New Challenges in Net Zero Design

July 16, 2014

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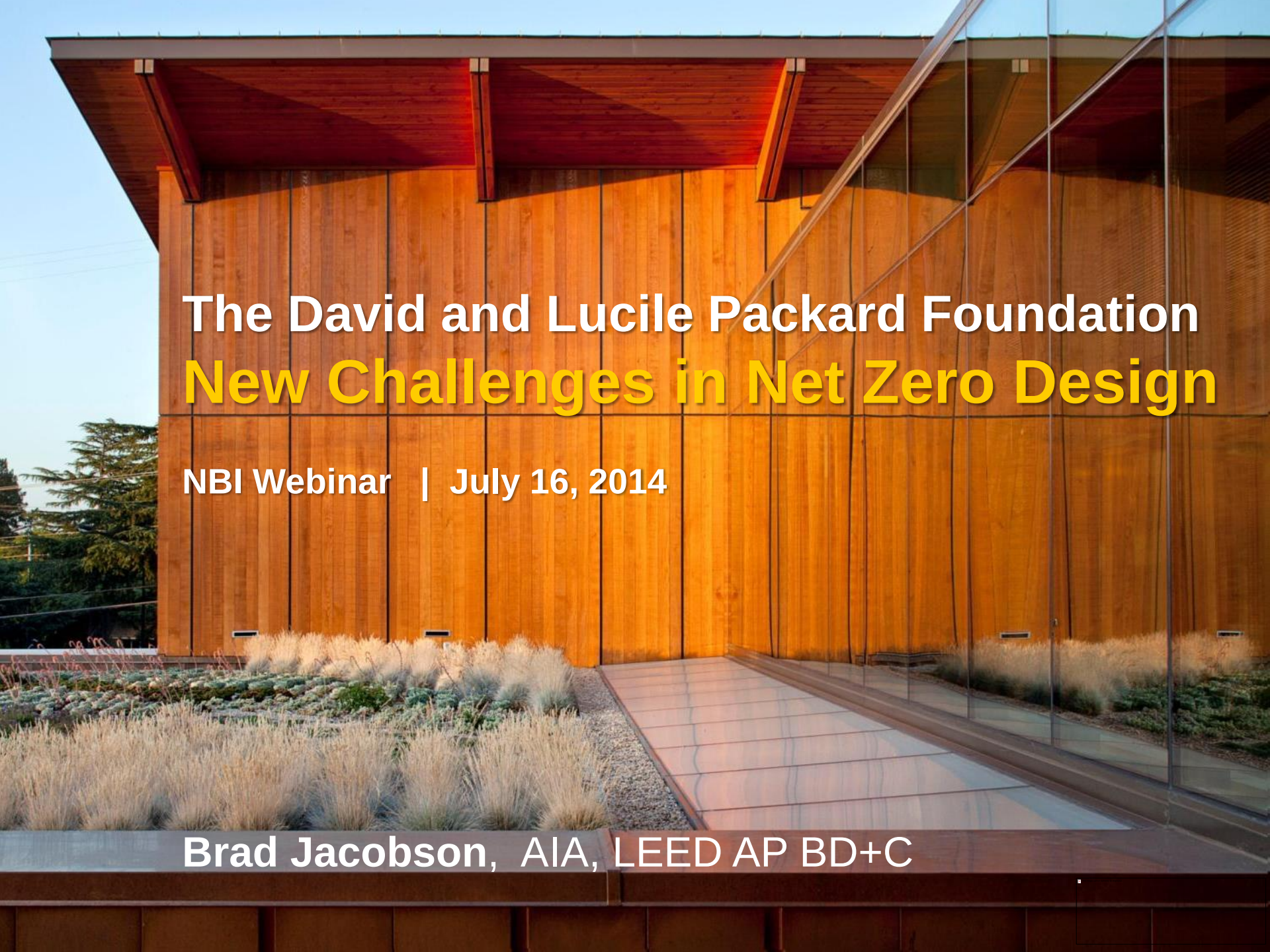


The David and Lucile Packard Foundation

New Challenges in Net Zero Design

NBI Webinar | July 16, 2014

Brad Jacobson, AIA, LEED AP BD+C

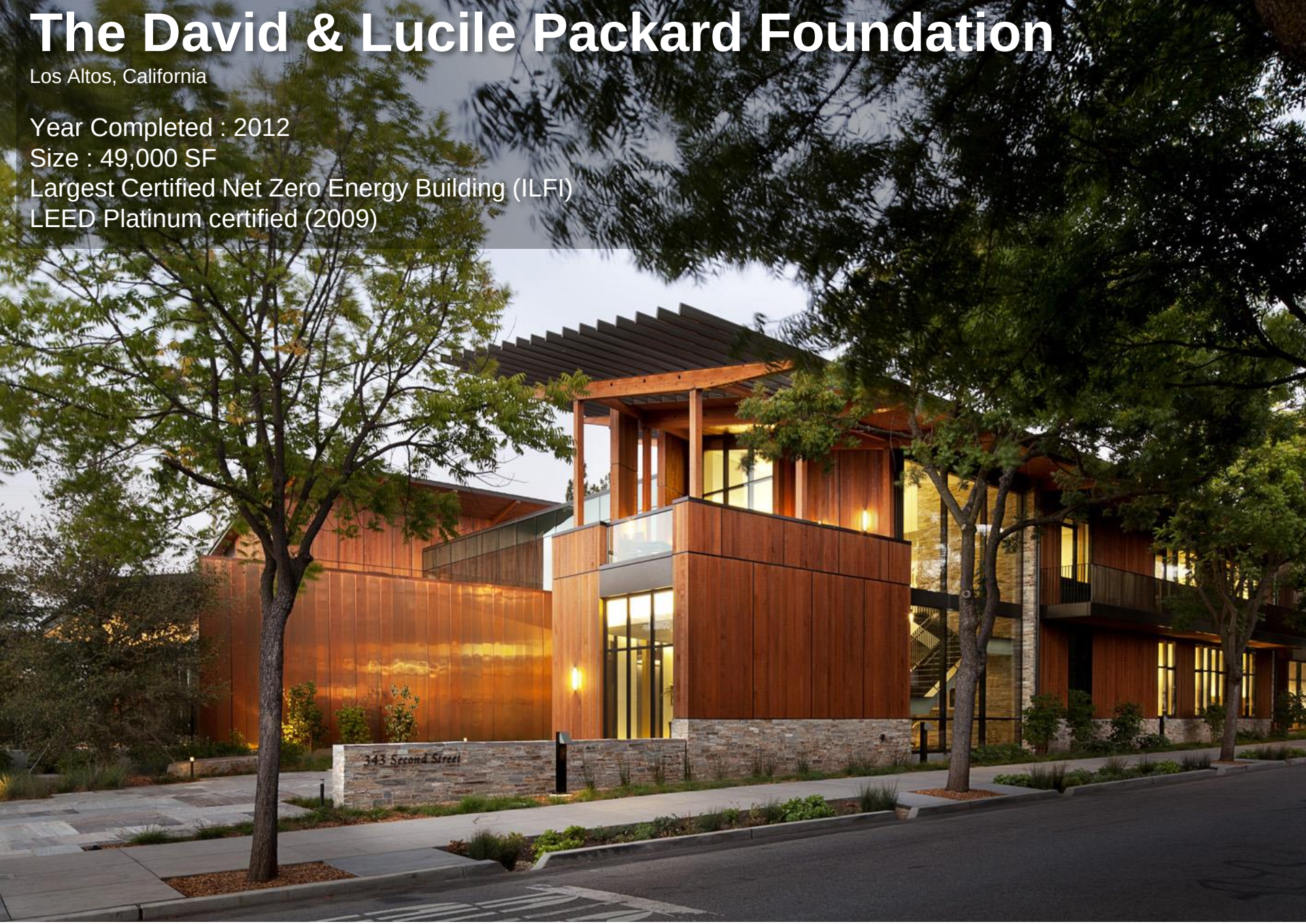
New Challenges

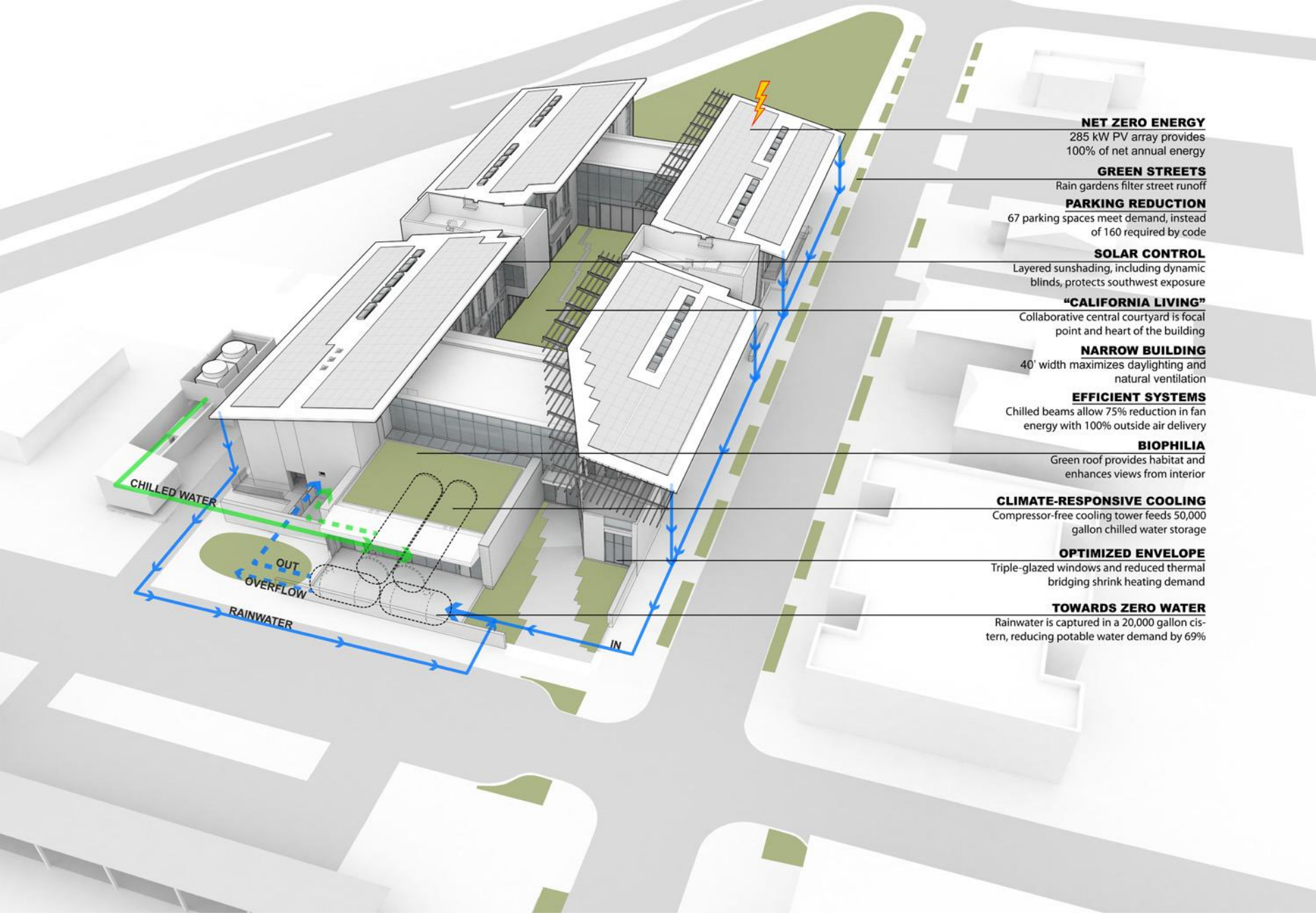
1. What’s Your EUI?
2. Push the Envelope
3. Count Every Watt
4. Expect the Unexpected

The David & Lucile Packard Foundation

Los Altos, California

Year Completed : 2012
Size : 49,000 SF
Largest Certified Net Zero Energy Building (ILFI)
LEED Platinum certified (2009)





NET ZERO ENERGY
285 kW PV array provides 100% of net annual energy

GREEN STREETS
Rain gardens filter street runoff

PARKING REDUCTION
67 parking spaces meet demand, instead of 160 required by code

SOLAR CONTROL
Layered sunshading, including dynamic blinds, protects southwest exposure

"CALIFORNIA LIVING"
Collaborative central courtyard is focal point and heart of the building

NARROW BUILDING
40' width maximizes daylighting and natural ventilation

EFFICIENT SYSTEMS
Chilled beams allow 75% reduction in fan energy with 100% outside air delivery

BIOPHILIA
Green roof provides habitat and enhances views from interior

CLIMATE-RESPONSIVE COOLING
Compressor-free cooling tower feeds 50,000 gallon chilled water storage

OPTIMIZED ENVELOPE
Triple-glazed windows and reduced thermal bridging shrink heating demand

TOWARDS ZERO WATER
Rainwater is captured in a 20,000 gallon cistern, reducing potable water demand by 69%

ehdd.

ehdd.

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New Challenges

1. What’s Your EUI?
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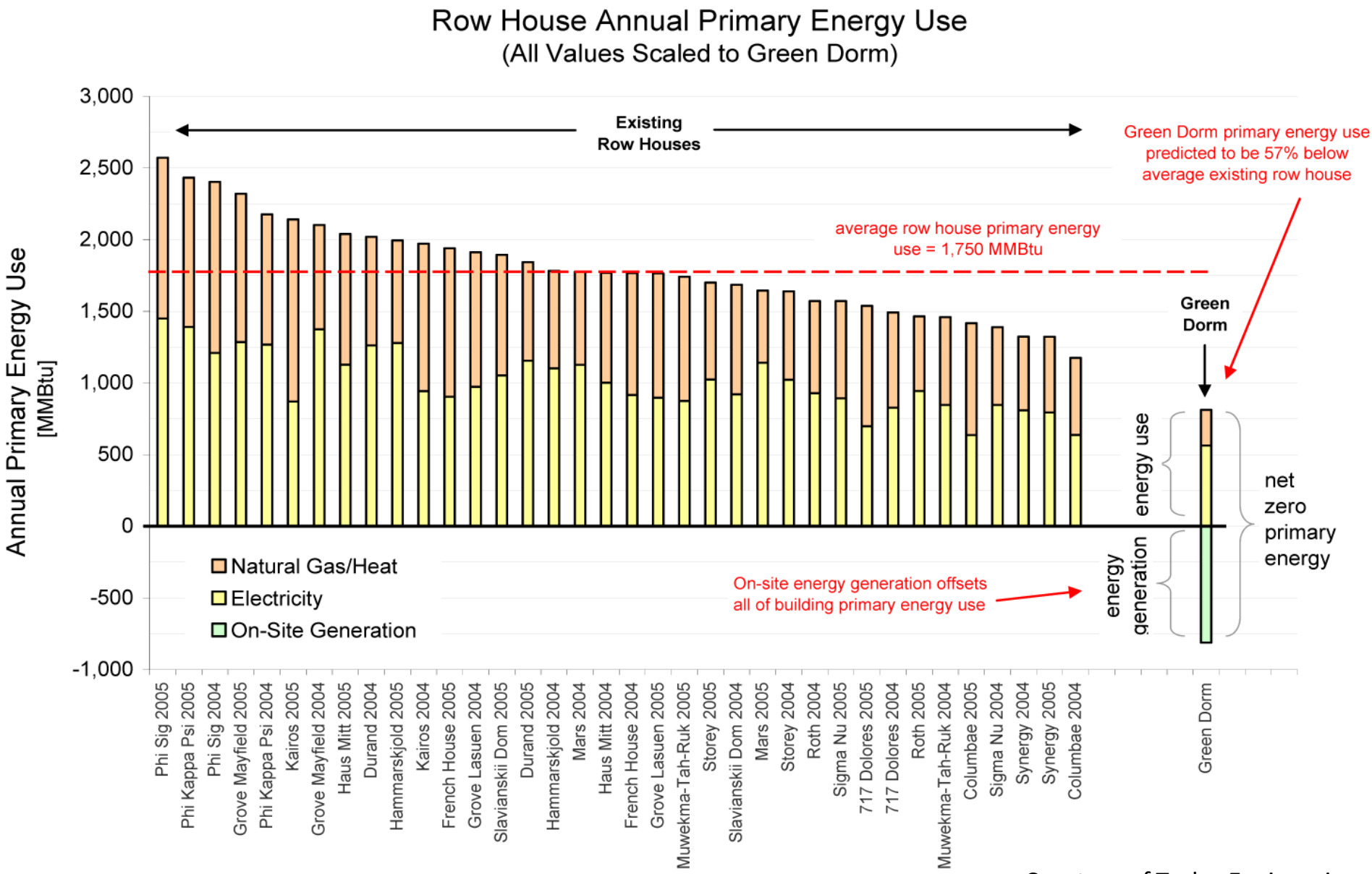
Finding the Right Benchmark Data



Courtesy of Taylor Engineering

Energy IQ | Benchmark

energyiq.lbl.gov/benchmark.jsp

URL: Energyiq.lbl.gov

EnergyIQ

LOGIN | ABOUT | HELP | BENCHMARK | TRACK | ACT | MY BUILDINGS

Define Peer Group

Back to Metrics & Features | DRAW CHART

Select floor area, vintage, and location.

Then, select your building types.

FLOOR AREA
- [x] All sizes
  - [x] 0 - 25000 sq. ft.
  - [x] 25000 - 150000 sq. ft.
  - [x] over 150000 sq. ft.

VINTAGE
- [x] All years
  - [x] 1991 - Present
  - [x] 1979 - 1990
  - [x] 1941 - 1978
  - [x] 1901 - 1940
  - [x] Pre-1900
  - [x] Unknown

LOCATION [MAP]
- [x] All Locations
  - [x] Central Coast
  - [x] Central Valley
  - [x] Desert
  - [x] Mountains
  - [x] North Coast
  - [x] South Coast
  - [x] South Inland

- [x] **OFFICE**
  - [x] Administration and Management
  - [x] Financial/Legal
  - [x] Insurance/Real Estate
  - [x] Government Services
  - [x] Software Development
  - [x] Medical/Dental Office
  - [x] Assorted/Multi-tenant
  - [x] Other Office
- [ ] **DATA CENTER**
- [ ] **LABORATORY**
- [ ] **RESTAURANT**
  - [ ] Fast Food or Self Service
  - [ ] Specialty/Novelty food service
  - [ ] Table Service
  - [ ] BAR/Tavern/Nightclub/Other
  - [ ] Other Food Service
- [ ] **FOOD STORE**
  - [ ] Supermarkets
  - [ ] Small General Grocery
  - [ ] Specialty Ethnic Grocery
  - [ ] Convenience Store
  - [ ] Liquor Store
  - [ ] Other Food Store

- [ ] **RETAIL**
  - [ ] Department/Variety Store
  - [ ] Retail Warehouse/Clubs
  - [ ] Shop in Enclosed Mall
  - [ ] Shop in Strip Mall
  - [ ] Auto Sales
  - [ ] Other Retail Store
- [ ] **WAREHOUSE** (REFRIGERATED)
- [ ] **WAREHOUSE** (NON-REFRIGERATED)
  - [ ] Unconditioned Warehouse High Bay
  - [ ] Unconditioned Warehouse Low Bay
  - [ ] Conditioned Warehouse High Bay
  - [ ] Conditioned Warehouse Low Bay
- [ ] **HEALTHCARE**
  - [ ] Hospital
  - [ ] Nursing Home
  - [ ] Clinic/Outpatient Care
  - [ ] Medical/Dental Lab
- [ ] **SCHOOL**
  - [ ] Daytime or Preschool
  - [ ] Elementary School
  - [ ] Middle/Secondary School
- [ ] **COLLEGE**
  - [ ] College or University
  - [ ] Vocational or Trade School

- [ ] **LODGING**
  - [ ] Hotel
  - [ ] Motel
  - [ ] Resort
  - [ ] Other Lodging
- [ ] **PUBLIC ASSEMBLY**
  - [ ] Library/Museum
  - [ ] Conference /Convention Center
  - [ ] Religious Assembly (Worship only)
  - [ ] Religious Assembly (Mixed use)
  - [ ] Health/Fitness Center
  - [ ] Theater/Performing Arts
  - [ ] Community Center
  - [ ] Other Recreation/Public Assembly
- [ ] **MISCELLANEOUS**
  - [ ] Gas Station
  - [ ] Gas with Convenience Store
  - [ ] Repair (Non-Auto)
  - [ ] Other Service Shop
  - [ ] Assembly / Light Mfg.
  - [ ] Police / Fire Stations
  - [ ] Post Office
  - [ ] Other Unlisted Type

BERKELEY LAB

California Environmental Protection Agency
Air Resources Board

Energy IQ | Benchmark

energyiq.lbl.gov/benchmark.jsp

EnergyIQ

LOGIN | ABOUT | HELP | BENCHMARK | TRACK | ACT | MY BUILDINGS

BACK TO PEERGROUPS

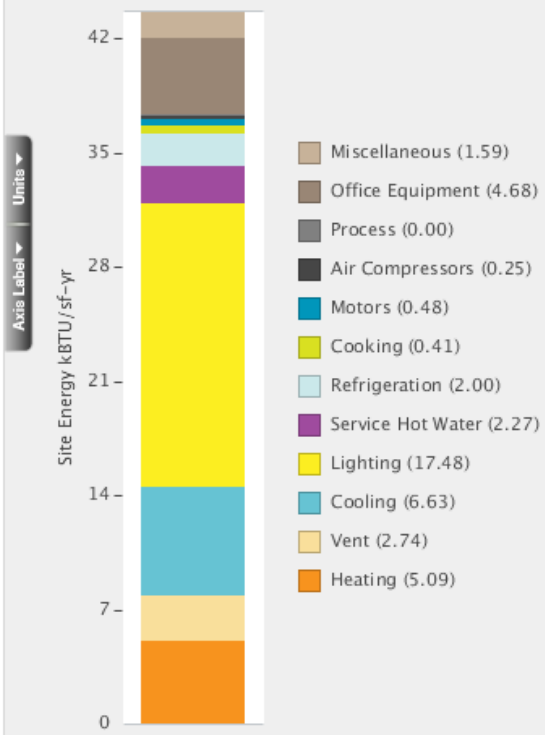
Export | Email | Add to Dashboard | Create New Chart | Add a Building

View

End Use Breakout - Total Site Energy (kBTU/sf-yr)

Absolute Value | By Percentage

Peer Group: 480 buildings



Peer Group Information

SUMMARY The Site Energy for typical buildings of the type(s) you've specified is 43.6 kBTU/sf-yr [median value], with a range of 13.8 to 82.3 kBTU/sf-yr [5th to 95th percentiles] for the population. Select "Add a Building" button to see how yours compares. Try other Views for graphical and tabular detail. This analysis includes population weights for each building.

