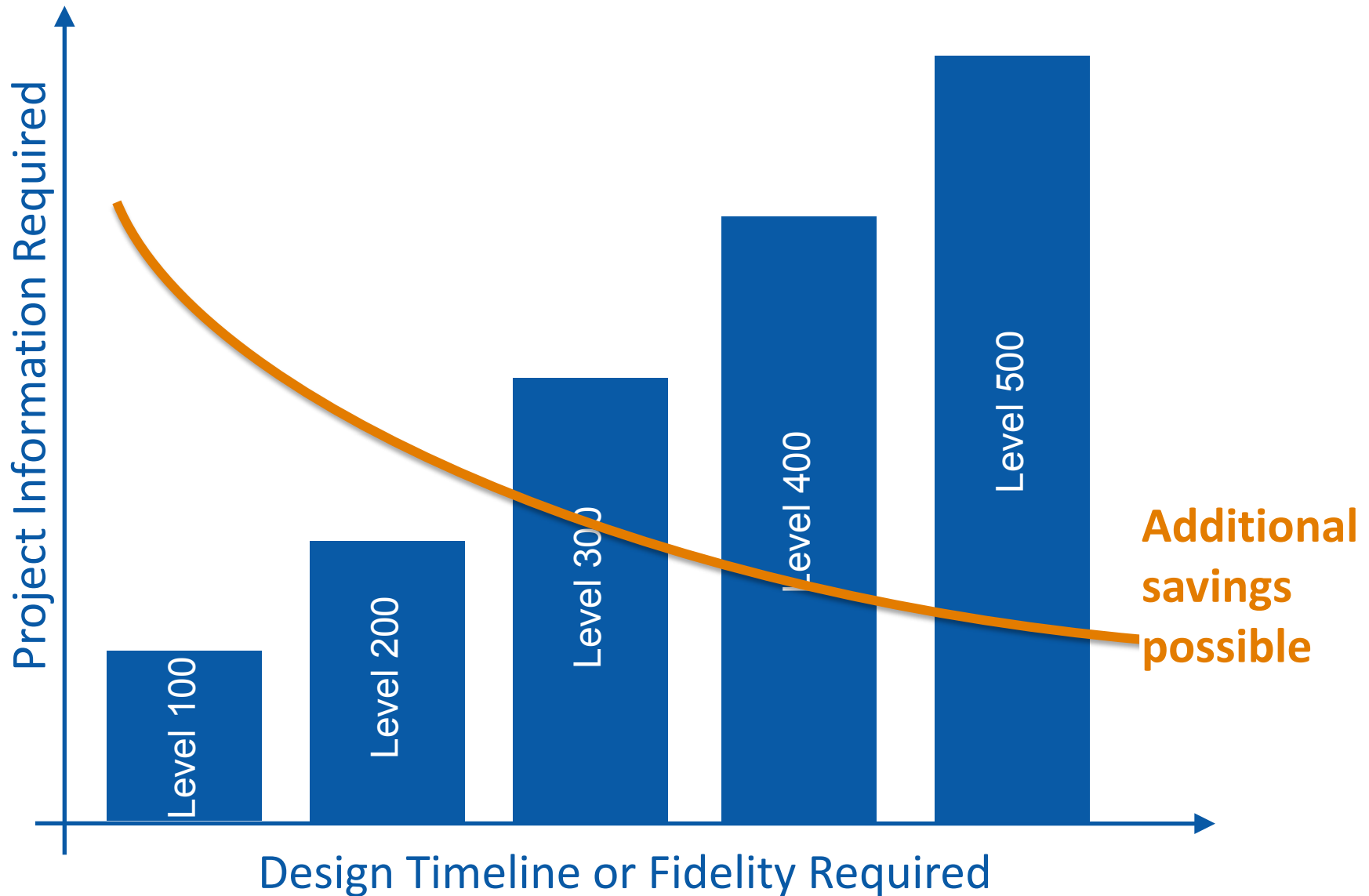
- spatiality: deals with more detailed geometry/program.

Example: zone refinement in the model. More accurate daylighting analyses.

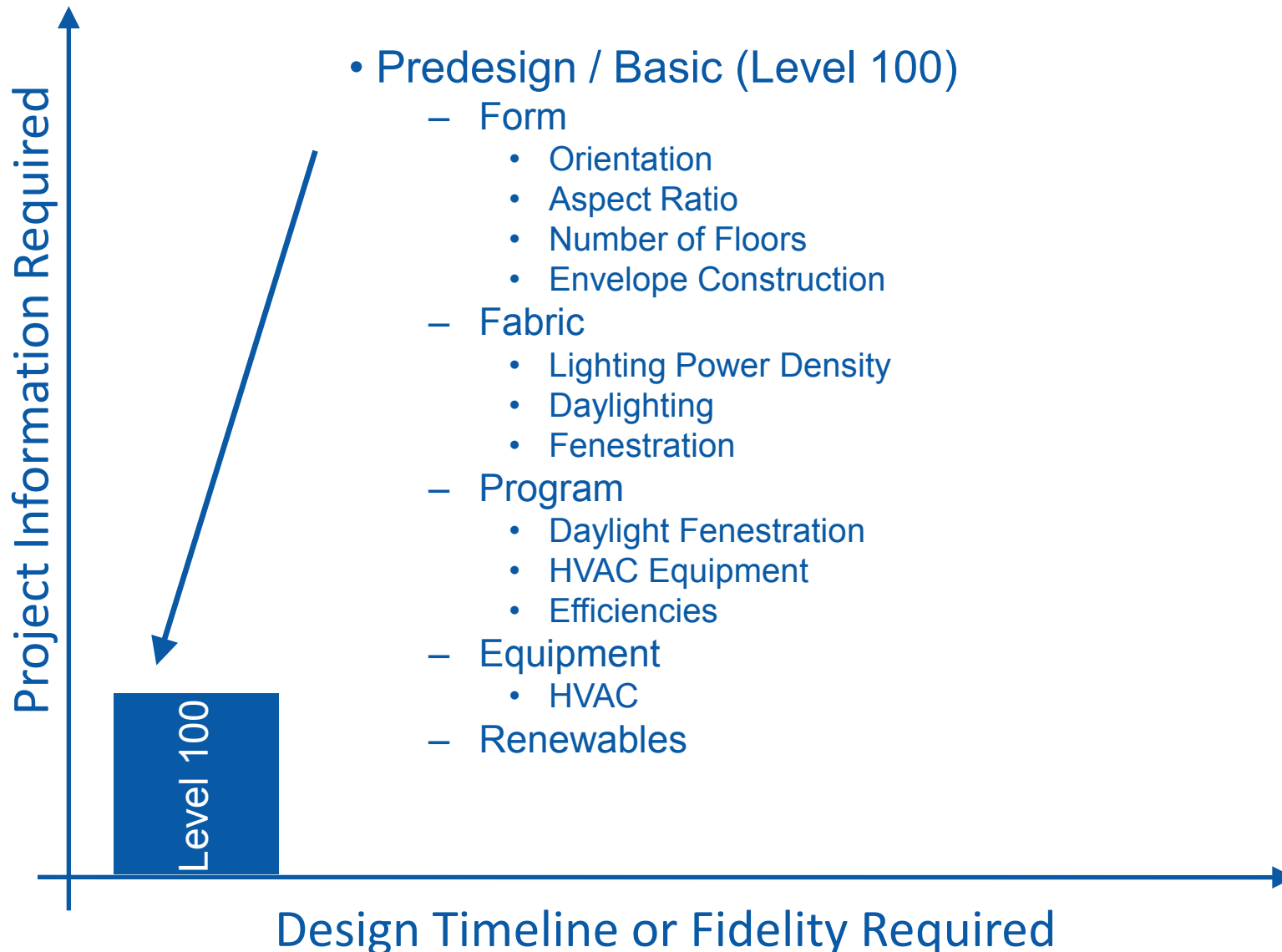
- dimensionality: deals with physical models of equipment and systems.

Example: adding more dimensions to a model's parameters (i.e. 50 inputs to define PV performance)

