Building Energy Modeling

Passive Design, Thermal Comfort, Daylighting, Lighting, Energy Efficiency and Renewable Energy…

…Energy Modeling & Performance Validation

September 17, 2014

INTEGRAL

Revolutionary Engineering

imagine | perform | accelerate | sustain

Energy Modeling and Data Collection

Why we Model the way we do…
Lessons Learned
Current High Performance Office Design Example
Current LBNL Lab Design Example
NZE Case Study: Packard Foundation

Why do we model?

Convey the value of architecture and mechanical systems

beyond energy into…

first cost…

true operational costs…

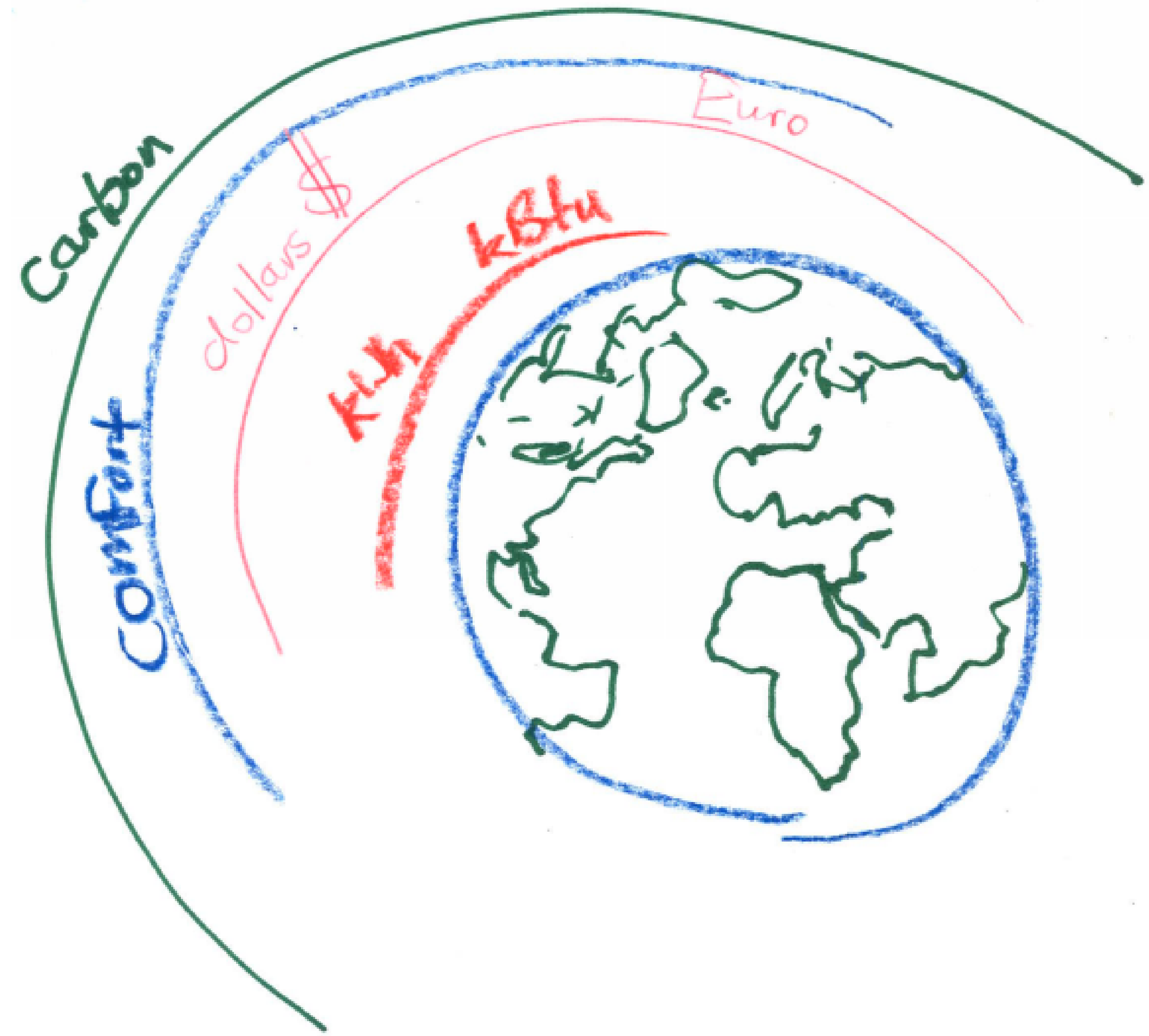
further into the comfort and wellness aspects.

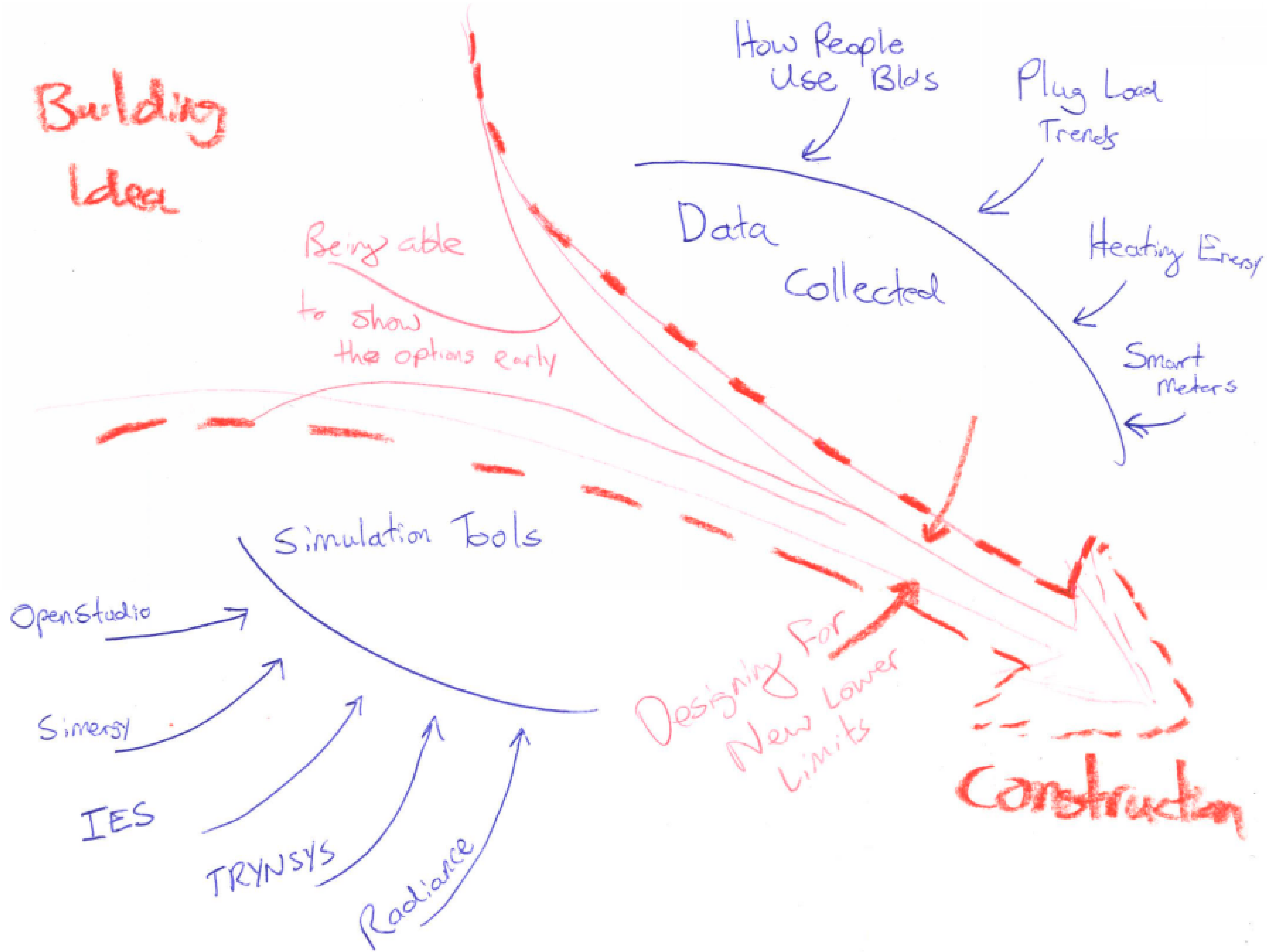
However our audience is rapidly changing

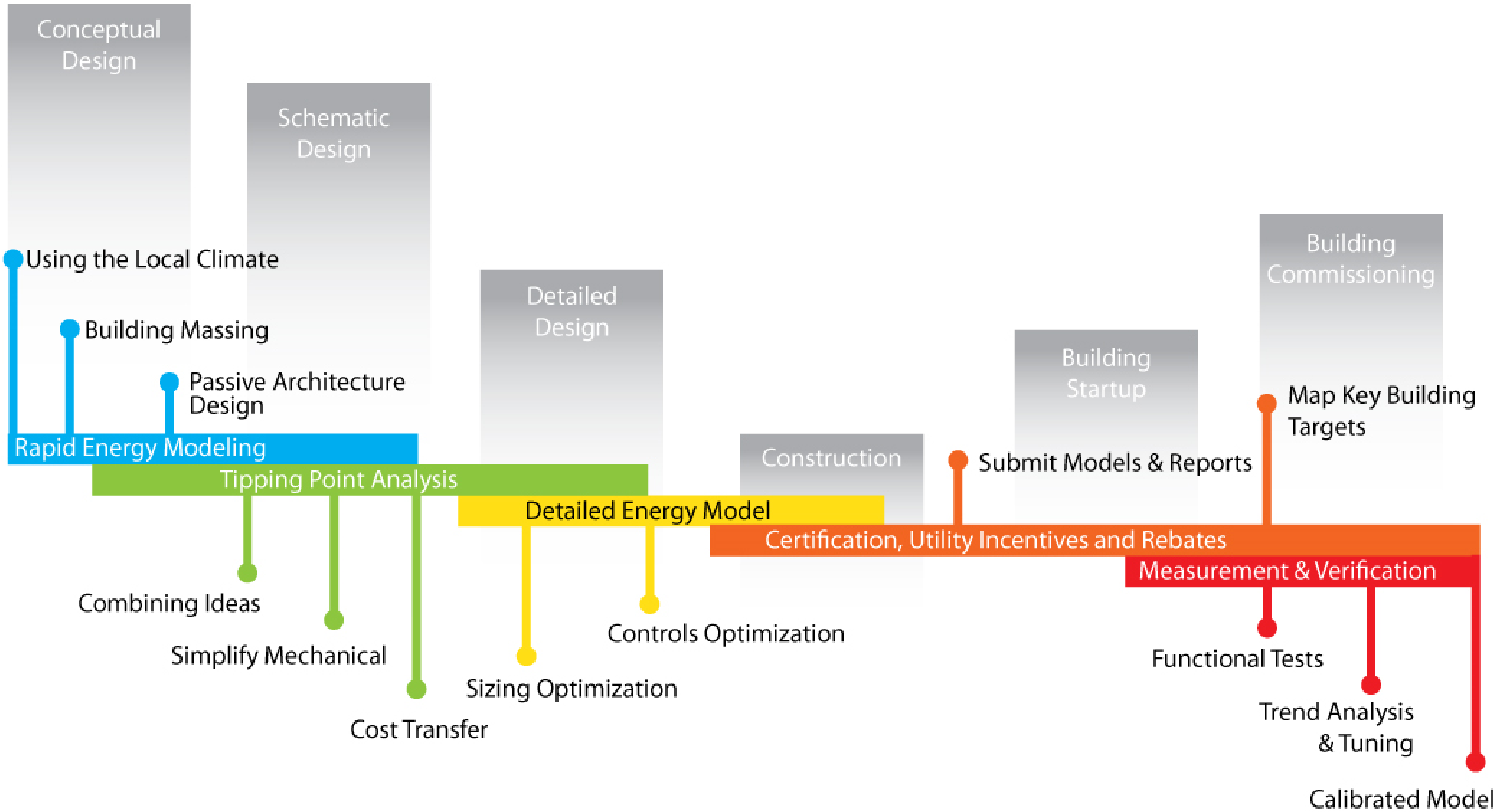
developer and investor driven

Now, developers are demanding all things in $

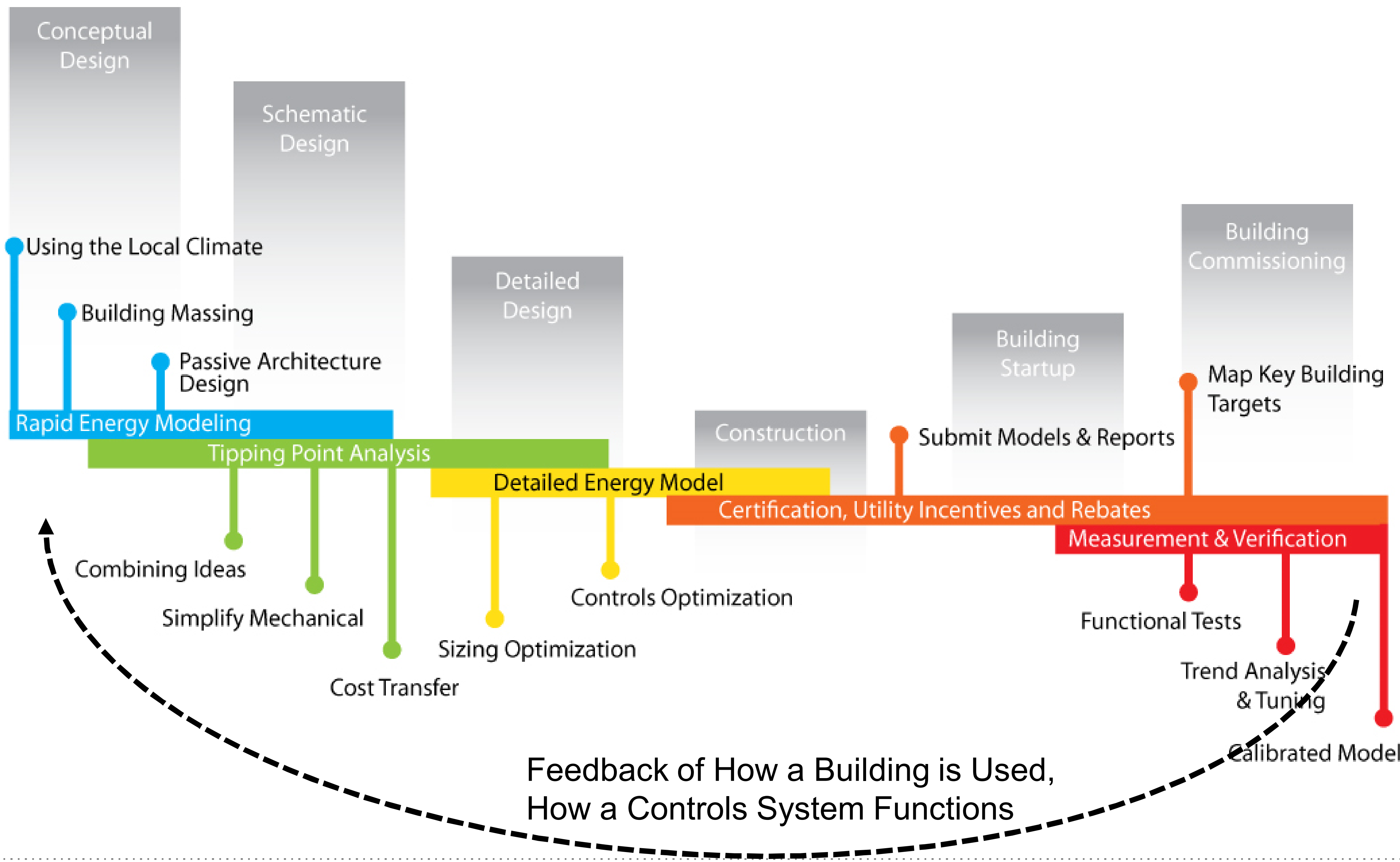
Institutional work focused on carbon neutrality




Building Idea
How People Use Blds
Plug Load Trends
Data Collected
Heating Energy
Smart Meters
Being able to show the options early
Simulation Tools
OpenStudio
Simergy
IES
TRYNSYS
Radiance
Designing For New Lower Limits
Construction



Conceptual Design
Schematic Design
Detailed Design
Construction
Building Startup
Building Commissioning
Using the Local Climate
Building Massing
Passive Architecture Design
Rapid Energy Modeling
Tipping Point Analysis
Detailed Energy Model
Certification, Utility Incentives and Rebates
Measurement & Verification
Submit Models & Reports
Map Key Building Targets
Combining Ideas
Simplify Mechanical
Cost Transfer
Sizing Optimization
Controls Optimization
Functional Tests
Trend Analysis & Tuning
Calibrated Model