DATA SET California only (CEUS)

LOCATION California= Central Coast, Central Valley, Desert, Mountains, North Coast, South Coast, South Inland

SIZE 0 - 25,000 sf, 25,001 - 150,000 sf, Over 150,000 sf

VINTAGE 1901 through 1940, 1941 through 1978, 1979 through 1990, 1991 through Present, Unknown

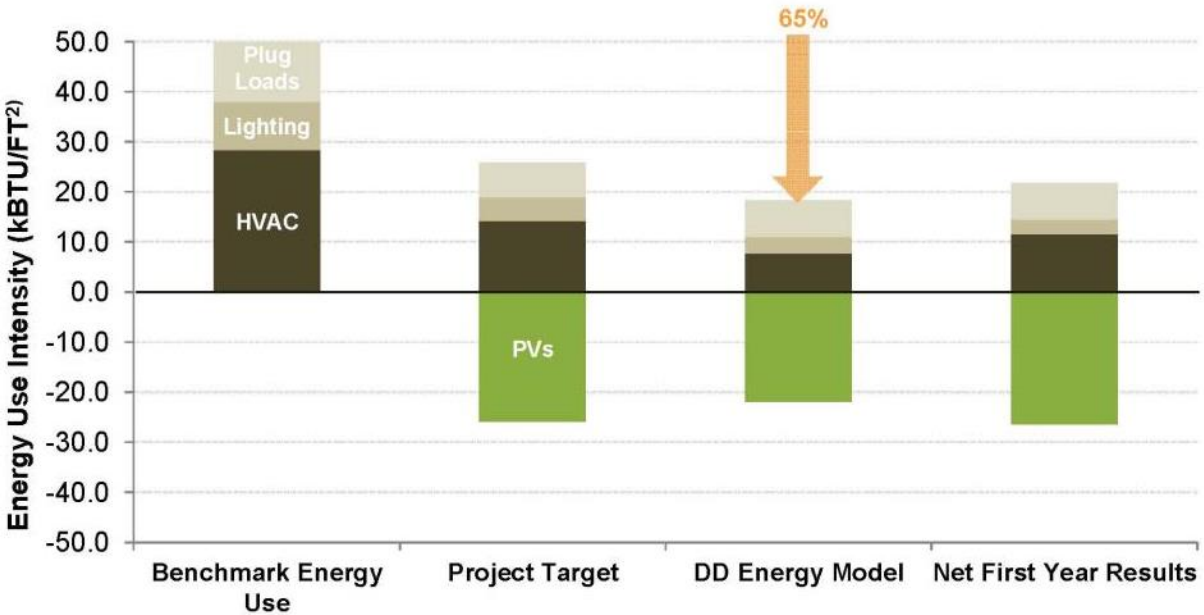
TYPE Administration and Management, Assorted/Multi-tenant, Financial/Legal, Government Services, Insurance/Real Estate, Medical/Dental Office, Other Office, Software Development

BERKELEY LAB

California Environmental Protection Agency
Air Resources Board

Packard Energy Tracking Process

	Whole Building	By End Use					Renewable Energy	
		HVAC	Hot H2O	Lighting	Plug Loads	[Other]	PVs	Thermal
	kBTU/FT²	kBTU/FT²	kBTU/FT²	kBTU/FT²	kBTU/FT²	kBTU/FT²	kBTU/FT²	kBTU/FT²
Pre-Design								
Benchmark Energy Use	51.7	28.4	0.0	9.6	13.7			
AIA 2030 Target	20.7							
Project Target	**25.8**	**14.2**	**0.0**	**4.8**	**6.9**		**-25.8**	
Design								
DD Energy Model	**18.3**	**7.7**	**0.0**	**3.3**	**7.2**		**-21.9**	**-0.4**
Occupancy								
Net First Year Results	**21.8**	**11.6**	**0.0**	**2.8**	**7.4**		**-26.5**	



New Challenges

1. What’s Your EUI?
2. Push the Envelope
3. Count Every Watt
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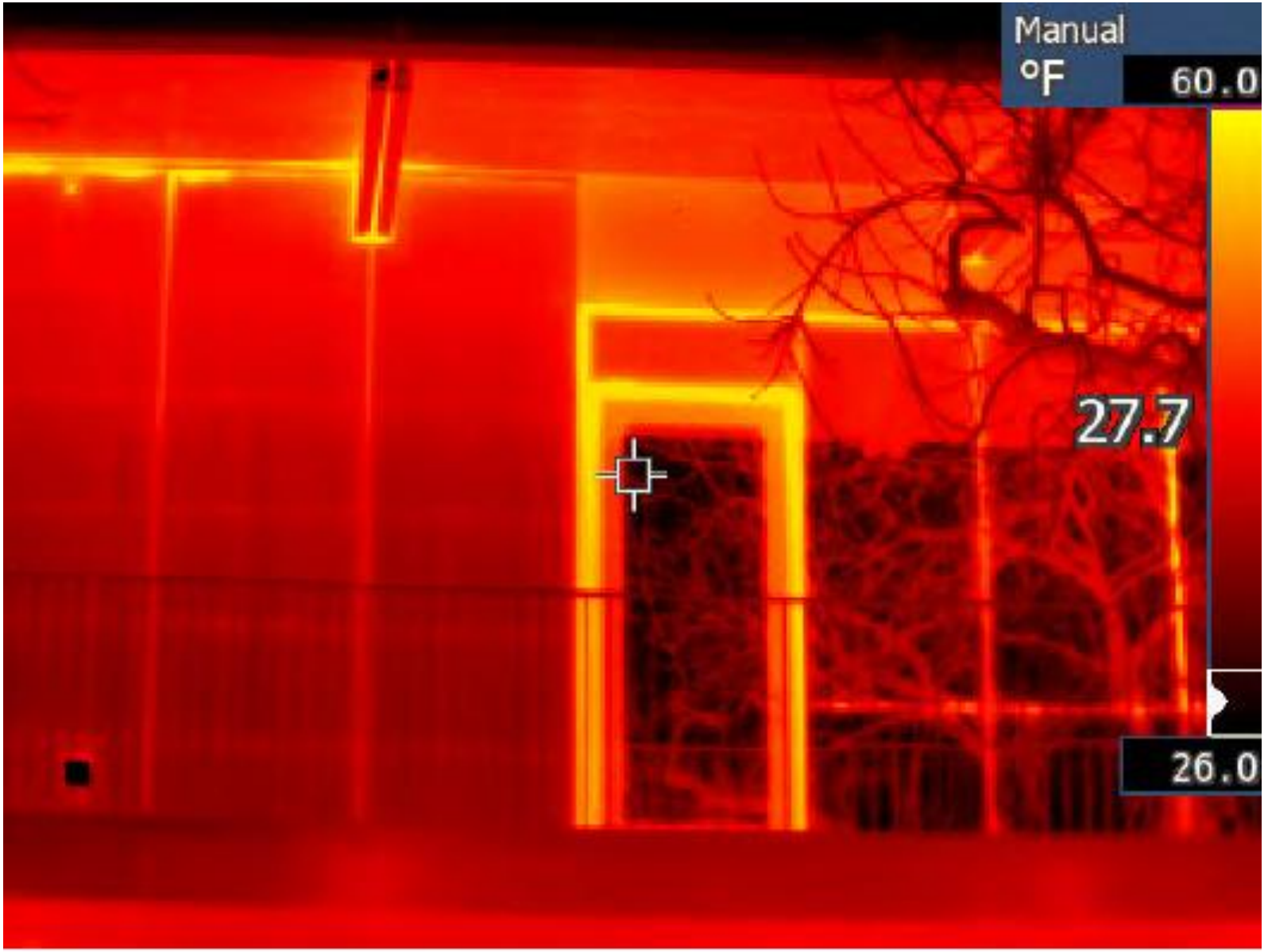
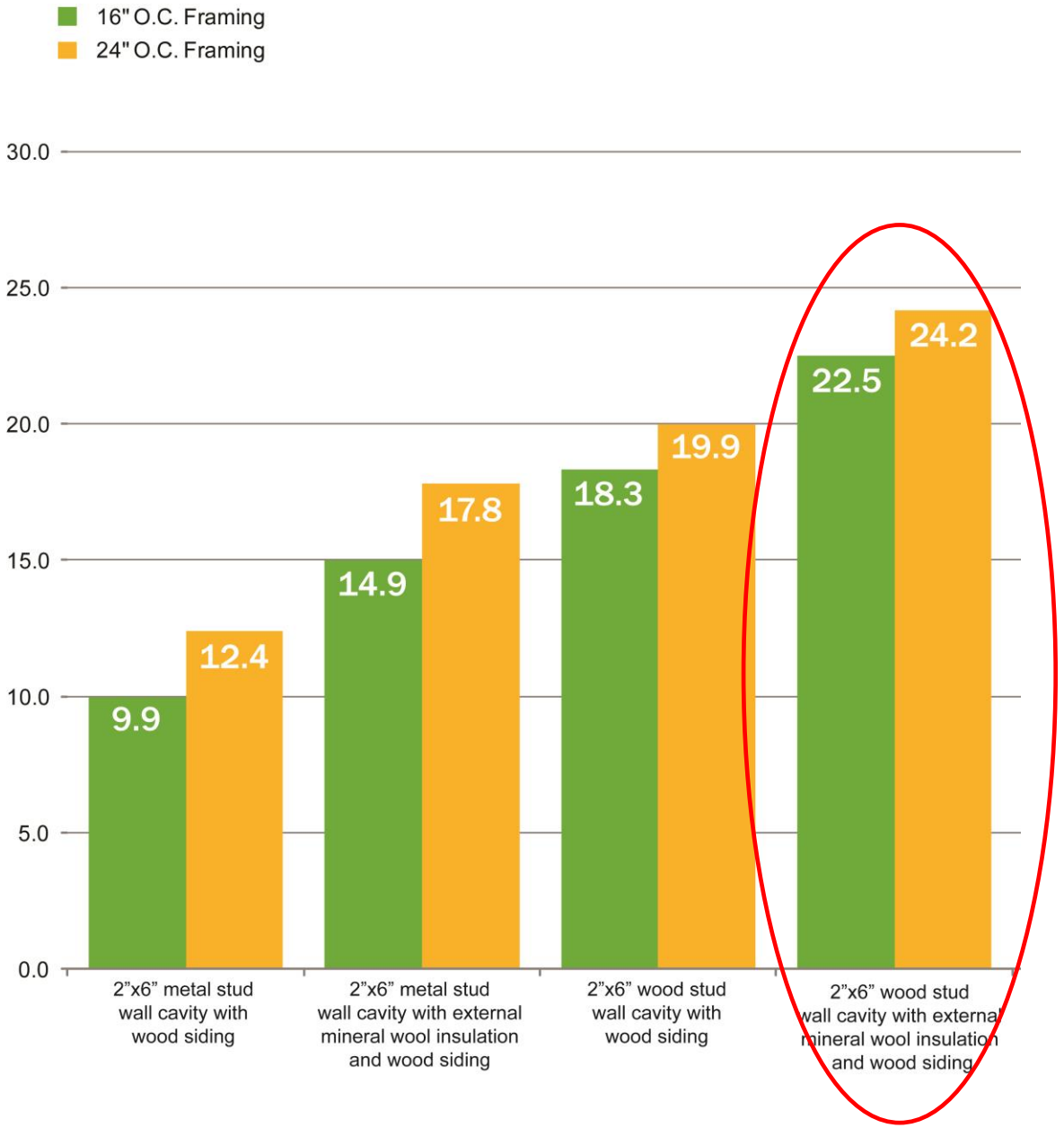
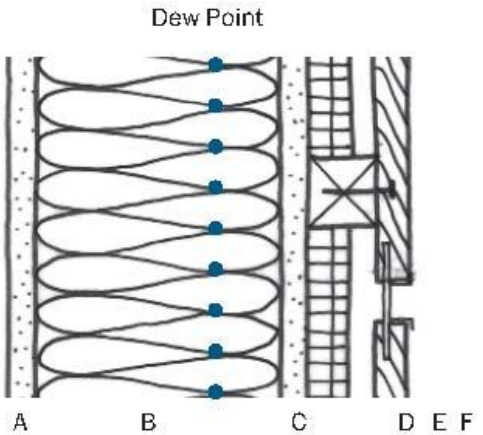
Energy Flow Through the Envelope



Optimizing Wall Assembly Insulation





ASSEMBLY 3: A 2"X6" WOOD STUD WALL CAVITY WITH EXTERNAL MINERAL WOOL INSULATION, 16" O.C. WOOD NAILERS, AND WOOD SIDING

Total R-Value:
16" O.C. Framing - R-22.3
24" O.C. Framing - R-24.0

A	5/8" Gypsum Board
B	6" Batt Insulation
C	5/8" Gypsum Board Sheathing
D	1" Mineral Wool Insulation with 16" O.C. Wood Nailer
E	1/2" Air Gap
F	3/4" Wood Siding


TYPICAL FRAMING AT 16" O.C.
3,780 BOARD FEET


ADVANCED FRAMING AT 24" O.C.
2,761 BOARD FEET

Upgrade to High-Performance Windows

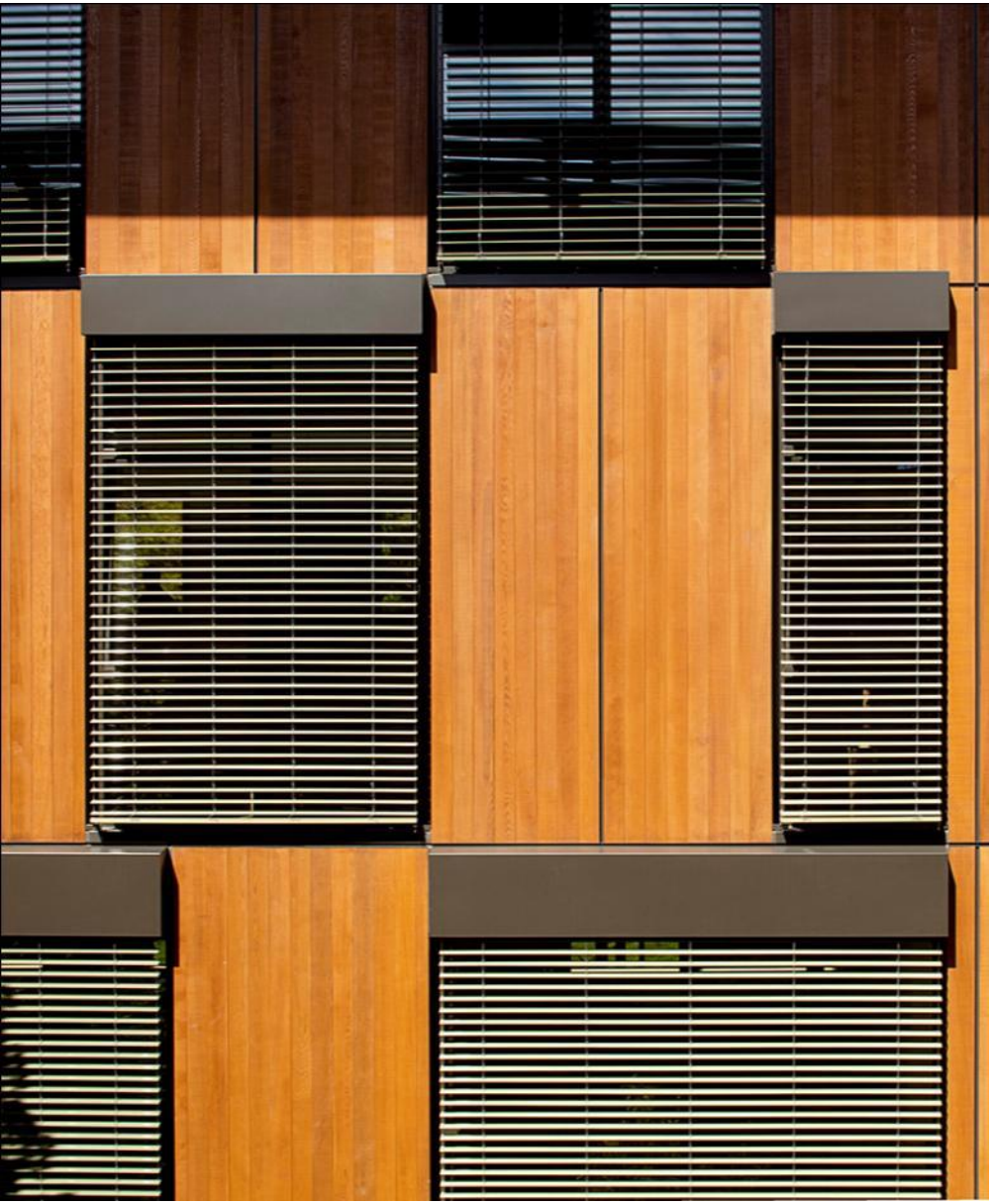
+ $75,000 Premium for installed glazing

- $150,000 Eliminate perimeter heating

= $75,000 first cost *savings*

+ $200,000 in PV system downsizing

Multiple Shading Strategies



ehdd.

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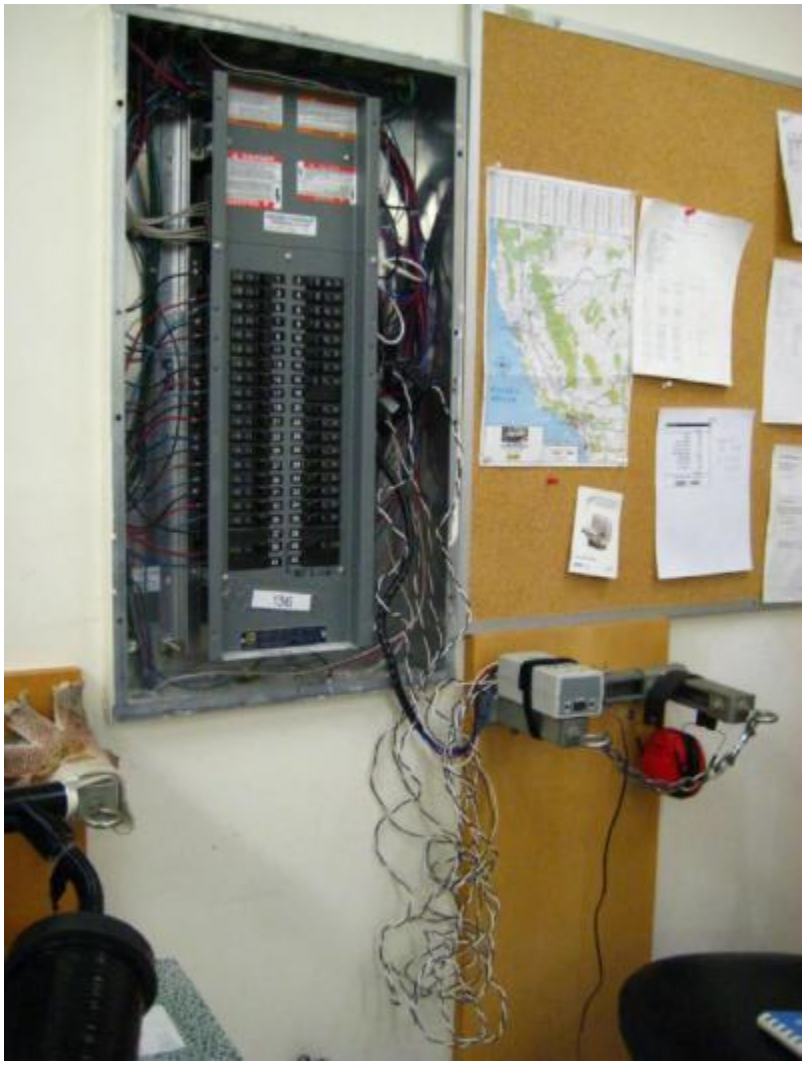
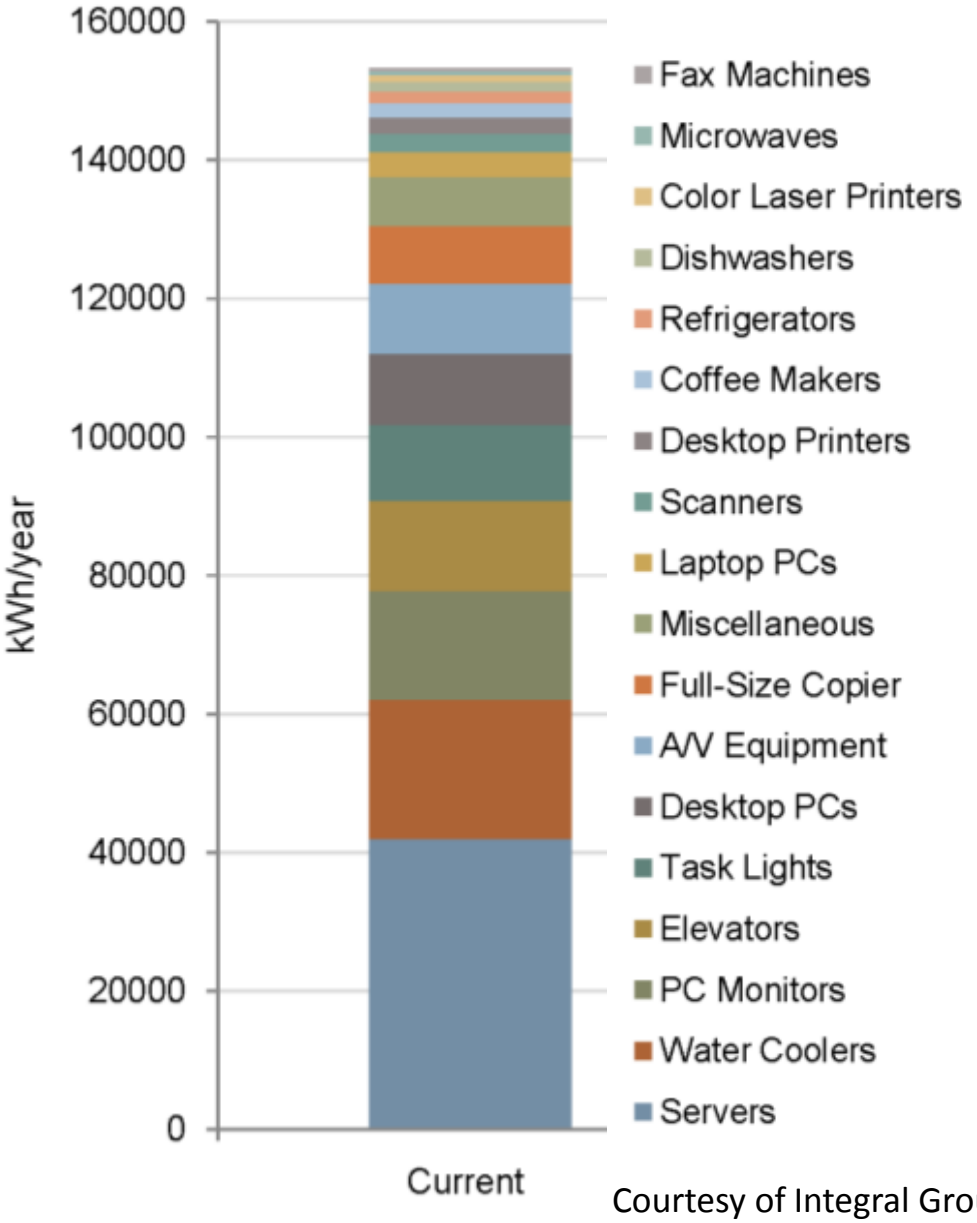
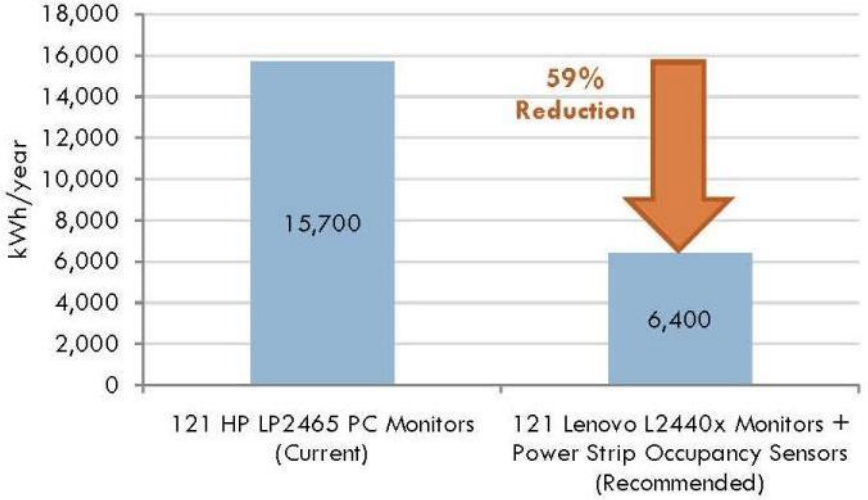
Plug Load Study





Courtesy of Integral Group

Computer Monitor Energy Use



Annual Energy Usage - Monitors

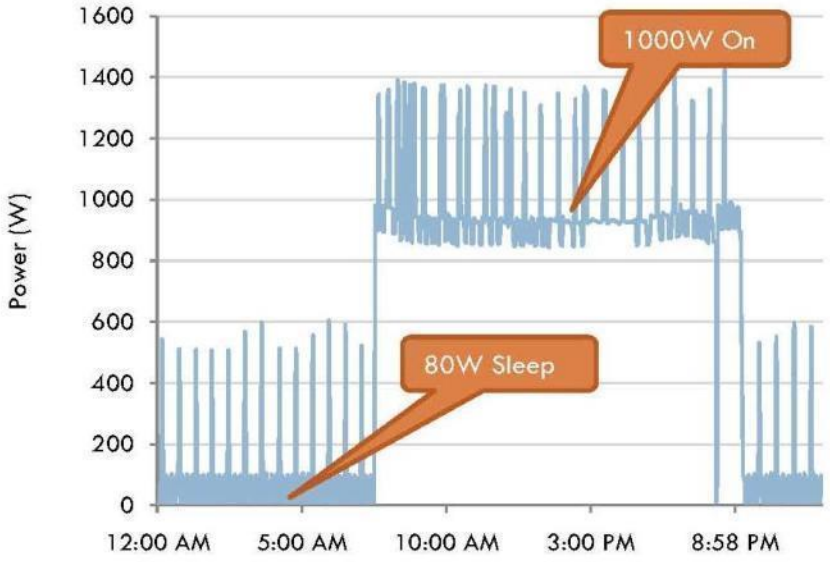
	Current	Recommended
Specifications		
Model	HP LP2465	Lenovo L2440x
Screen Size	24" LCD	24" LCD
Brightness	500	300
Contrast Ratio	1000:1	1000:1
Resolution	1920 x 1200	1900 x 1200
Bulb Type	CCFL	LED
Energy Usage Per Unit		
On (W)	65	28
Standby (W)	1	0.9
Used w/ Occupancy Sensor?	No	Yes
Avg. Plug Load (W)	21	9
Annual Consumption (kWh)	134	56

Current Monitor: HP LP2465 24"

Recommended Monitor: Lenovo L2440x 24"

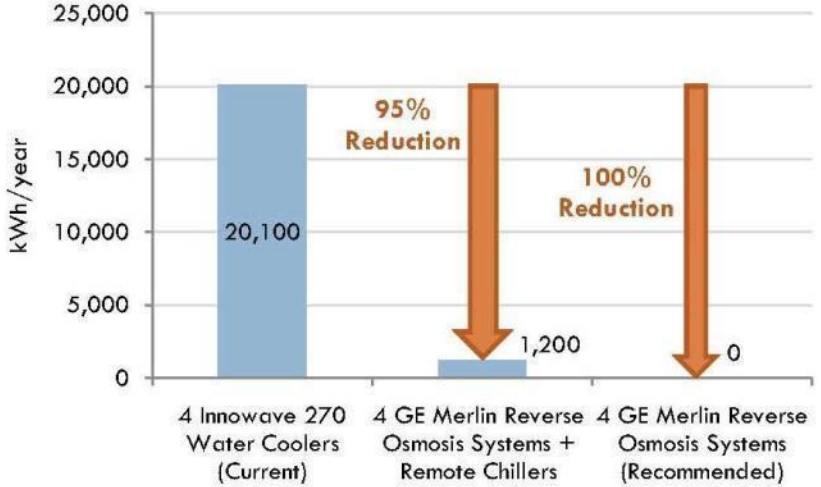
Courtesy of Integral Group

Filtered Water Cooler Energy Use



Daily Power Usage of Current Water Cooler (Innowave 270)