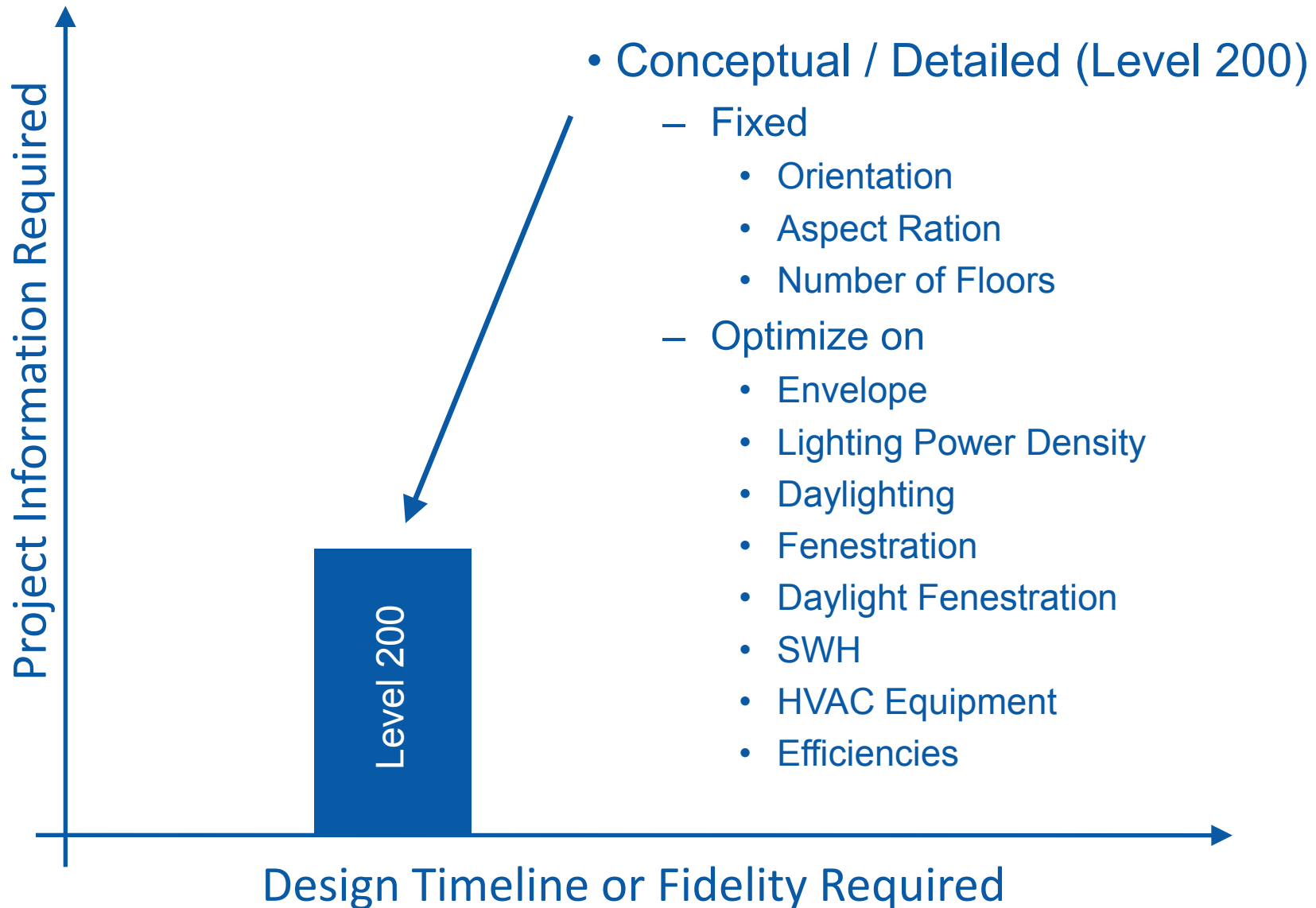
Building Model Progression



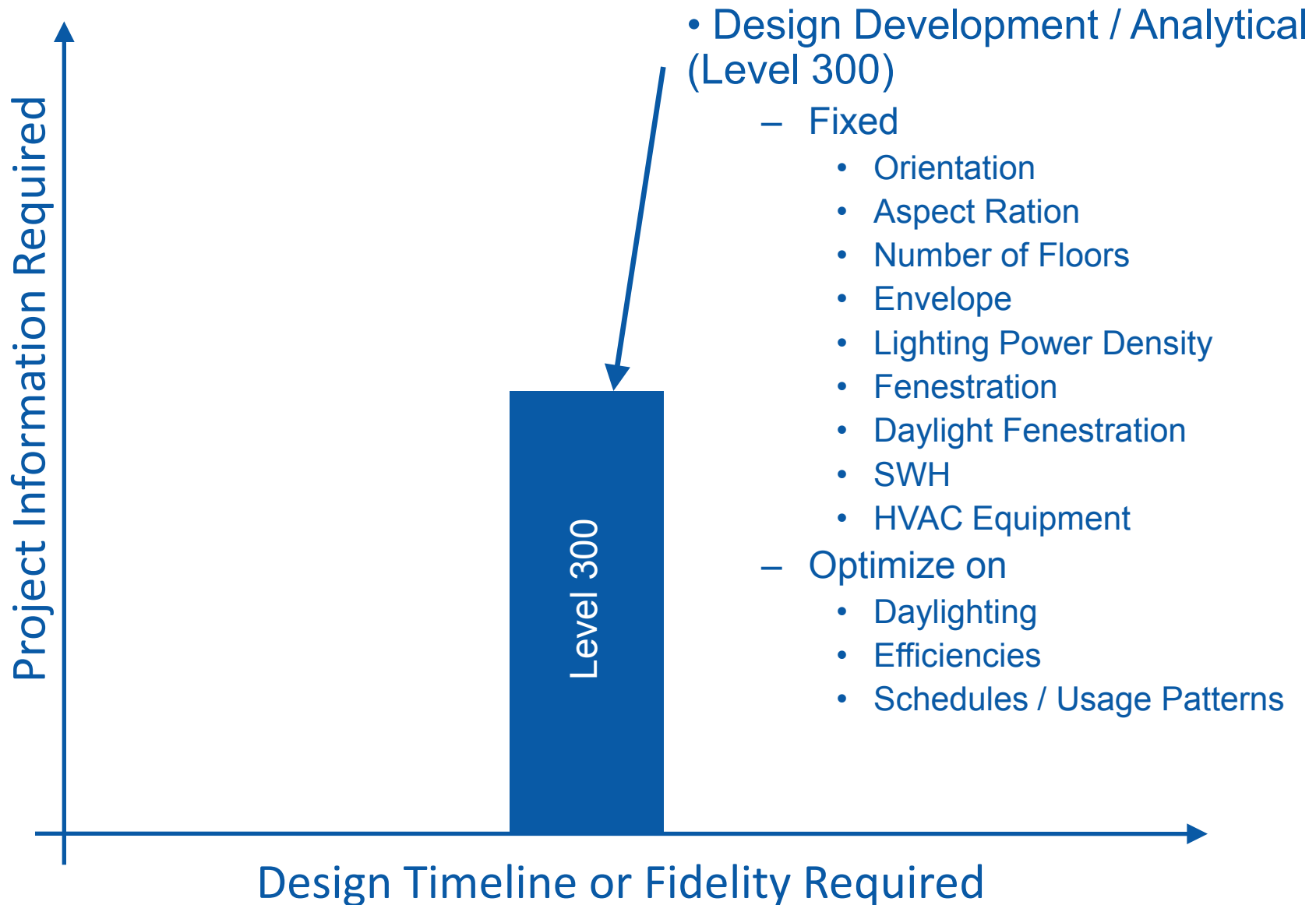
Building Model Progression



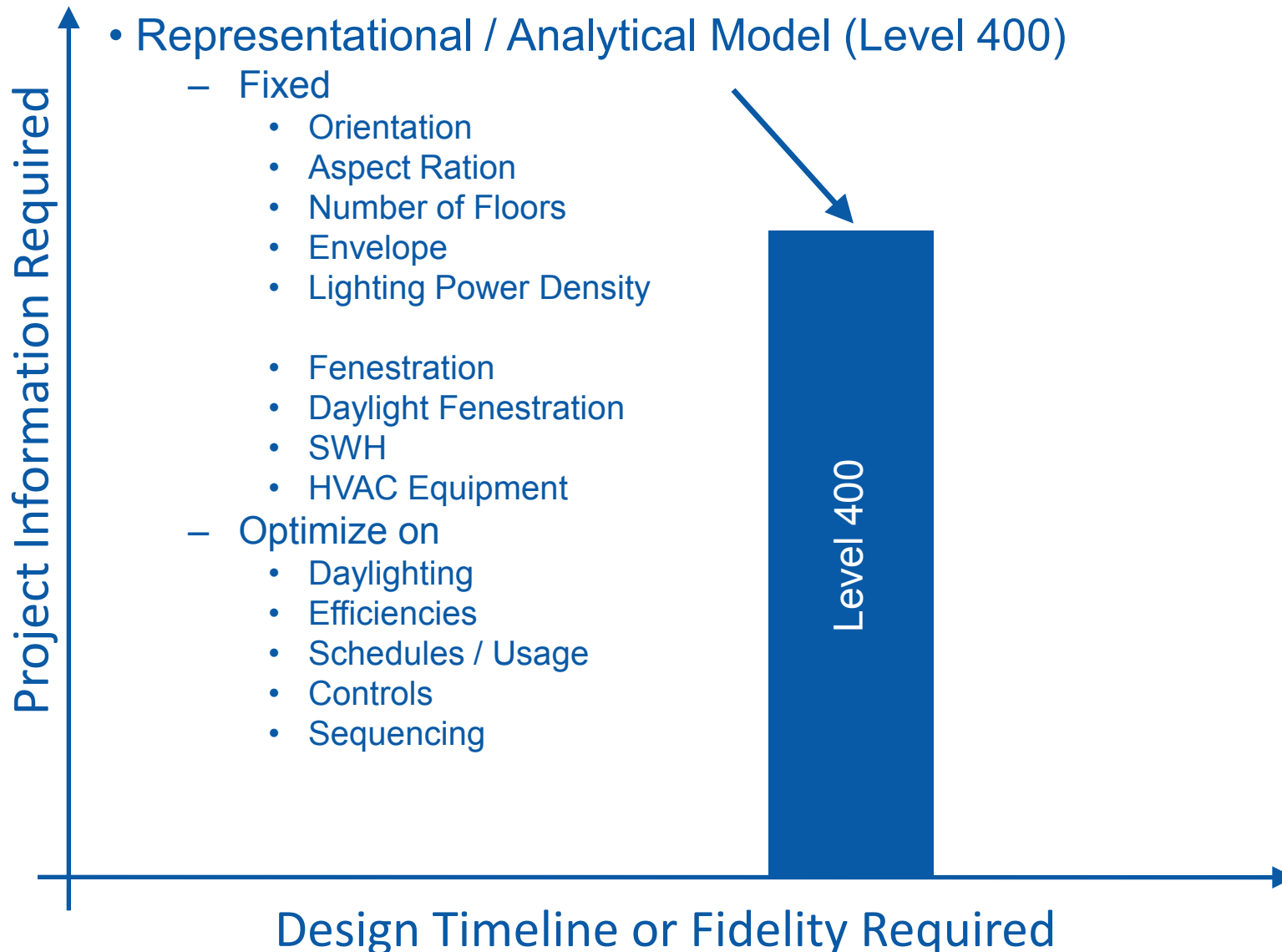
Building Model Progression



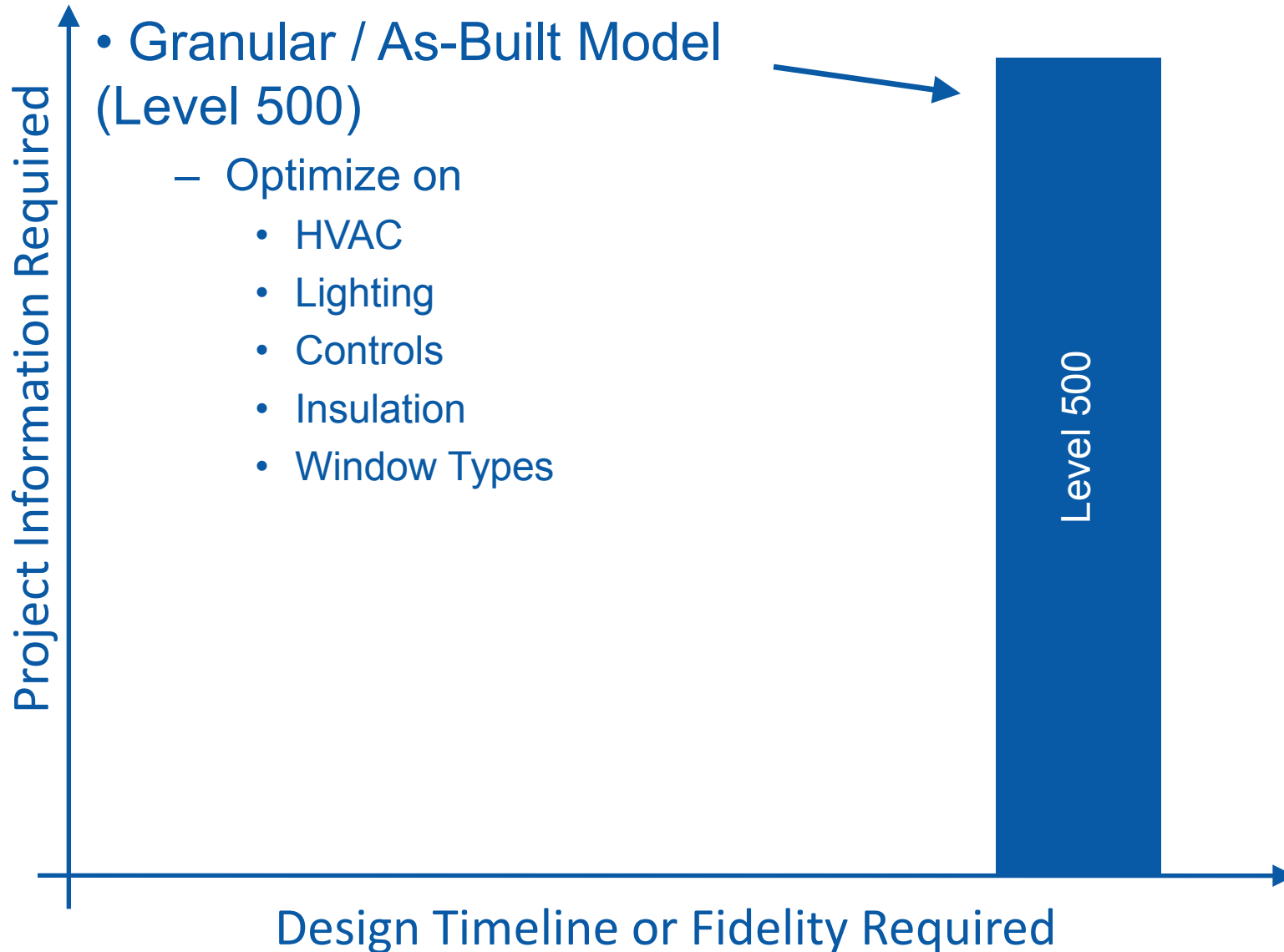
Building Model Progression



Building Model Progression

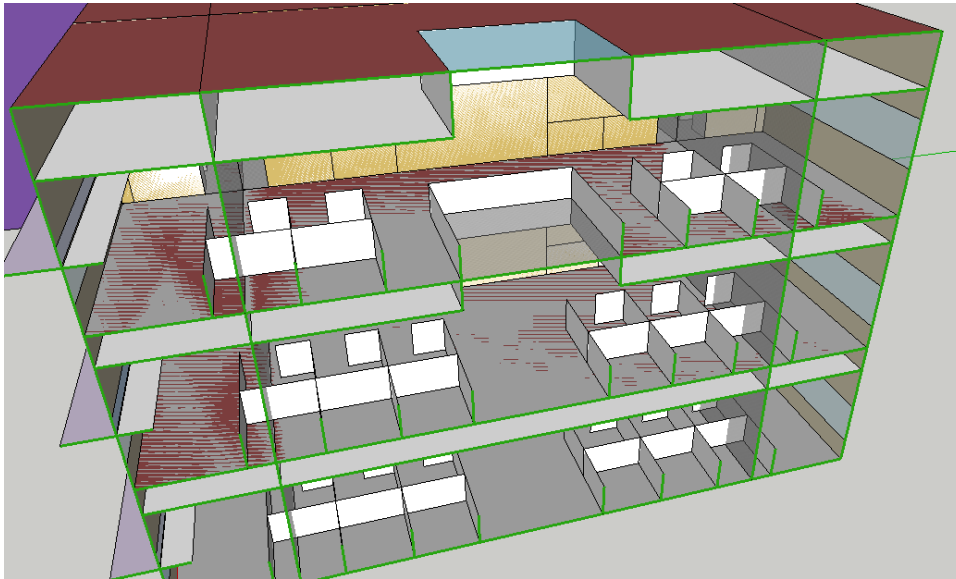


Building Model Progression

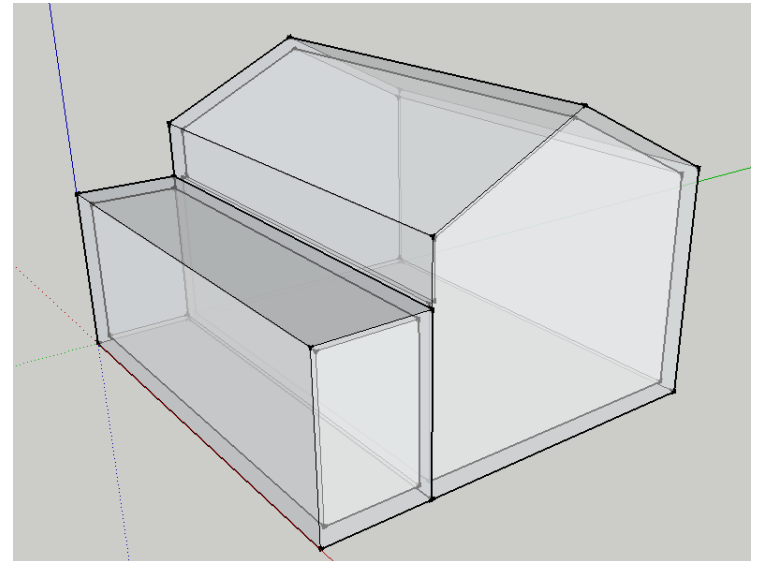


Thick Wall vs Thin Wall

- Level 500 exposes the “Thick Wall” model