Conceptual Design
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Simplify Mechanical
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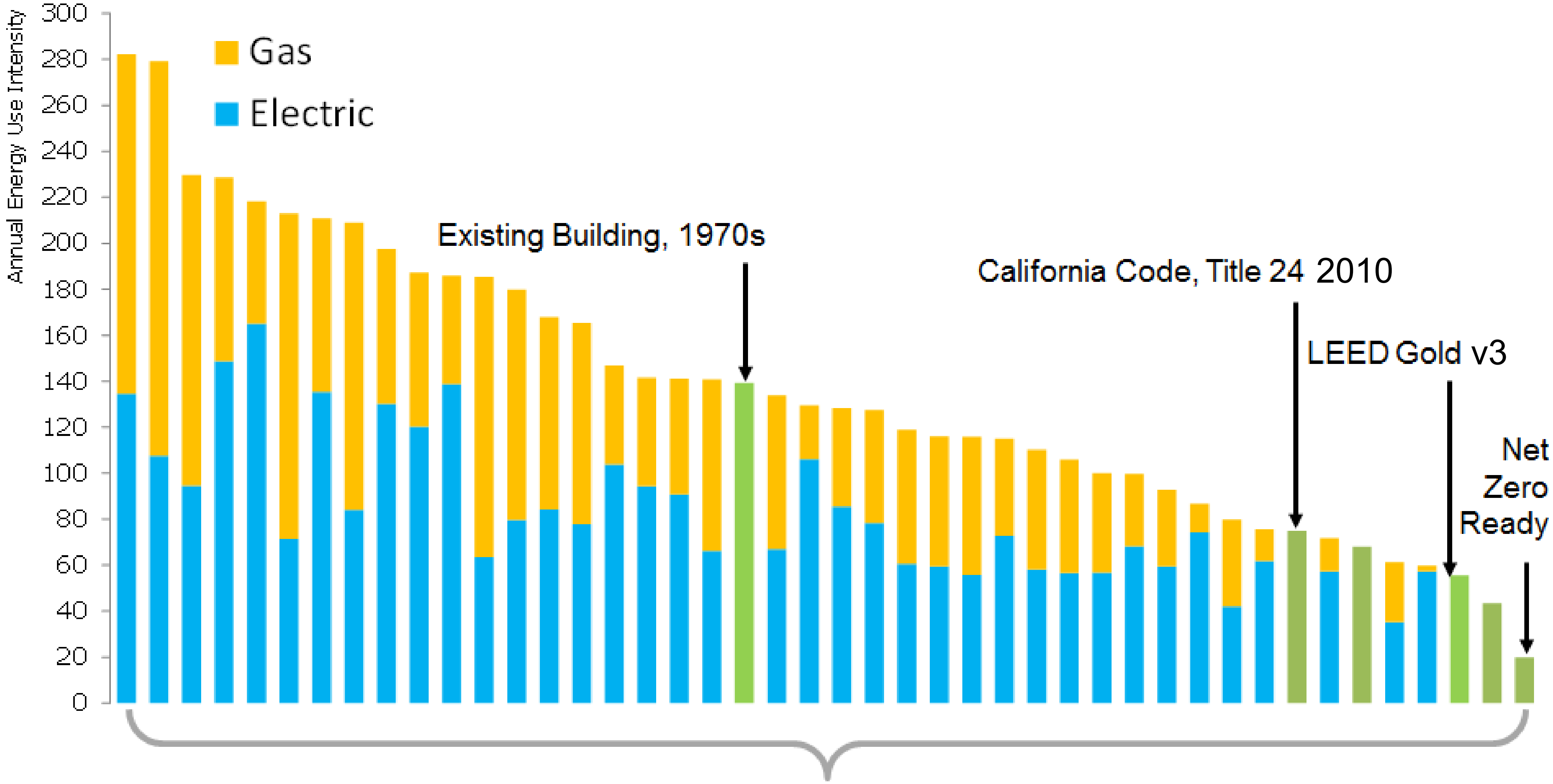
Controls Optimization
Functional Tests
Trend Analysis & Tuning
Calibrated Model
Feedback of How a Building is Used,
How a Controls System Functions

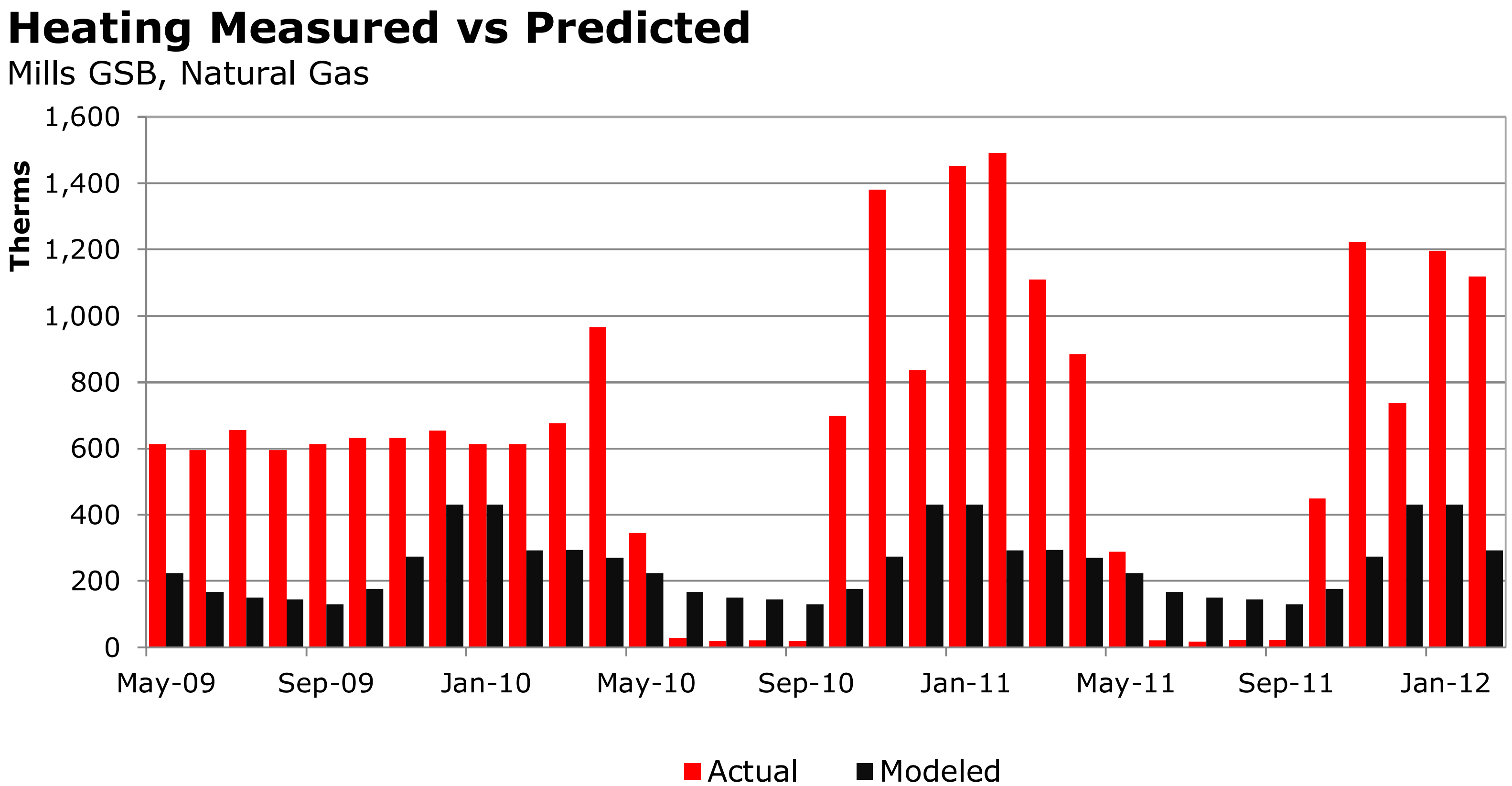
Lessons Learned

Building Heating Energy Use Underpredicted



How Buildings Actually Perform

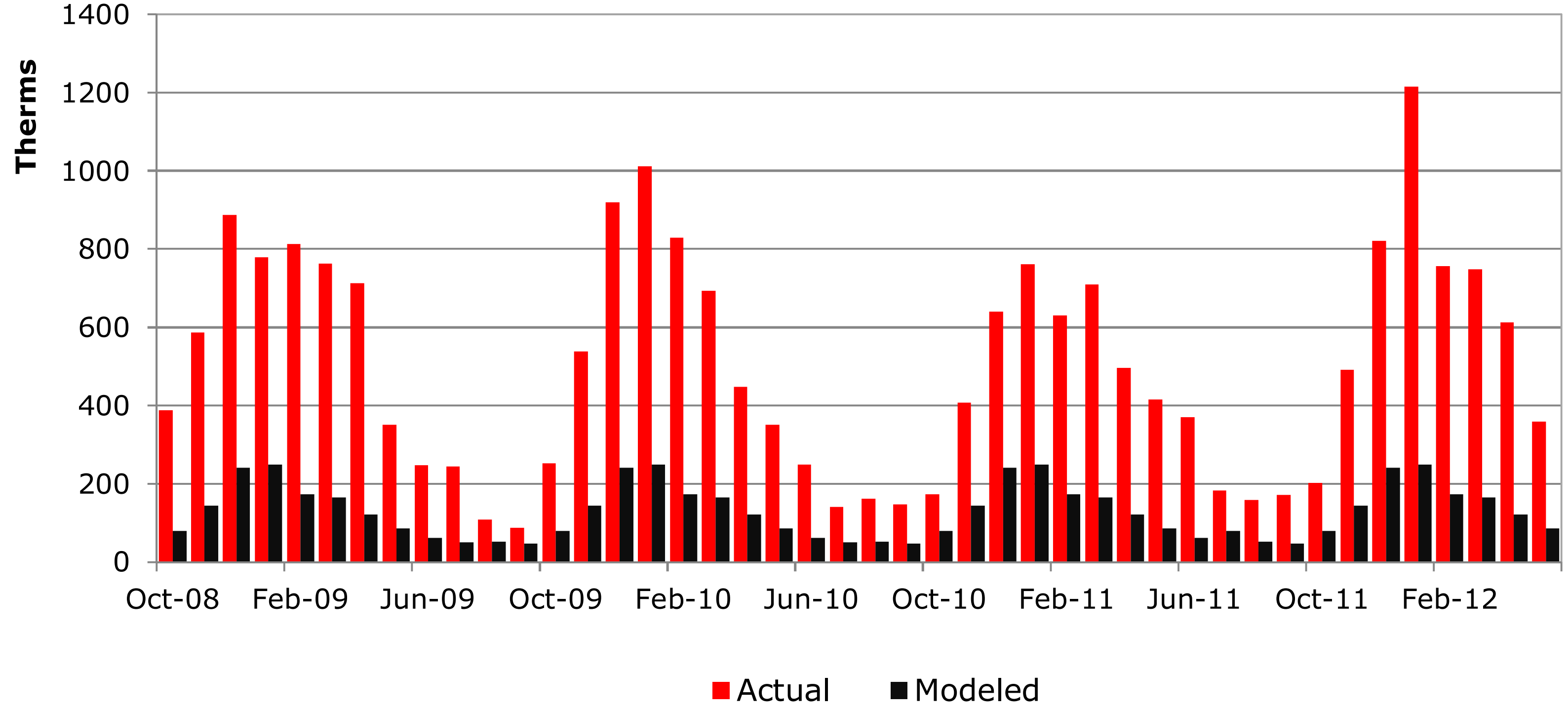
(Large Silicon Valley Technology Company 2011-2012)