Current Water Cooler: Innowave 270

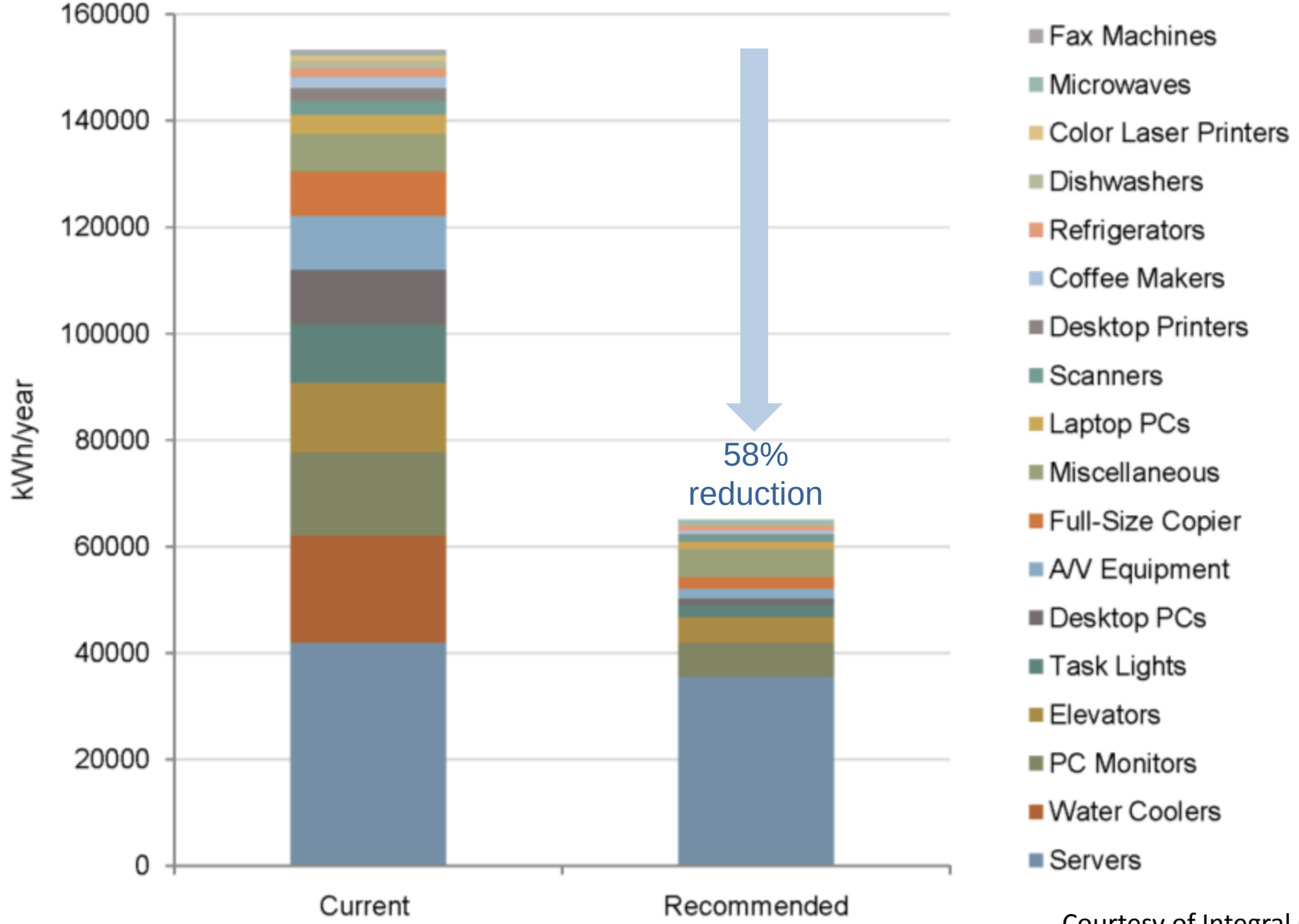


Annual Energy Consumption - Water Coolers

Recommended: GE Merlin Reverse Osmosis System

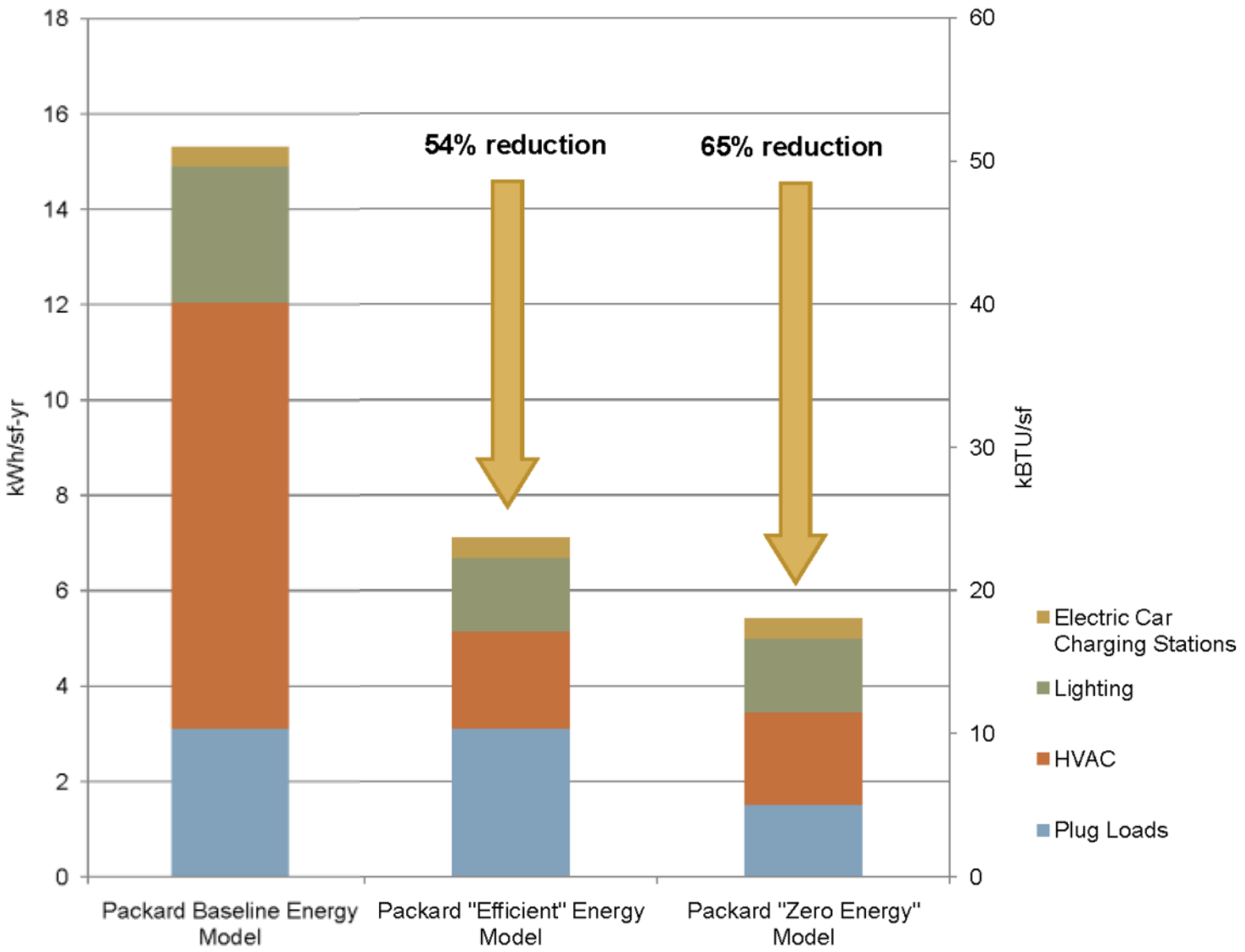
Courtesy of Integral Group

Plug Loads Annual Energy Consumption



Courtesy of Integral Group

Estimated Annual Energy Use



New Challenges

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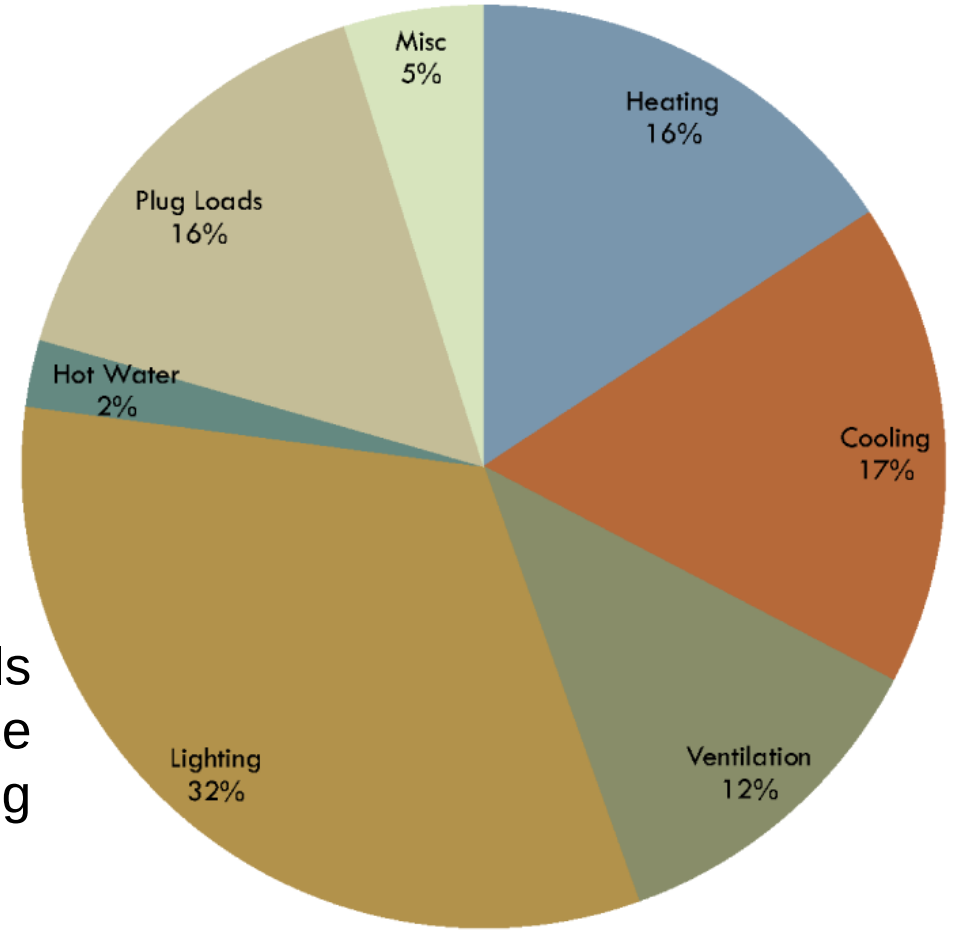
Energy Performance, Two Ways

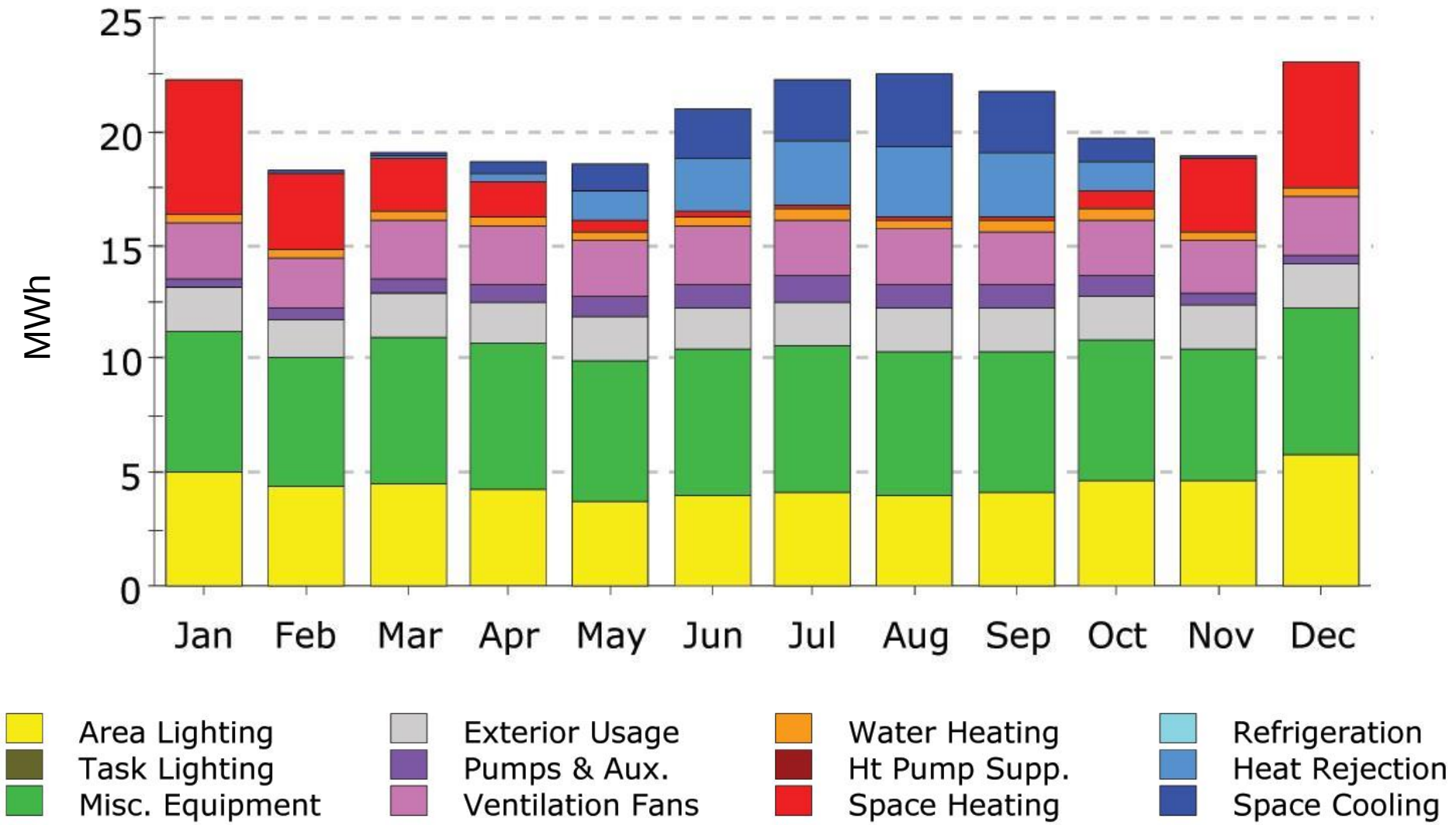
Equipment
Lighting Use
Schedule



Controls
Maintenance
Commissioning

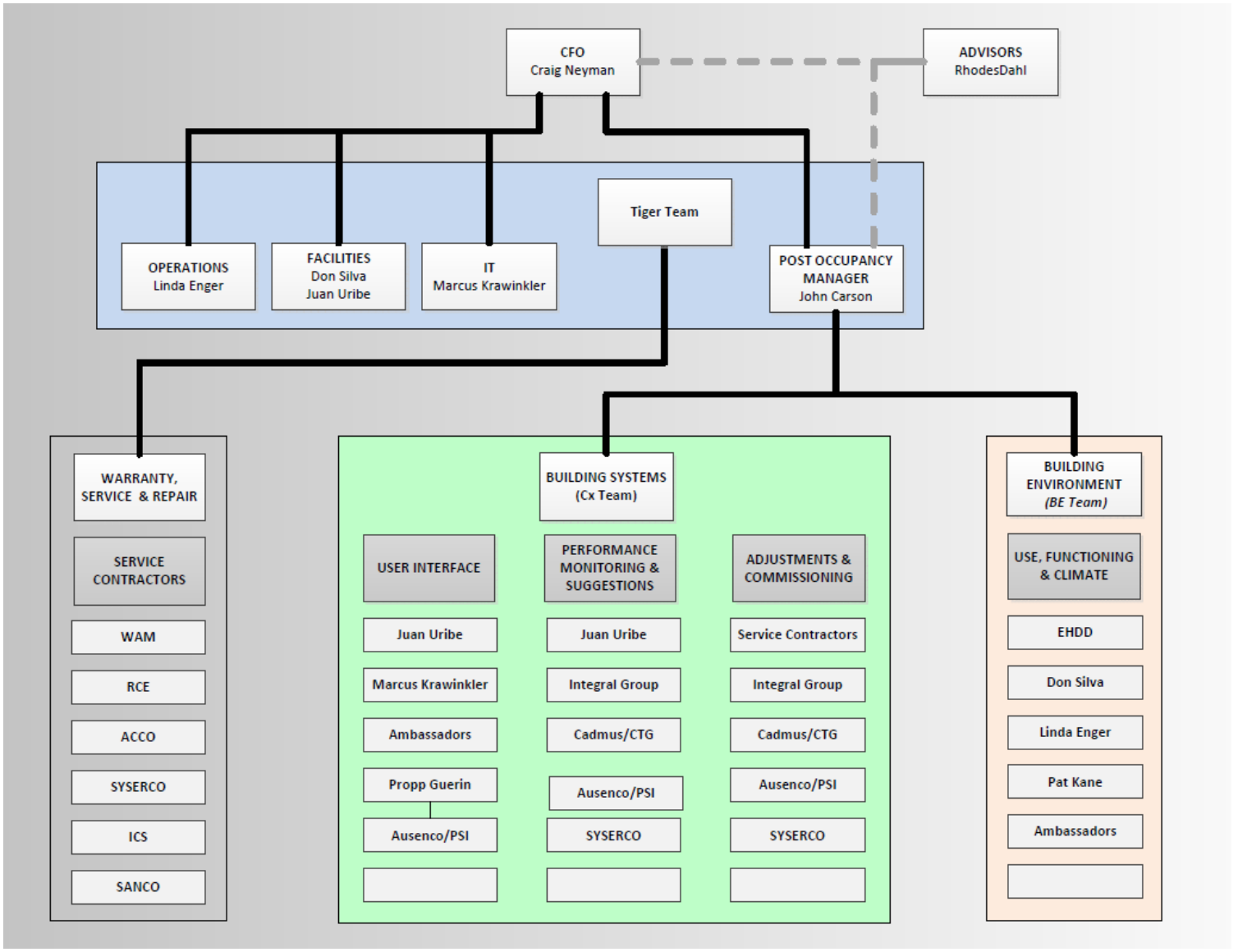
Orientation
Insulation
Glass type
System selection