- Most Energy Modeling occurs on “Thin Wall” models.

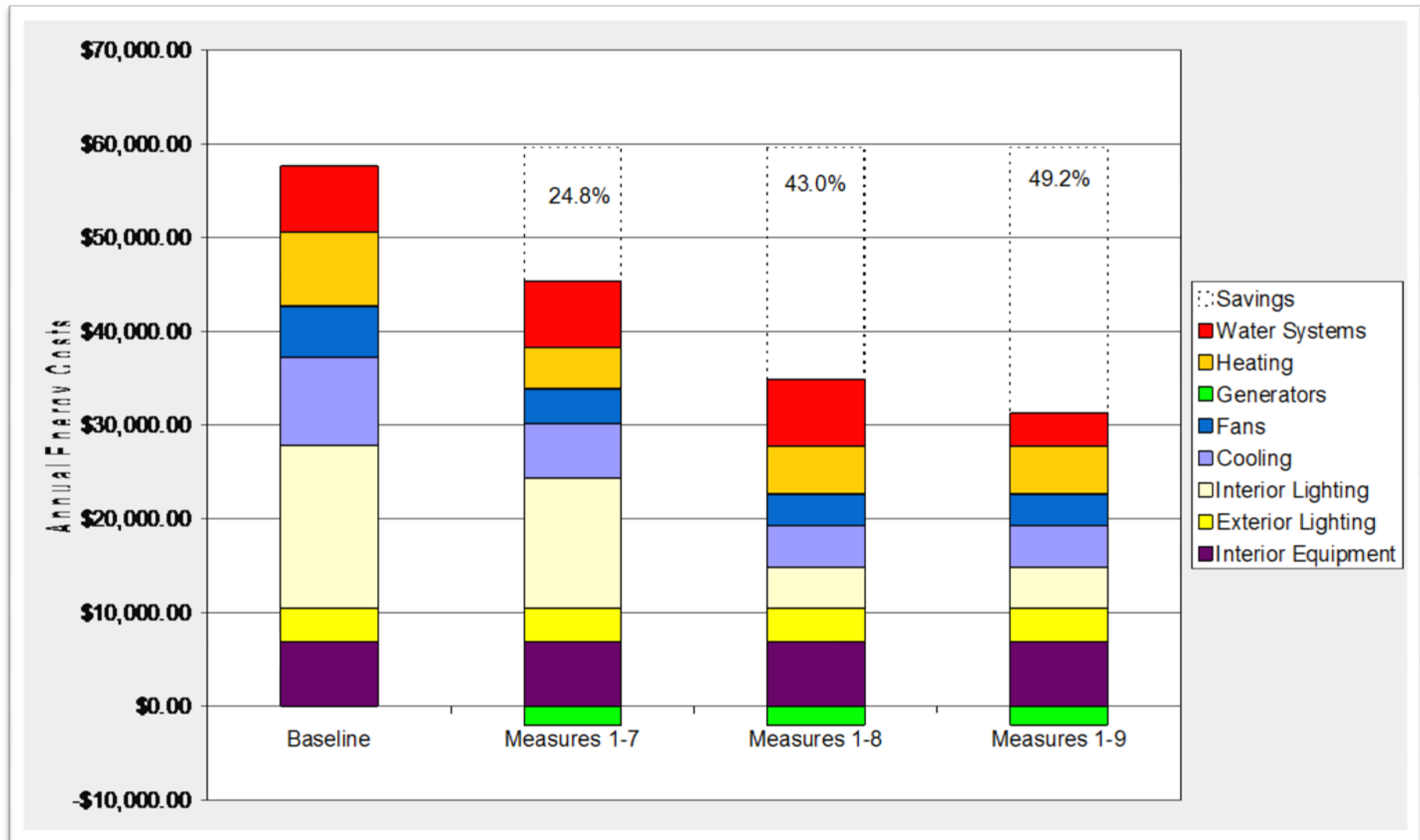


VS



Credit: David Goldwasser / NREL

Combining design measures for more savings



Credit: Nicholas Long / NREL

Energy Modeling Results

Skylight Analysis: Daylighting for Large Retail Building

Start with 133,275 ft² energy model

- Refined with comparisons to sub-metered data

Add skylights and lighting controls to the sales and grocery areas (103,750 ft² total)