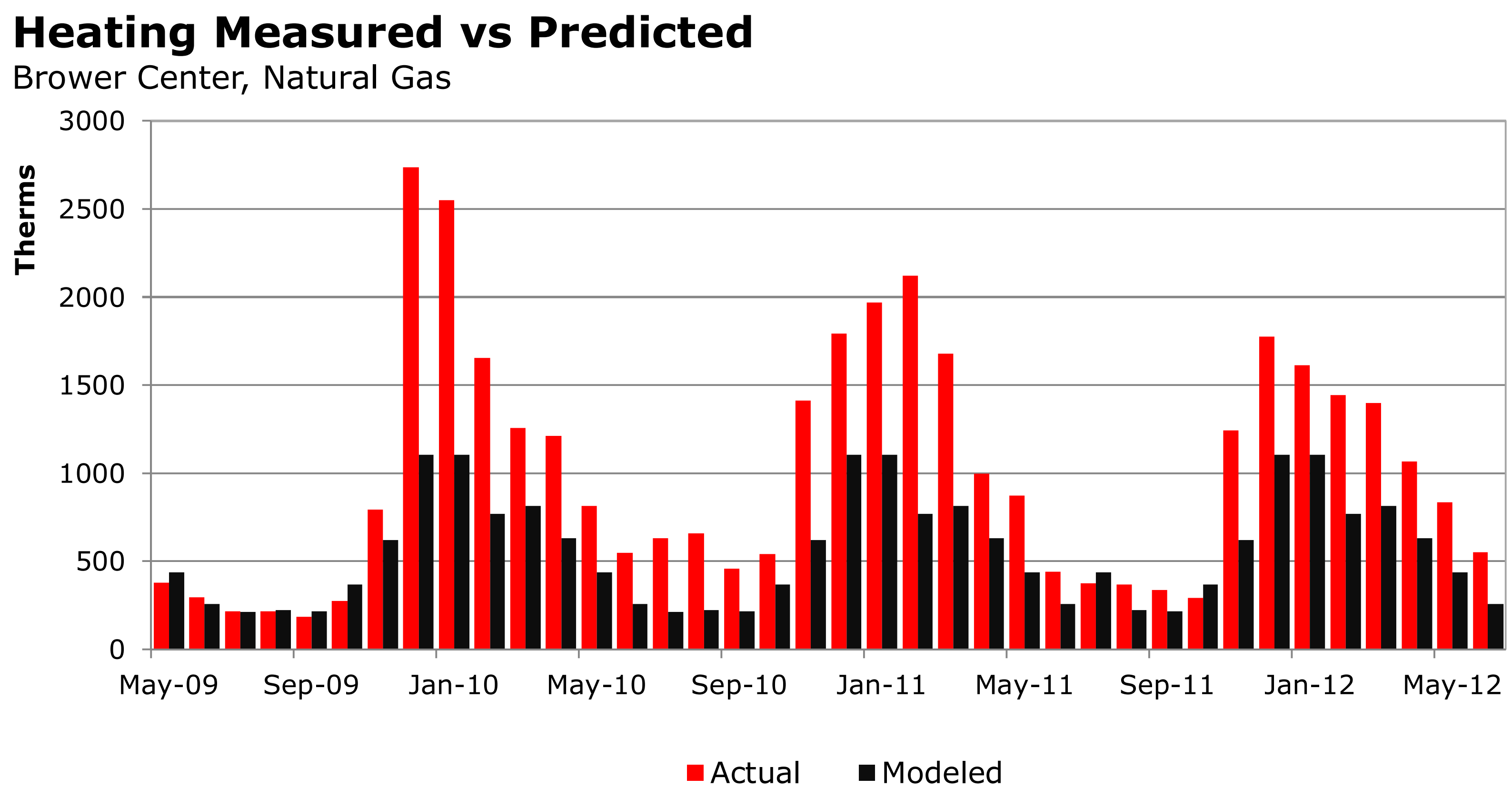
250%
More
Heating
Required

Heating Measured vs Predicted

Portola Valley Center, Natural Gas

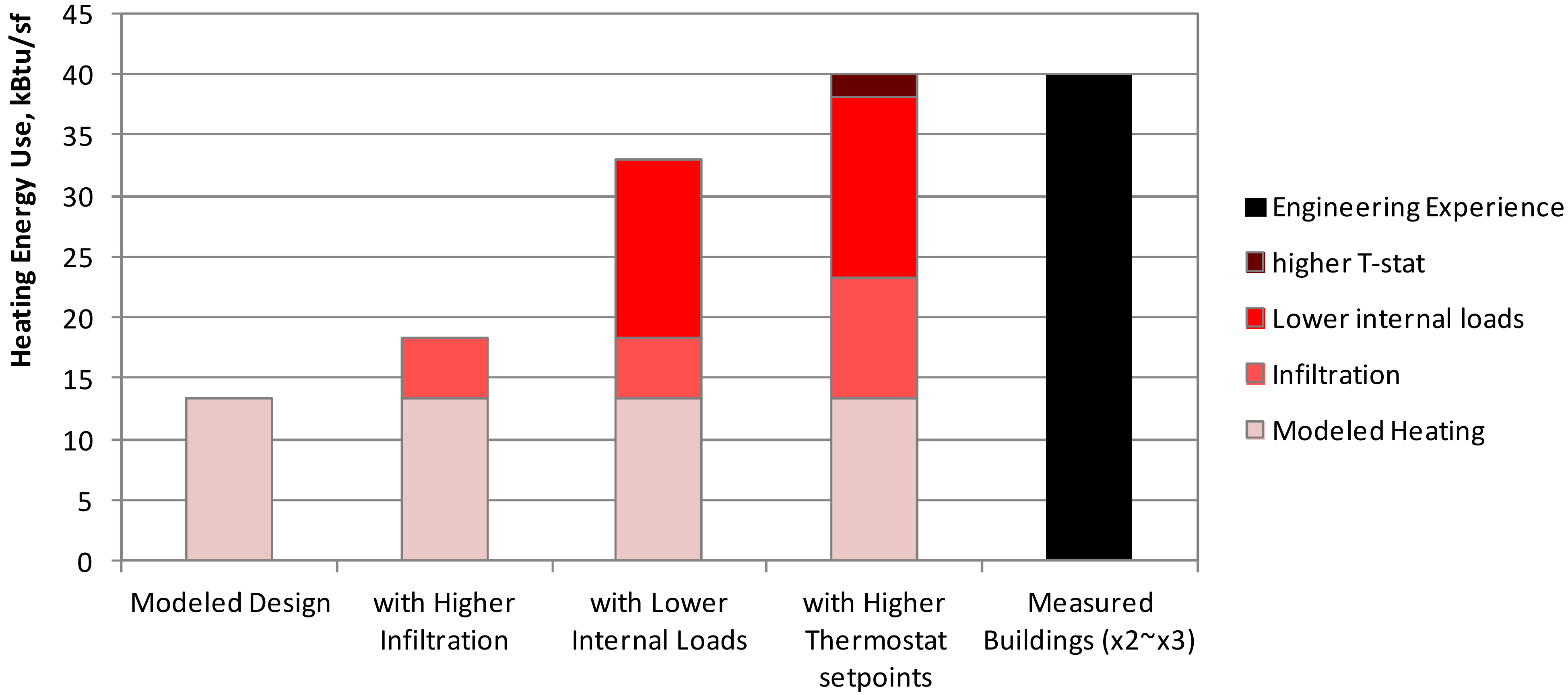


390%
More
Heating
Required



180%
More
Heating
Required

Modeled vs Metered Heating Use in Buildings



Conceptual Design: Defining the Range of Energy and Loads

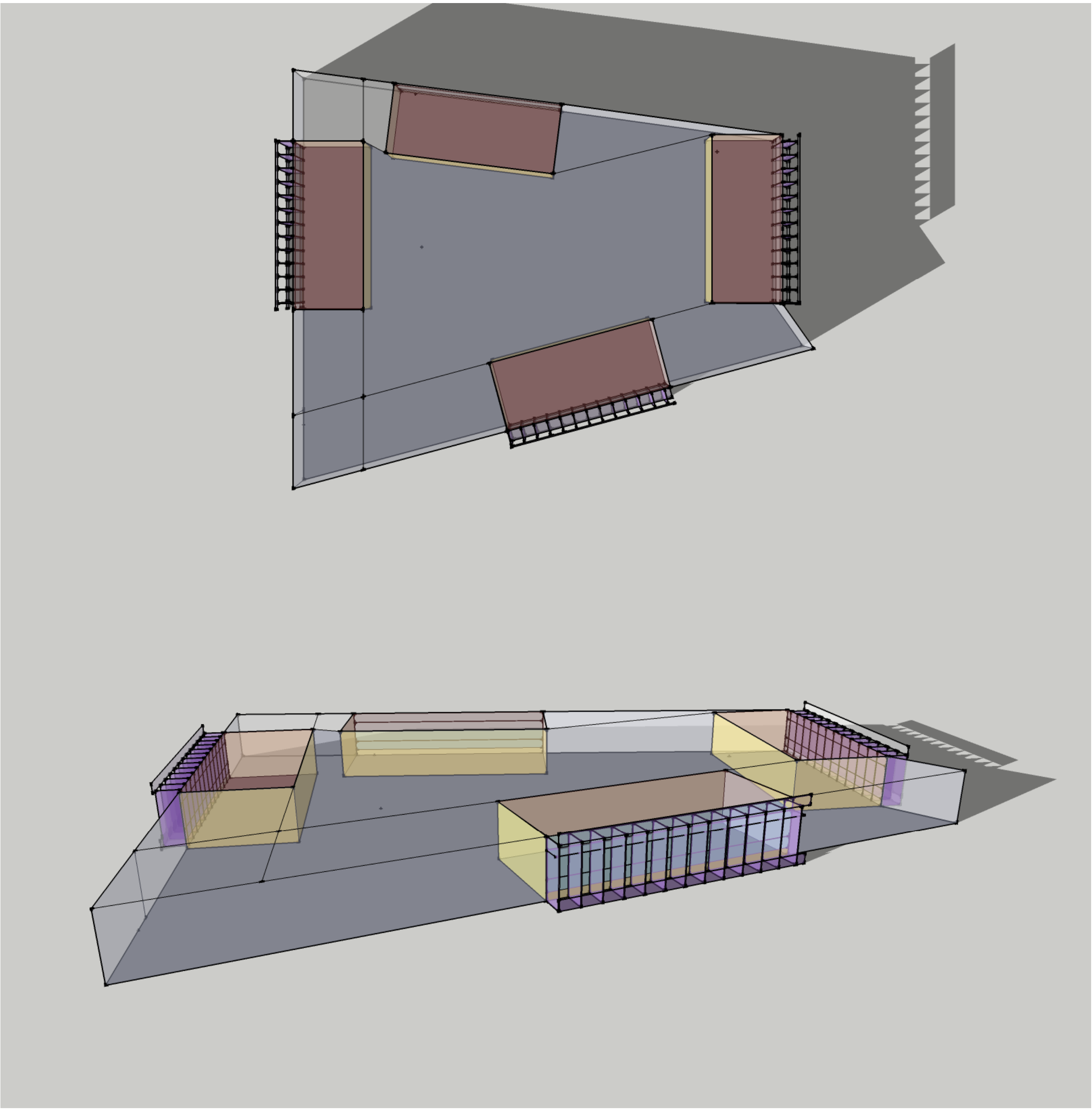
How can we use an energy model to inform What If Design Scenarios?

Energy Model – Conceptual Loads

The thermal energy model is based on a typical floor with a typical zone representing each major façade.

Thermal implications, solar peak loads from these models represent the typical load per floor area on each façade.

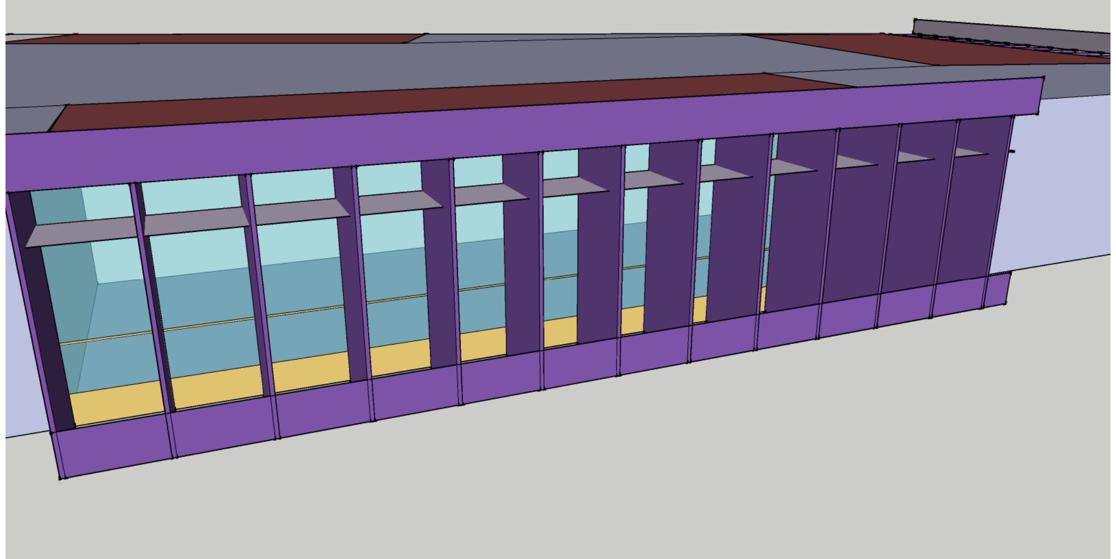
These loads were used to anticipate the cooling design loads in conjunction with additional space use assumptions and thermal loads for estimating the annual energy use intensity.



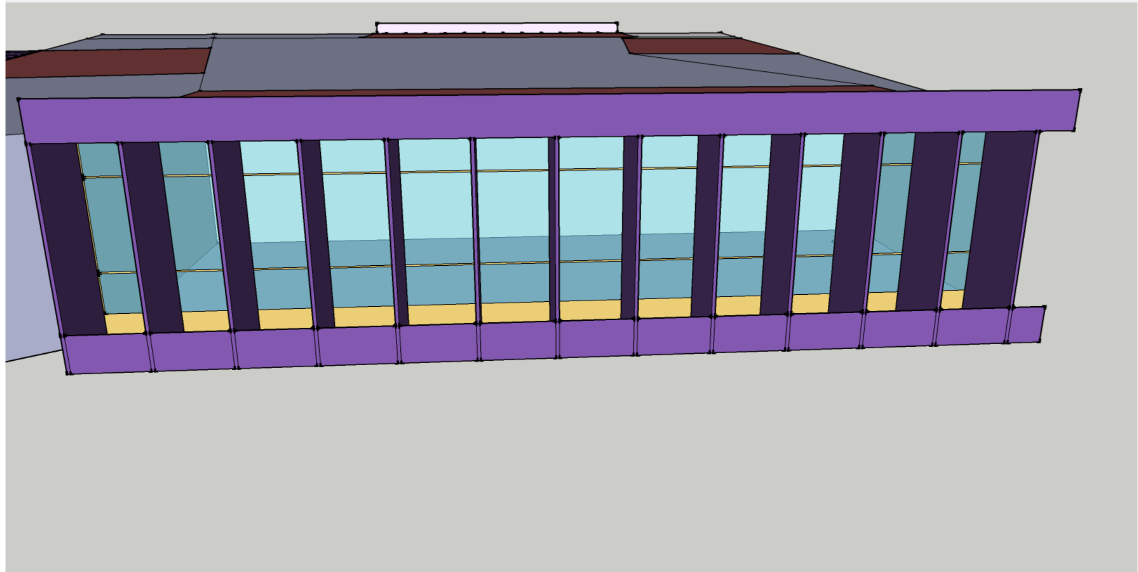
Energy Model – Conceptual Loads

South Side – vertical fins with single overhang and horizontal shading.

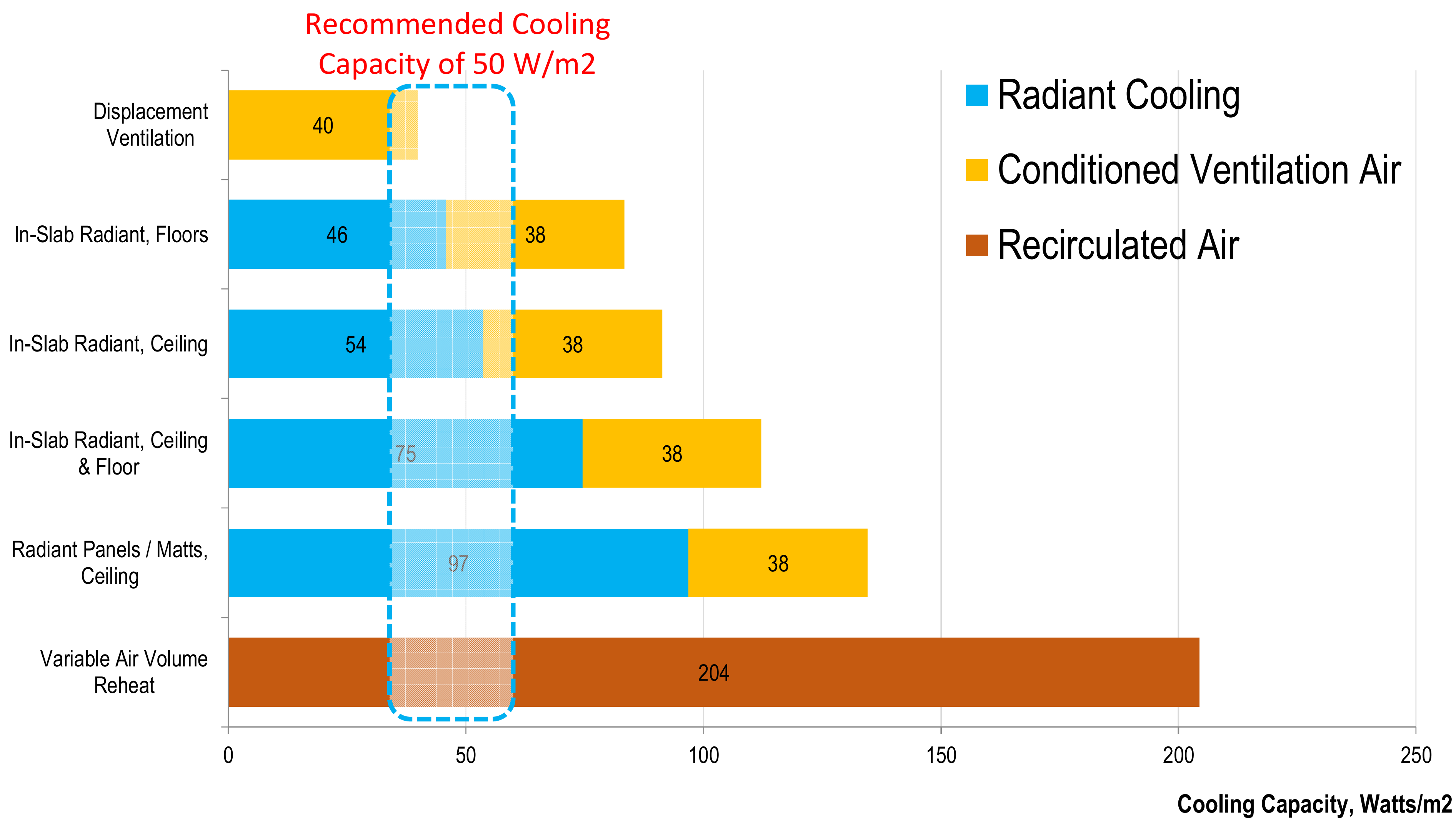
North Side – not shown, no shading elements included.



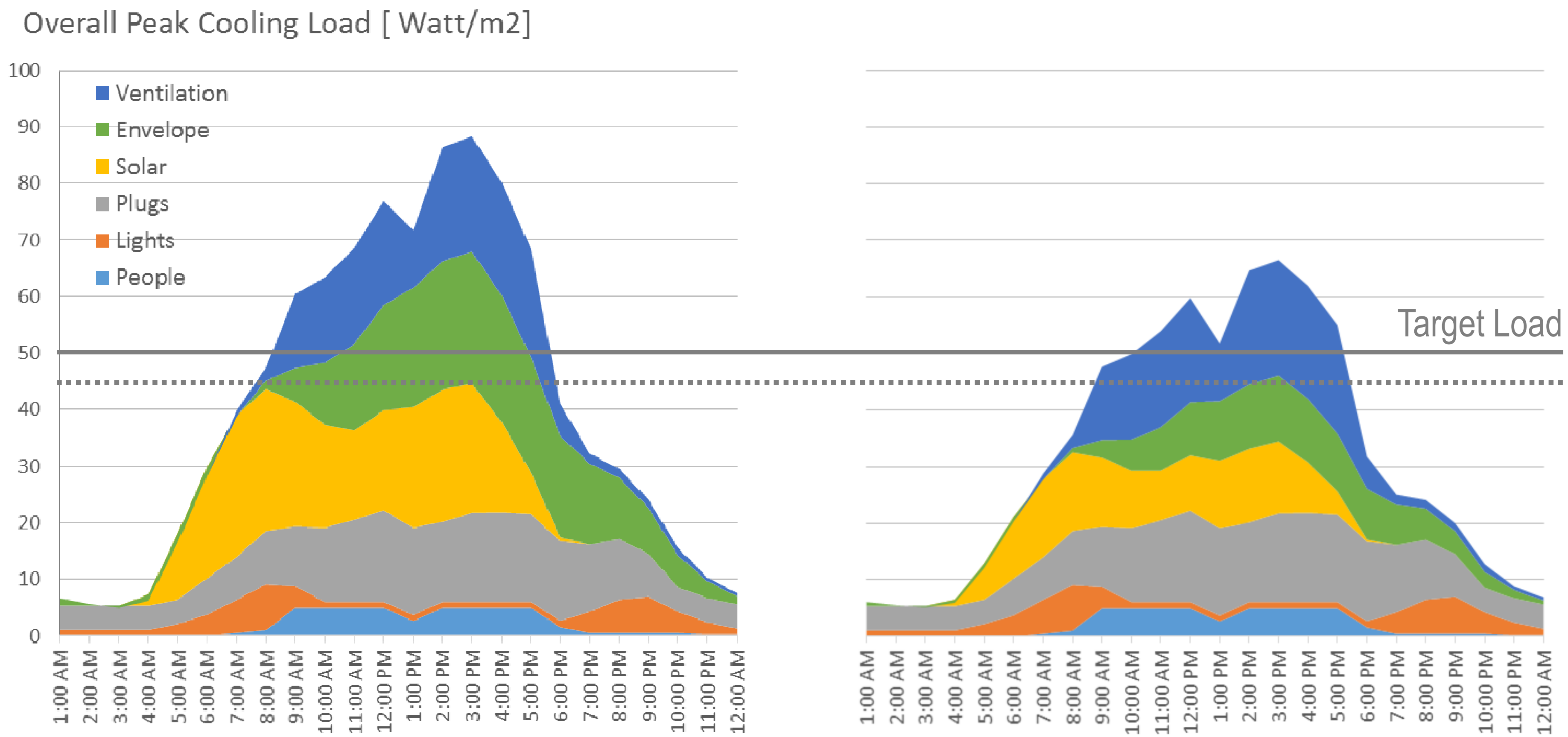
East and West sides – vertical fins with horizontal shading elements.



Zone Cooling Load for Distribution Sizing



Package 1: Improved Glazing & Envelope Only

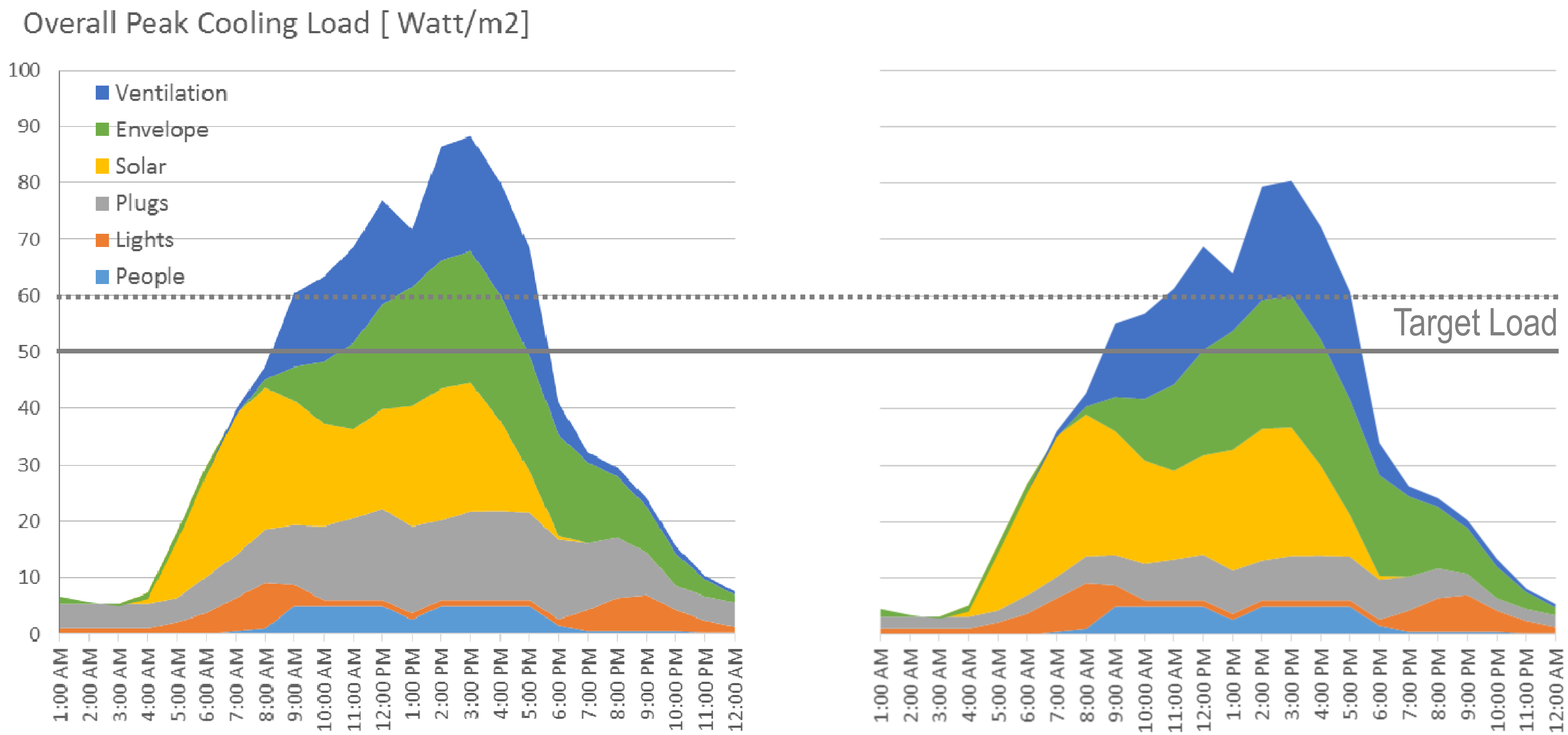


Plug Load 22 W/m2
Lighting Power 10.8 W/m2
People Density 14 m2/person
People Sens 73 W/per
Glass Type SKN 174
Airflow 0.0142 m3/s*person
Wall R-Value 2.8 W/m2-K

Plug Load 22 W/m2
Lighting Power 10.8 W/m2
People Density 14 m2/person
People Sens 73 W/per
Glass Type CLEX
Airflow 0.0142 m3/s*person
Wall R-Value 1.4 W/m2-K

Envelope improvements include improved glazing to reduce direct solar transmission from 0.38 SHGC to 0.25 and overall wall & glazing insulated performance x2.