A “Real Energy” Model

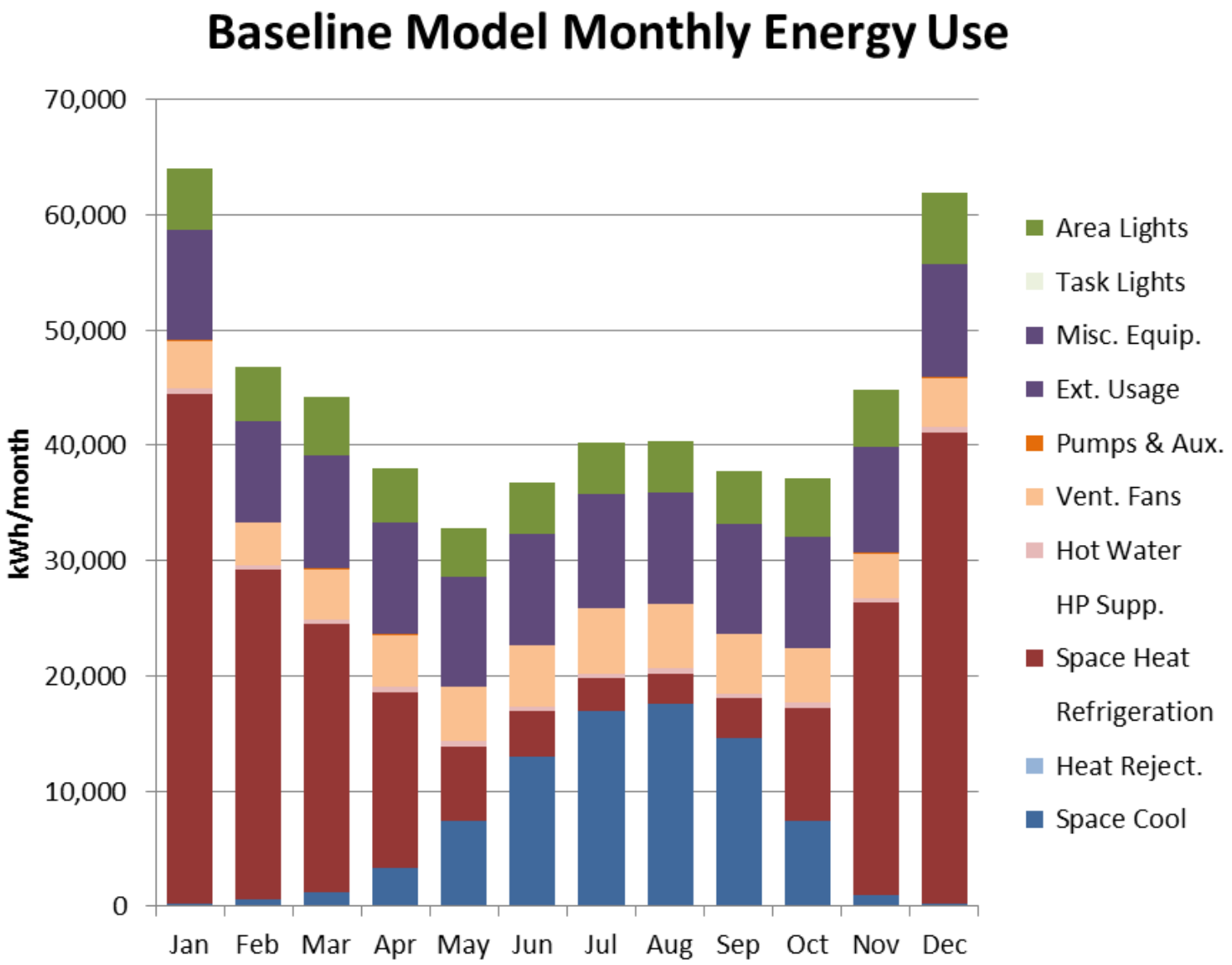


Courtesy of Integral Group

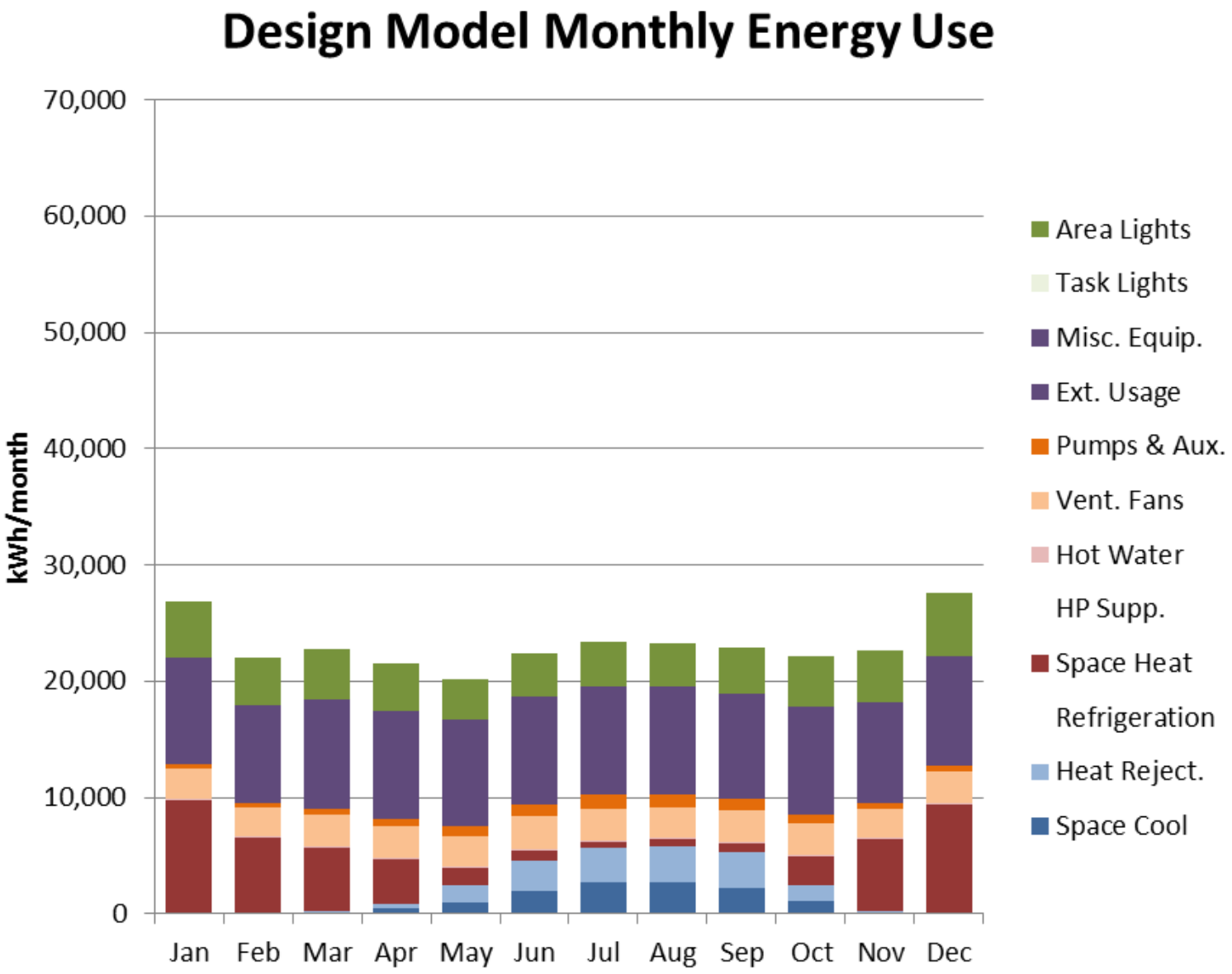
Post-Occupancy Phase Services



Energy Data


Baseline 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
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
Hot Water
HP Supp.
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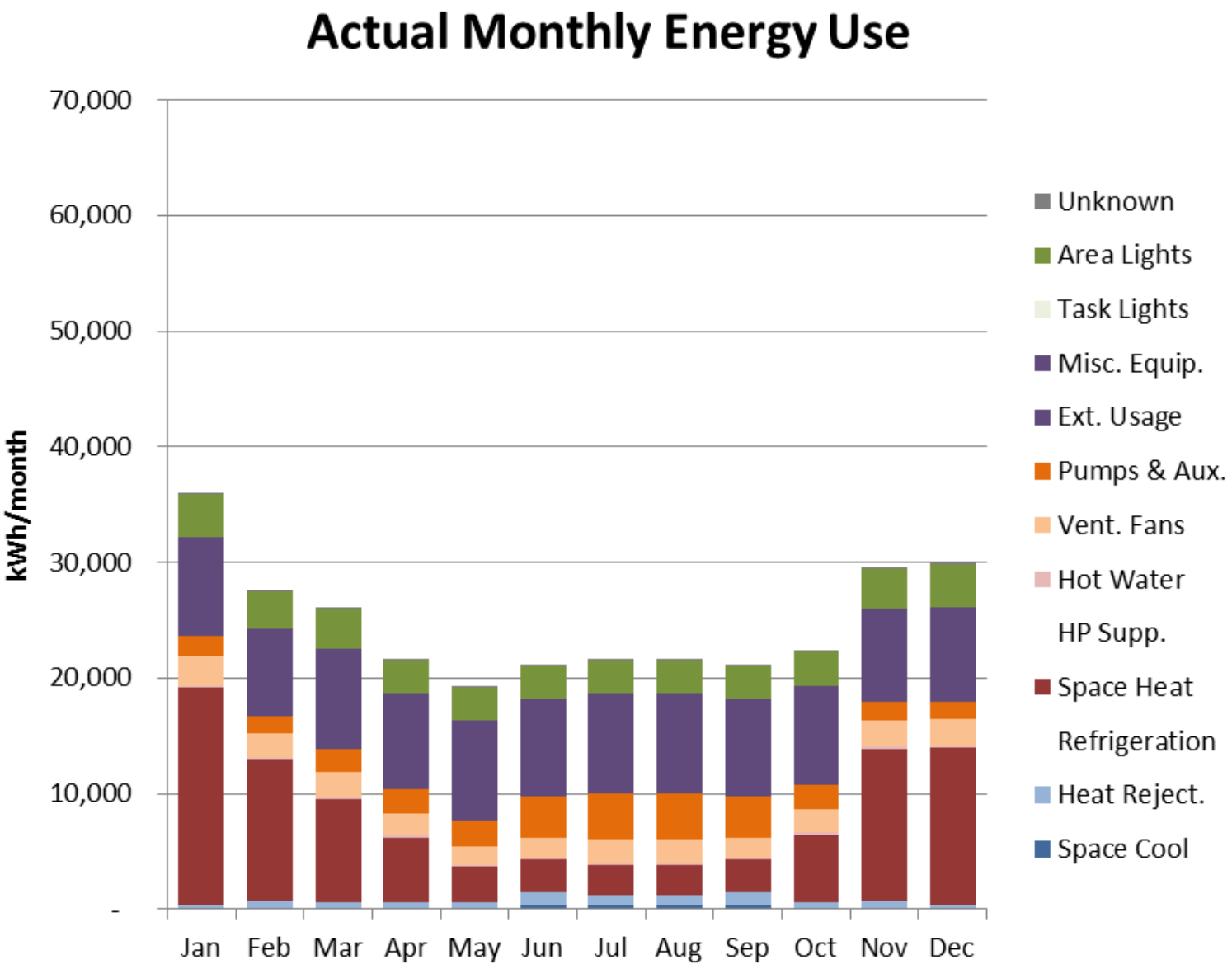
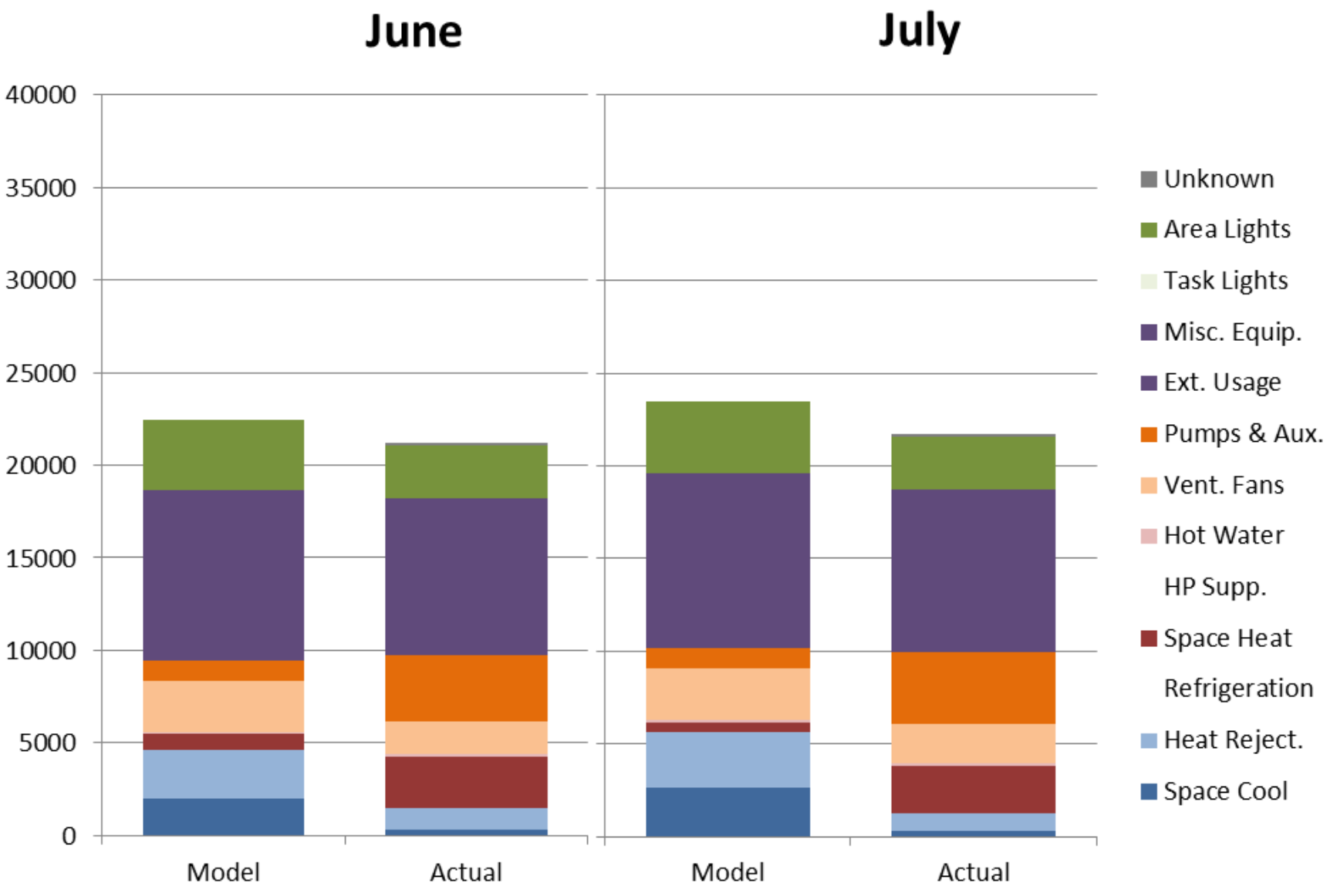
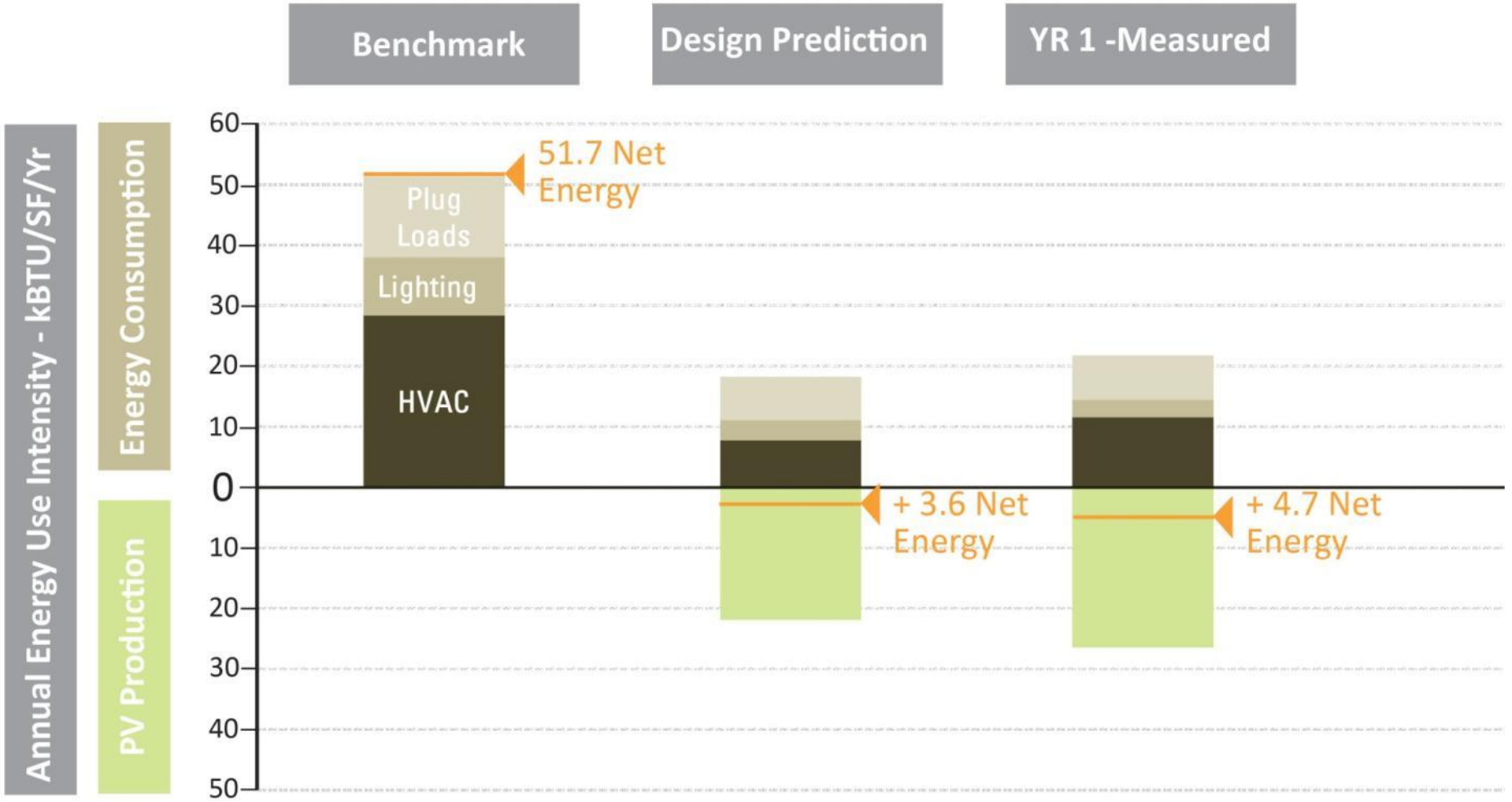
Energy Data


Actual Monthly Energy Use
kWh/month
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
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



Year One Results



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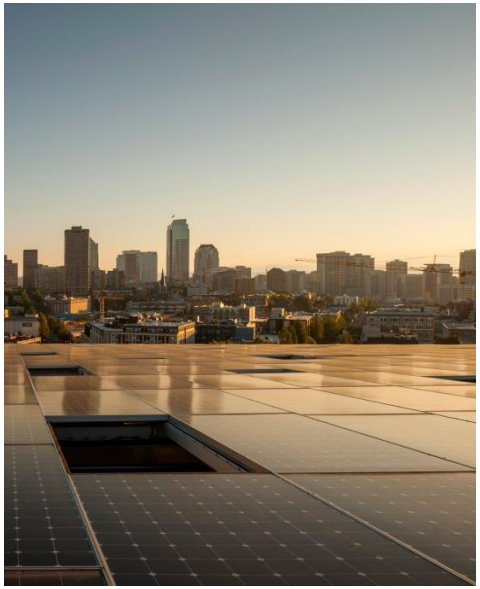
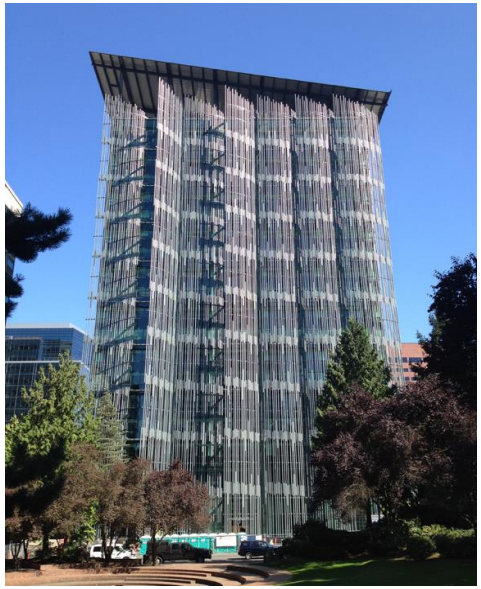
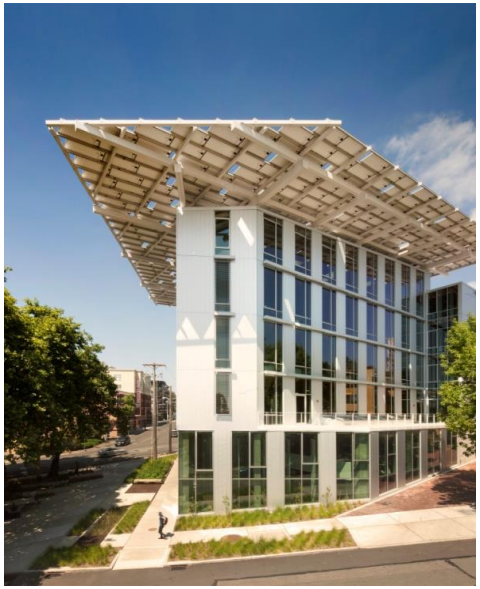




PAE

Getting to Net Zero

July 16, 2014

PRESENTED BY:
Paul Schwer, PE, LEED AP – President
Scott Bevan, PE, LEED AP – Associate Principal

inspire interpret integrate

Discussion Topics

PV in Utility Networks

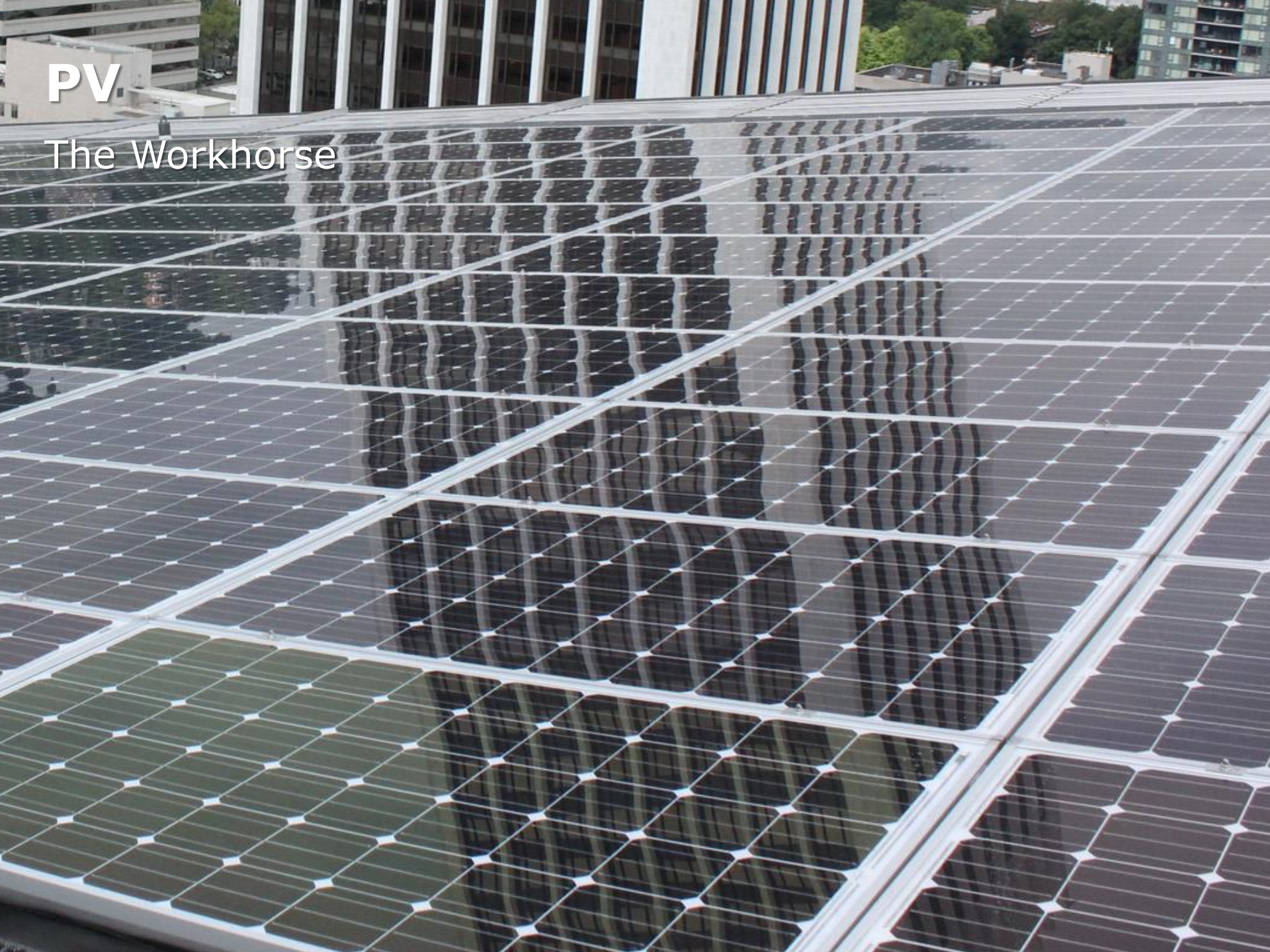
Real Plug Load Reduction

Green Leases

Heating and Cooling People Not Buildings

PV

The Workhorse



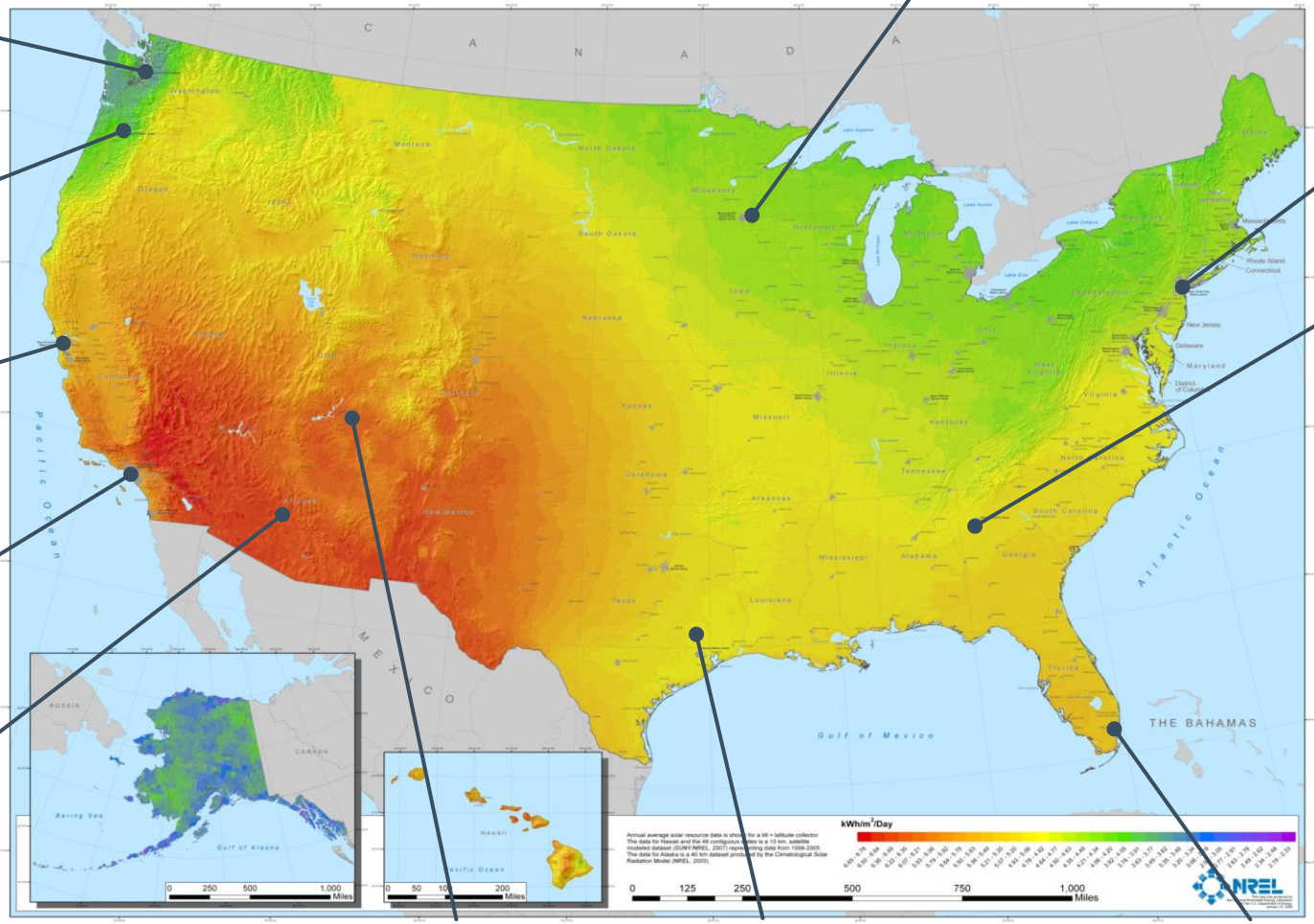
Solar Resource

The earth receives more energy from the sun in just one hour than the whole world uses in a year. *