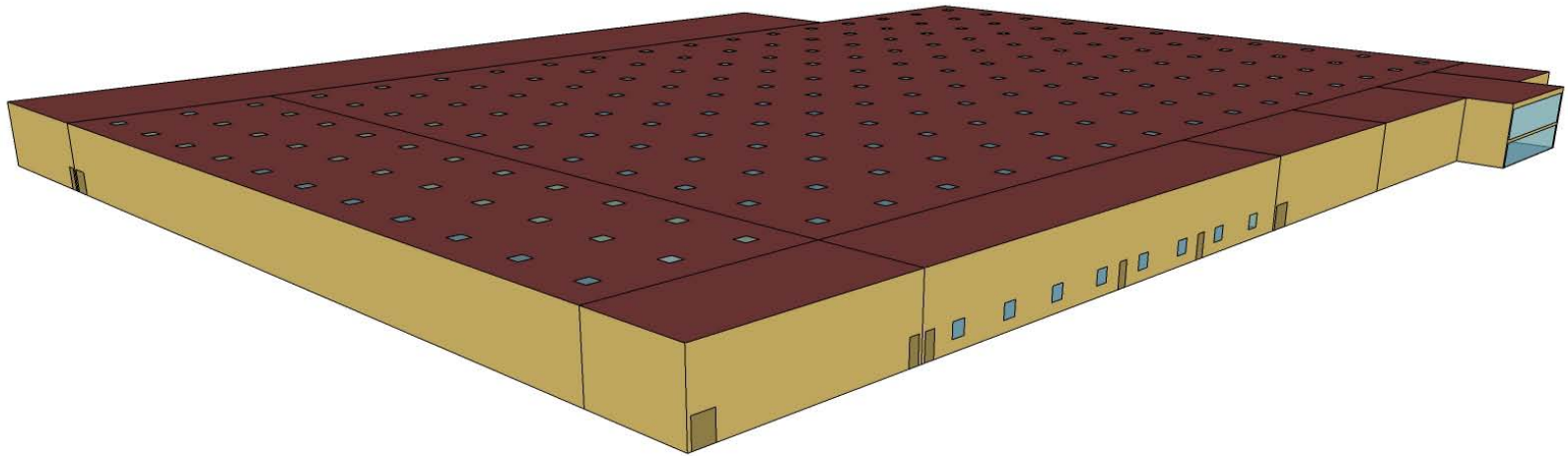
- Skylights: modeled 1% to 5% skylight to floor area (SFA) ratio in 1% increments
- Skylight properties: U-Value = 0.82, SHGC = 0.49, VLT = 0.65
- Lighting control: one sensor per zone, 50 footcandle setpoint, continuous dimming to off

Investigate annual energy performance of the different models using weather data from 7 different climate zones across the United States

Reported results for 3% SFA ratio

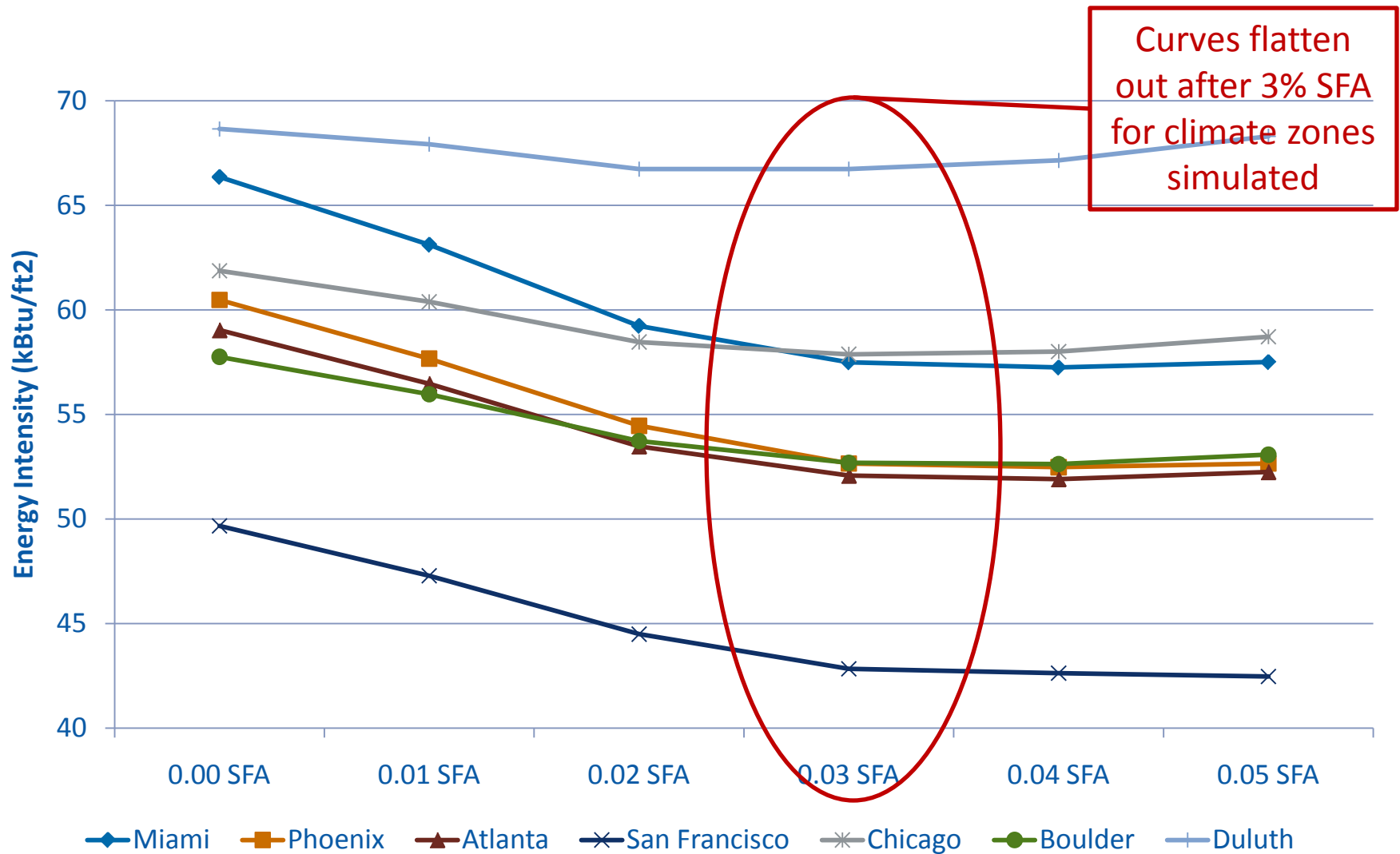
- Diminishing returns for higher SFA ratios