Package 2: Reduced Internal Plug Loads Only

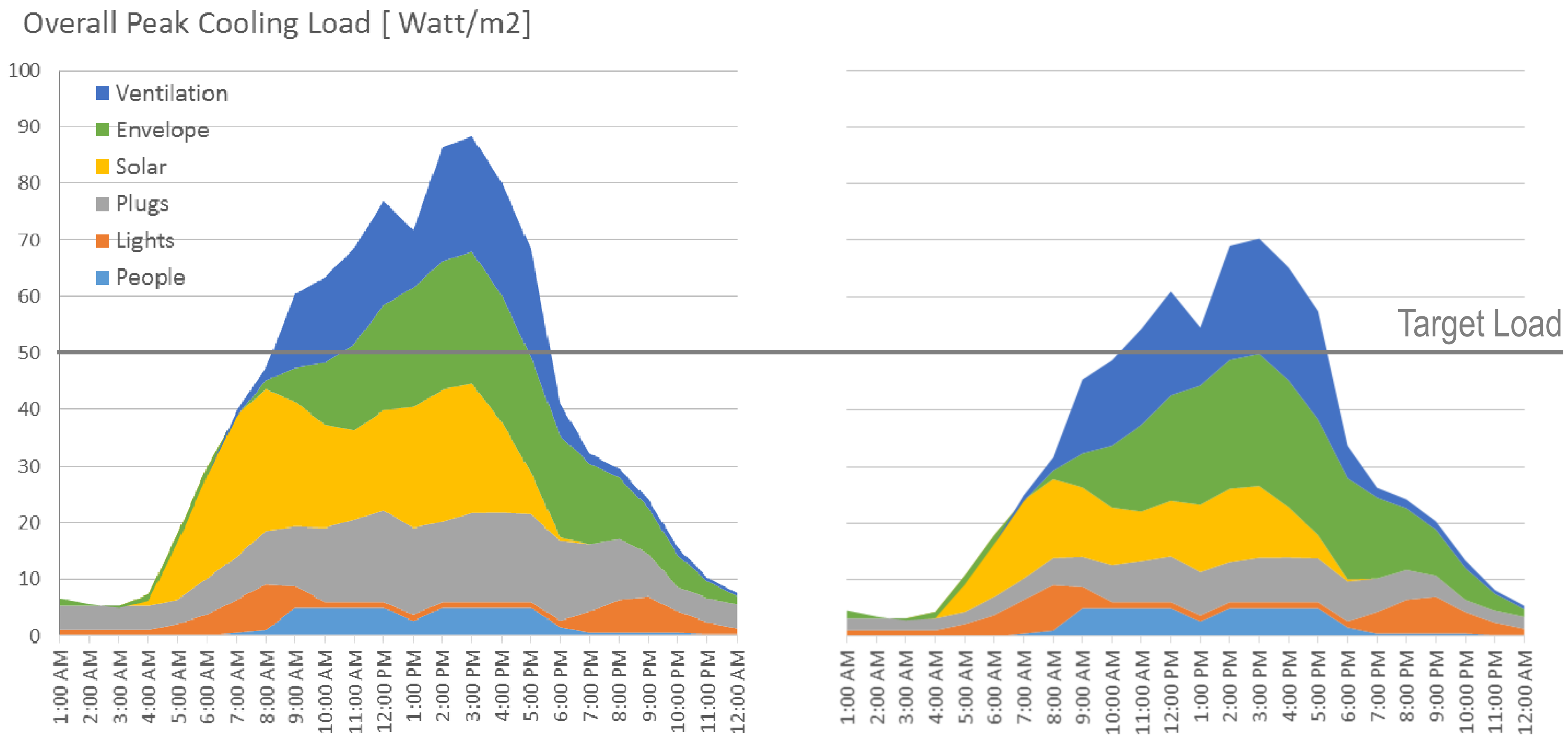


Plug Load 22 W/m2
Lighting Power 10.8 W/m2
People Density 14 m2/person
People Sens 73 W/per
Glass Type SKN 174
Airflow 0.0142 m3/s*person
Wall R-Value 2.8 W/m2-K

Plug Load 11 W/m2
Lighting Power 10.8 W/m2
People Density 14 m2/person
People Sens 73 W/per
Glass Type SKN 174
Airflow 0.0142 m3/s*person
Wall R-Value 2.8 W/m2-K

Plug loads per area are reduced by 50% through high efficiency computers, laptops, monitors and other equipment.

Package 3: Improved Glazing & Reduced Internal Plug Loads



Plug Load 22 W/m2
Lighting Power 10.8 W/m2
People Density 14 m2/person
People Sens 73 W/per
Glass Type SKN 174
Airflow 0.0142 m3/s*person
Wall R-Value 2.8 W/m2-K

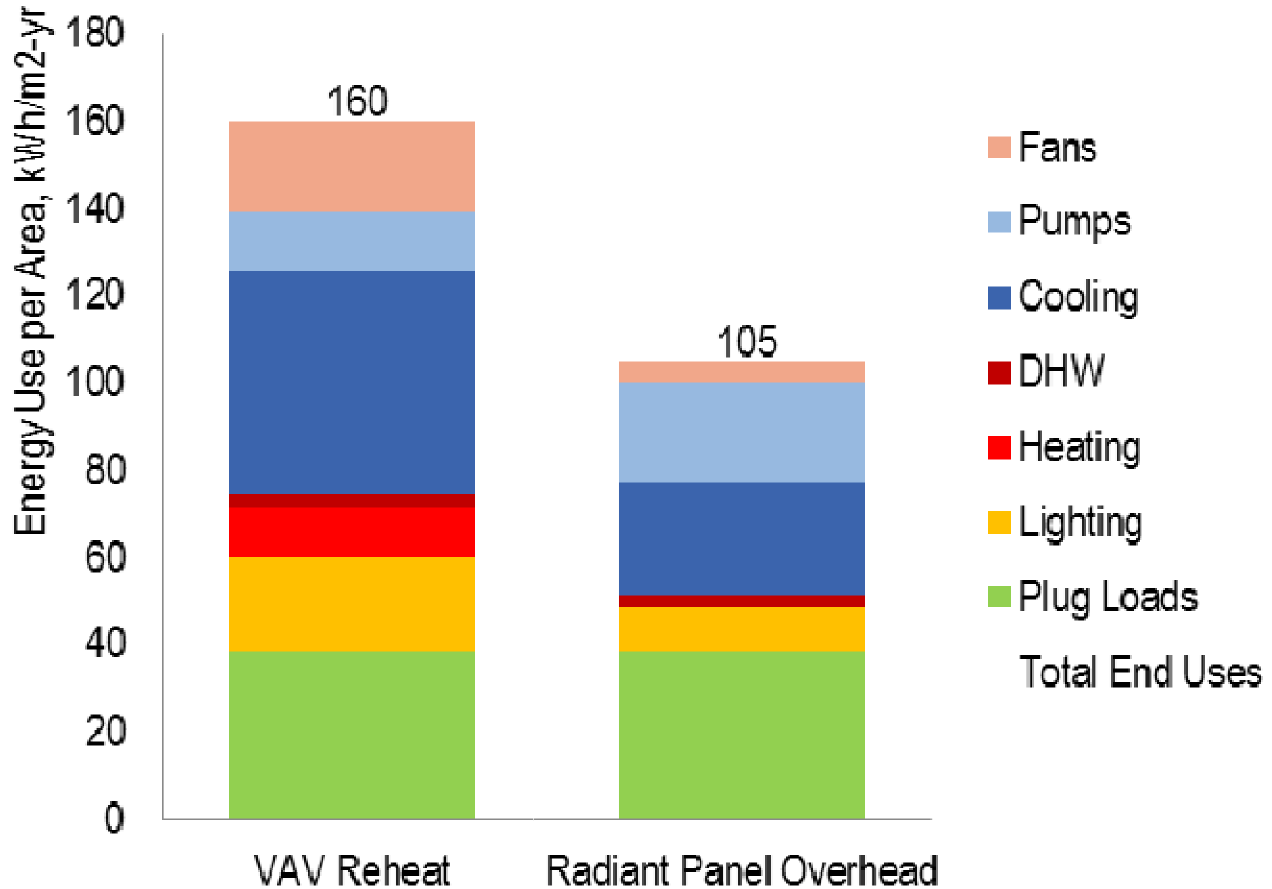
Plug Load 11 W/m2
Lighting Power 10.8 W/m2
People Density 14 m2/person
People Sens 73 W/per
Glass Type CLEX
Airflow 0.0142 m3/s*person
Wall R-Value 2.8 W/m2-K

Plug loads per area are reduced by 50% through high efficiency computers, laptops, monitors and other equipment.

Glazing improved in solar transmission from 0.38 SHGC to 0.25 SHGC.

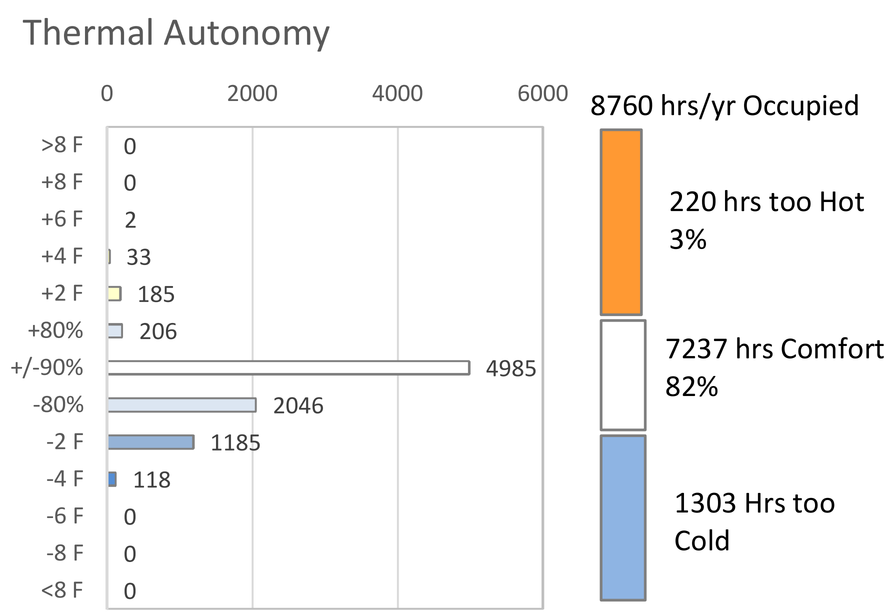
Envelope insulation values are kept fixed.

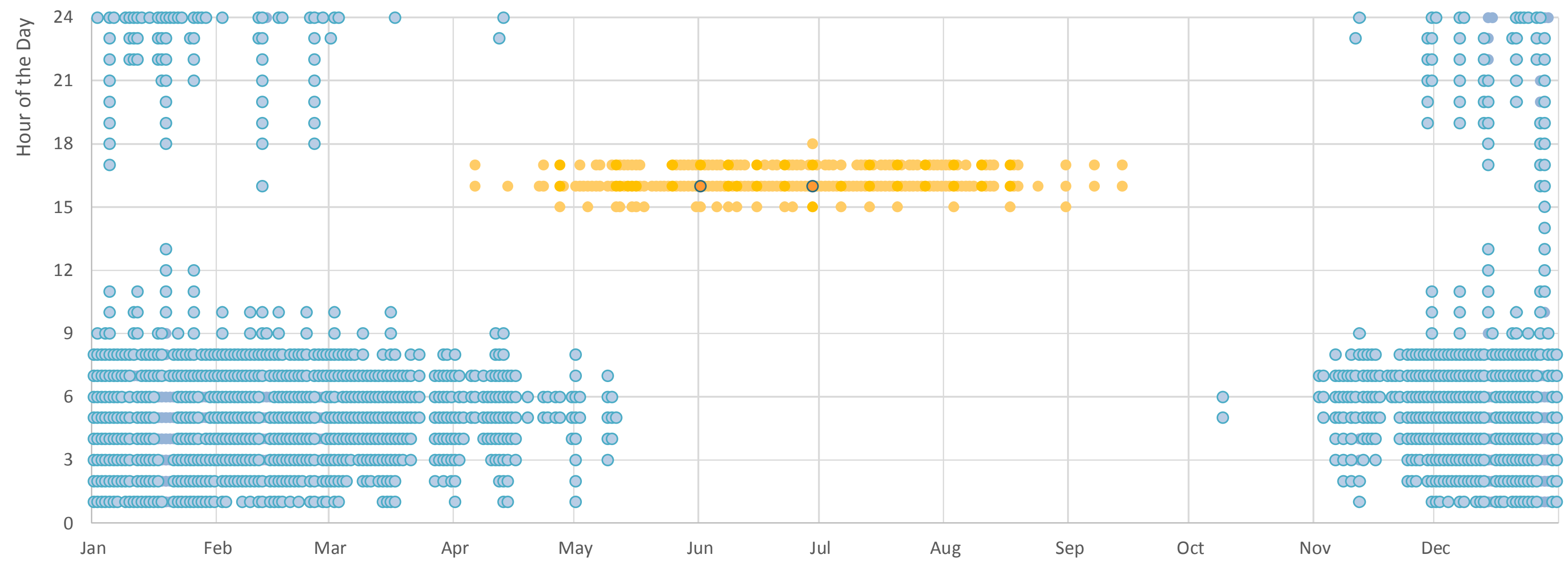
Annual Energy Use Estimate



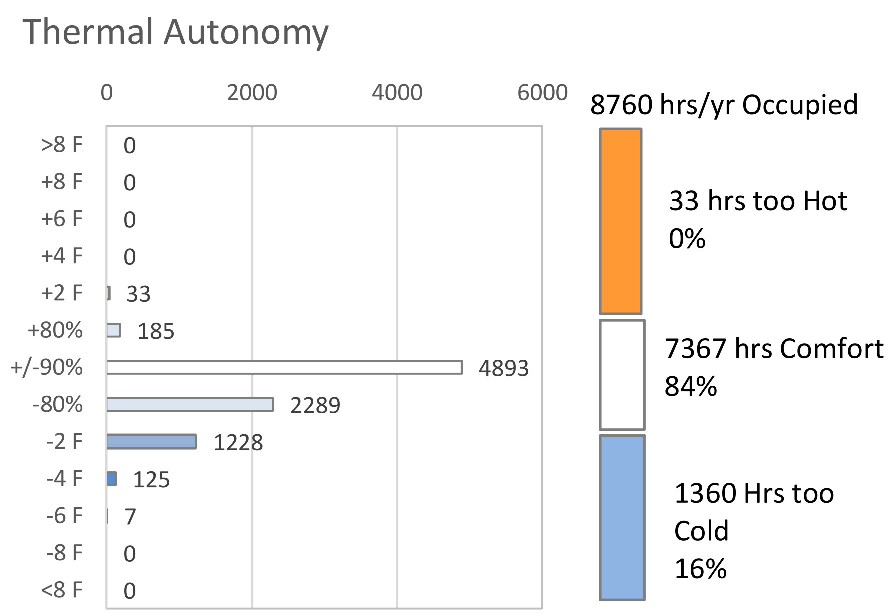
Estimated at 30 to 34% cost savings for 10 to 12 pts for LEED v3 EA credit 1.
Energy costs estimated at $0.20/kWh and $1.0/therm (est. equivalent for price of fuel) for initial estimates.