*solarbuzz.com

Solar Resource

Array Tilt = Latitude



Minneapolis
553
kBTU/sf/yr

Seattle
435
kBtu/Sf/Yr

Portland
457
kBtu/Sf/Yr

San Francisco
631
kBtu/Sf/Yr

Los Angeles
652
kBtu/Sf/Yr

Phoenix
760
kBTU/sf/yr

New York
528
Kbtu/Sf/Yr

Atlanta
604
kBTU/sf/yr

kWh/m² /day

6.78
6.00
5.00
4.00
3.00
2.19

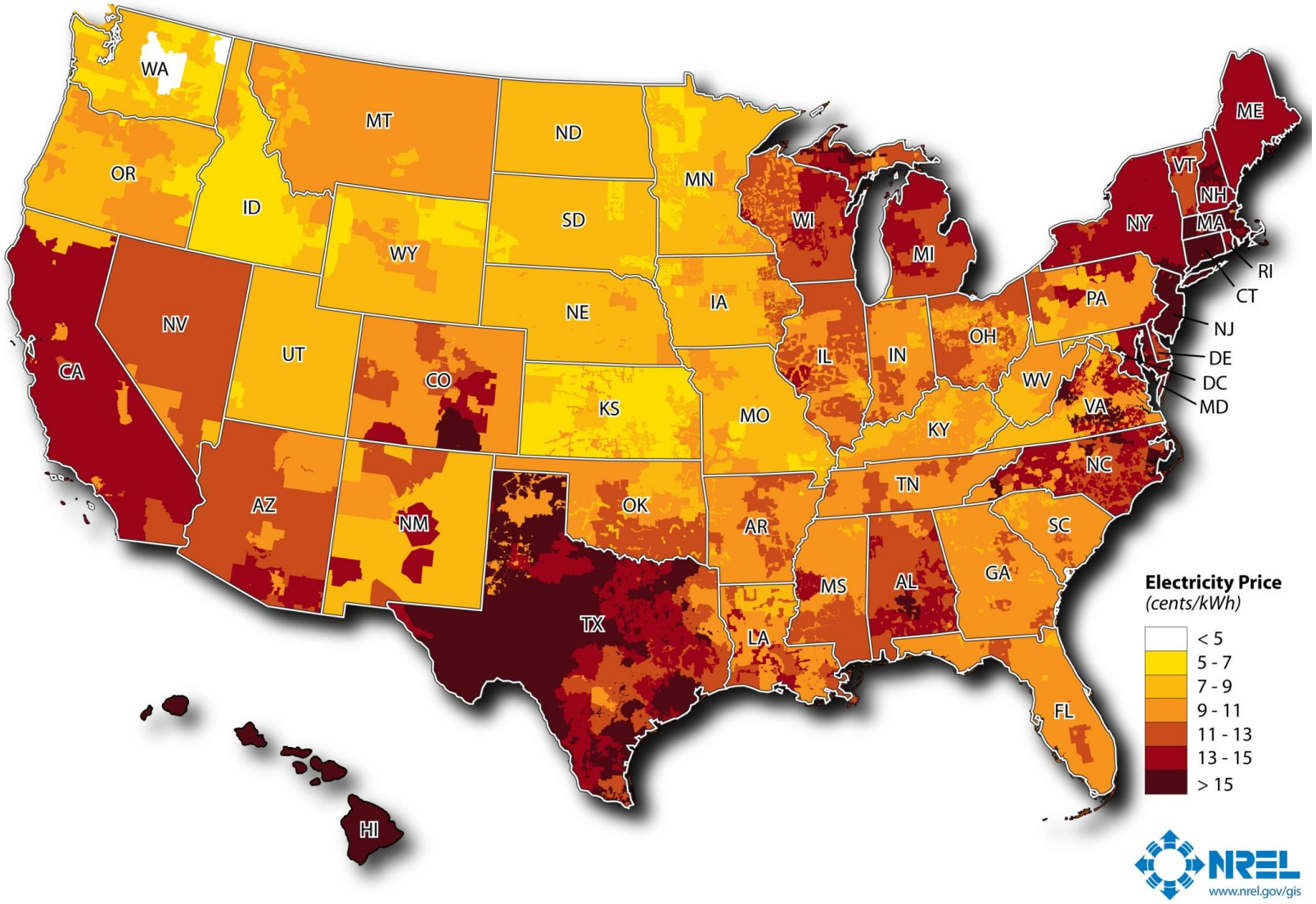
Denver
649
kBTU/sf/yr

Houston
559
kBTU/sf/yr

Miami
614
kBTU/sf/yr

Electricity

Costs

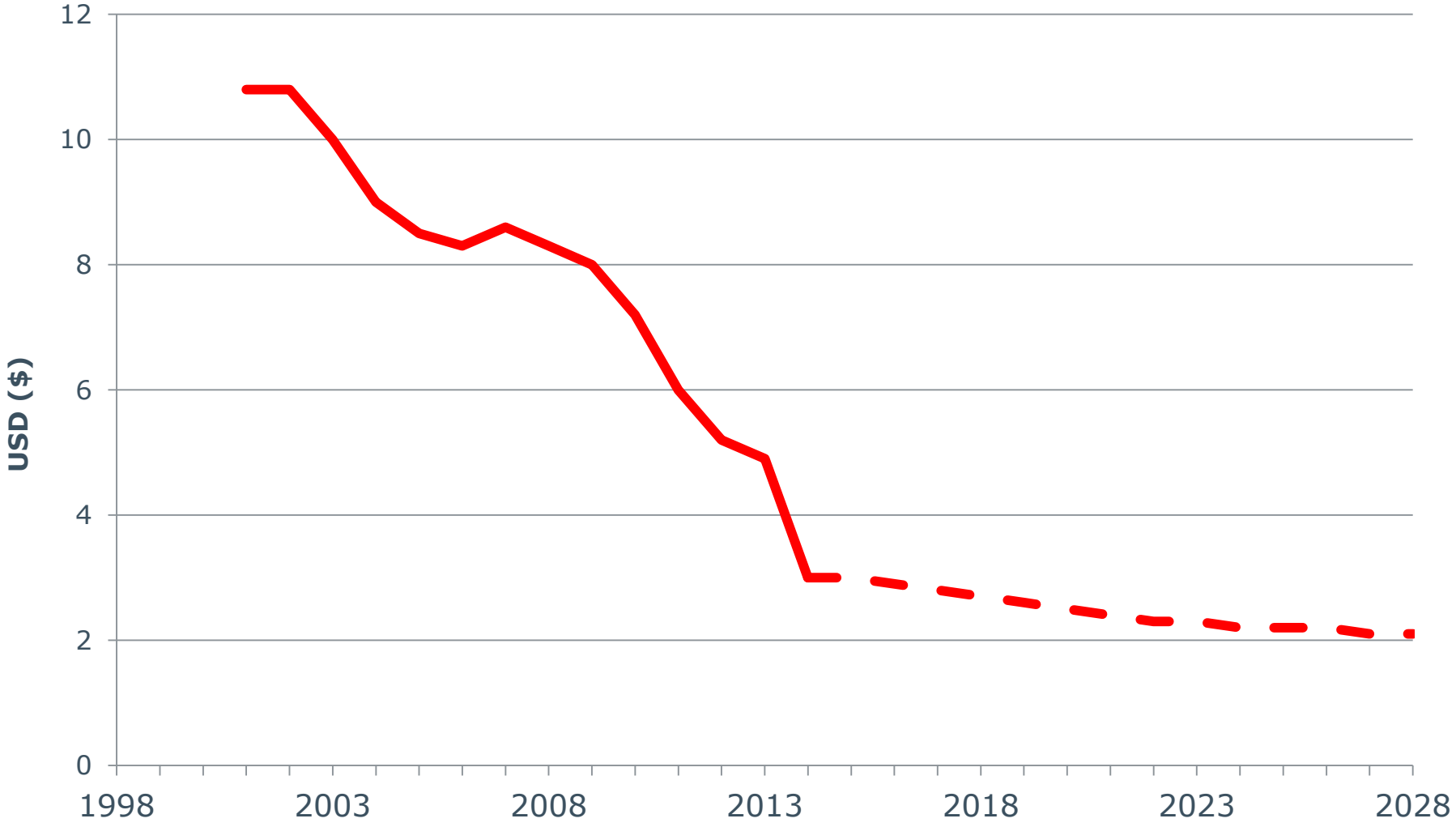


Author : Billy Roberts - March 30, 2010

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.

First Cost Trend

Average Price of PV

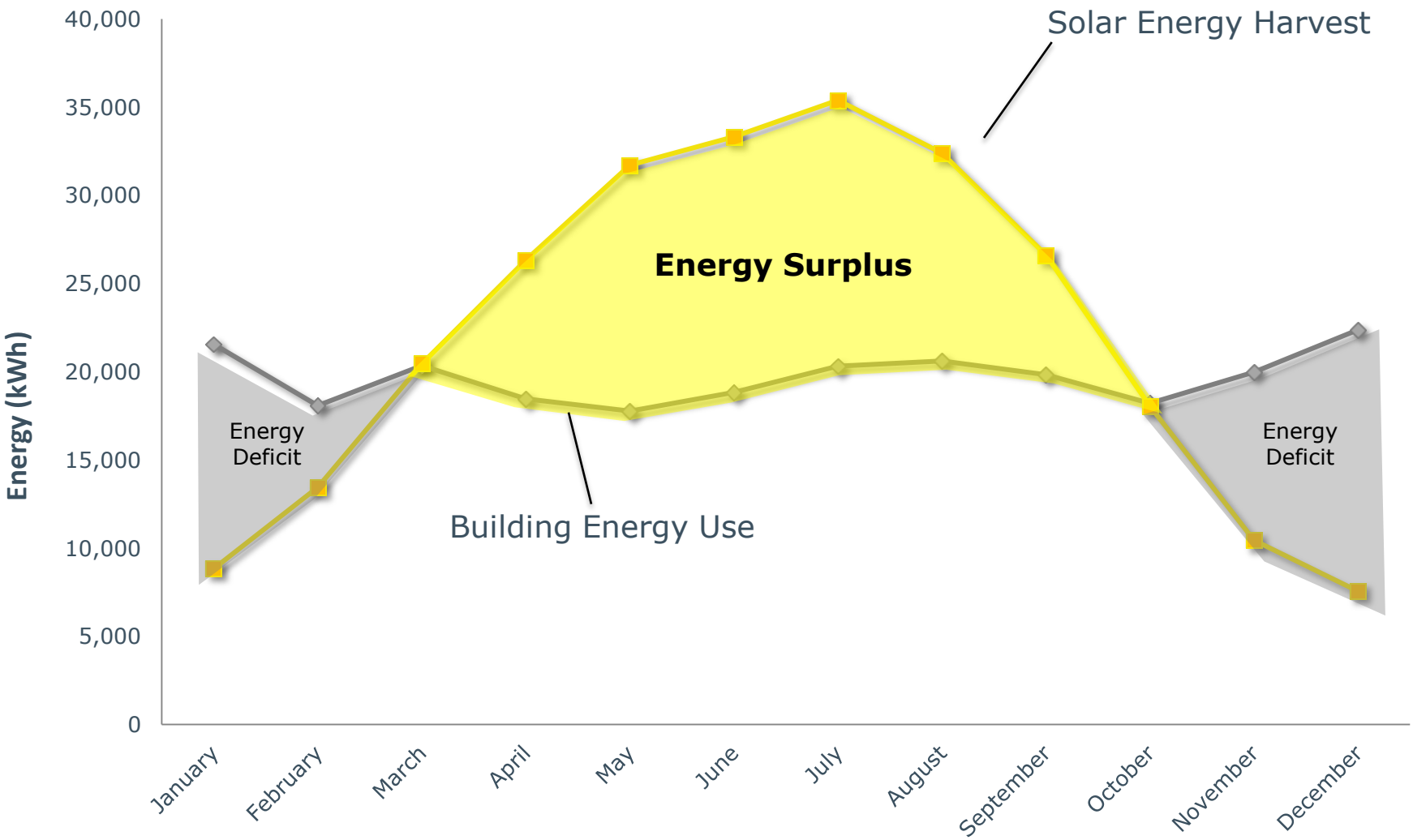


Energy Storage

Making it Happen

Net Zero Energy

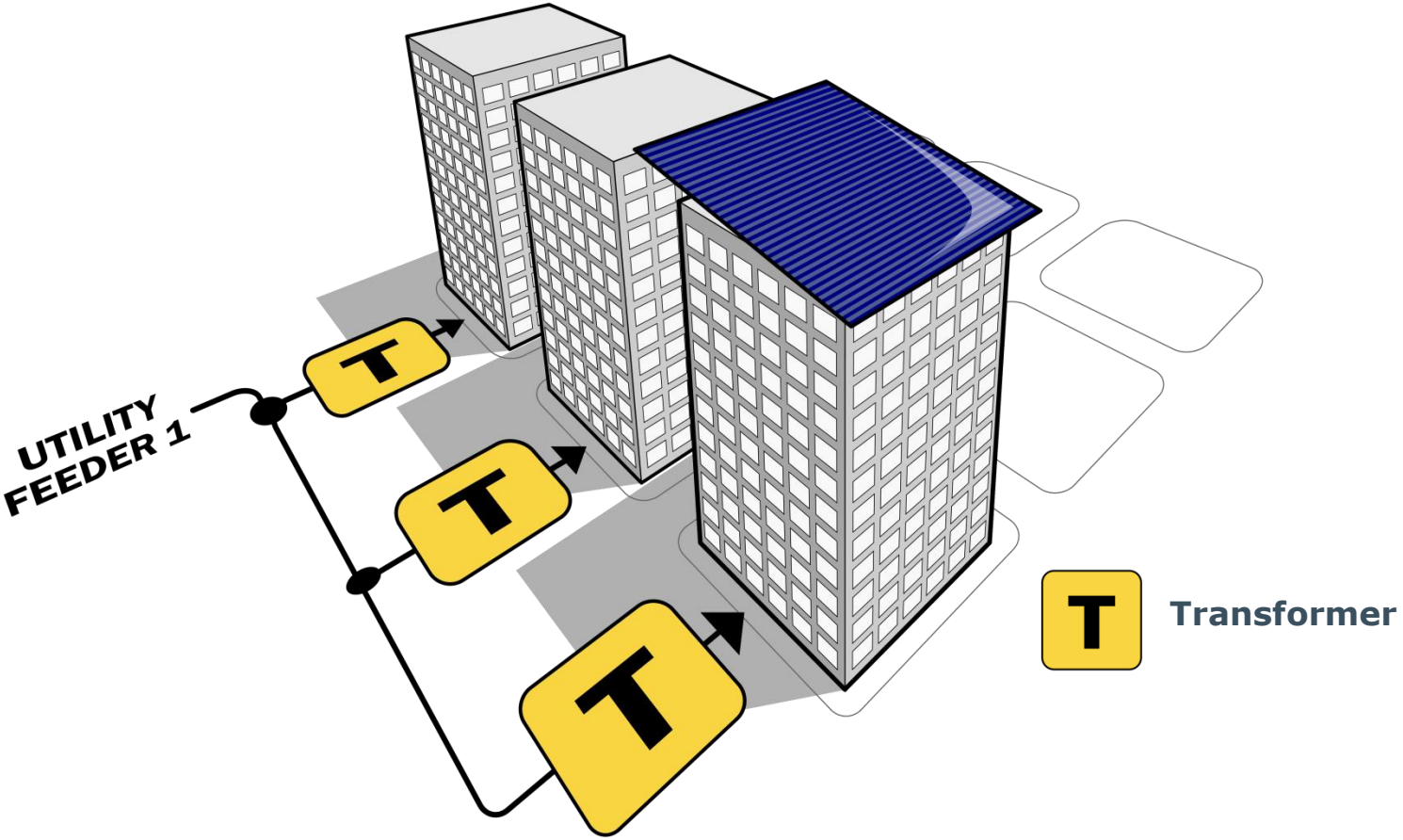
Energy Use | Solar Budget



Utility Grids

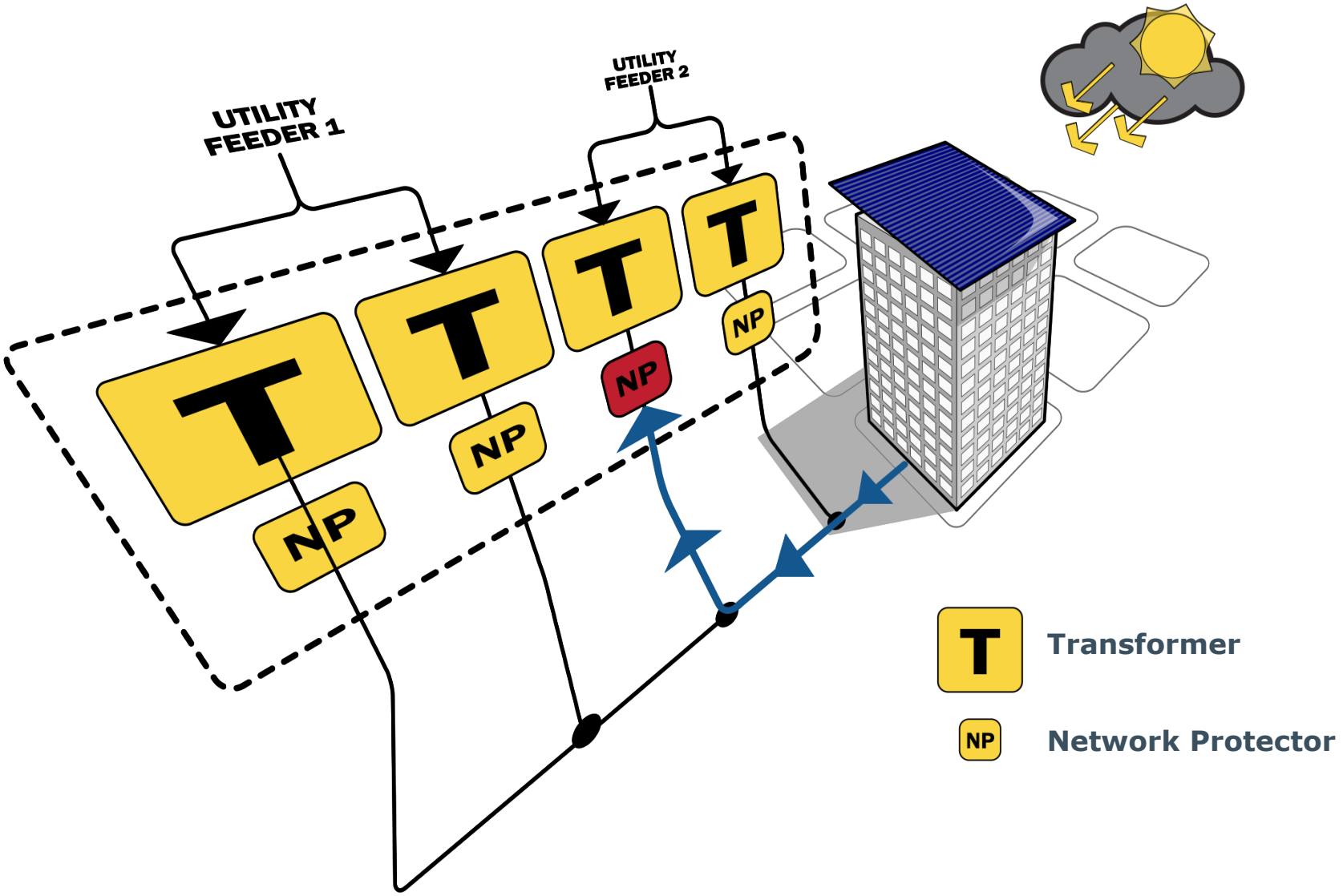
Grid

Radial



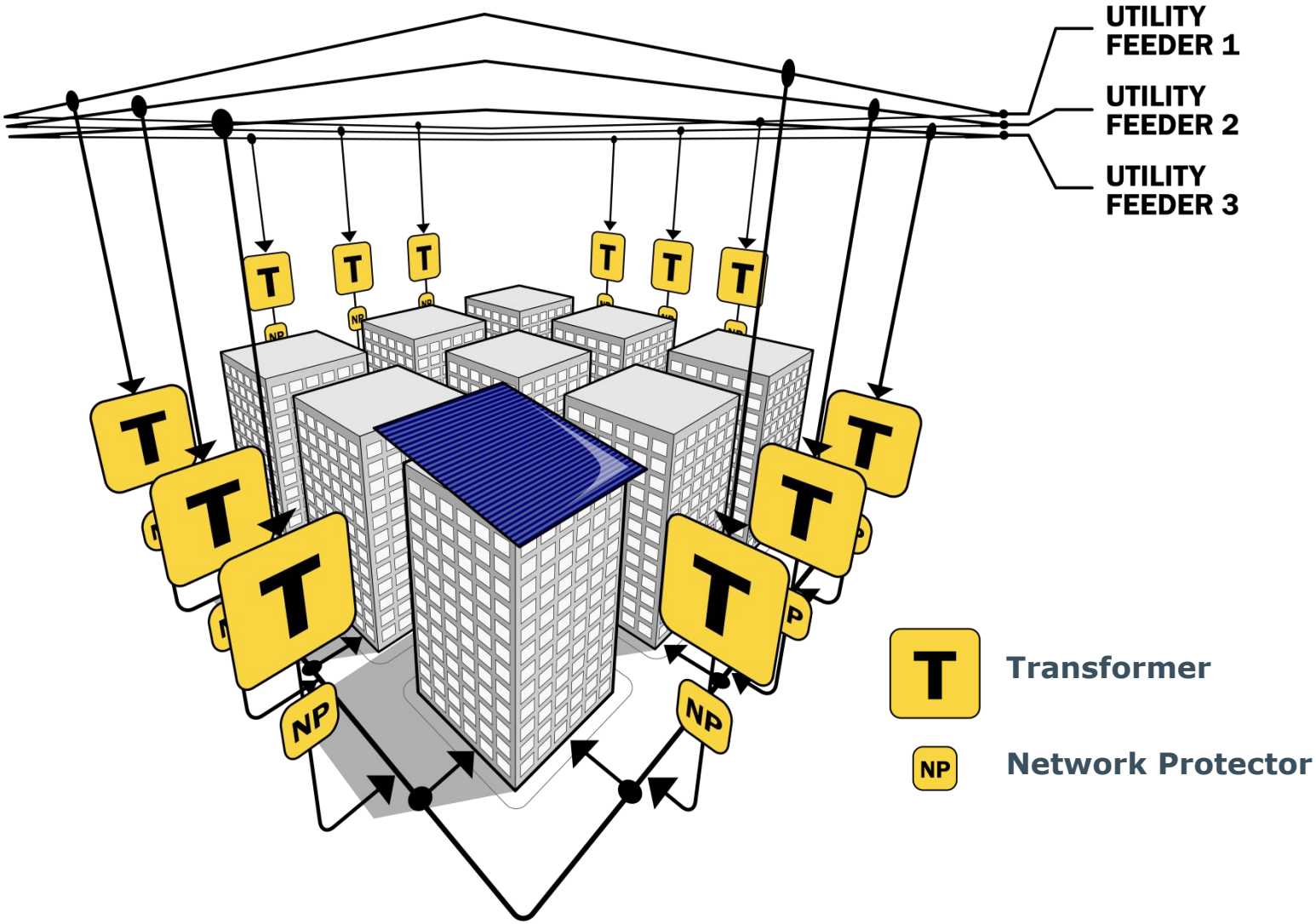
Grid

Spot Network



Grid

Area Network



Portland

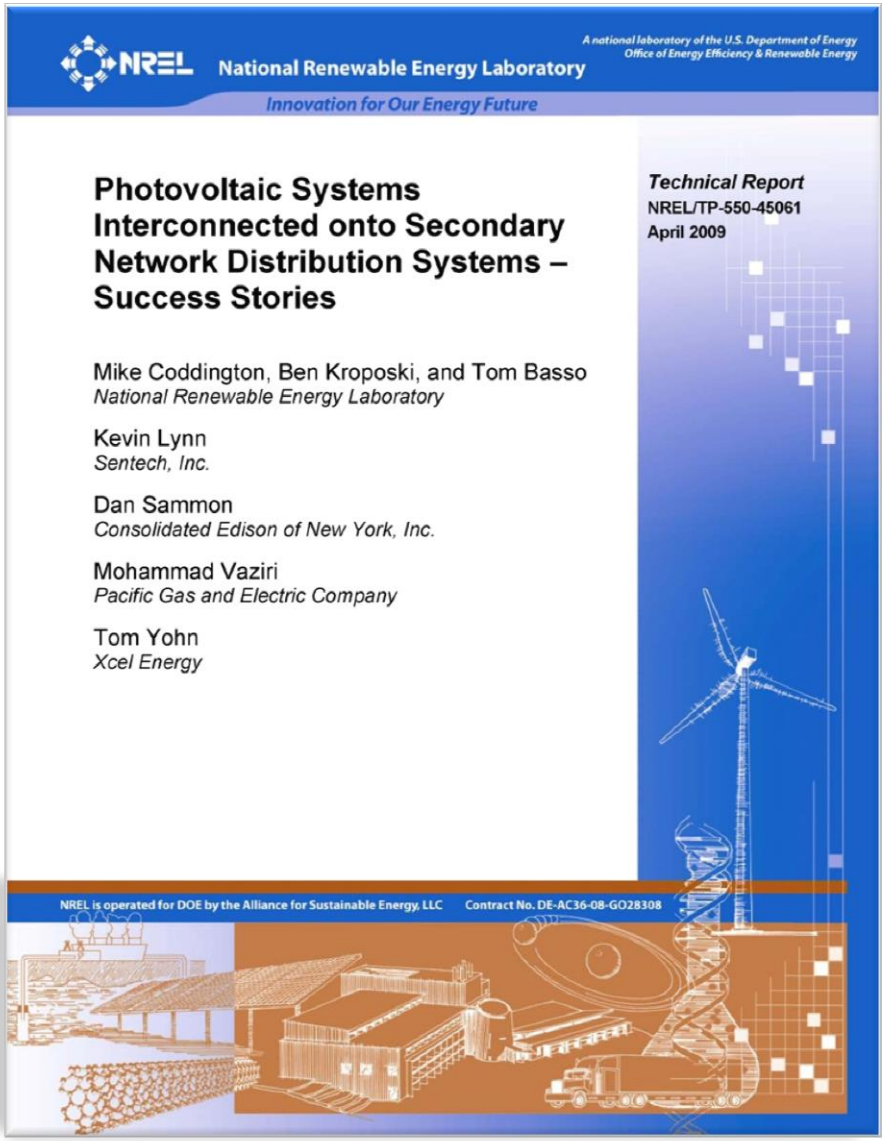
Downtown Network

Edith Green-Wendell Wyatt

Edith Green-Wendell Wyatt

NREL

Success Stories…



NREL National Renewable Energy Laboratory

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

Innovation for Our Energy Future

Photovoltaic Systems Interconnected onto Secondary Network Distribution Systems – Success Stories

Technical Report
NREL/TP-550-45061
April 2009

Mike Coddington, Ben Kroposki, and Tom Basso
National Renewable Energy Laboratory

Kevin Lynn
Sentech, Inc.

Dan Sammon
Consolidated Edison of New York, Inc.