Skylight Analysis: 3% SFA Energy Model Rendering



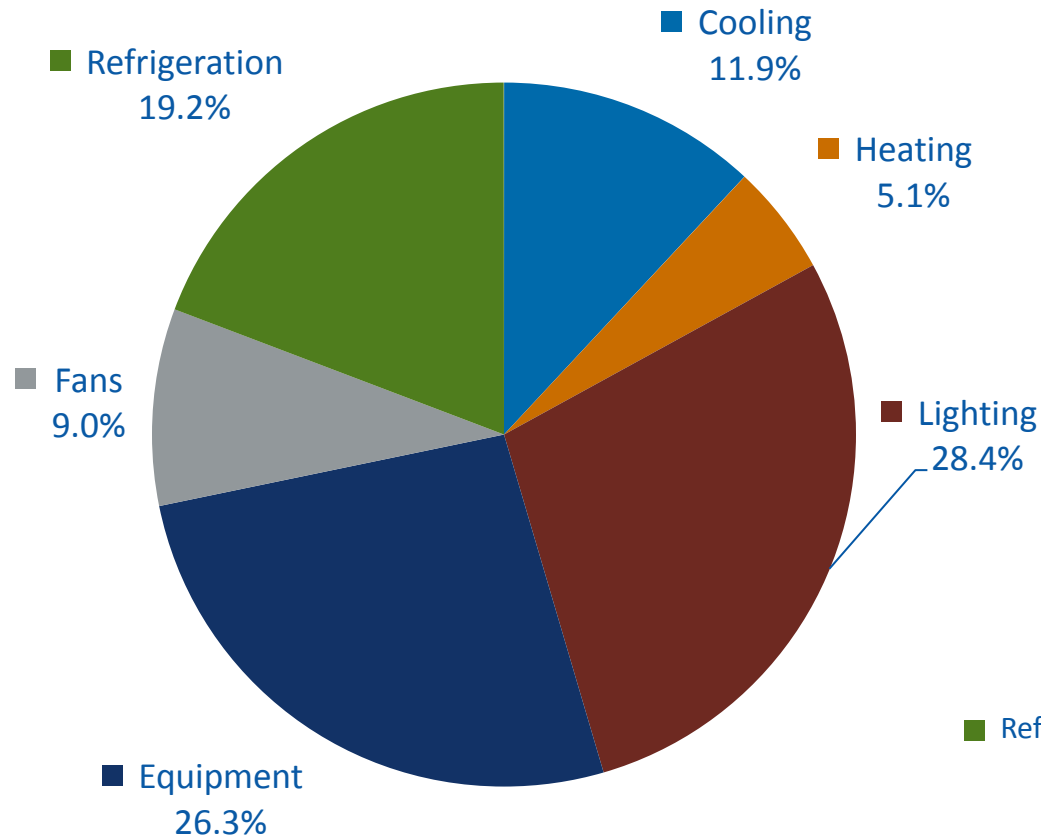
Credit: Eric Bonnema / NREL

Skylight Analysis: Determining SFA Ratio to Report

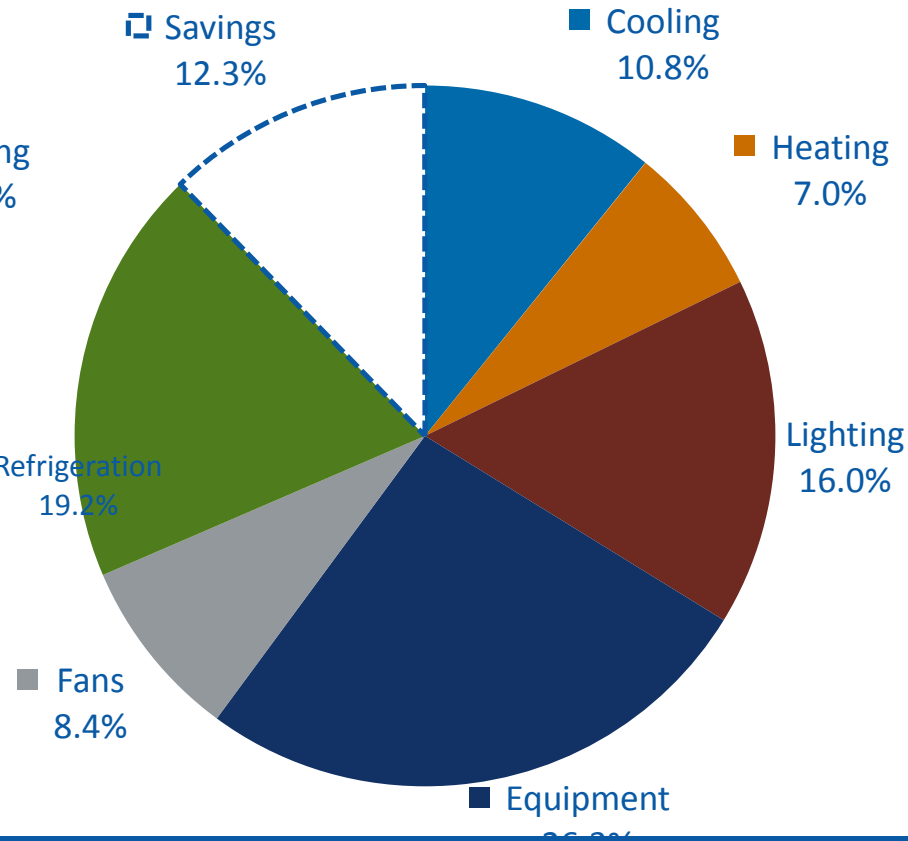


Skylight Analysis: Energy Savings: Atlanta Climate Zone 3A: Hot and Humid

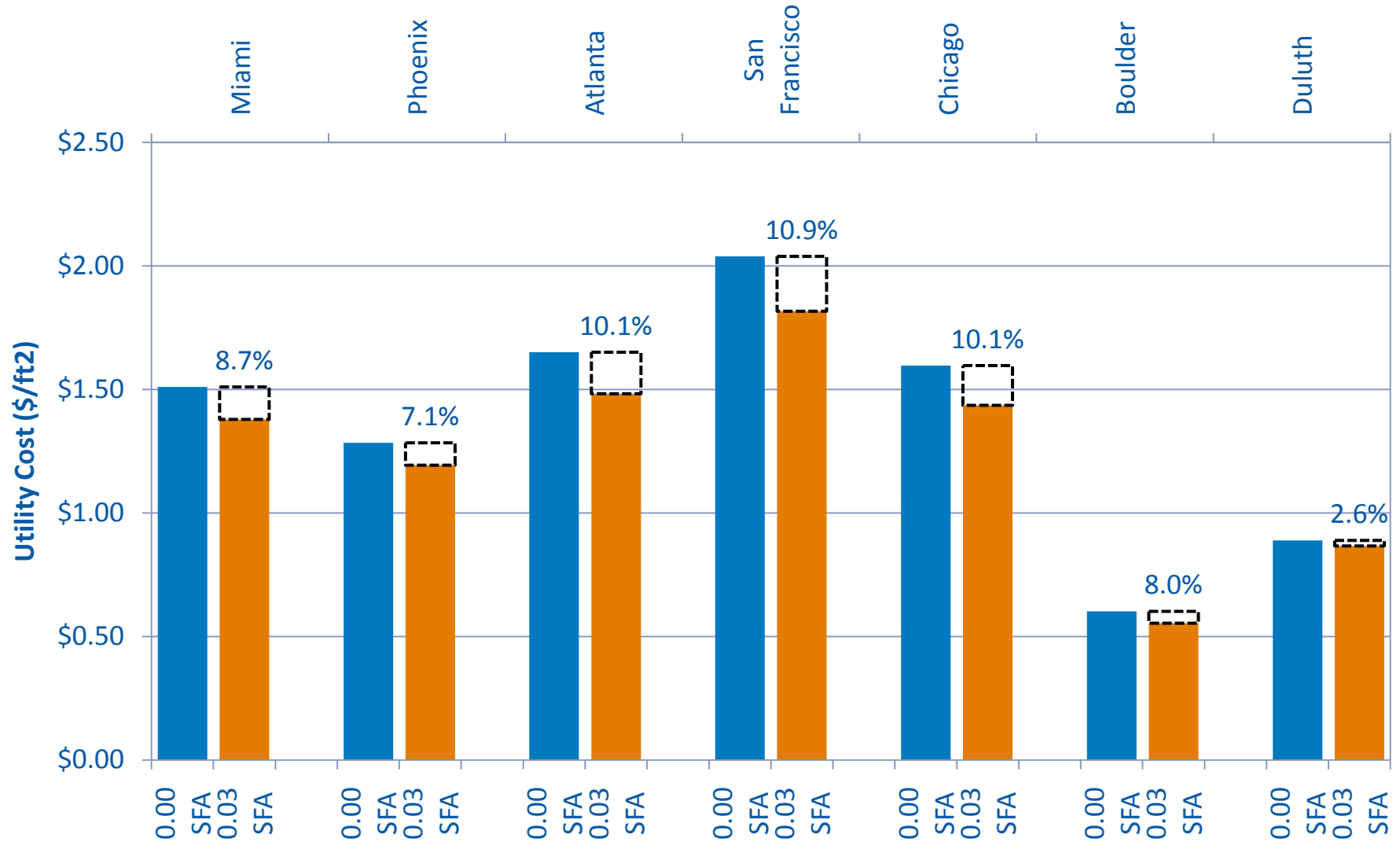
Baseline Model



3% SFA Daylit Model

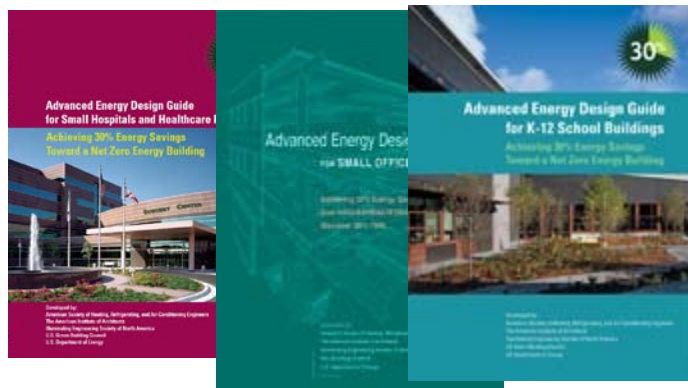


Skylight Analysis: Cost Savings

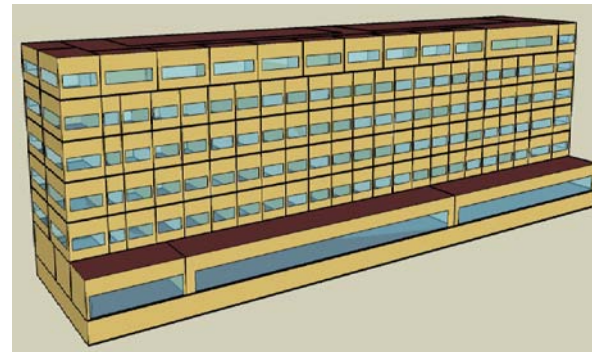


Codes & Standards Development

- Whole Building Energy Modeling is major part of ASHRAE Codes and Standards Development
- ASHRAE 90.1 and the Reference Buildings
(http://www1.eere.energy.gov/buildings/commercial_initiative/reference_buildings.html)
- High level evaluation of ASHRAE Standard 189.1
- AEDG / TSD
- Appendix G
- Energy Cost Budget Method