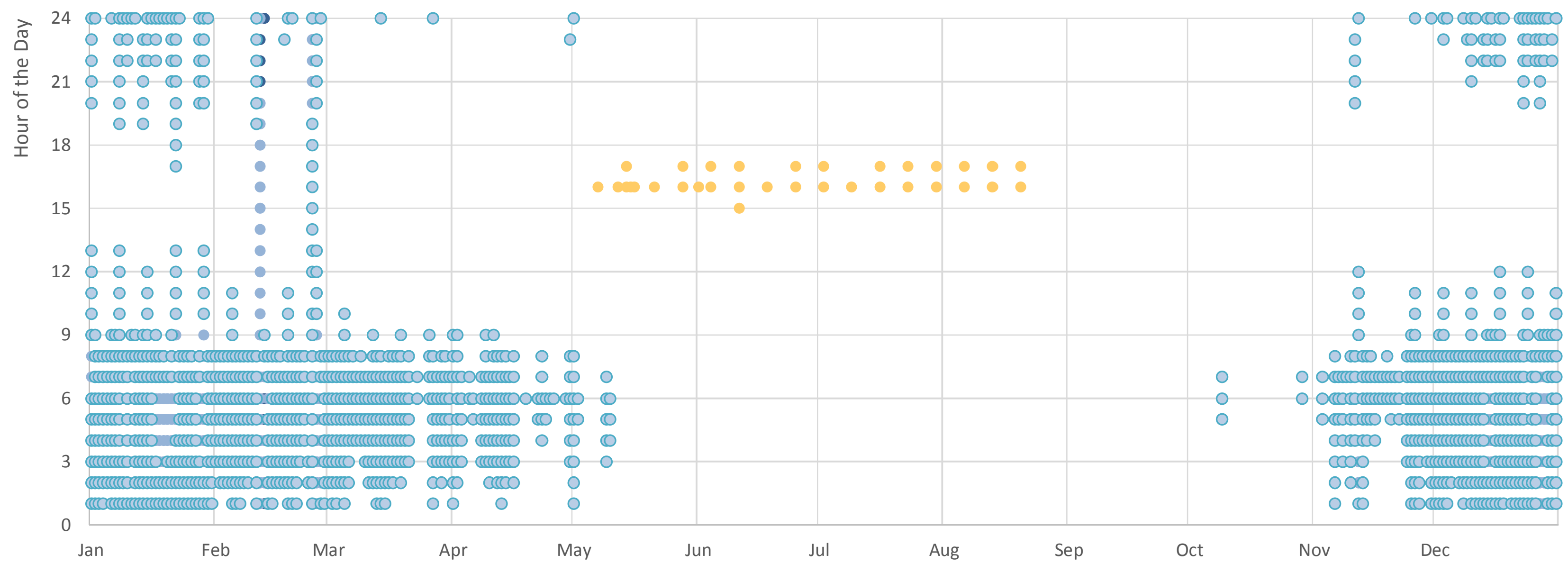
Thermal Comfort Autonomy: 12M Glazing



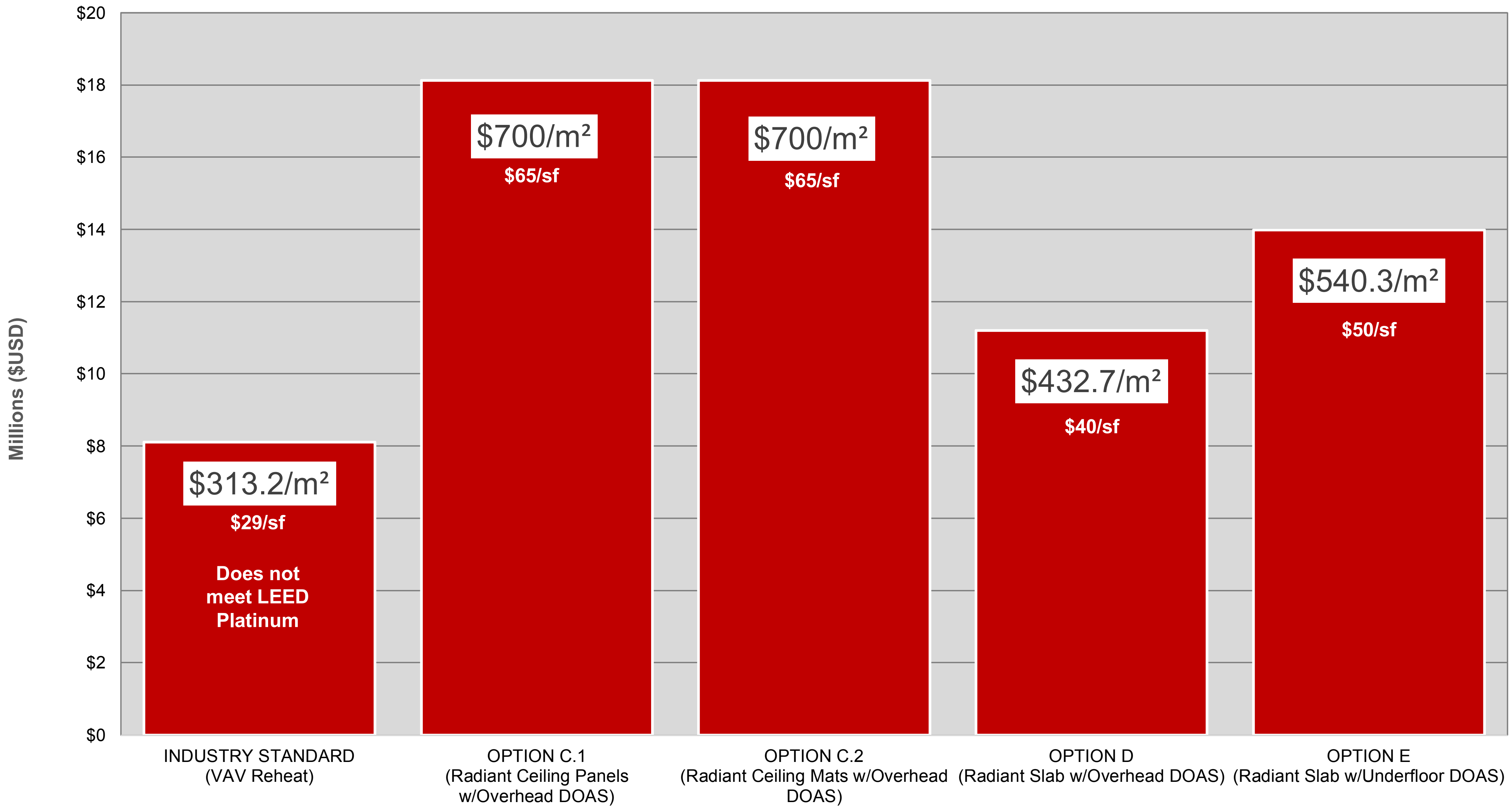


Thermal Comfort Autonomy: CLEX Glazing

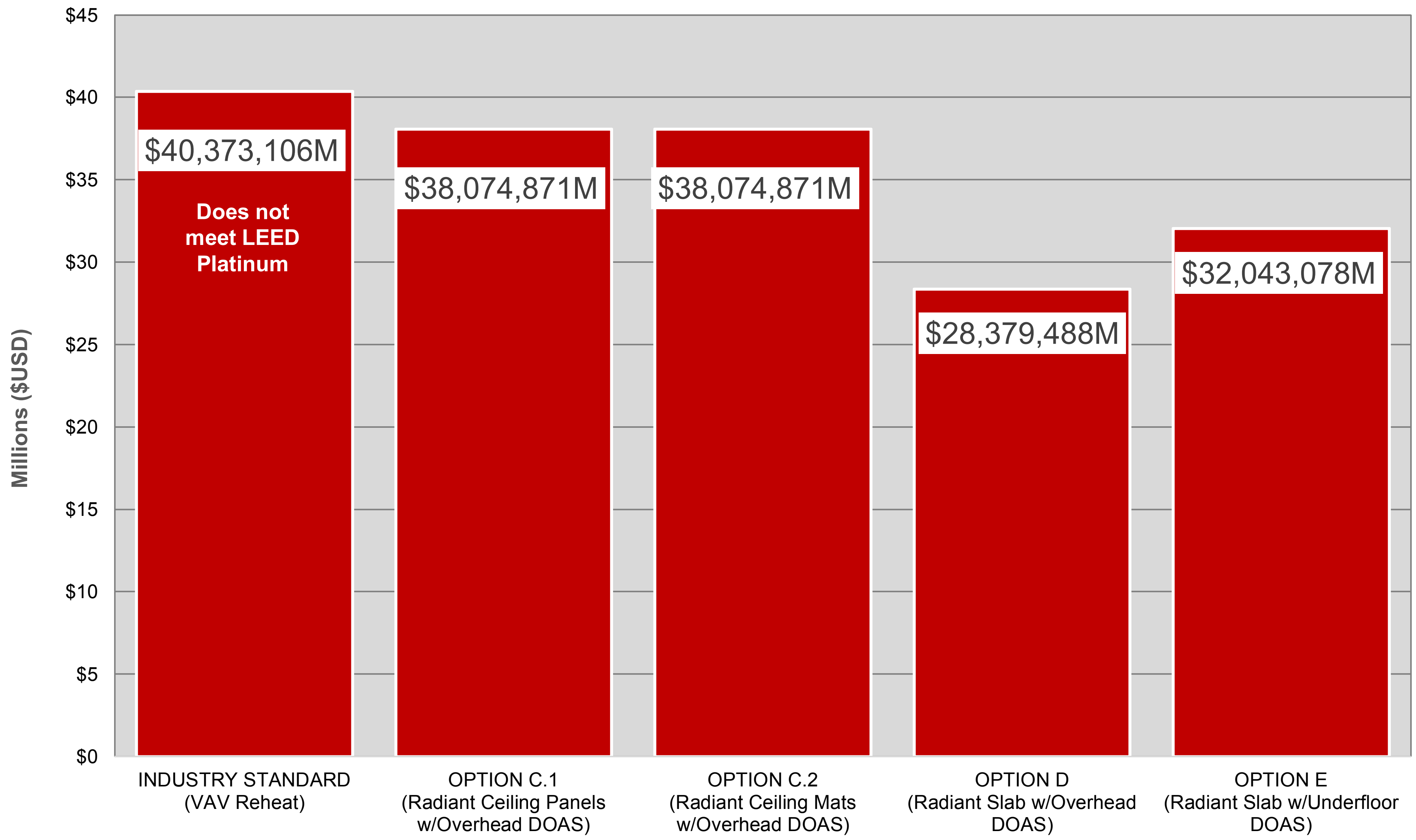




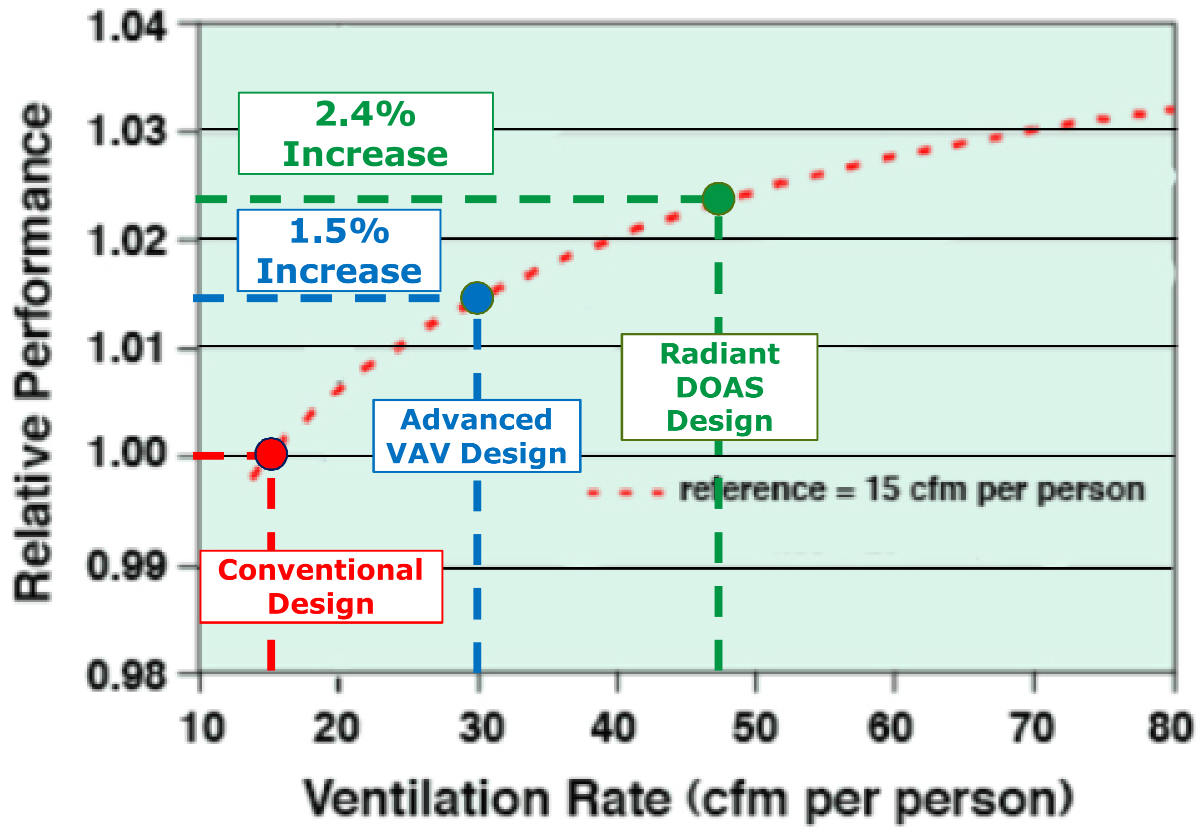
HVAC Distribution Options – Total Mechanical First Cost Estimate



HVAC Distribution Options - Total Cost of Ownership
25 Year Period



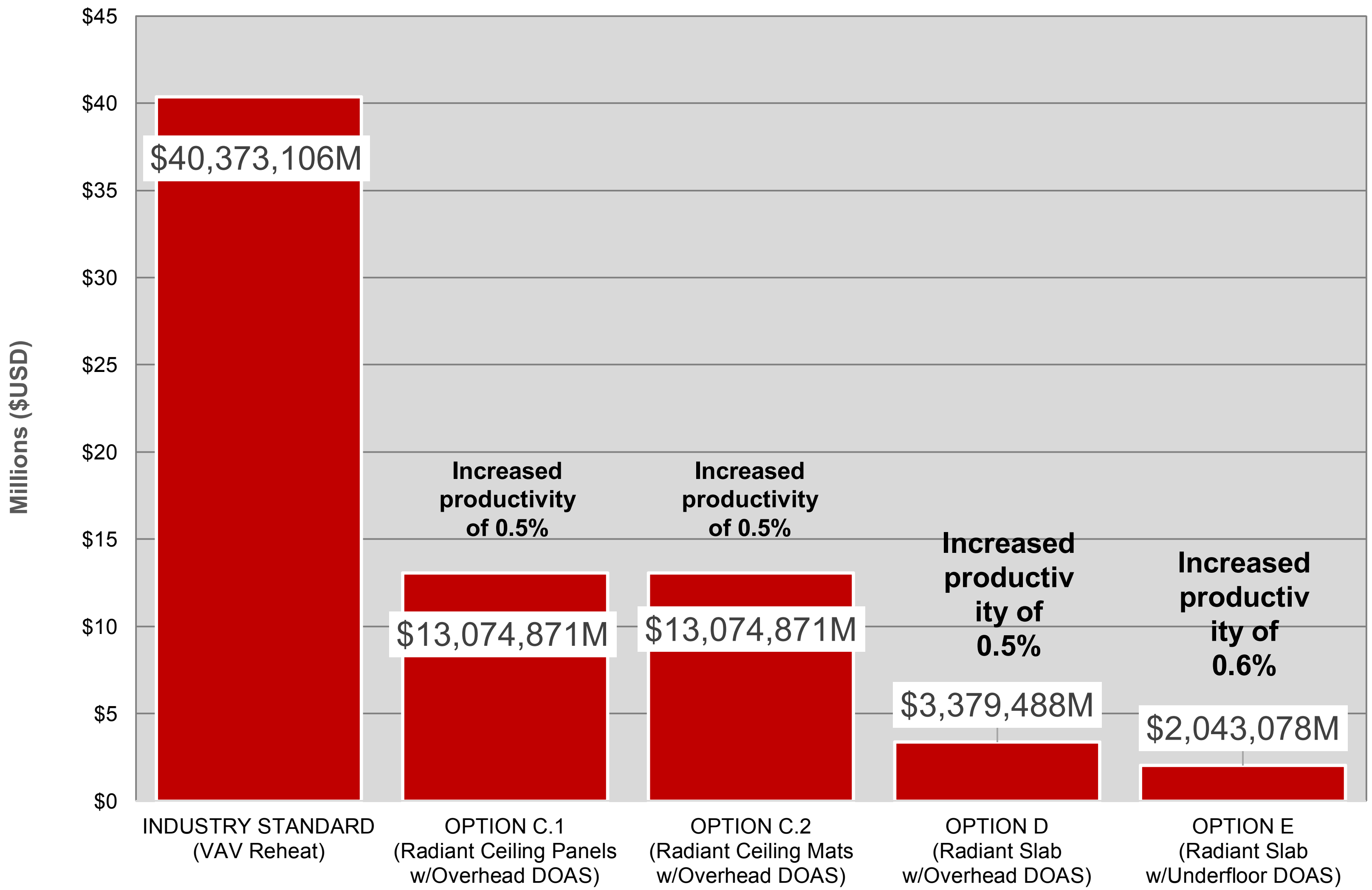
Ventilation & Productivity



Lawrence Berkeley National Lab
Impacts of Building Ventilation on Health and Performance
Ventilation Rates and Sick Building Syndrome