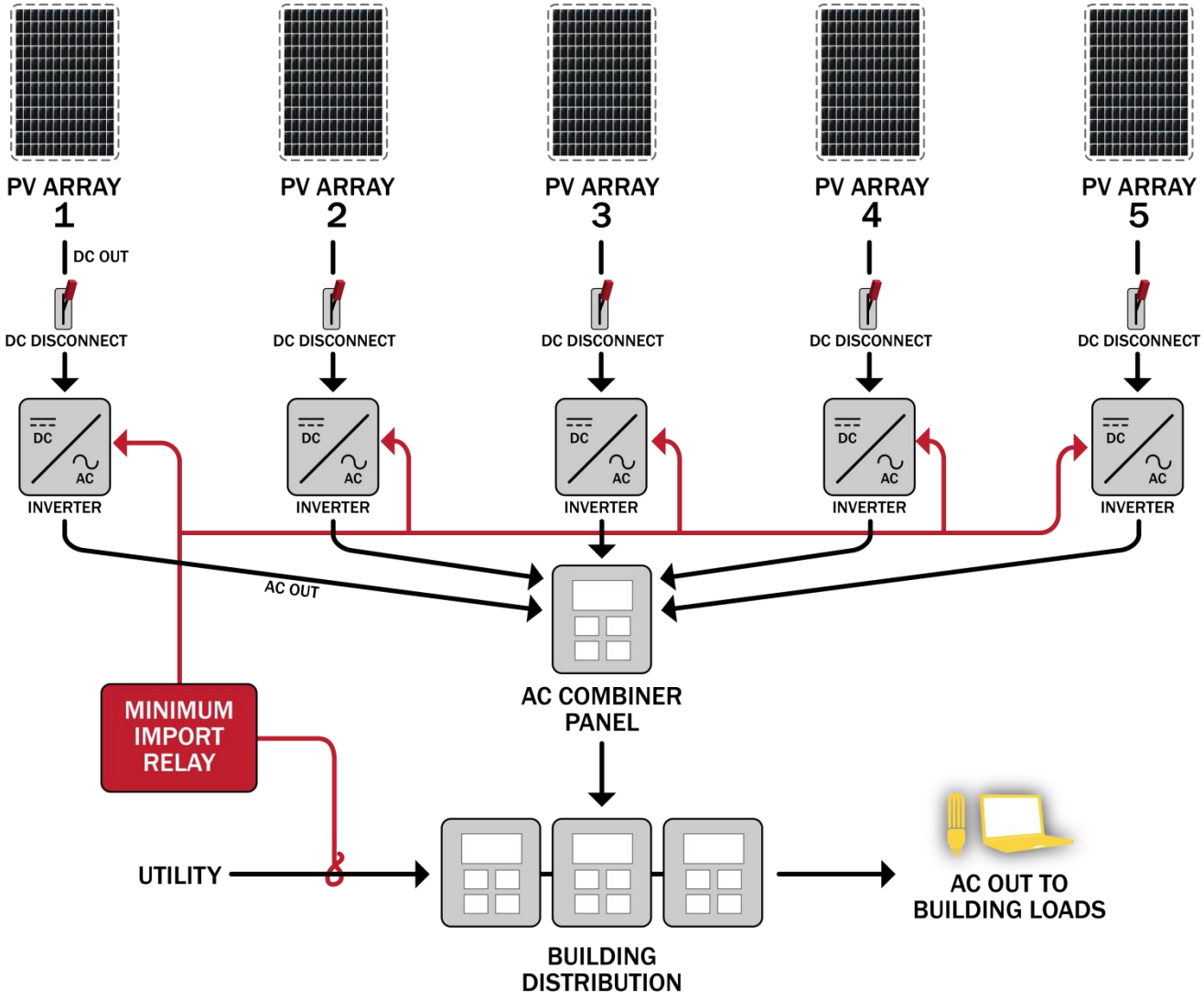
Mohammad Vaziri
Pacific Gas and Electric Company

Tom Yohn
Xcel Energy

NREL is operated for DOE by the Alliance for Sustainable Energy, LLC Contract No. DE-AC36-08-GO28308