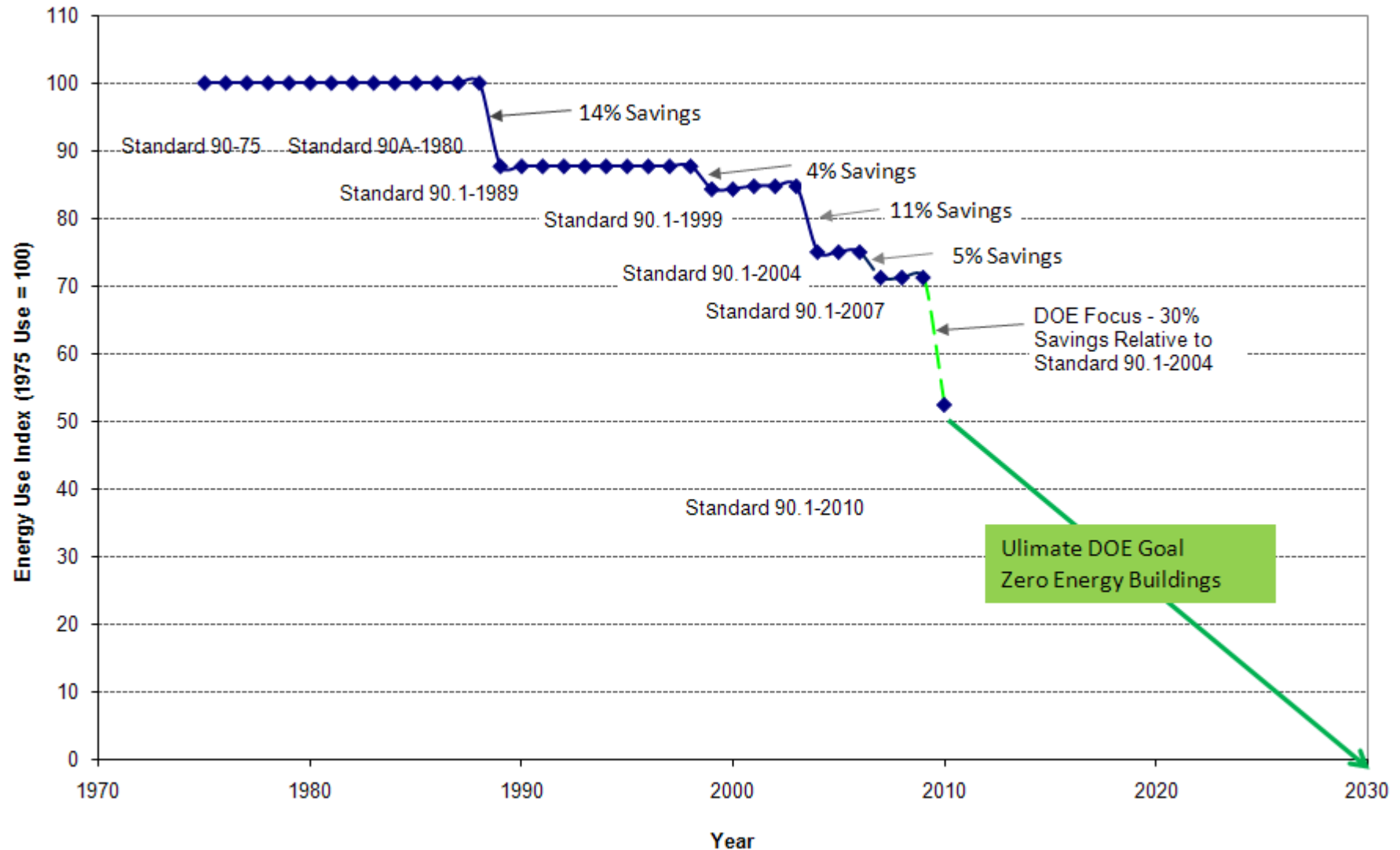


Large Hotel

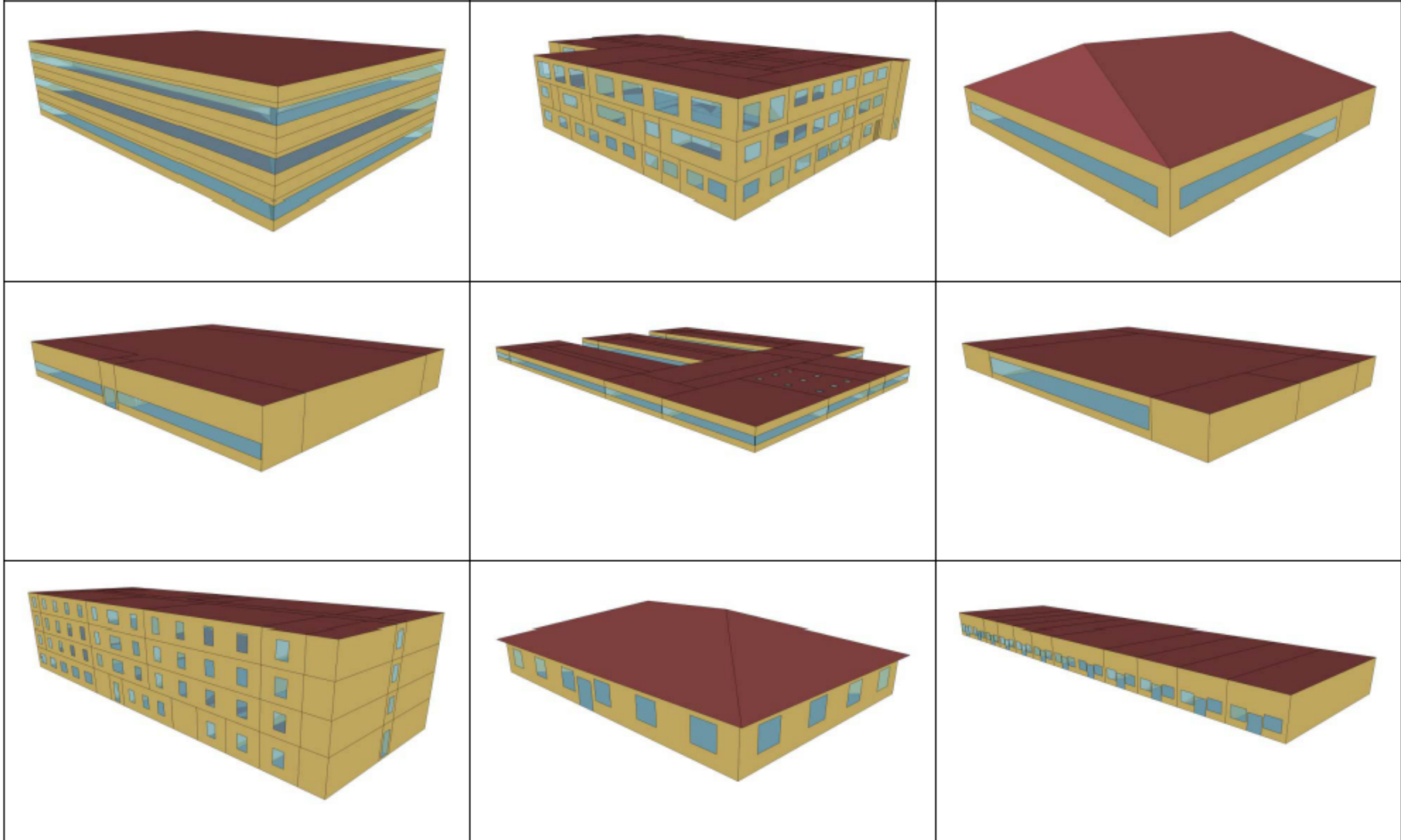


Floor area (ft ²)	Number of Floors	Aspect Ratio	WWR
122,132	6 (plus basement)	Ground & basement floor: 3.8 All other floors: 5.1	27%

History of ASHRAE Standard 90.1



Std 189.1: Wide Variation in Sizing/Zoning Among Reference Models



Std 189.1: Items Included in Simulations

Form

- Skylights

Fabric

- Roofs/Walls/Floors/Slabs
- Vertical Glazing/Skylights
- Continuous Air Barrier
- High-albedo Roofs

Lighting

- Daylighting controls
- LPD
- Exterior Lighting Controls
- Exterior LPD

Plug and Process

- Energy Efficient Equipment

HVAC

- Cooling/Heating Efficiencies
- Economizers
- Energy Recovery
- Fan Power Limitations
- Supply Fans
- Ventilation
- Dampers

SWH

- Efficiencies
- Lower flow rates

Other

- On-site renewables

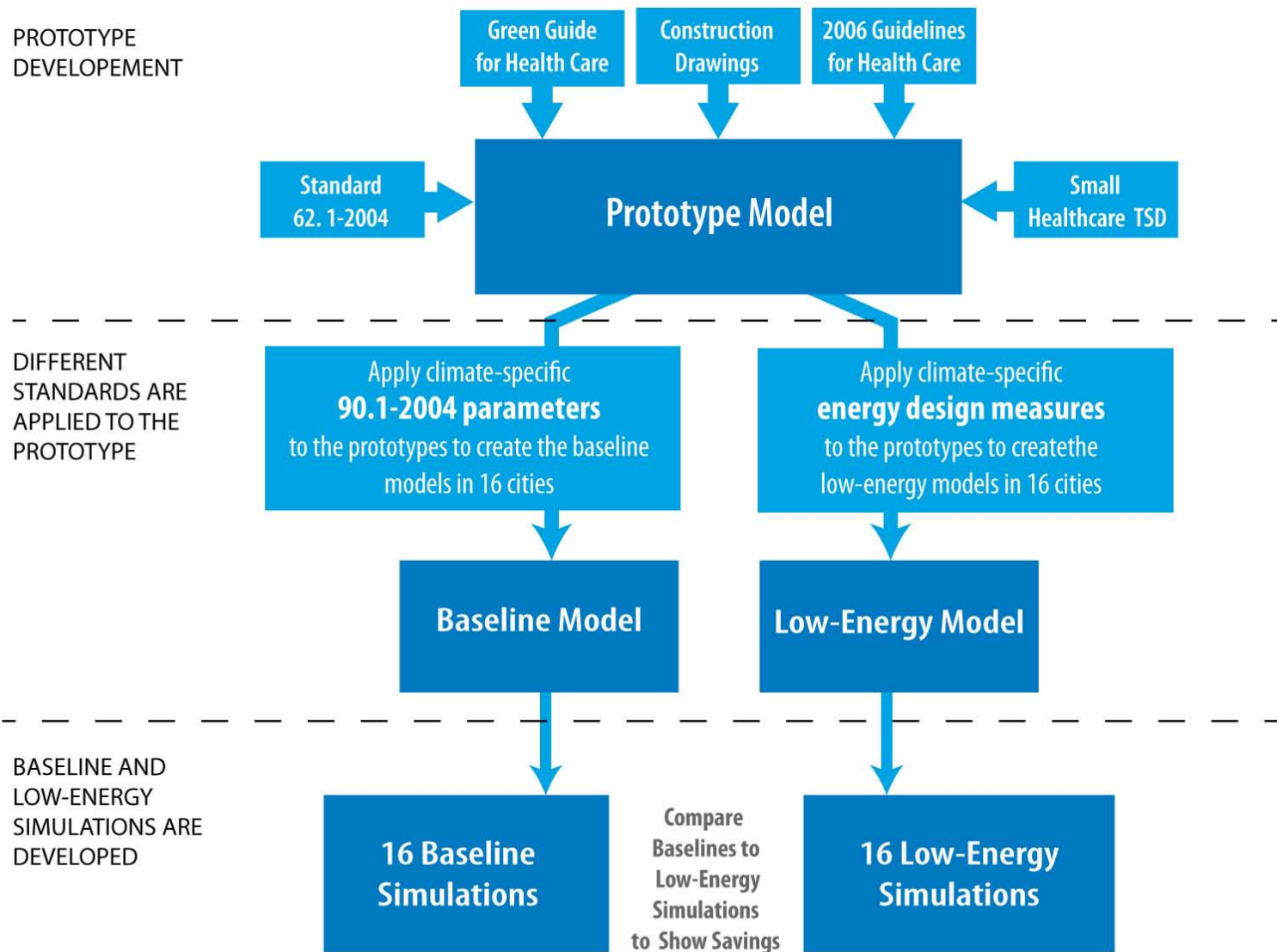
Std 189.1: Weighted Percent Savings

Building Type Name	90.1-2007 v. 90.1-2004	189.1P v. 90.1-2007
Small Hotel	1.5%	37.8%
Large Hotel	0.7%	27.2%
Small Office	4.5%	35.0%
Medium Office	3.5%	36.0%
Large Office	3.1%	37.5%
Hospital	1.8%	21.0%
Mid-rise Apartment	*	*
Outpatient Care	4.8%	15.4%
Primary School	4.3%	24.3%
Secondary School	4.1%	32.2%
Quick Service Restaurant	0.6%	29.3%
Full Service Restaurant	0.5%	33.5%
Supermarket	1.6%	20.4%
Stand-alone Retail	4.2%	22.6%
Strip Mall	3.9%	24.5%
Warehouse	1.2%	54.6%
Average	3.3%	30.2%

* No weighting factors were defined for the Mid-rise Apartment

<http://www.nrel.gov/docs/fy10osti/47906.pdf>

Large Hospital TSD: Modeling Process



16 Climate Zones: 1A, 2A, 2B, 3A, 3B: CA, 3B: Other, 3C, 4A, 4B, 4C, 5A, 5B, 6A, 6B, 7, 8

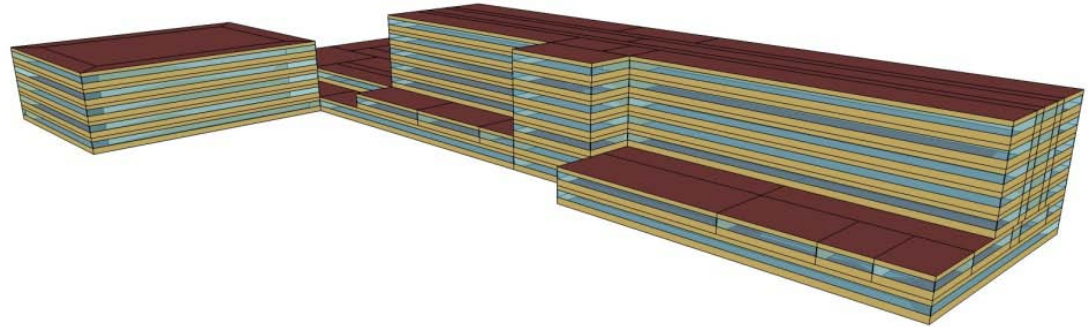
Large Hospital TSD: Prototype Model

Form

- 527,000 ft²
- 40% window-to-wall ratio

Space Types

- Floor 1: offices, laboratories, dining, mechanical, support spaces, clinic
- Floor 2: emergency department, surgery suite, imaging,
- Floor 3: birthing center
- Floor 4-7: patient tower
- 5-story attached medical office building



Envelope

- Slab-on-grade
- Steel framed exterior walls
- Insulation above deck roof
- Double pane fixed windows