HVAC Distribution Options - Total Cost of Ownership
25 Year Period

Accounting for Increased Productivity



LBNL Bevatron Review
Berkeley, CA

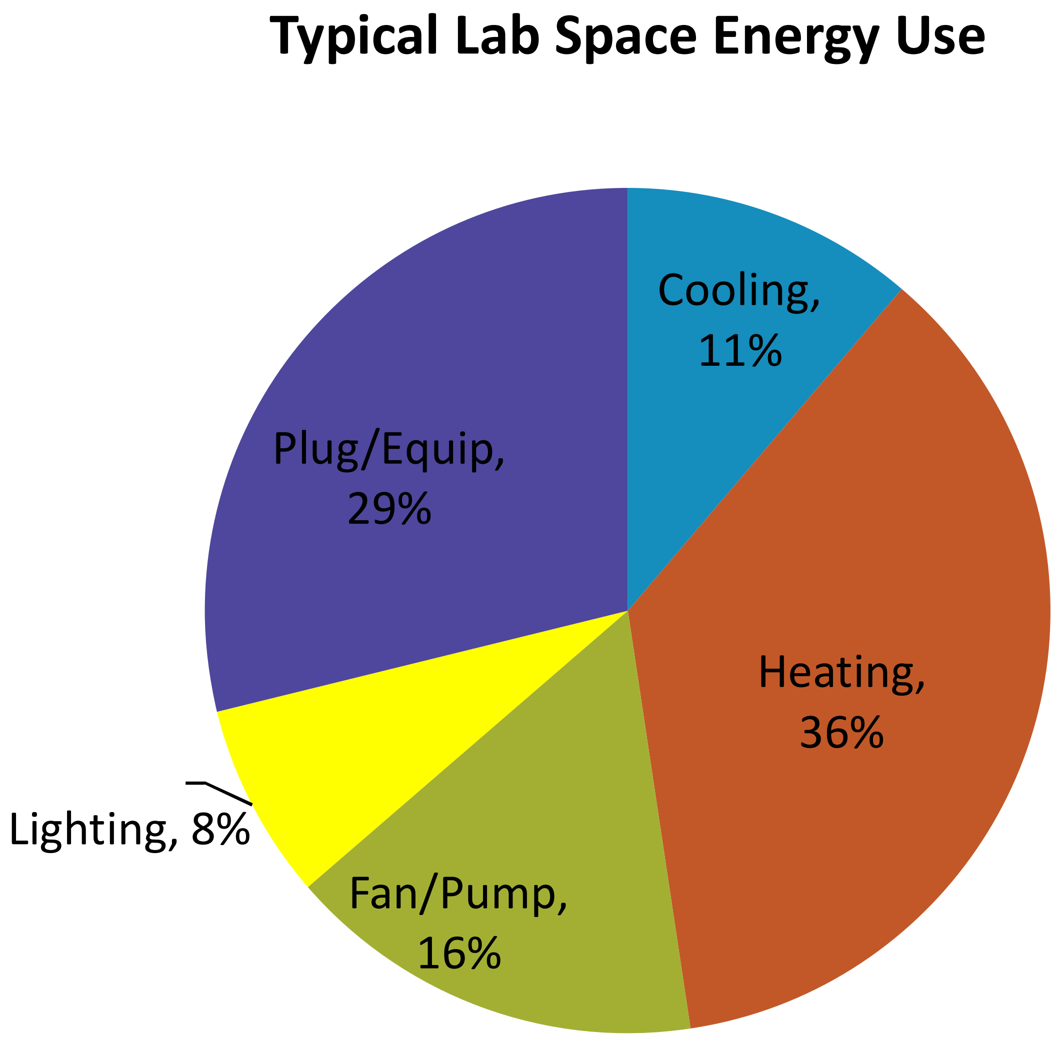
LBNL Energy & Sustainability Targets
Concept Design Energy Analysis

Sustainability Targets

Energy Target	**30% better than ASHRAE 90.1-2010** (or latest T24) before on-site generation
Lighting	Exterior and Interior Lighting controls with mandatory measures in **T24-2013**
Renewables	Renewable generation must be designed to generate at least **7.5%** of the estimated project energy consumption
Green Building	**LEED Gold** (v2009) minimum and where applicable the prerequisites for Lab 21
Solar-ready	Building should be solar-ready

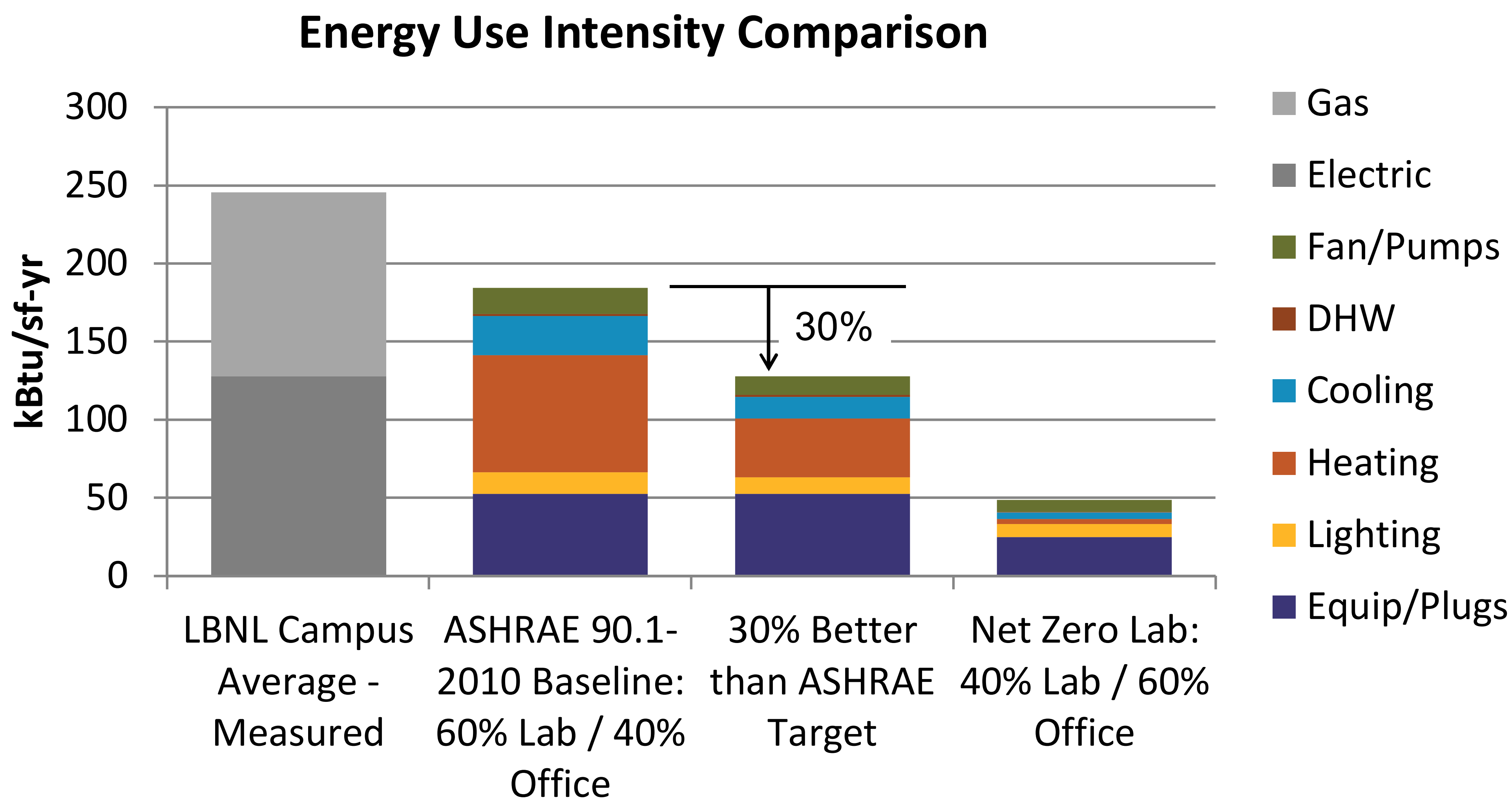
* From LBNL's Sustainability Standards for New Construction

Energy - Typical Lab Space

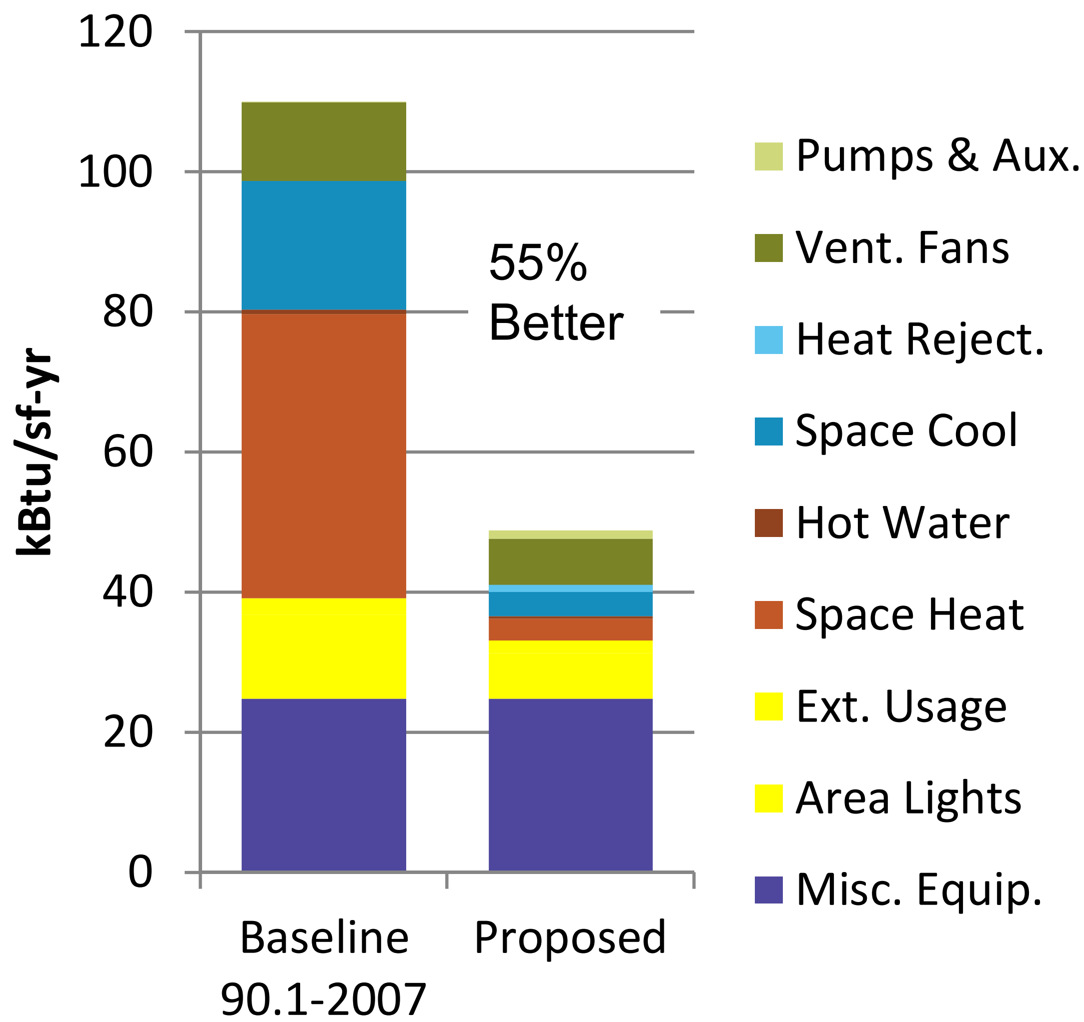


- Typical of lab dominated buildings (80% Lab / 20% Office)
- Ventilation and plug loads dominate energy use
- Heating is a mixture of reheat and outside air conditioning for ventilation

Energy Comparison - Summary



Example – J. Craig Venter Net Zero Energy Lab



Genetics/Chemistry Lab in San Diego, CA

- 30% Lab / 70% Office
- Optimized air change rates to maintain safety and maximize efficiency (~4 ACH average); **also reflected in baseline**
- Reduced plug loads; **also reflected in baseline**
- Low Temp and Medium Temp Chilled Water with Thermal Energy Storage
- Air source heat-pump for heating
- Dedicated outside air unit with chilled beams
- Air side heat recovery

Net Zero Case Study: Packard Foundation

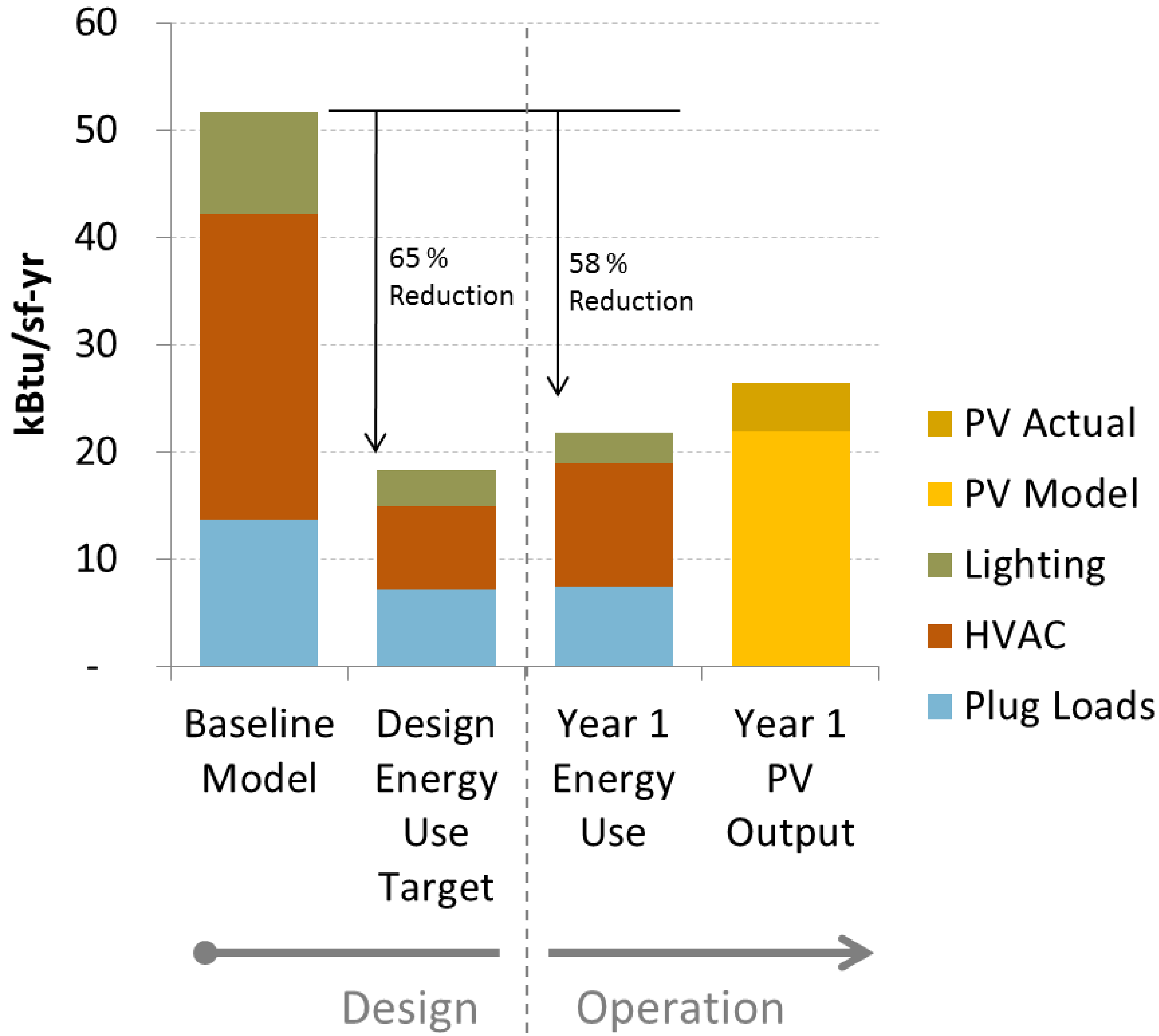
NZE in first year of operation

The David & Lucile Packard Foundation

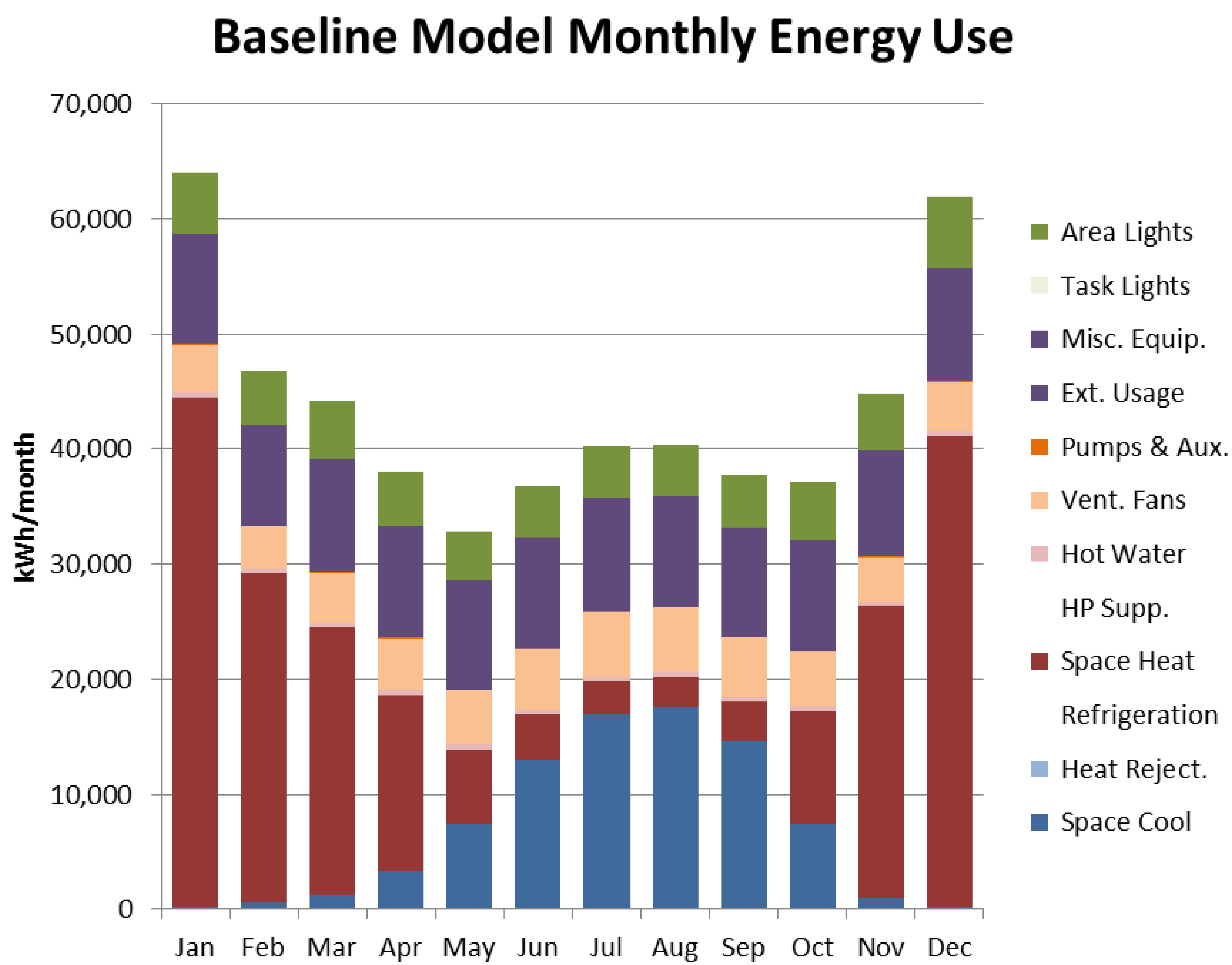
Los Altos, California

Size : 49,000 SF
Year Completed – 2012
LEED Platinum certified – 2012
ILFI Certified Net Zero Energy – 2013
AIA COTE Top 10 – 2014
ASHRAE Award of Engineering Excellence - 2014
CBE Livable Building Award – 2014