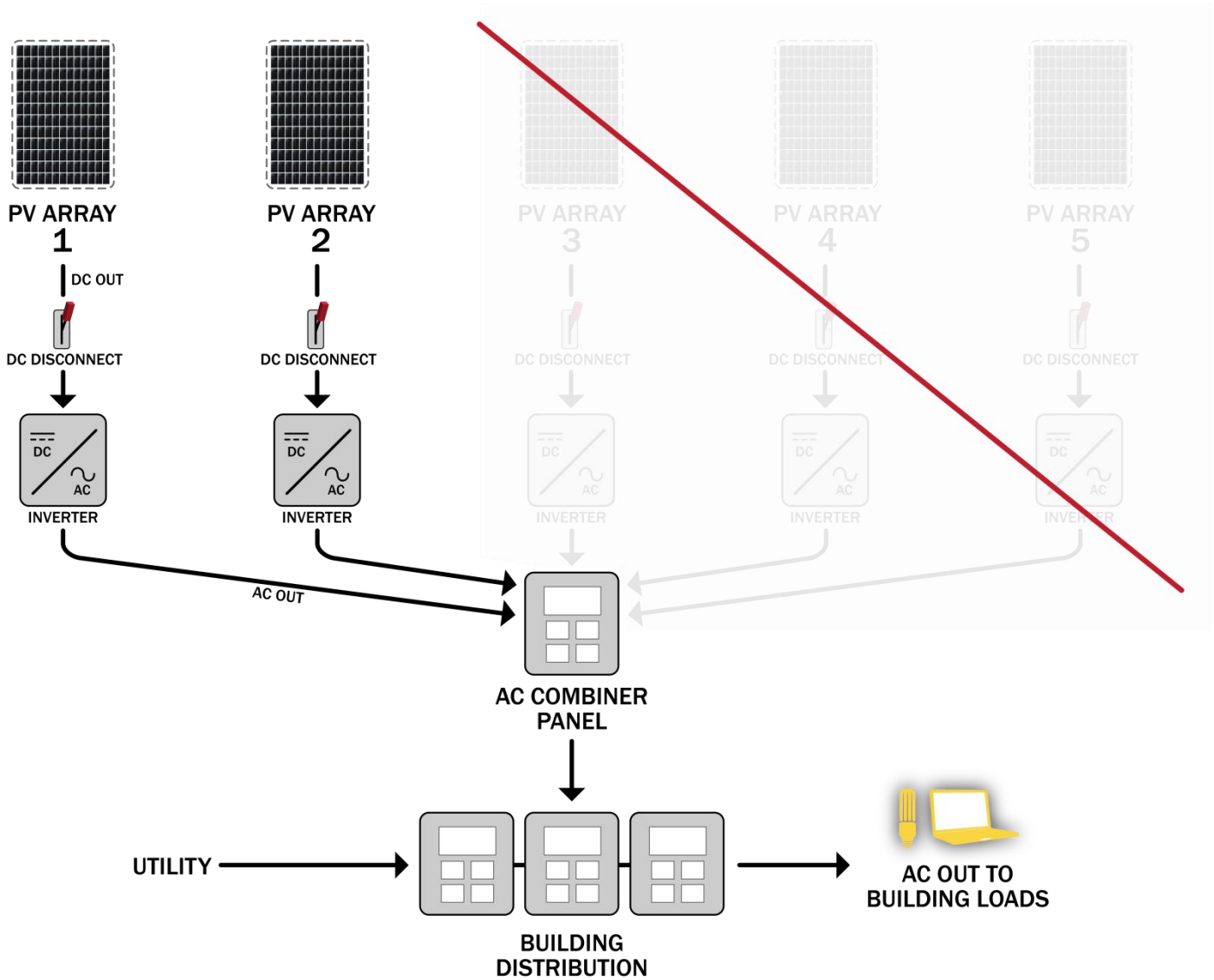
PV Array

Minimum Import Relay



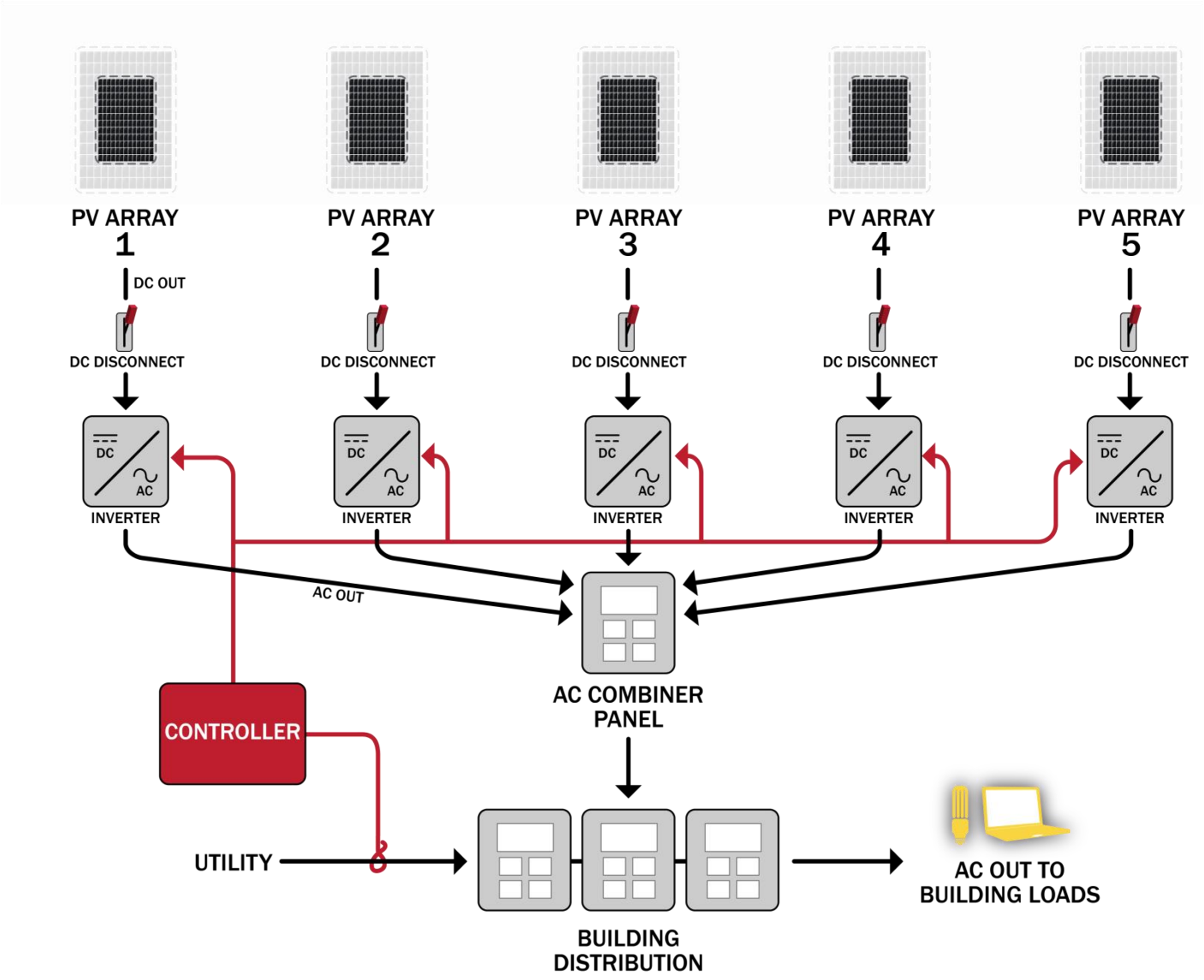
PV Array

Minimize Array Size

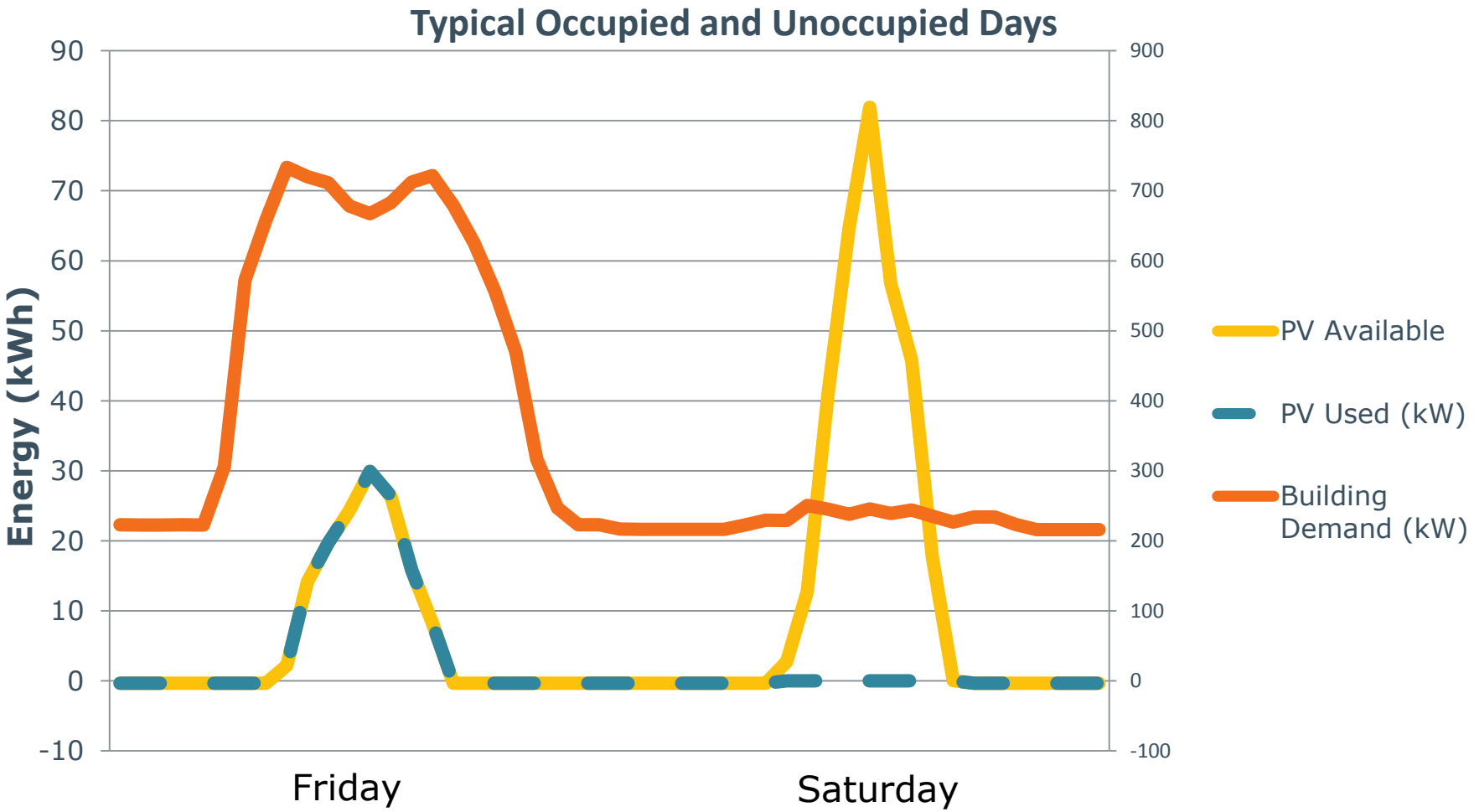


PV Array

Dynamically Controlled Inverters

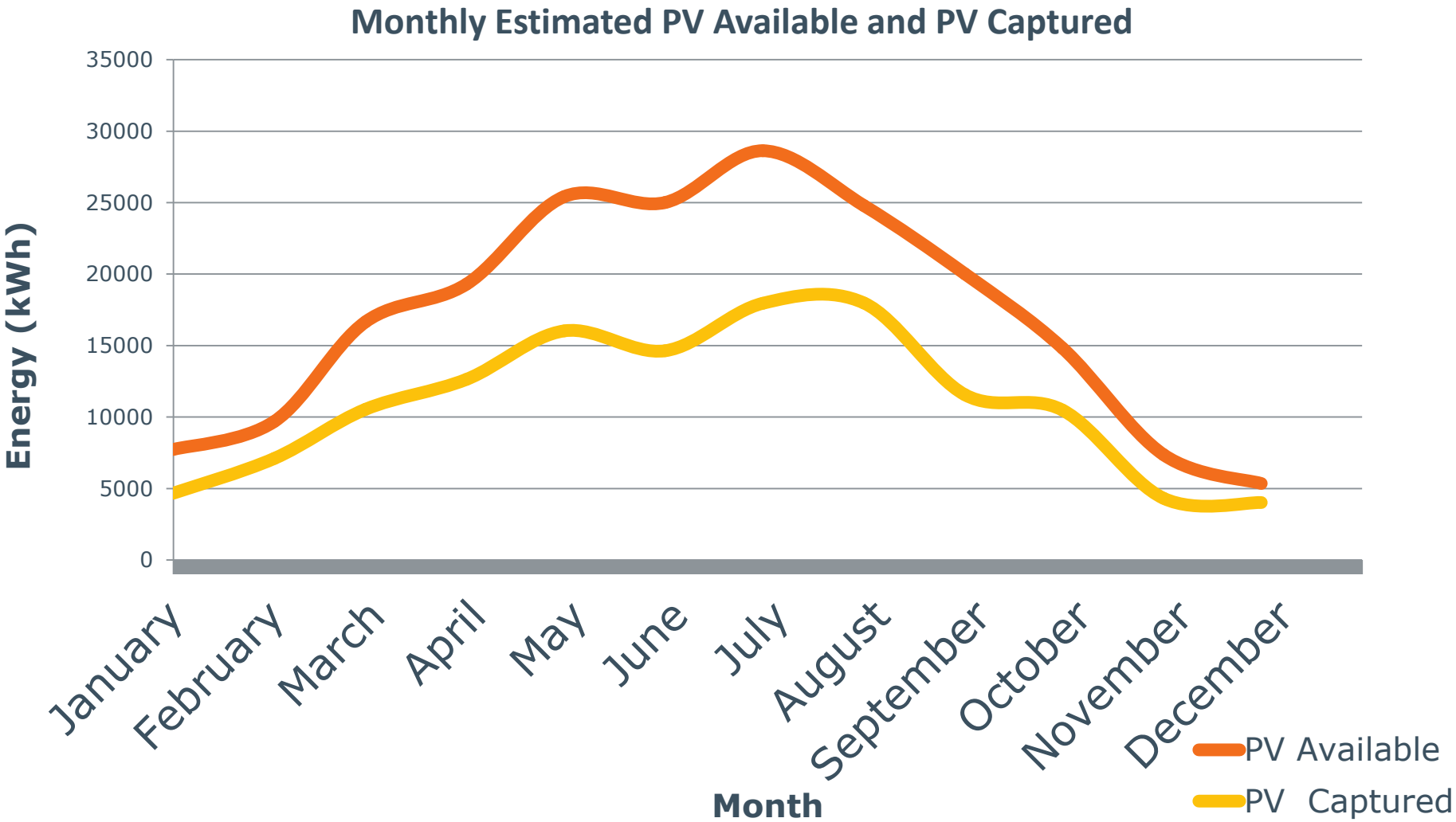


Net Electricity



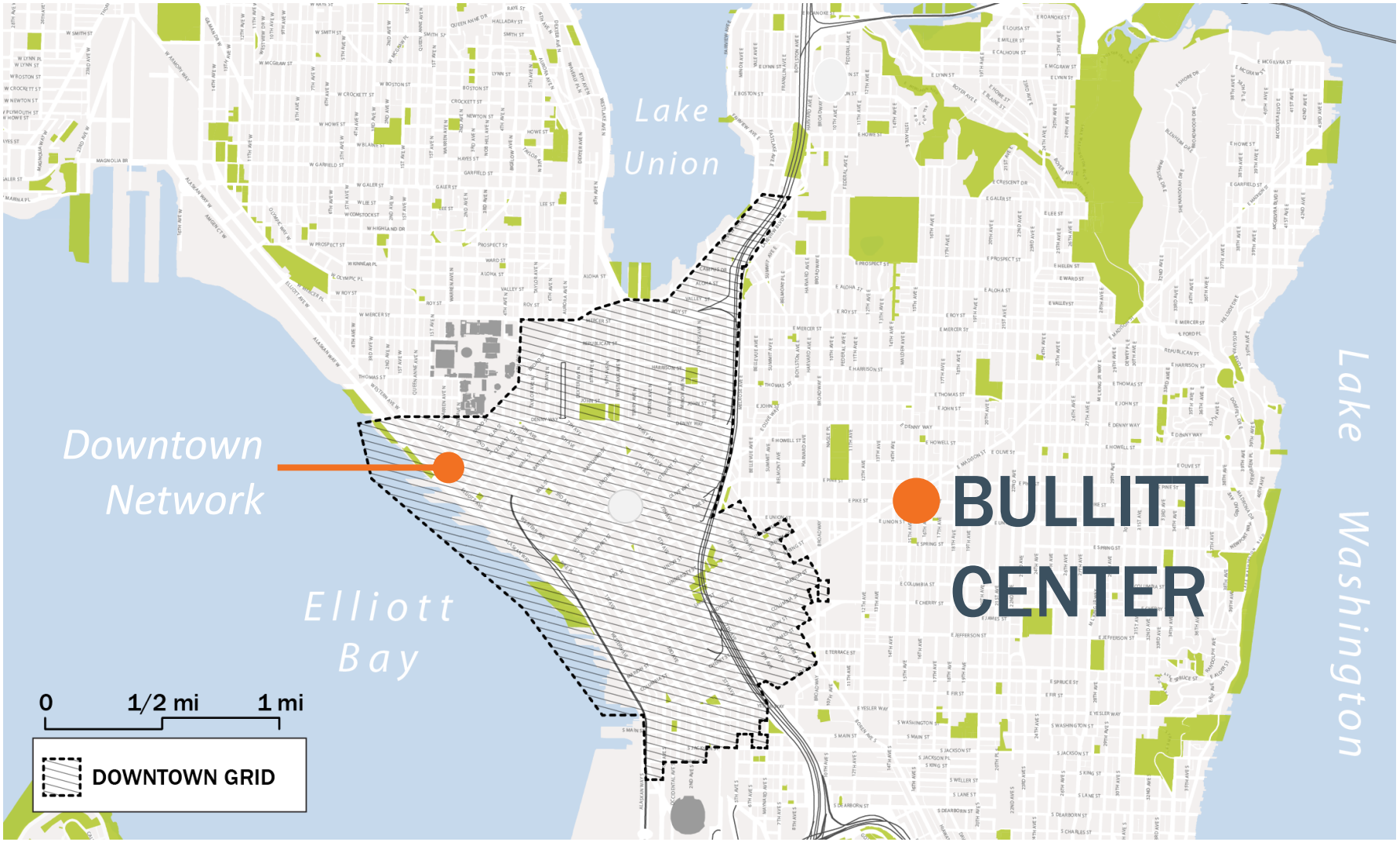
Opportunity Lost

More Than 35% of Possible Production Lost



Seattle

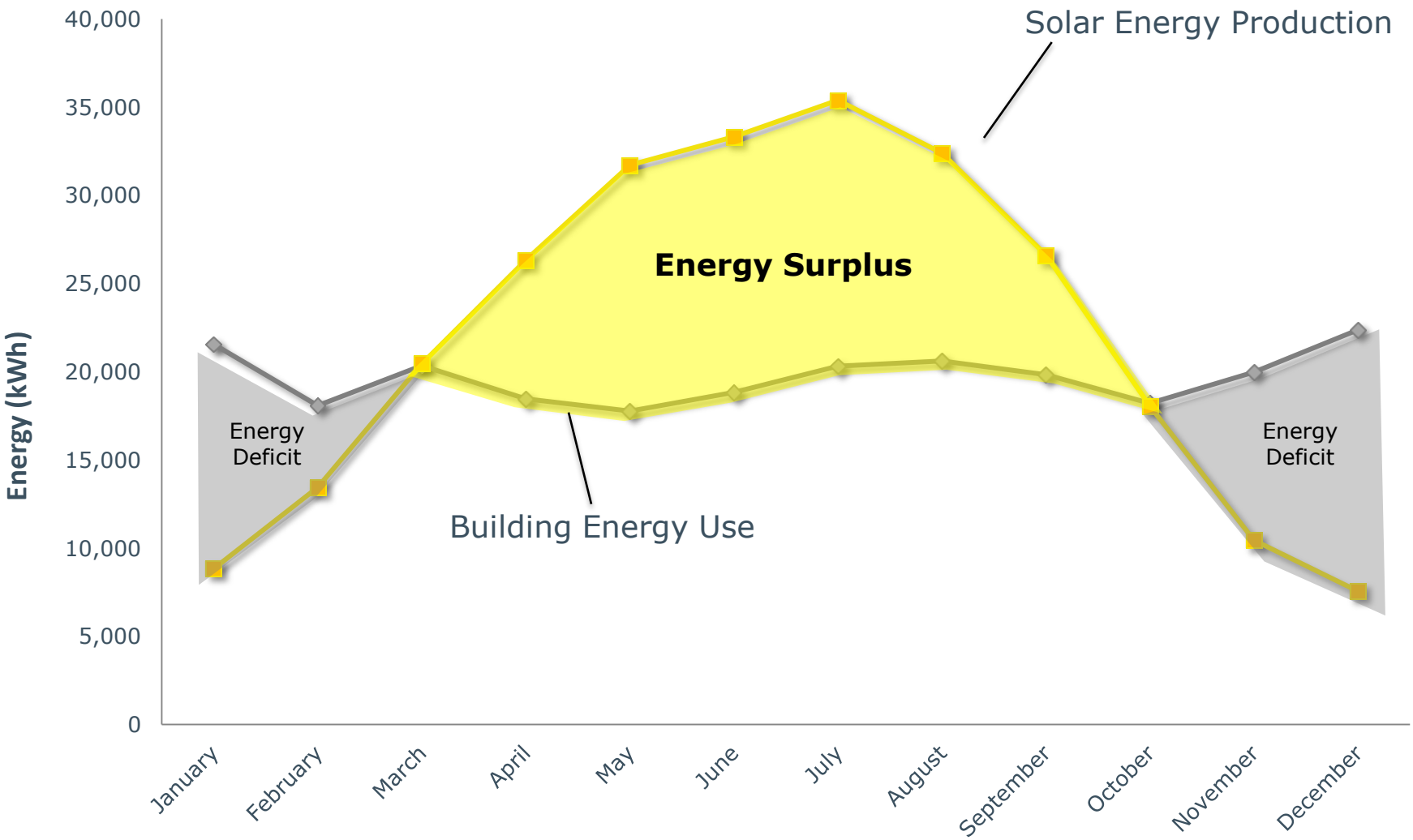
Downtown Network



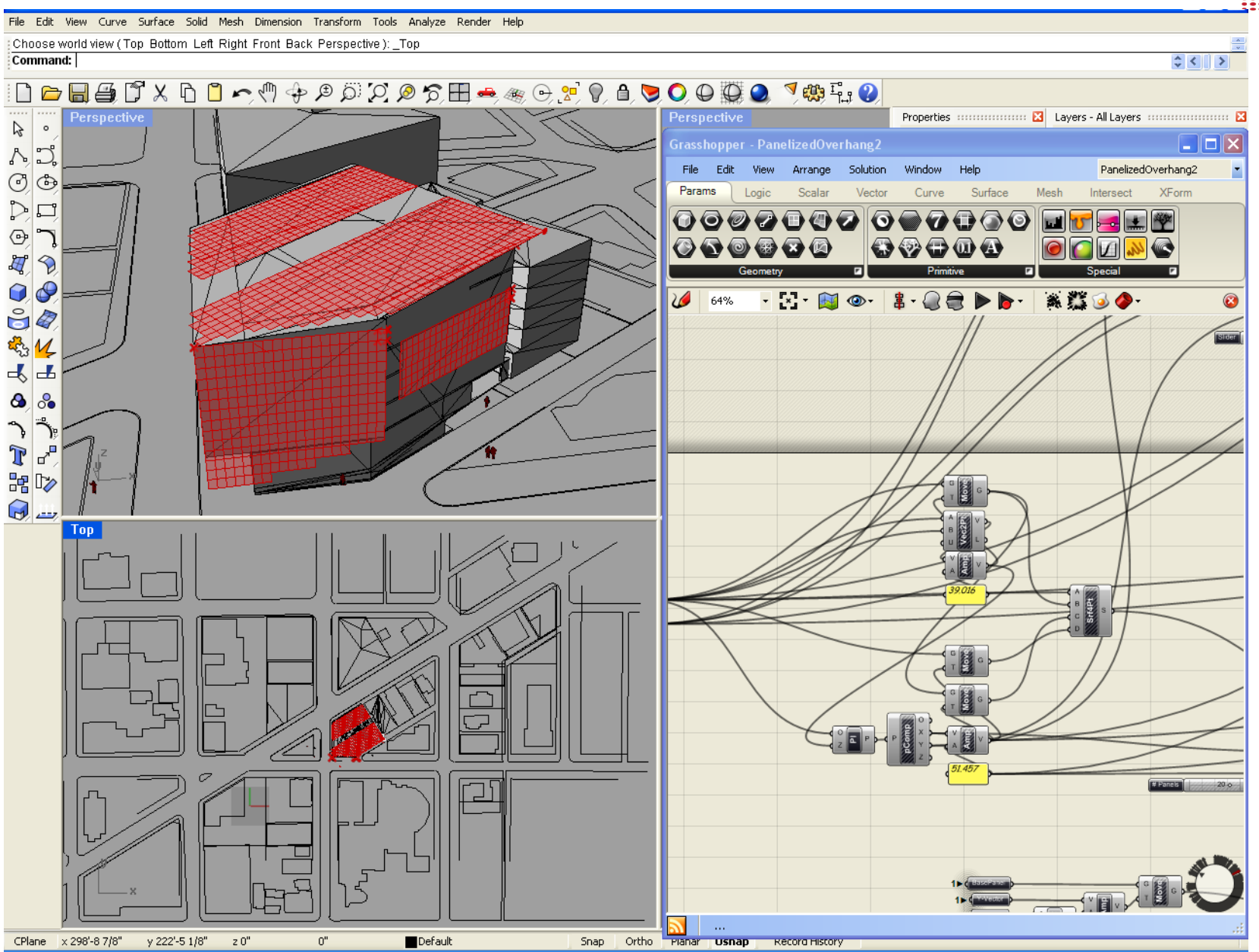
The Power Plant

Net Zero Energy

Energy Use | Solar Budget

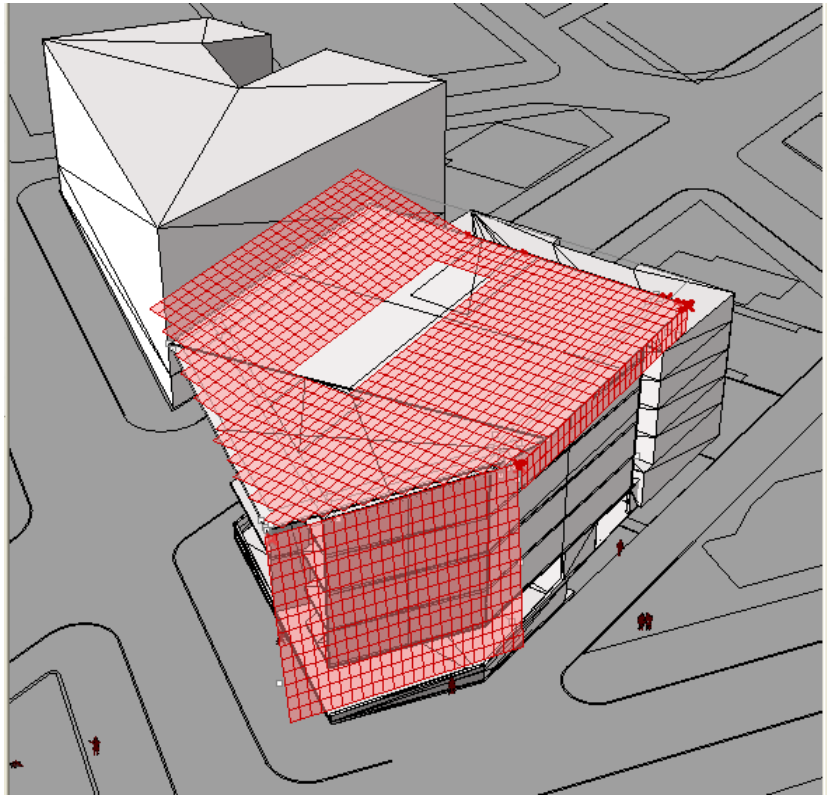


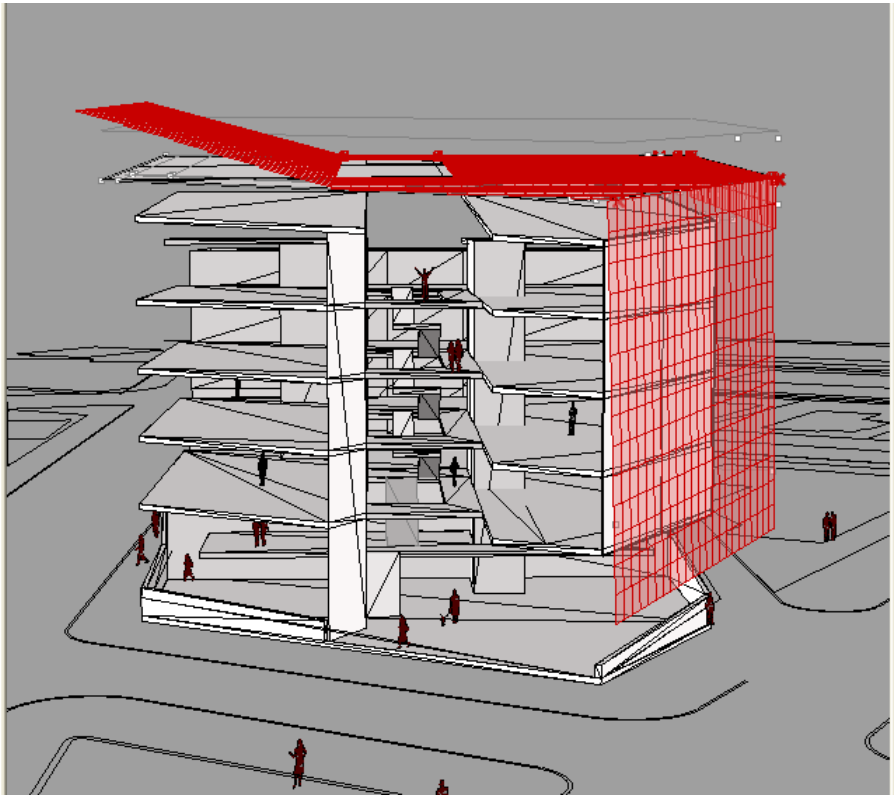
Grasshopper



Net Zero Energy - PV

Scheme II



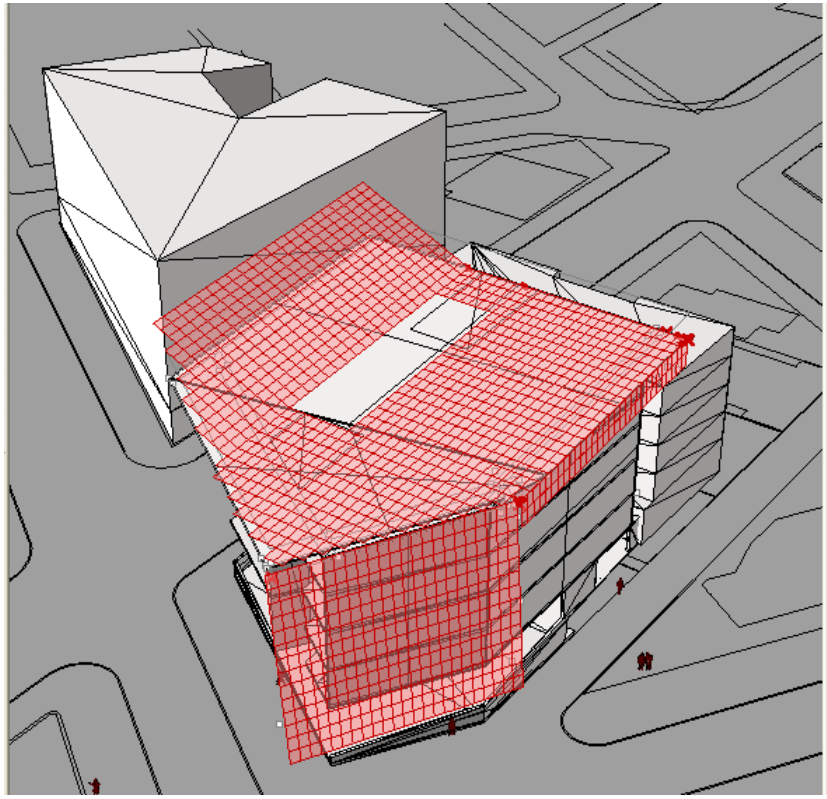


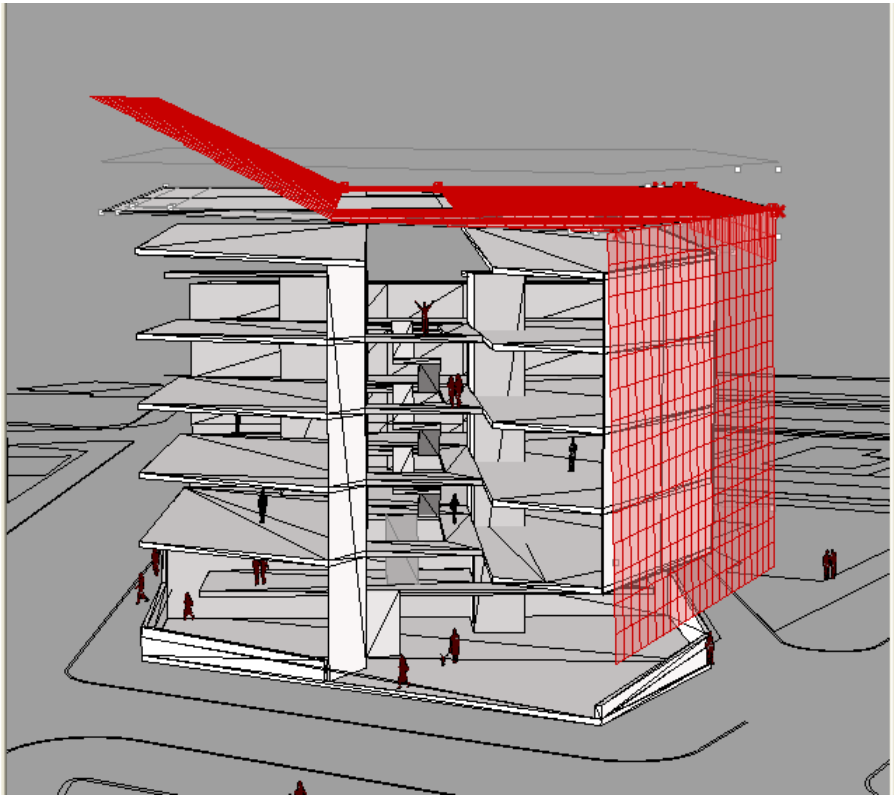
Scheme 2 - TILTED ROOF ARRAY (15 deg tilt @ Back):

ROOF (5 deg West) =	7,258sf =	123,000 kWh/yr
ROOF (15 deg Southeast) =	4,240sf =	73,000 kWh/yr
SOUTHEAST WALL =	750sf =	9,000 kWh/yr
SOUTH WALL =	4,015sf =	50,000 kWh/yr *(3,500kWh/yr/row)*
		255,000 kWh/yr (+9K v. BASE)

Net Zero Energy - PV

Scheme III



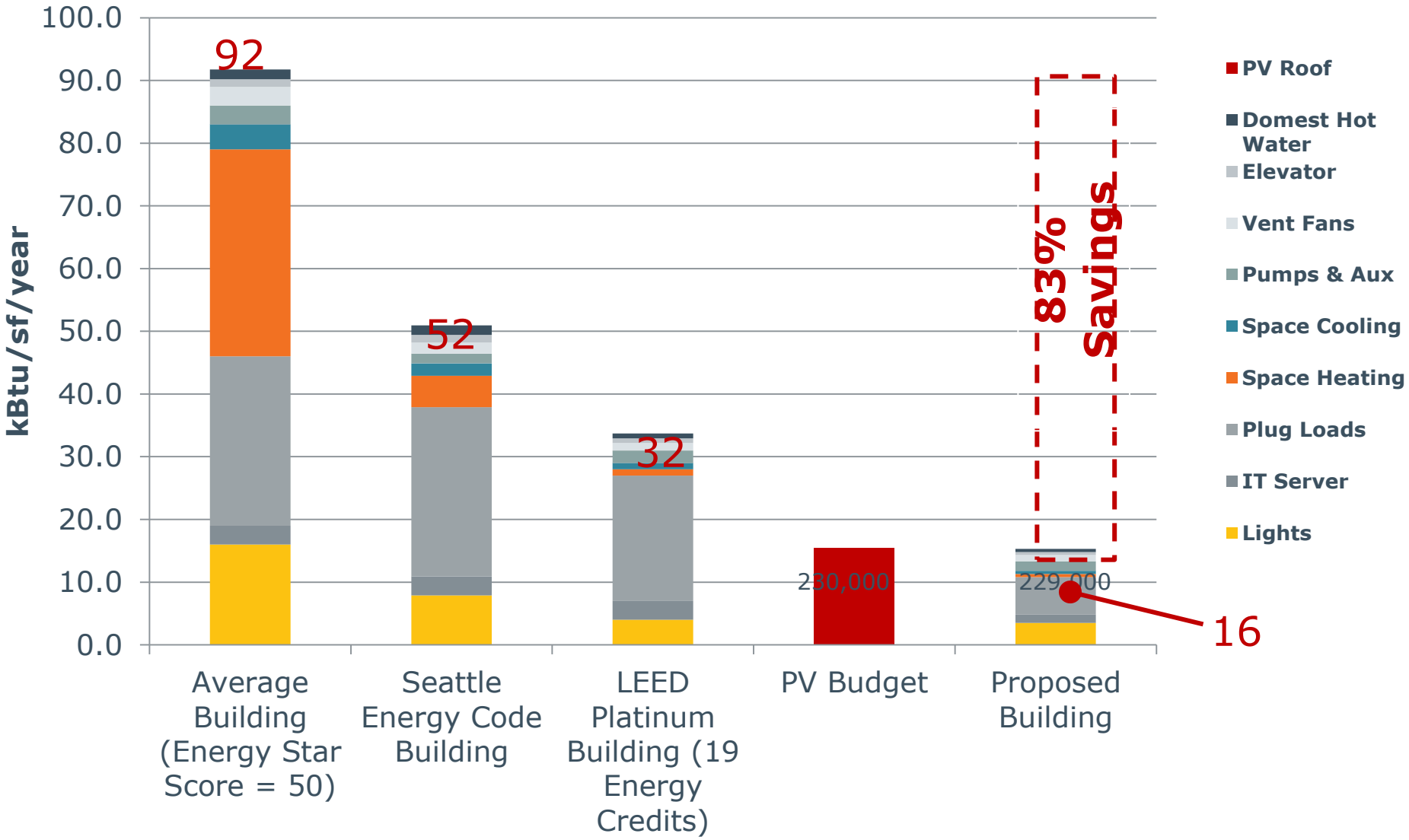


Scheme 3 - TILTED ROOF ARRAY (25 deg tilt @ Back):

ROOF (5 deg West) =	7,258sf =	123,000 kWh/yr
ROOF (25 deg Southeast) =	4,514sf =	80,000 kWh/yr
SOUTHEAST WALL =	750sf =	9,000 kWh/yr
SOUTH WALL =	4,015sf =	50,000 kWh/yr *(3,500kWh/yr/row)*
		262,000 kWh/yr (+18K v. BASE)

Net Zero Energy in Seattle

Energy Use + Solar Budget

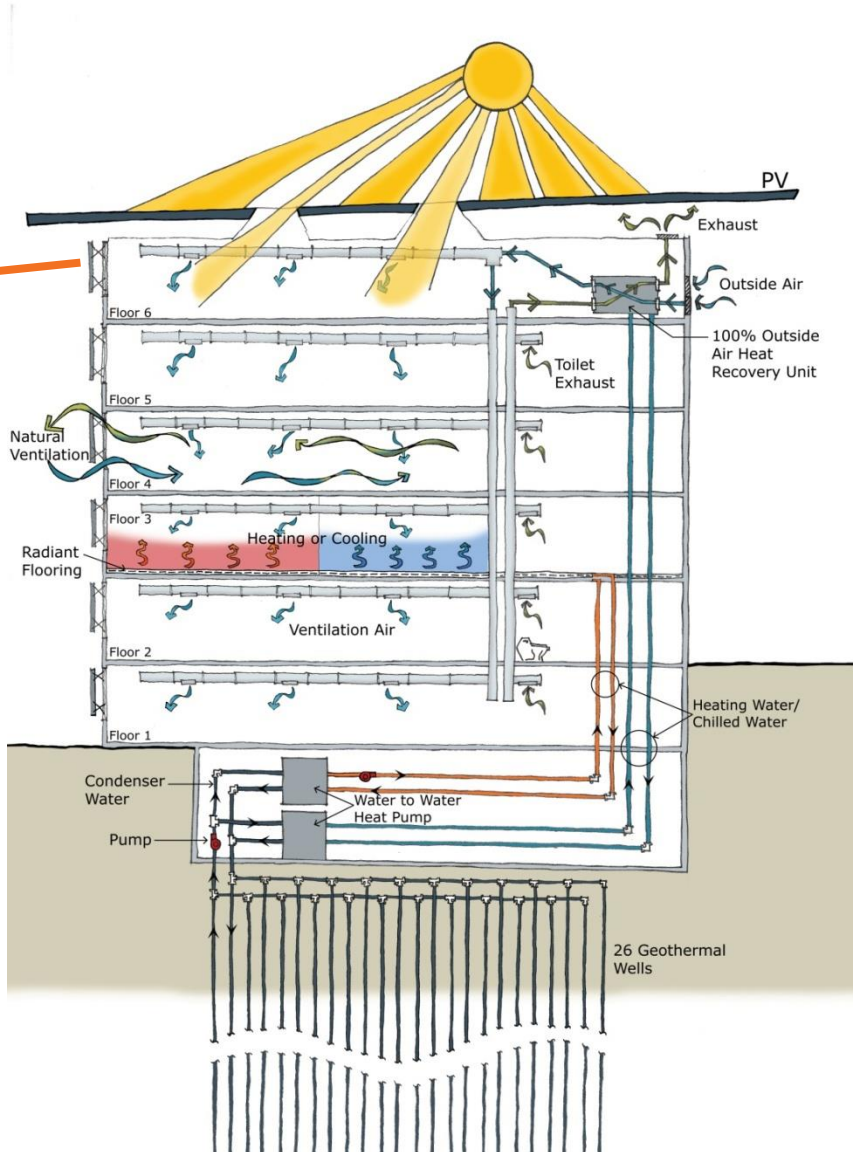


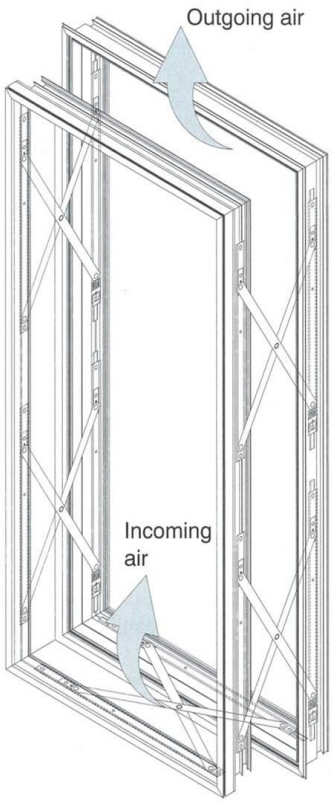
Building Envelope

Daylighting

Bullitt Center

HVAC System Overview





Radiant Floor

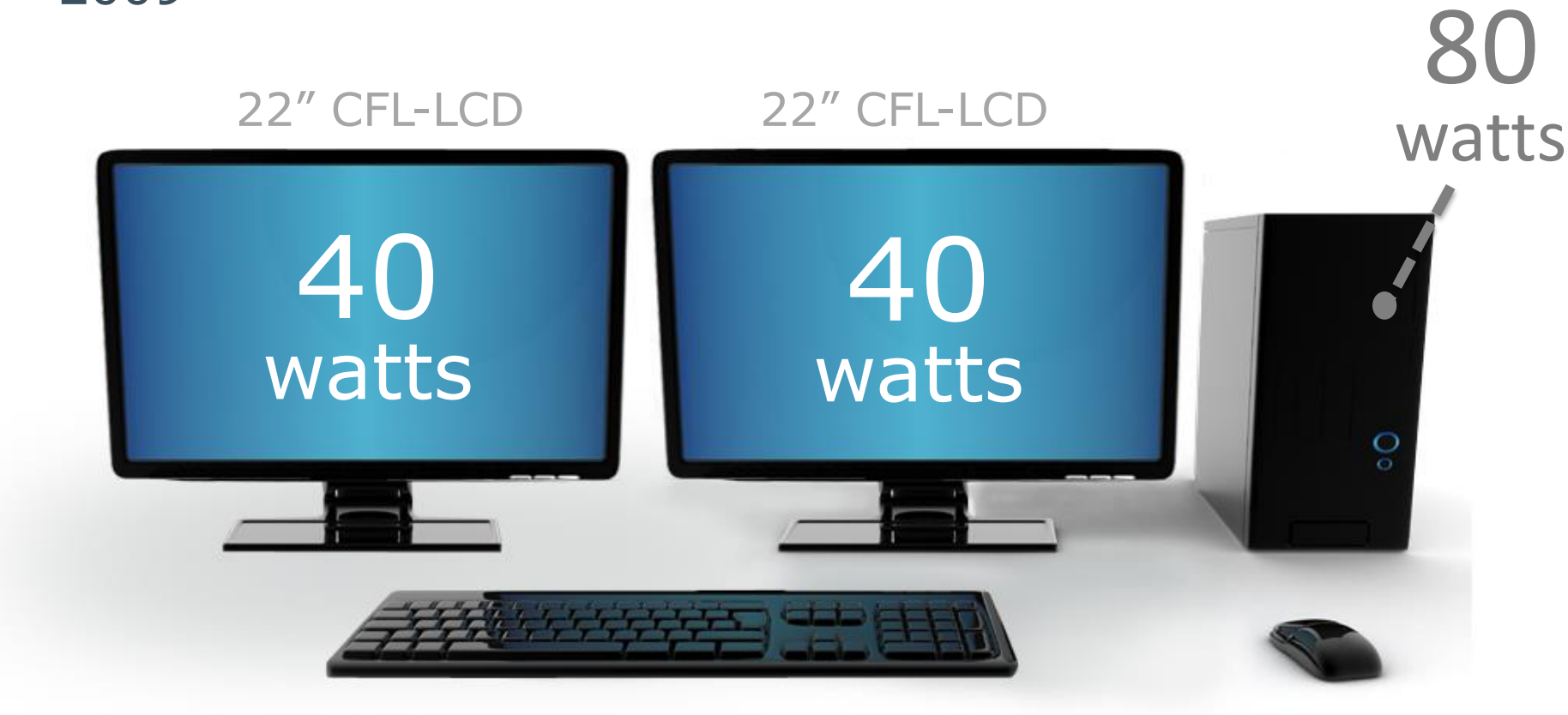
Reducing Plug Loads

2007

250 watts

Reducing Plug Loads

2009



160 watts

Reducing Plug Loads

2013

22″ LED-LCD

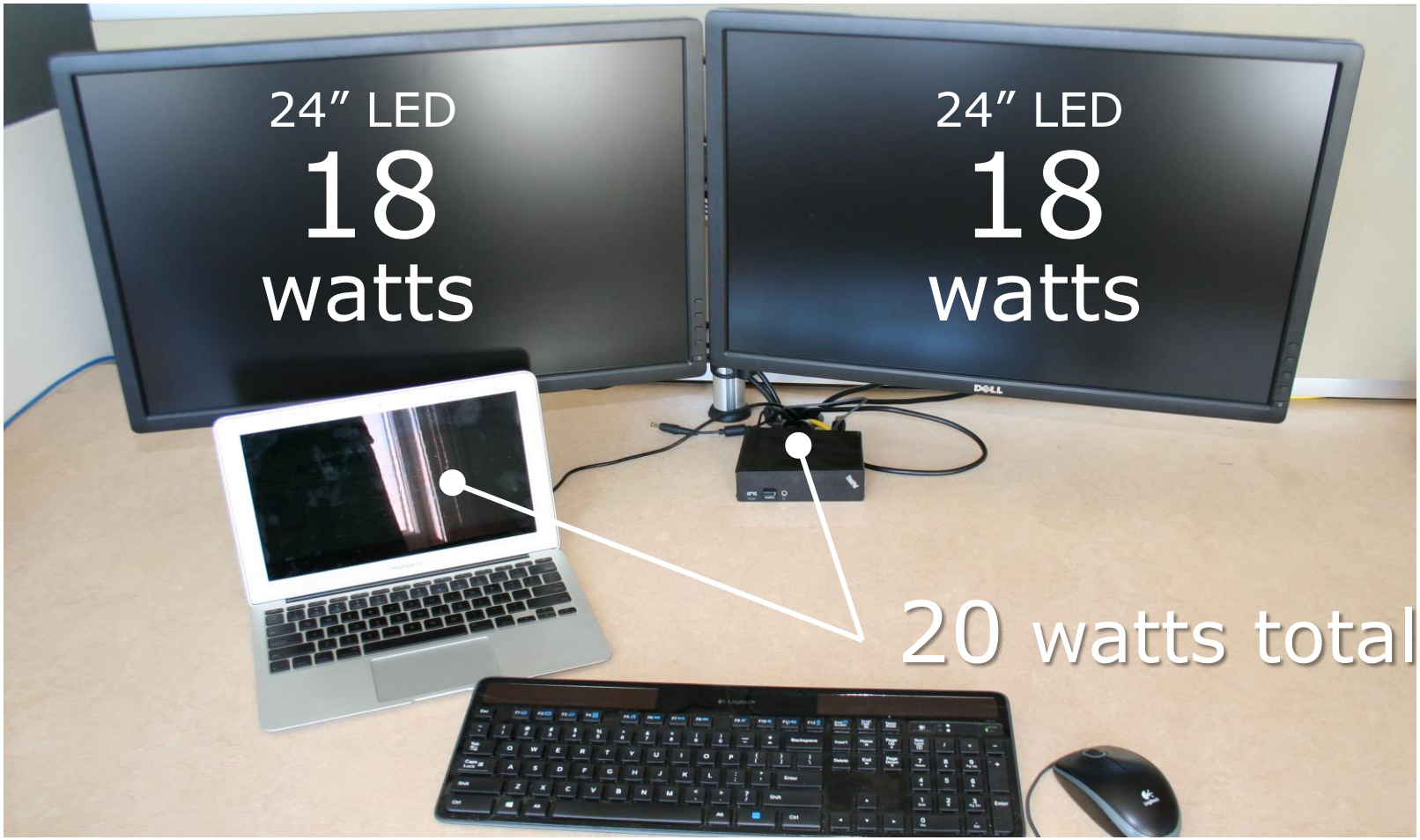
22″ LED-LCD

14
watts

42 watts

Reducing Plug Loads

2013



56 watts

Commercial Lease Agreement

This Lease agreement is made on this _____ day of _____ (Month), _____ (Year) by and between

_____ (hereinafter "Landlord")

AND

_____ (hereinafter "Tenant").

In consideration for the shared promises and agreements contained herein, and for other good and valuable consideration, the parties hereby agree as follows:

1. The Landlord leases to the Tenant, and the Tenant rents from the Landlord the following located around:

_____

_____

2. The tenure of the Lease shall be for _____ beginning _____ and ending _____.

3. The Tenant shall pay to Landlord as rent $_____ per year in equal monthly installments of $ _____ payable in advance _____ (Time Period).