Internal Loads

- Plug load density: 2.6 W/ft²
- Occupant density: 136 ft²/person

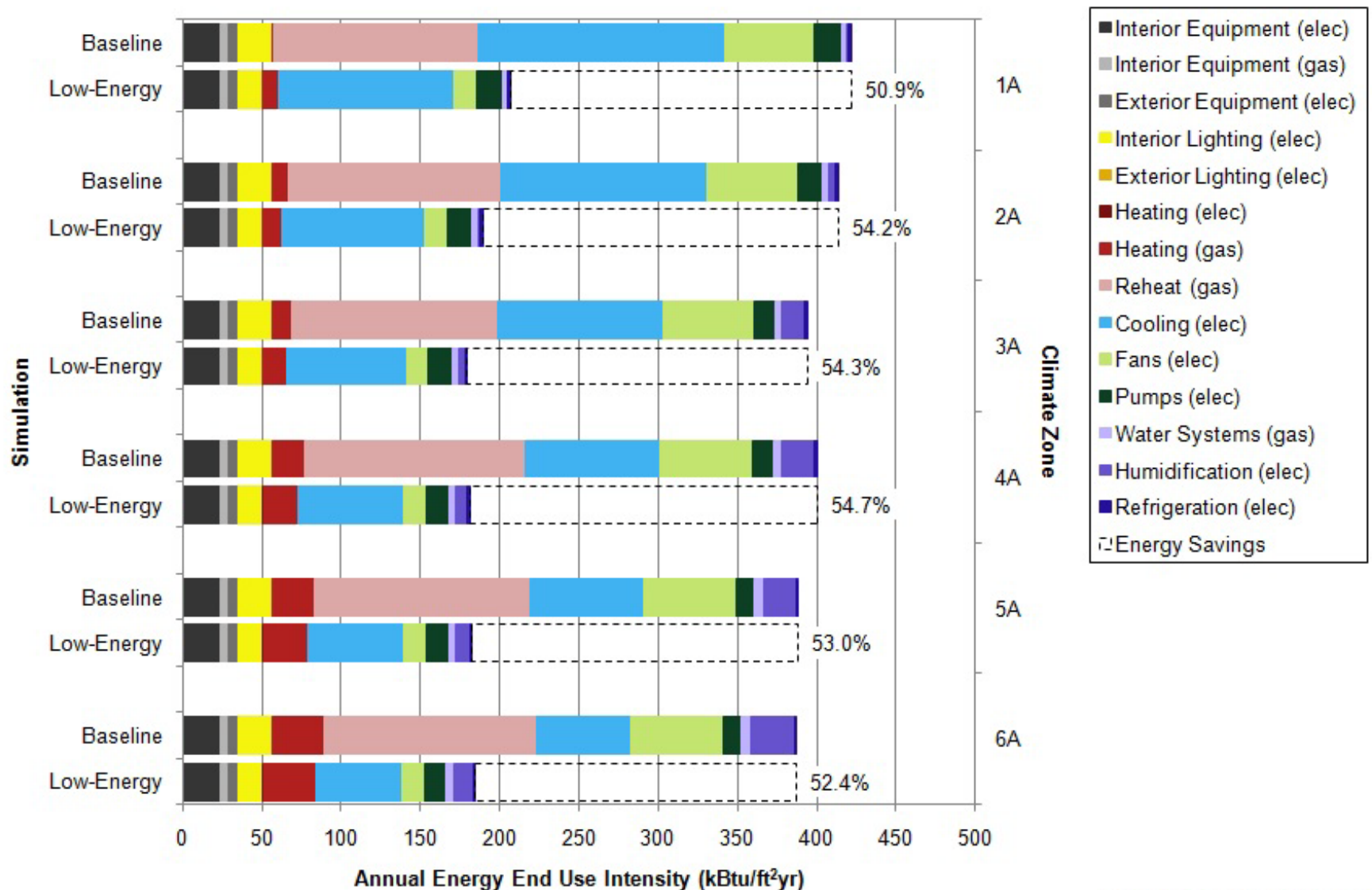
Ventilation/Airflow Standards

- Healthcare spaces
 - 2006 AIA Guidelines
 - Standard 170-2008
- Administrative spaces
 - Standard 62.1-2004



Used with permission from KJWW

Large Hospital TSD: Annual Energy Savings



Credit: Eric Bonnema/NREL

NREL RSF: Performance Based Design Build Procurement

NREL Research Support Facility

- Building type = office with data center
- Size = 222,000 ft², 3 stories
- Occupancy = approx. 600 people
- Energy use before PV = 25 kBtu/ft²
- 50% savings over ANSI/ASHRAE/IESNA Standard 90.1-2004
- Targeted LEED™ Platinum rating



Credit: NREL PIX

NREL RSF: Performance Based Design Build

RFP - Priority List Rank

MISSION CRITICAL

Attain Safe Work Performance/Safe Design practices

LEED™ Platinum

ENERGY STAR First —Plus , unless other system outperforms

HIGHLY DESIRABLE

Up to 800 staff capacity

25 kBTU/sf/year

Architectural integrity

Honor future staff needs

Measurable ASHRAE 90.1 - 50% plus

Support culture and amenities

Expandable building

Ergonomics

Flexible workspace

Support future technologies

Documentation to produce a —How to manual on DB

Allow secure collaboration with outsiders

Building information modeling

Substantial Completion by May 2010

NREL RSF: Energy Goal Risk Analysis

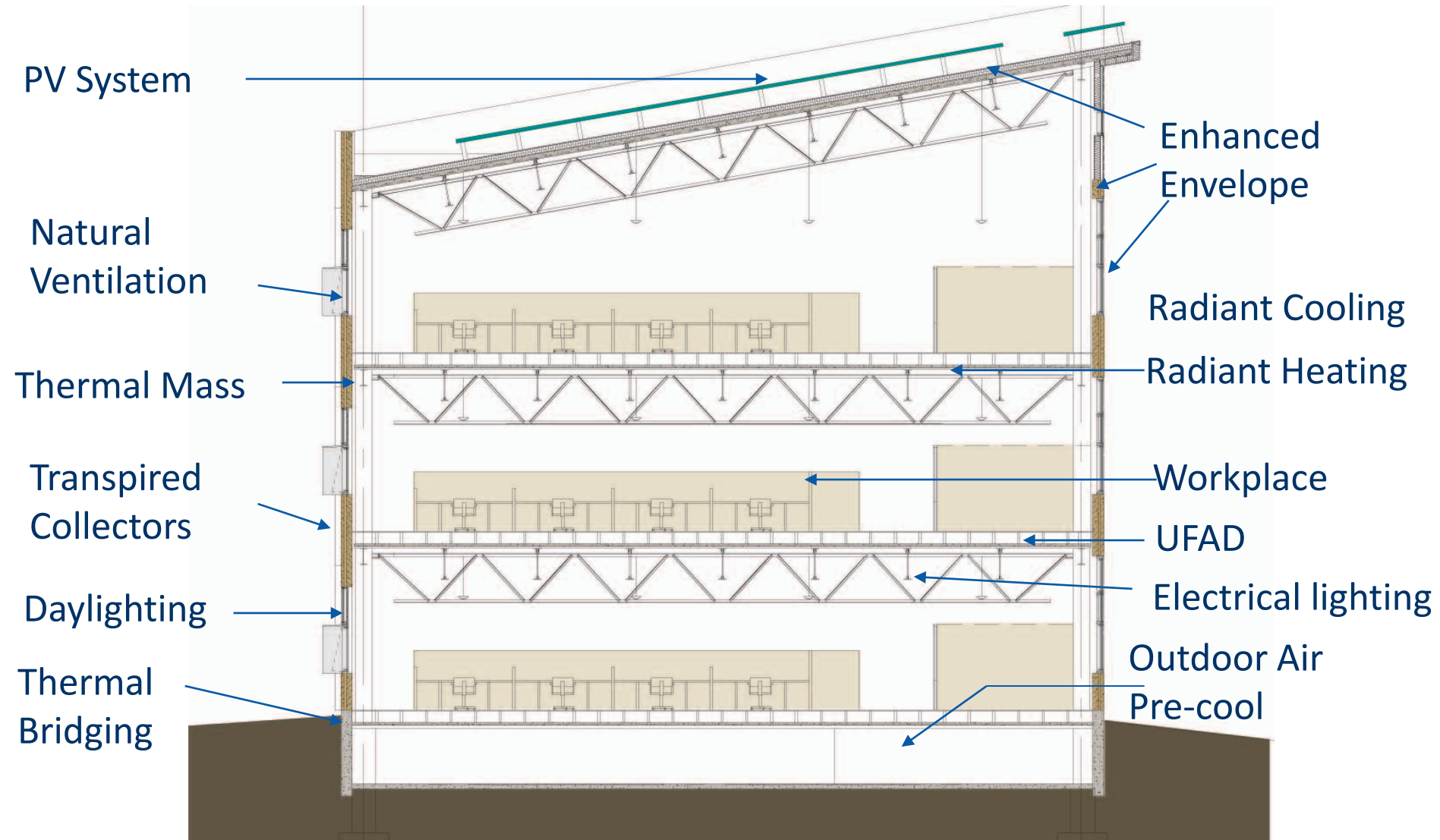
25 kBTU/sf/Year

- a. The Owner's requirements demand innovation and creativity. Unfortunately, the assumption by the industry is that the construction of an efficient facility increases the cost to the project.
- b. The **Owner** will be required to **control the energy consumption at the plug loads** which will require the tight interface with the NREL staff and management.
- c. It should be noted that the Data Centers **will be** included in the facility energy consumption goals.

NREL RSF: Plug Load Reduction



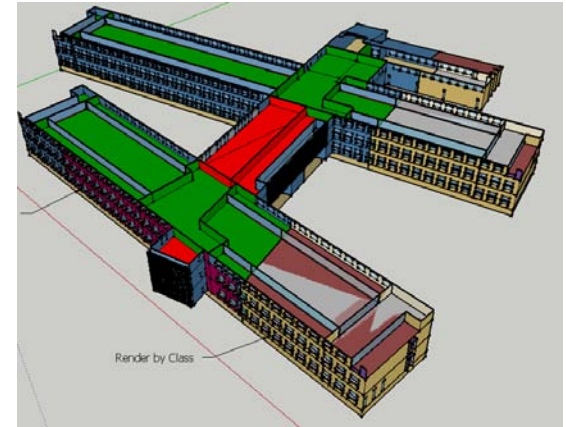
NREL RSF: Design Features



NREL RSF: Achieving the Goal

How did the RSF team turn the goal of a net zero building into a reality?