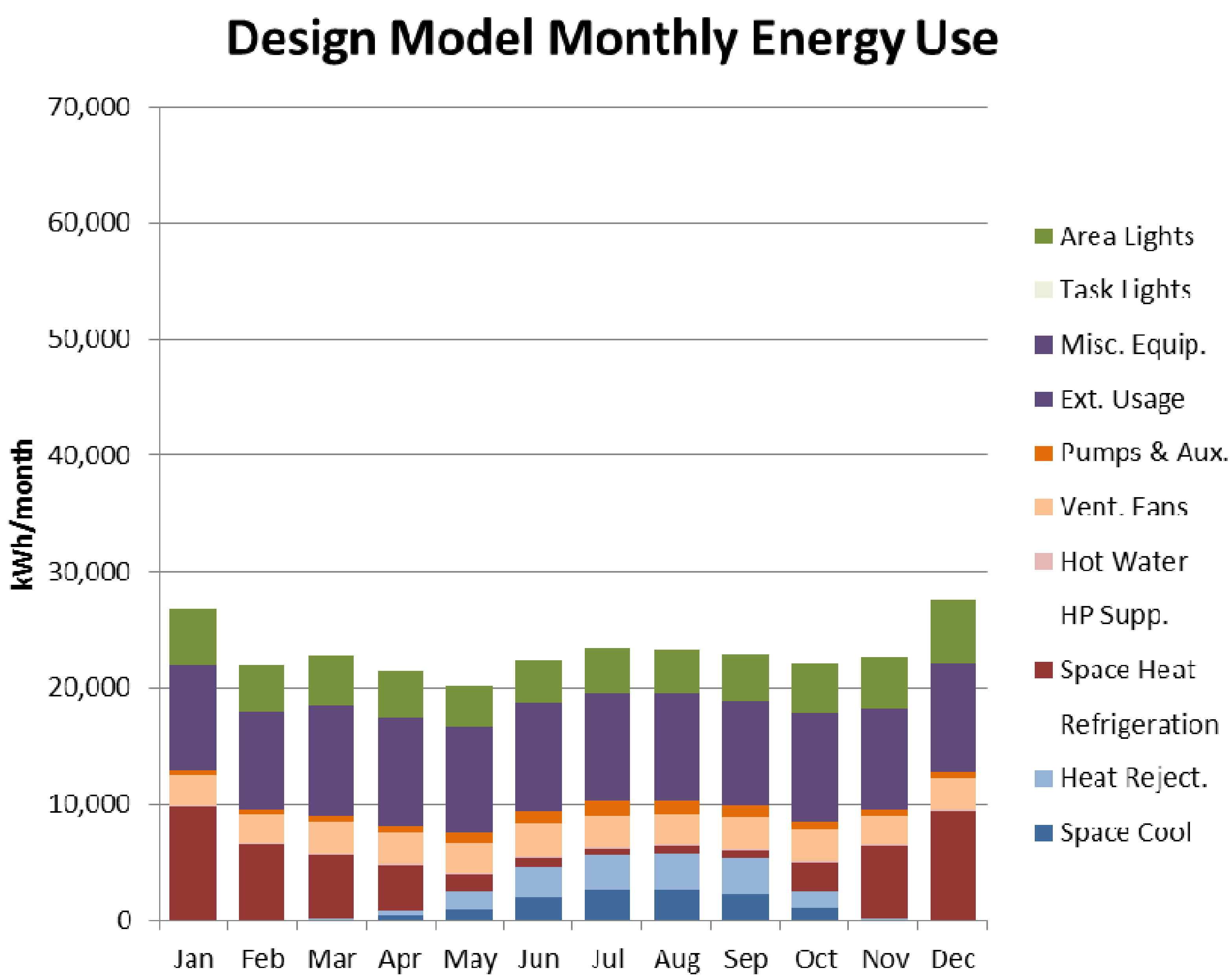
Total Annual Energy Use



Energy Data


Baseline Model Monthly Energy Use
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
kWh/month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Area Lights
Task Lights
Misc. Equip.
Ext. Usage
Pumps & Aux.
Vent. Fans
Hot Water
HP Supp.
Space Heat
Refrigeration
Heat Reject.
Space Cool

Energy Data


Design Model Monthly Energy Use
kWh/month
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Area Lights
Task Lights
Misc. Equip.
Ext. Usage
Pumps & Aux.
Vent. Fans
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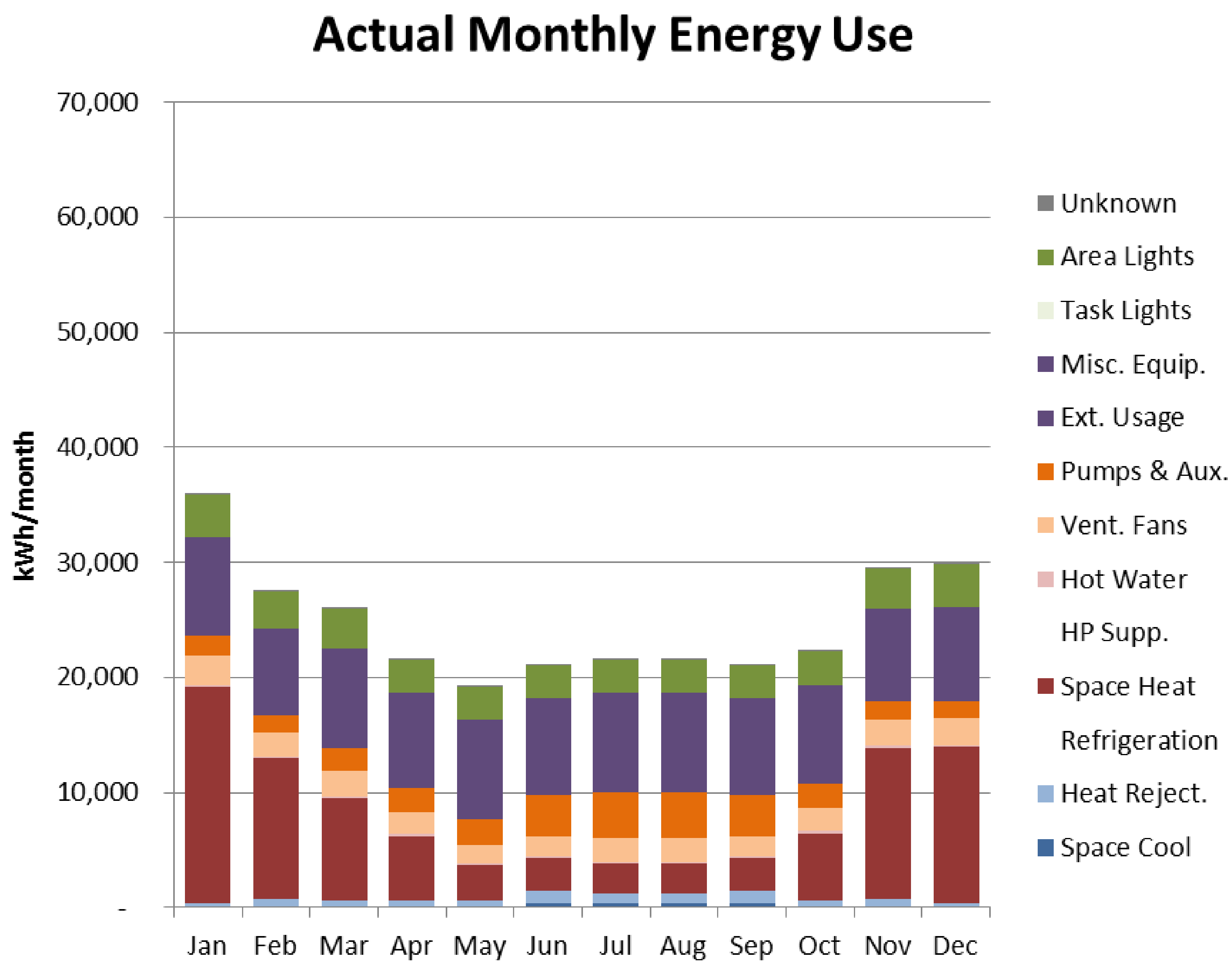
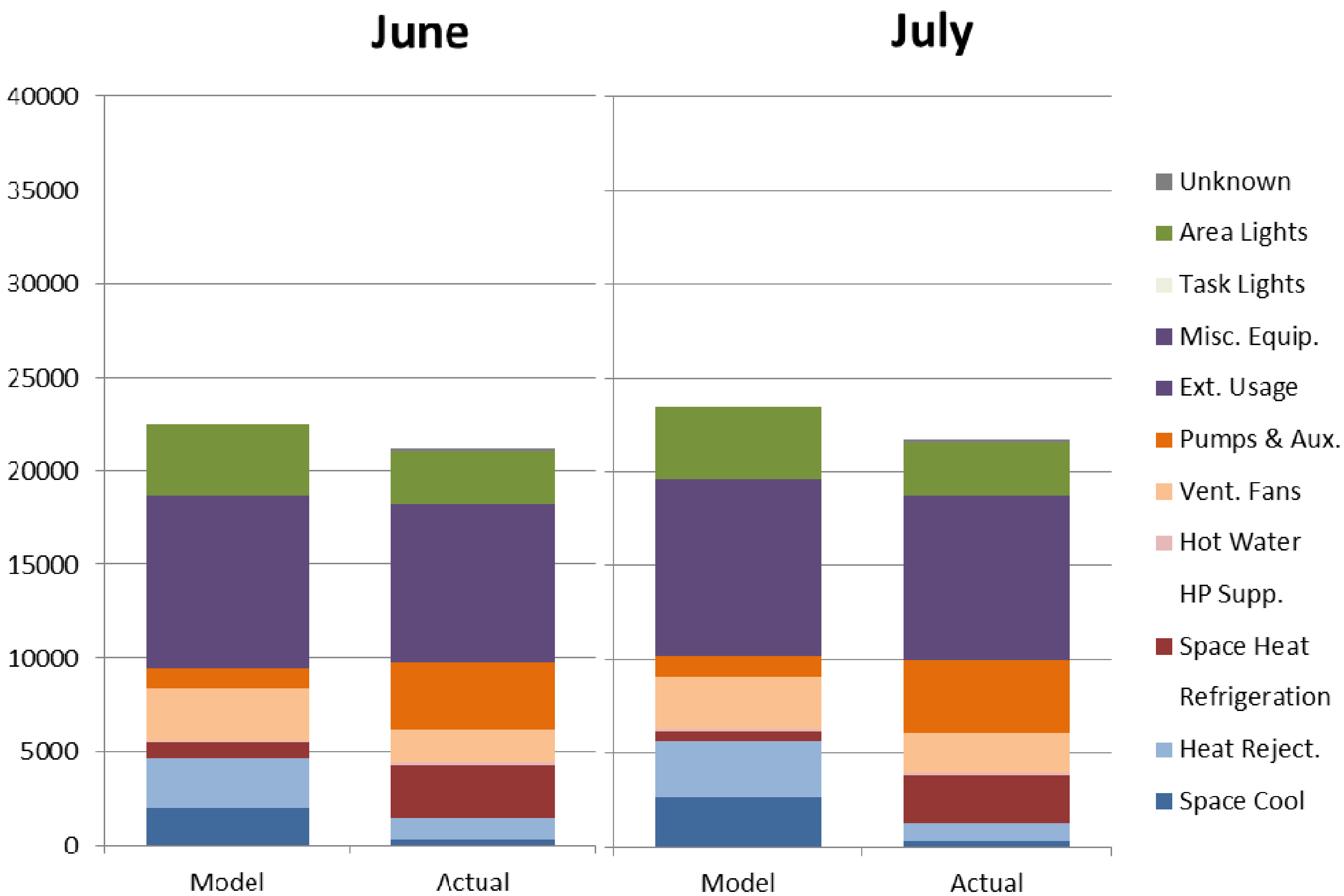
Energy Data

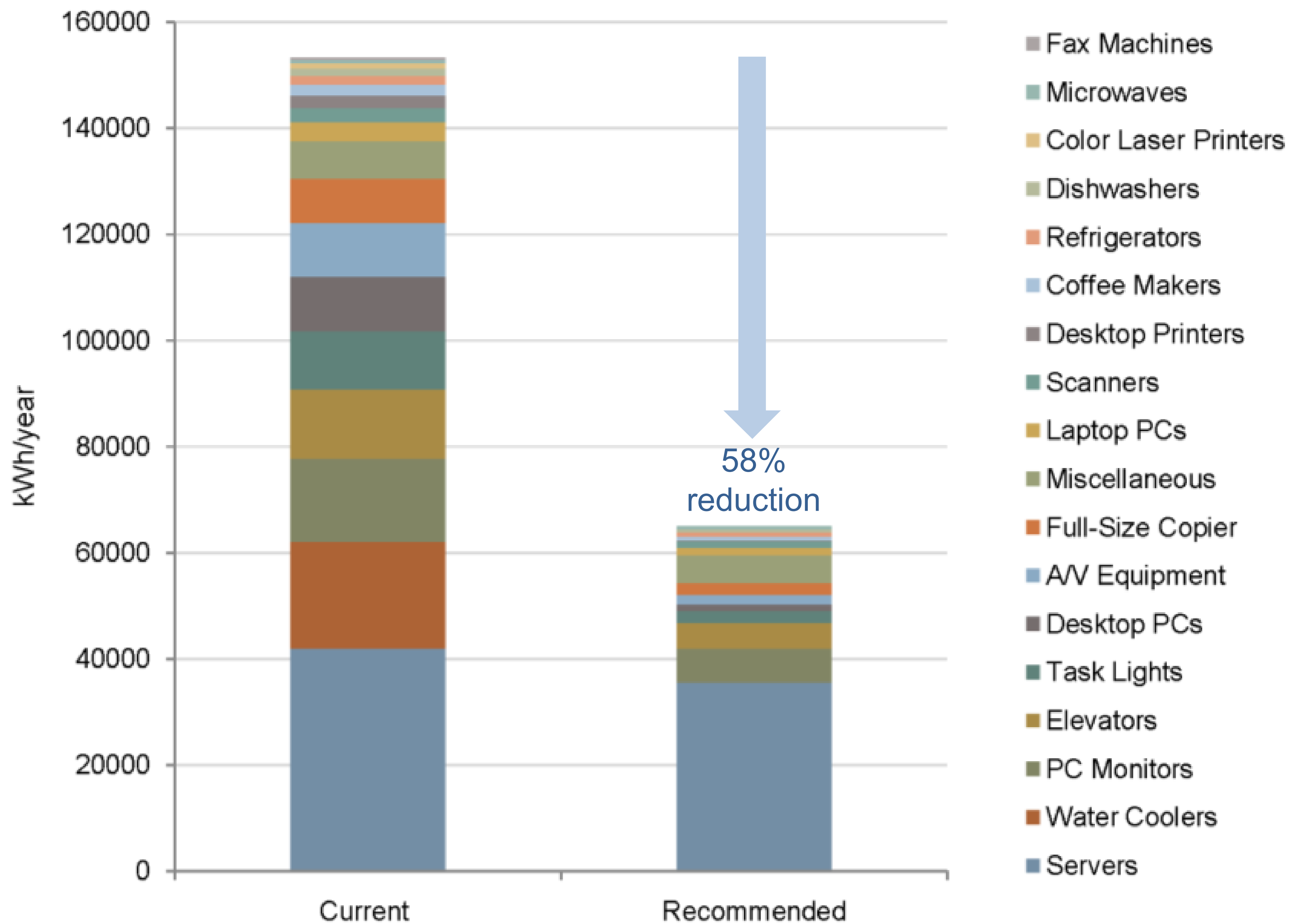


Actual Monthly Energy Use
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
kWh/month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Unknown
Area Lights
Task Lights
Misc. Equip.
Ext. Usage
Pumps & Aux.
Vent. Fans
Hot Water
HP Supp.
Space Heat
Refrigeration
Heat Reject.
Space Cool