4. This Lease is subject to all present and prospective changes affecting the property.

5. Tenant shall use and occupy the building only as a _____ (Tenant Rental Status) subject at all times to the approval of the Landlord.

6. The Tenant shall not make any amendments, additions or improvements to the building without the prior written permission of the Landlord.

7. The property-owner, at his own cost, shall equip the following utilities or facilities for the benefit of the occupant:

_____

_____

8. The leaseholder, at his own cost, shall provide the following:

_____

_____

9. The leaseholder shall purchase at his own cost public liability insurance in the amount of $ _____ as well as fire and exposure insurance in the amount of $ _____ for the property and shall provide satisfactory proof thereof to the property-owner and shall continue same in force and effect throughout the Lease period hereof.

Financial Considerations

Market Rate Lease Rates – Seattle Class A

	Class A ($/sf)
Triple Net Lease	**~$30-40**
Operating Cost	**~$10**

Financial Considerations

Direct Construction Costs

$350 / SF

Includes city infrastructure improvements and costs associated with the PV array.

$265 / SF

Does not include PV, water system, or city infrastructure improvements.

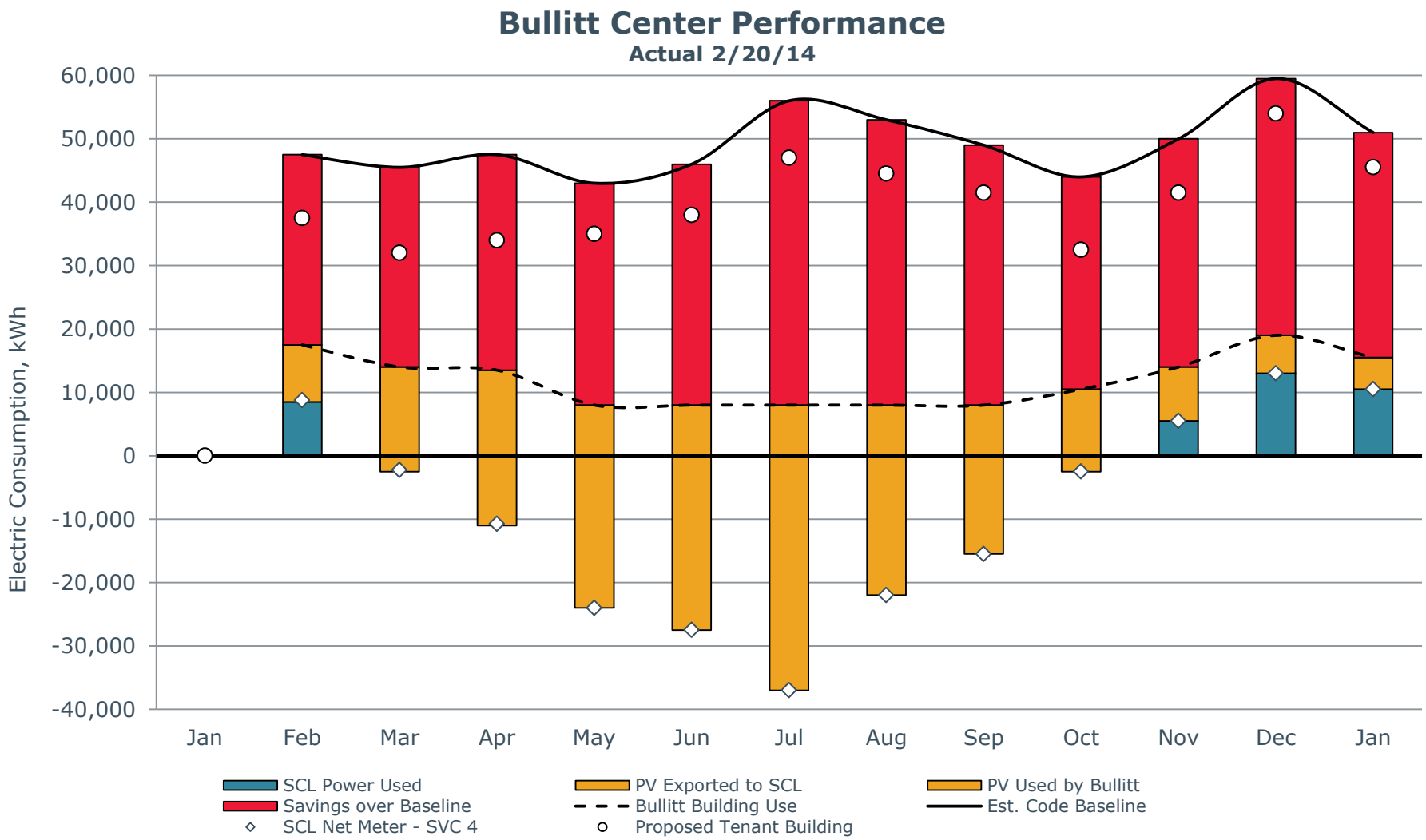
How's Bullitt Doing?

Energy production **5% mo** than predicted

Building energy use **15% les** than predicted

How's Bullitt Doing?

Predicted EUI: **16** | First Year EUI: **10** | After PV EUI: **-10**



How Public Policy Can Help

Living Building Challenge

Seattle Living Building Pilot Ordinance

- 10 foot building height bonus
- Additional height for PV and “rooftop features” (skylights)
- Elimination of on site commercial loading berth

Term Permit

- PV over right-of-way
- Greywater infiltration in right-of-way

Rocky Mountain Institute Headquarters

"A wise, detailed, and comprehensive blueprint" —President Bill Clinton

REINVENTING FIRE®

BOLD BUSINESS SOLUTIONS FOR THE NEW ENERGY ERA

AMORY B. LOVINS AND
ROCKY MOUNTAIN INSTITUTE

FOREWORDS BY
MARVIN ODUM, PRESIDENT, SHELL OIL COMPANY
JOHN W. ROWE, CHAIRMAN AND CEO, EXELON CORPORATION

Reinventing Fire

DESIGN TARGET	UNITS	EXISTING (U.S.)	BETTER	BEST PRACTICE	RMI BUILDING
Delivered energy intensity	kBTU/sf-y	90	40-60	<30	Targeting 19
Lighting power density: connected load	W/sf	1.5	0.8	0.4-0.6	Targeting 0.7
Lighting power density: as-used net of controls	W/sf	1.5	0.6	0.1-0.3	Targeting 0.1
Installed computers/appliances/tasklighting	W/sf	4-6	1-2	<0.5	1.6 installed (0.5 operating)
Glazing R-value (center of glass)	sf-F°-h/BTU	1-2	6-10	≥20	11
Window R-value (including frame)	sf-F°-h/BTU	1	3	7-8	8
Glazing spectral selectivity*	$k_e = T_{vis}/SC$	1.0	1.2	>2.0	1.0
Roof solar absorptance and infrared emittance	α, ε	0.8, 0.2	0.4, 0.4	0.08, 0.97	Mostly PV, 0.8, 0.2
Whole-building airtightness	cfm/sf @ 0.3" w.g.	1	0	<0.25	0.6 AC/hr at 50 Pa (~0.2cfm/sf equivalent)
Installed mechanical cooling	sf/ton	250-350	500-600	1,200-1,400+	1500-2000 sf/ton
Cooling design-hour efficiency**	kW/ton	1.9	1.2-1.5	<0.6	1.1
Level of installed perimeter heating	-	extensive	minimal	none	Minimal
*A measure of how well the glazing lets in light without heat **Whole system, including pumps, fans, and cooling towers as well as chillers					
ADDITIONAL DESIGN TARGET ITEMS (not included in original RMI table)					
Wall R-value	sf-F°-h/BTU				R-40
Roof R-value	sf-F°-h/BTU				R-60
Wall to window ratio	%				>30%
Heat recovery effectiveness	%				> 75% operating
Installed mechanical heating	BTU/h-sf				Target 8 BTU/h-sf

This table (except the RMI Column) is from a Book entitled "Re-inventing Fire: Bold Business Solutions for the New Energy Era" by Amory Lovins (2011). It is Table 3.3-2 ".Benchmarking a New U.S. Office Building". (p. 108). These targets were developed by the Rocky Mountain Institute and are typical of a new midsize -to-large Class A office in an average US climate like the Mid-Atlantic states.


Advanced Shading System
Super Insulating Building Envelope
Native Landscaping Irrigated with Pond Water
Connection to Nature, Views Stimulate Productivity
Photovoltaics
Natural Ventilation
Outdoor Workspace
High Performance Daylighting

Phase Changing Materials

Personal Comfort System

Hyper-Chair

Beyond Net Zero

Rocky Mountain Institute Headquarters

Building EUI

Snow Loss

Transportation

Beyond Net Zero

In the Rocky Mountains

1 Parking Space
9x18’

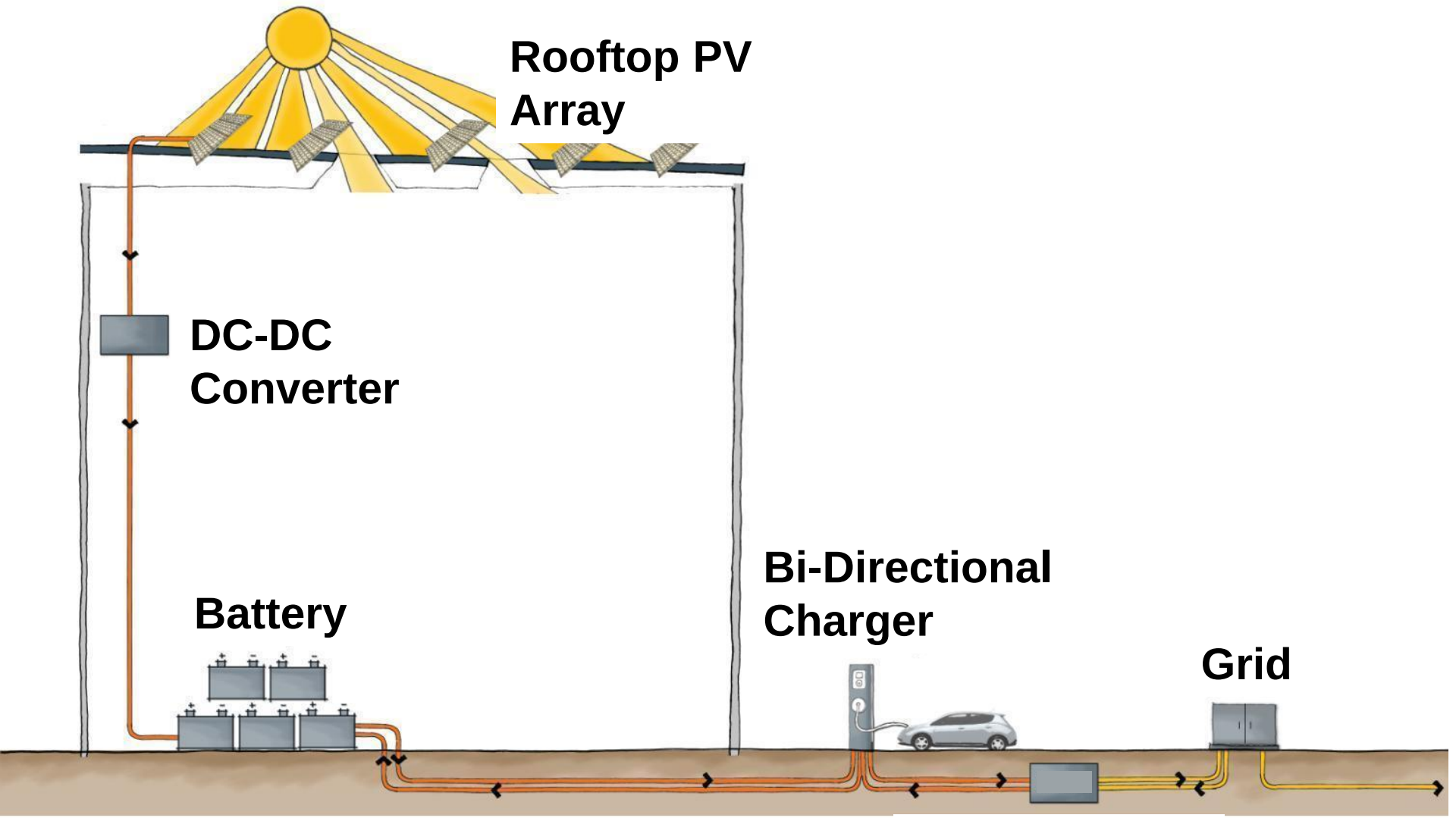
=

PV Production
1.6 kW

=

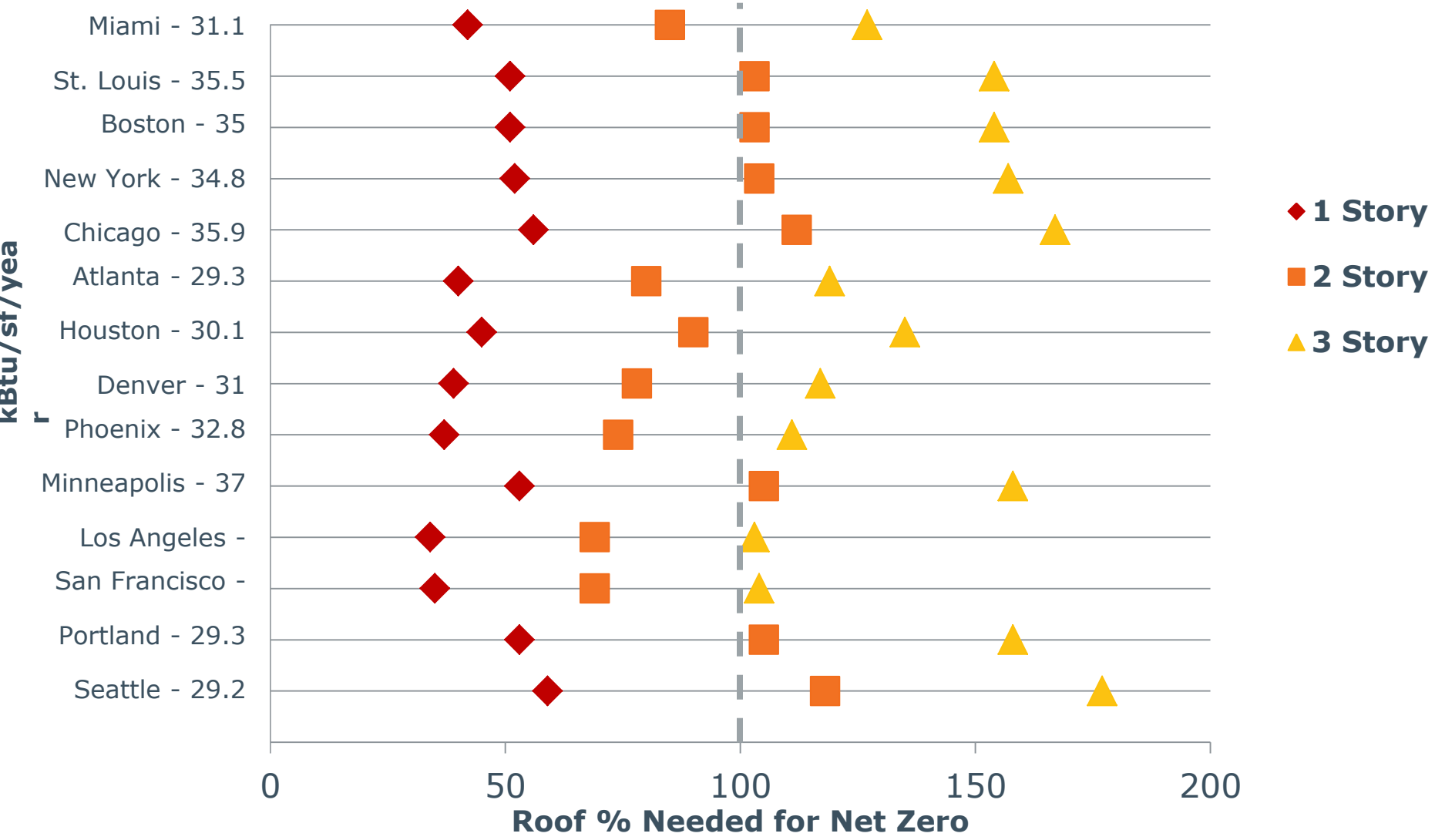
EV Travel
30 miles/day

Renewable Commuting



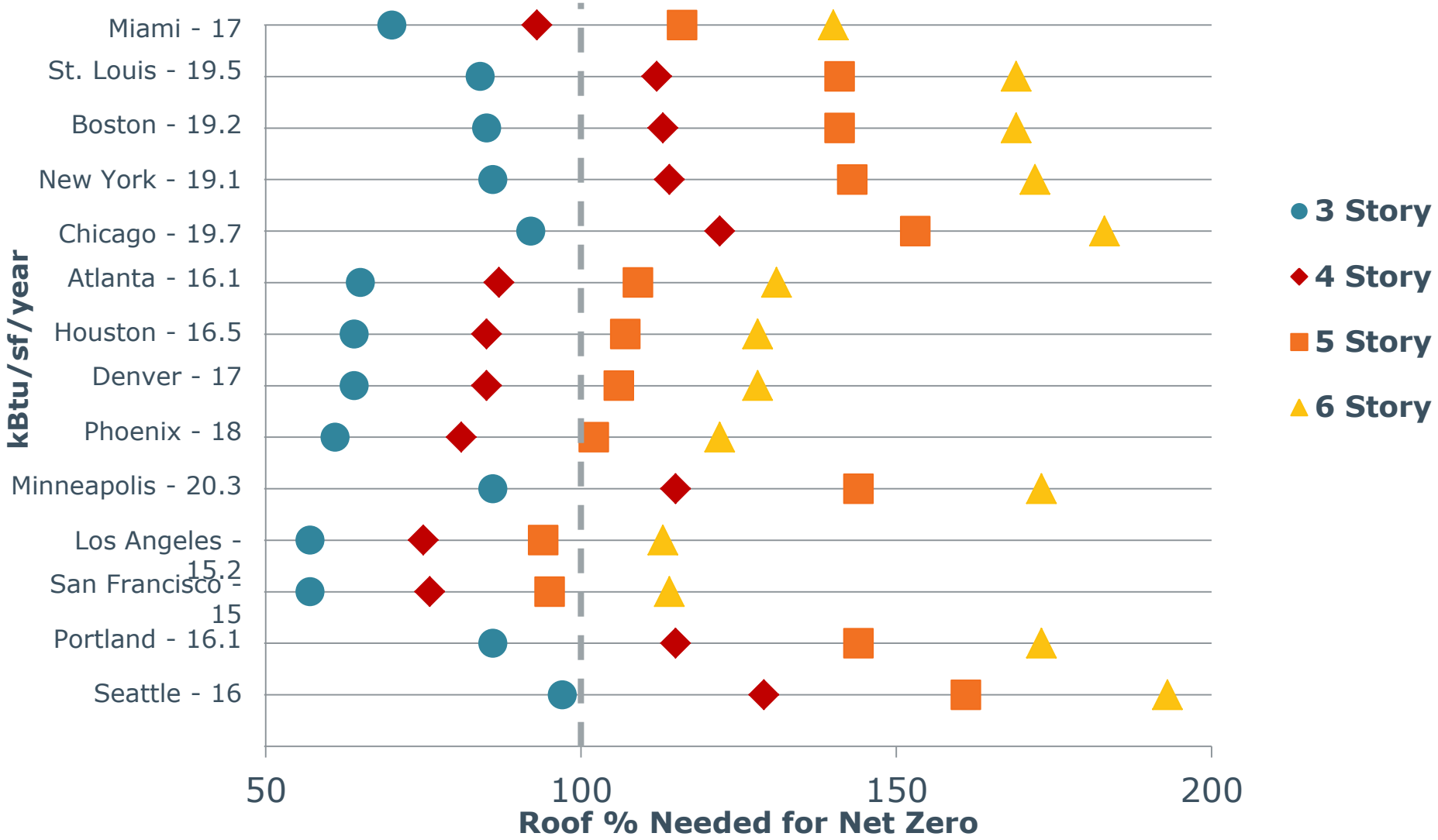
Target Finder Score of 100

% of Roof Area to Achieve Net Zero

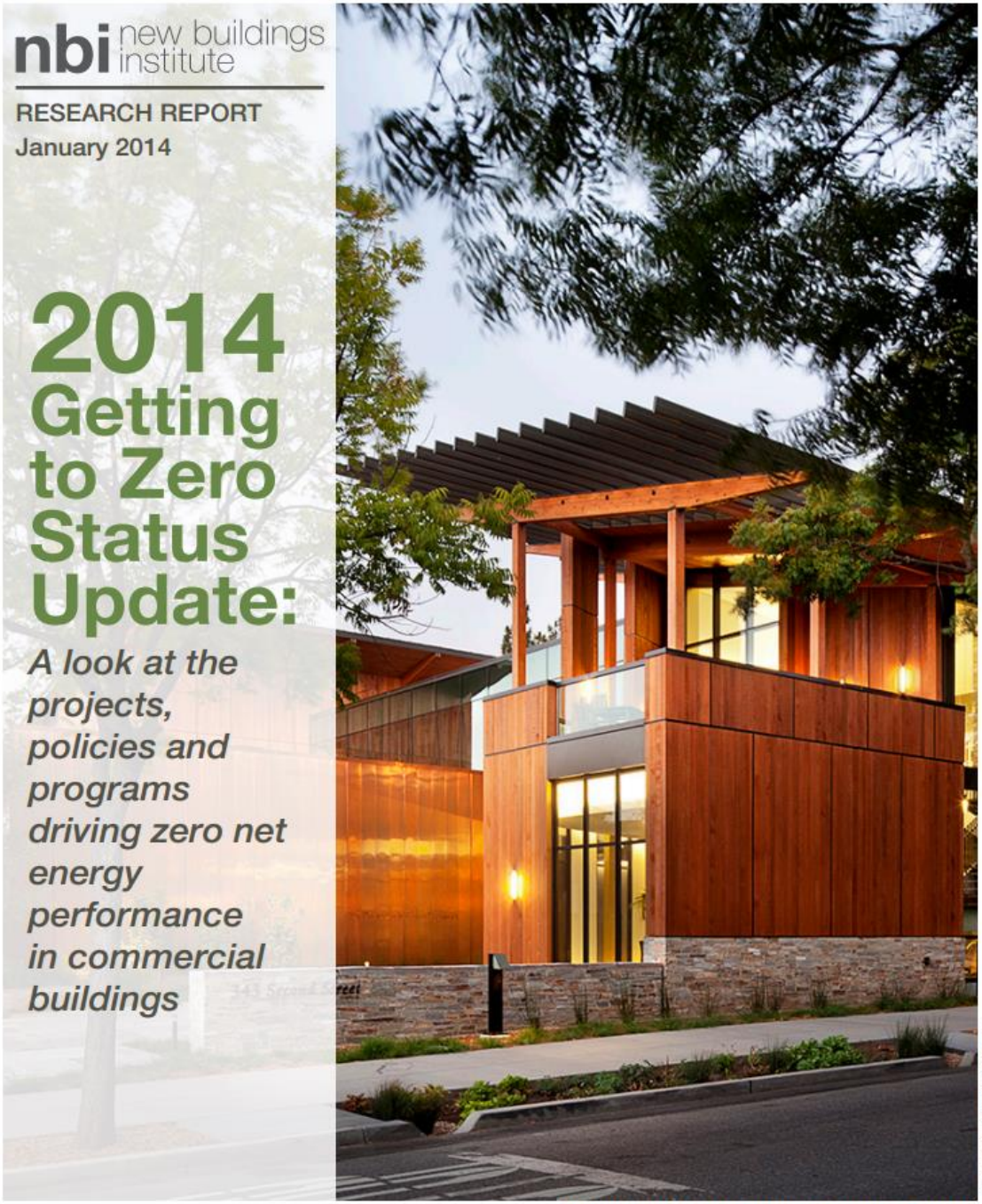


Bullitt Center Equivalent Buildings

% of Roof Area to Achieve Net Zero



Getting to Zero



David and Lucile Packard Foundation, Los Altos, California

http://newbuildings.org/sites/default/files/2014_Getting_to_Zero_Update.pdf

Conclusion

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