- Early, strong commitment to energy savings
- Integrated design-build process
- Focus on efficiency to reduce PV needed
- Energy Modeling and Analysis

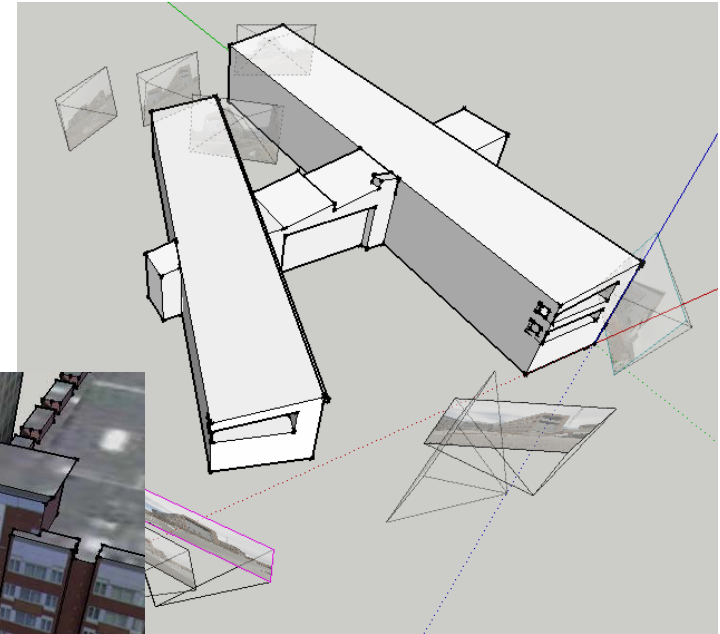


Credit: Rob Guglielmetti / NREL

Energy Modeling and Retrofits

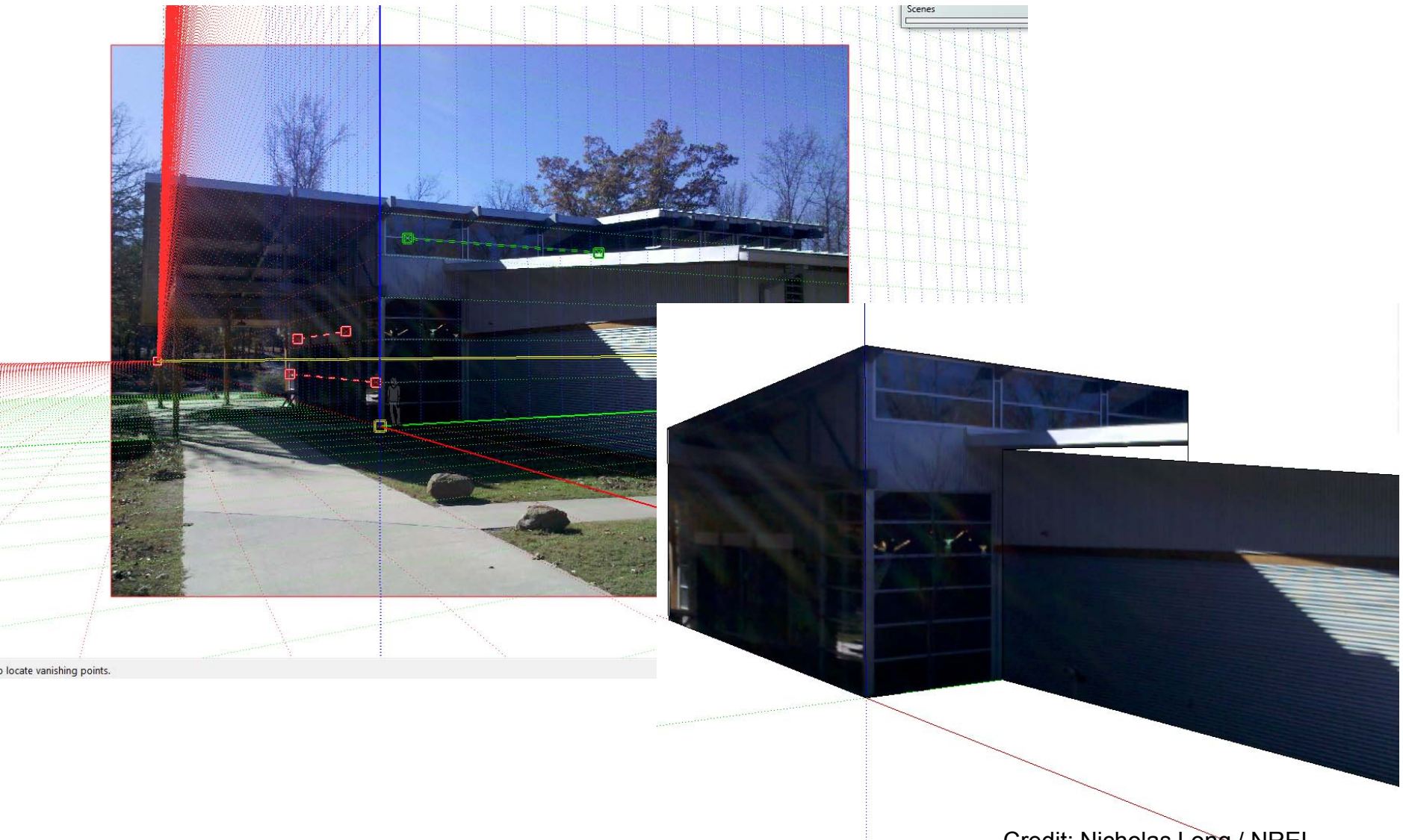
Large amount of existing data and advanced photometrics exist.

Leverage audit information with existing geometry



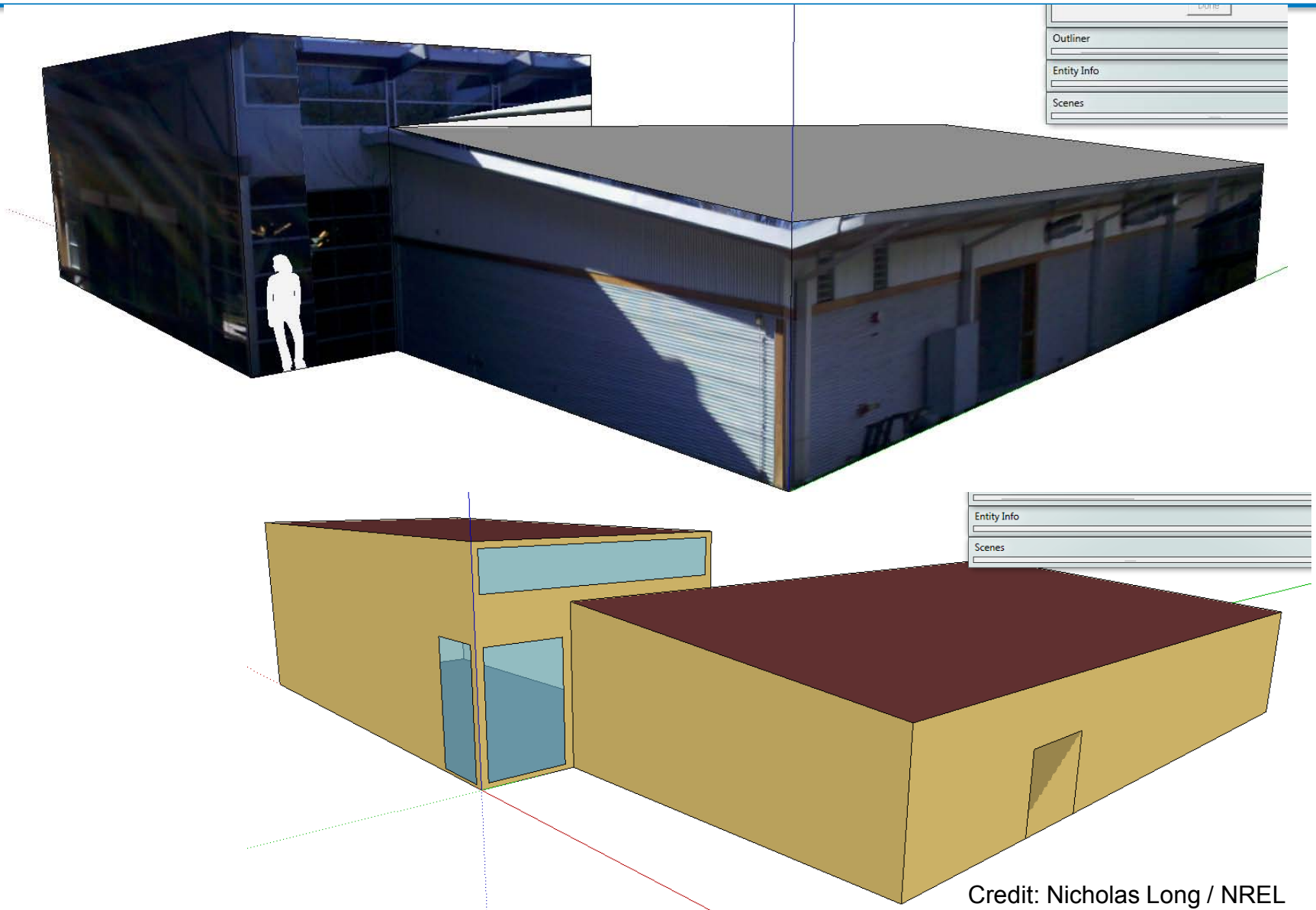
Credit: David Goldwasser / NREL

Retrofit Modeling



Credit: Nicholas Long / NREL

Retrofit Modeling



Credit: Nicholas Long / NREL

Retrofit Modeling

Electricity [GJ]	Natural Gas [GJ]	Other Fuel [GJ]	District Cooling [GJ]	District Heating [GJ]	Water [m3]	
Heating	0.00	0.00	0.00	0.00	76.97	0.00
Cooling	0.00	0.00	0.00	29.53	0.00	0.00
Interior Lighting	22.71	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	35.14	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	57.86	0.00	0.00	29.53	76.97	0.00

Typical Barriers to Using Simulation

Some real, some perceived

- Complexity
- Time Investment
- Experience required
- Lack of Data
- Belief of Inaccurate Results

How to overcome?

- Training courses
- User listservs (i.e. bldg-sim)
- Software documentation
- Conference proceedings (IBPSA)
- Sessions like this
- Design Guides
 - ASHRAE/AIA/DOE/IES/USGBC Advanced Energy Design Guide series
 - Other
- Example files as starting point / Wizards
 - Included with some software
 - DOE's commercial reference buildings



Credit: Nicholas Long / NREL

Conclusions

Energy modeling can accurately represent real building energy use as long as

- Input data is reasonable
- Weather data is accurate
- Schedules are calibrated
- Occupants are predictable
- Performance curves are correct

Energy modeling is useful for performance based metrics, for codes & standards compliance, and for validating design strategies

Save the Date

ASHRAE's Energy Modeling Conference

April 4-5, 2011

***Location: ASHRAE Headquarters
Atlanta, GA***

Presentations and Panels on:

- HVAC Modeling, Envelope, Daylighting, Various Modeling Tools, Codes & Standards, Controls, etc.

Thank You – nicholas.long@nrel.gov