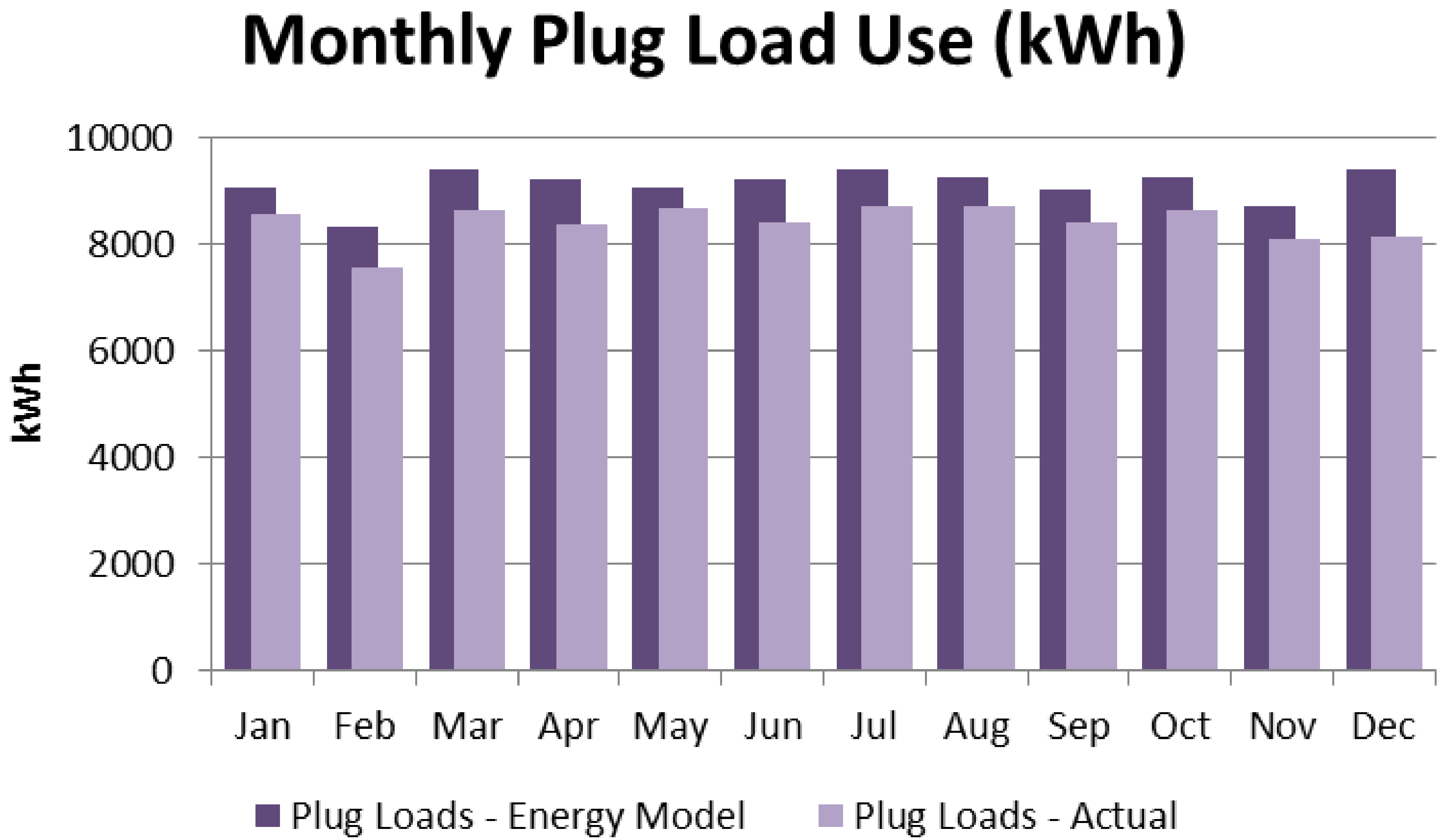
Energy Data : Less Cooling than Predicted



Plug Load Annual Energy Consumption

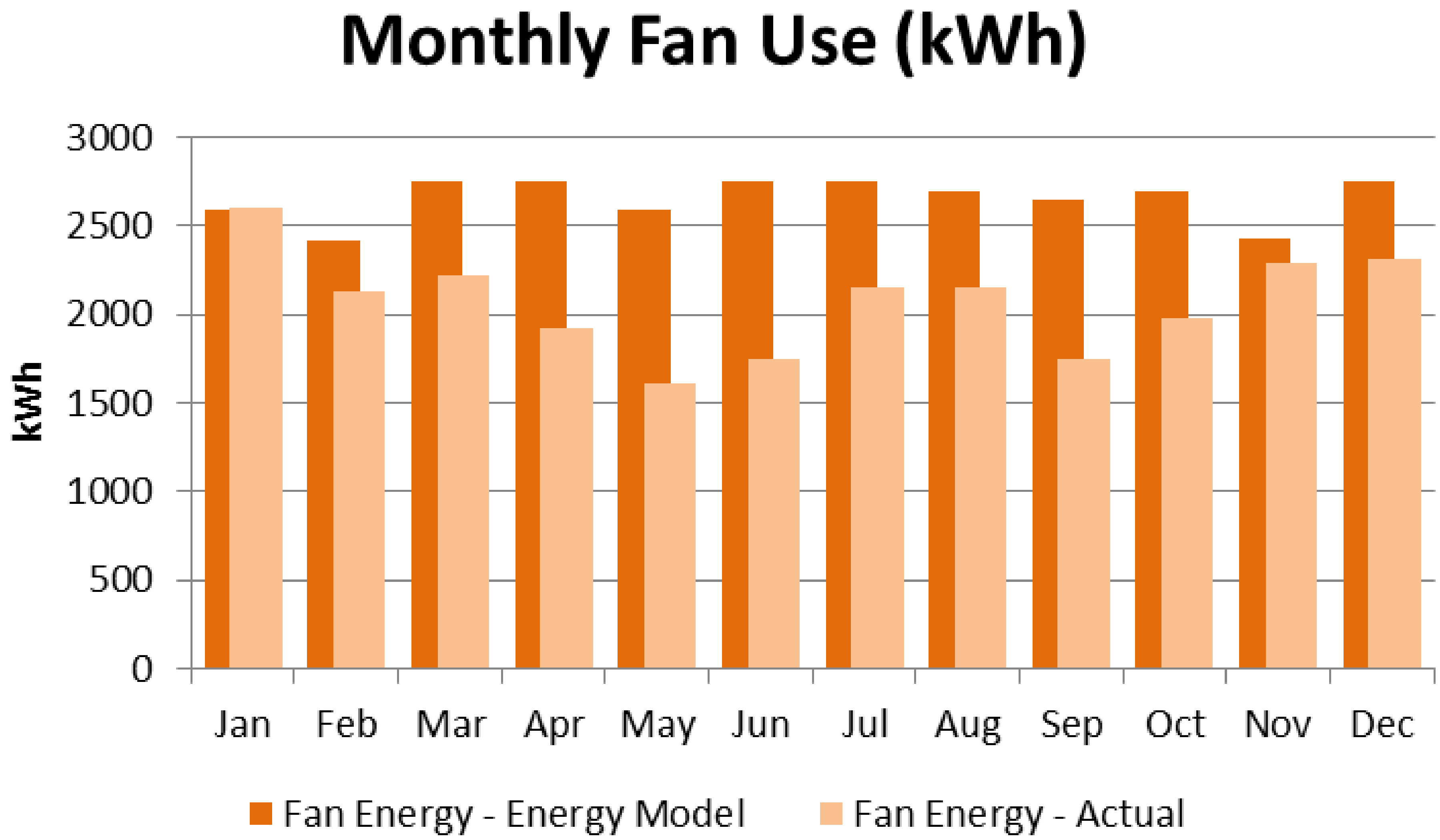


Energy Data



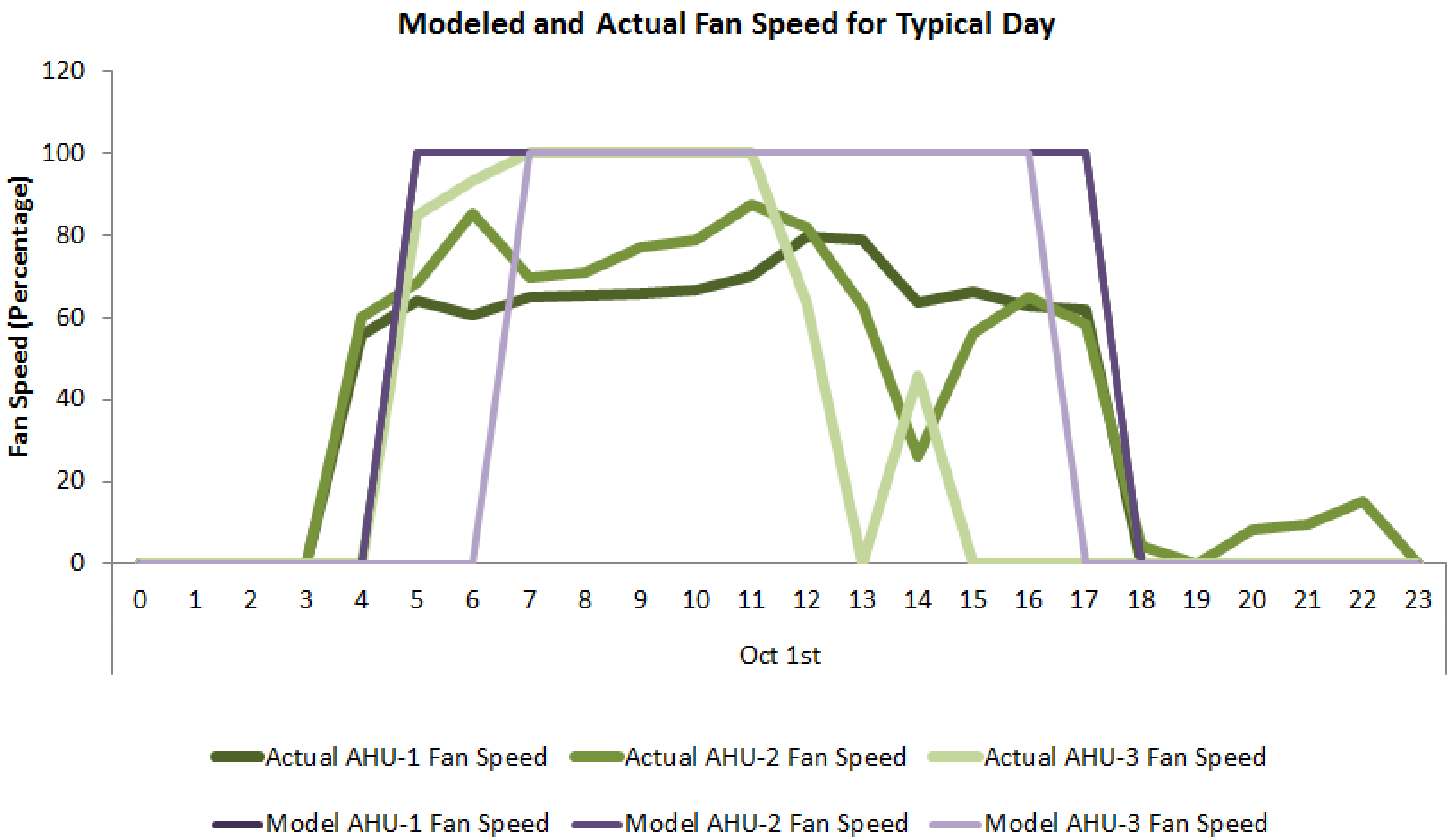
Monthly Plug Load Use (kWh)
10000
8000
6000
4000
2000
0
kWh
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Plug Loads - Energy Model
Plug Loads - Actual

Energy Data

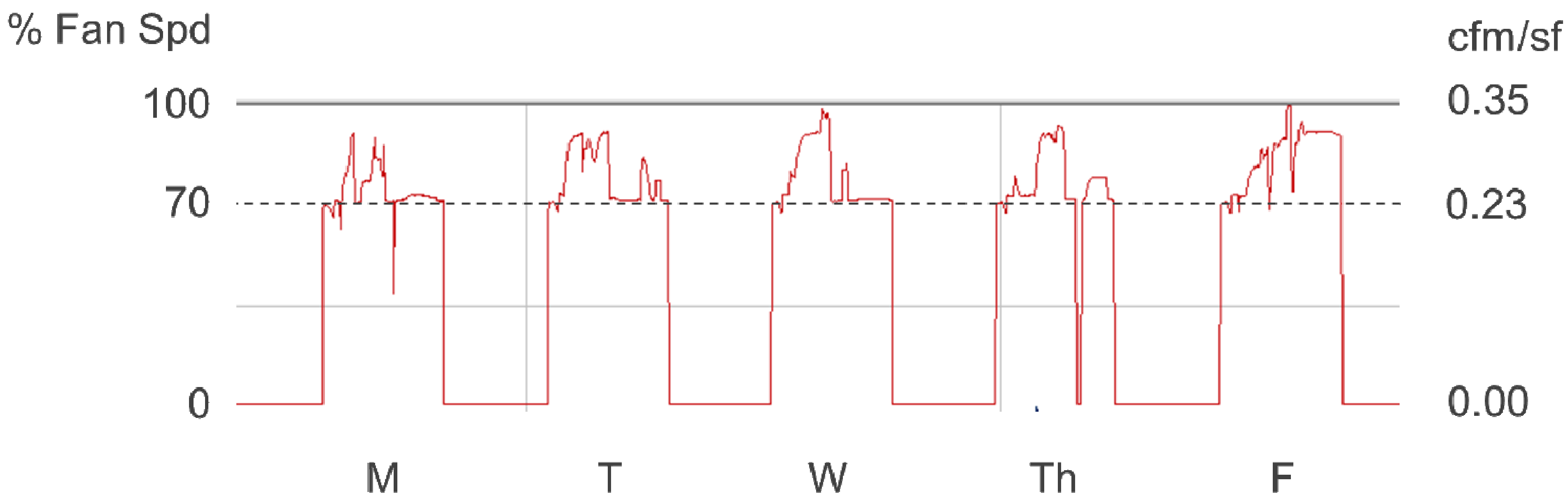


Monthly Fan Use (kWh)
kWh
3000
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Fan Energy - Energy Model
Fan Energy - Actual

Energy Data


Modeled and Actual Fan Speed for Typical Day
Fan Speed (Percentage)
0
20
40
60
80
100
120
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Oct 1st
Actual AHU-1 Fan Speed
Actual AHU-2 Fan Speed
Actual AHU-3 Fan Speed
Model AHU-1 Fan Speed
Model AHU-2 Fan Speed
Model AHU-3 Fan Speed

Variable Primary Air – Active Chilled Beams

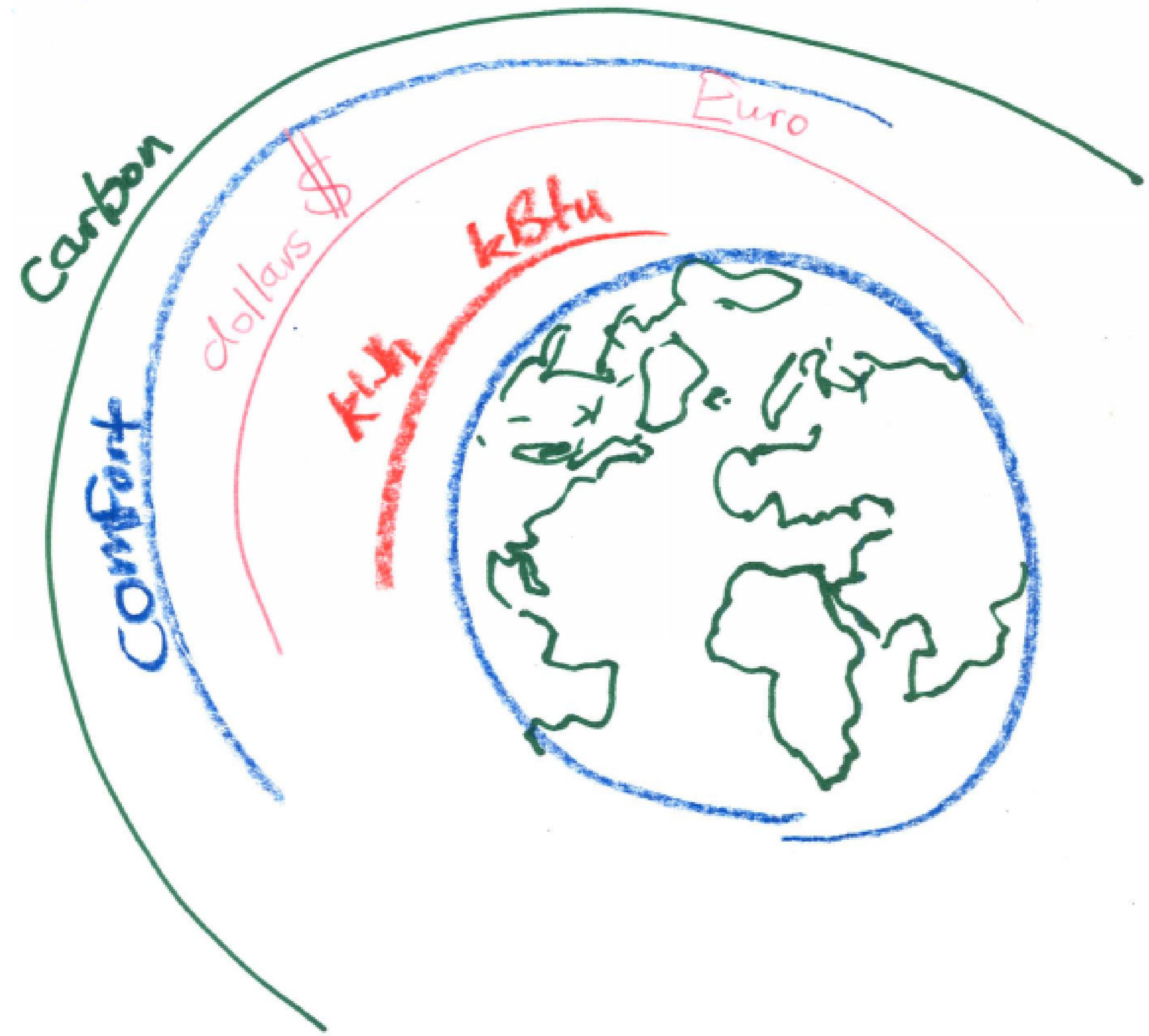


What do we need?

Rapid early modeling
- Based on experience
- Informed by data
- Incorporate robust financial analysis

Real world models
- Accurate predictions
- Integrated with control sequences
- No PhD required

Performance data
- Show us the data!
- Monitoring challenges
- Lack of performance



Thank You!

Eric Soladay, PE
esoladay@integralgroup.com

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imagine | perform | accelerate | sustain