



PV and the Electrical Grid | The Bullitt Center

# Getting to Net Zero

September 17, 2013

PRESENTED TO: NASEO Getting to Net Zero National Forum

PRESENTED BY:

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Scott Bevan, PE, LEED AP

*inspire interpret integrate*

# How?

## Strategies



Set aggressive goals



Analyze the climate



Reduce energy use



Choose efficient systems



Opt for renewables



Verify performance



# How?

## Strategies



Set aggressive goals



Analyze the climate



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Choose efficient systems



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Verify performance







# Renewable Energy Sources



**PV**

The Workhorse



# Solar Resource



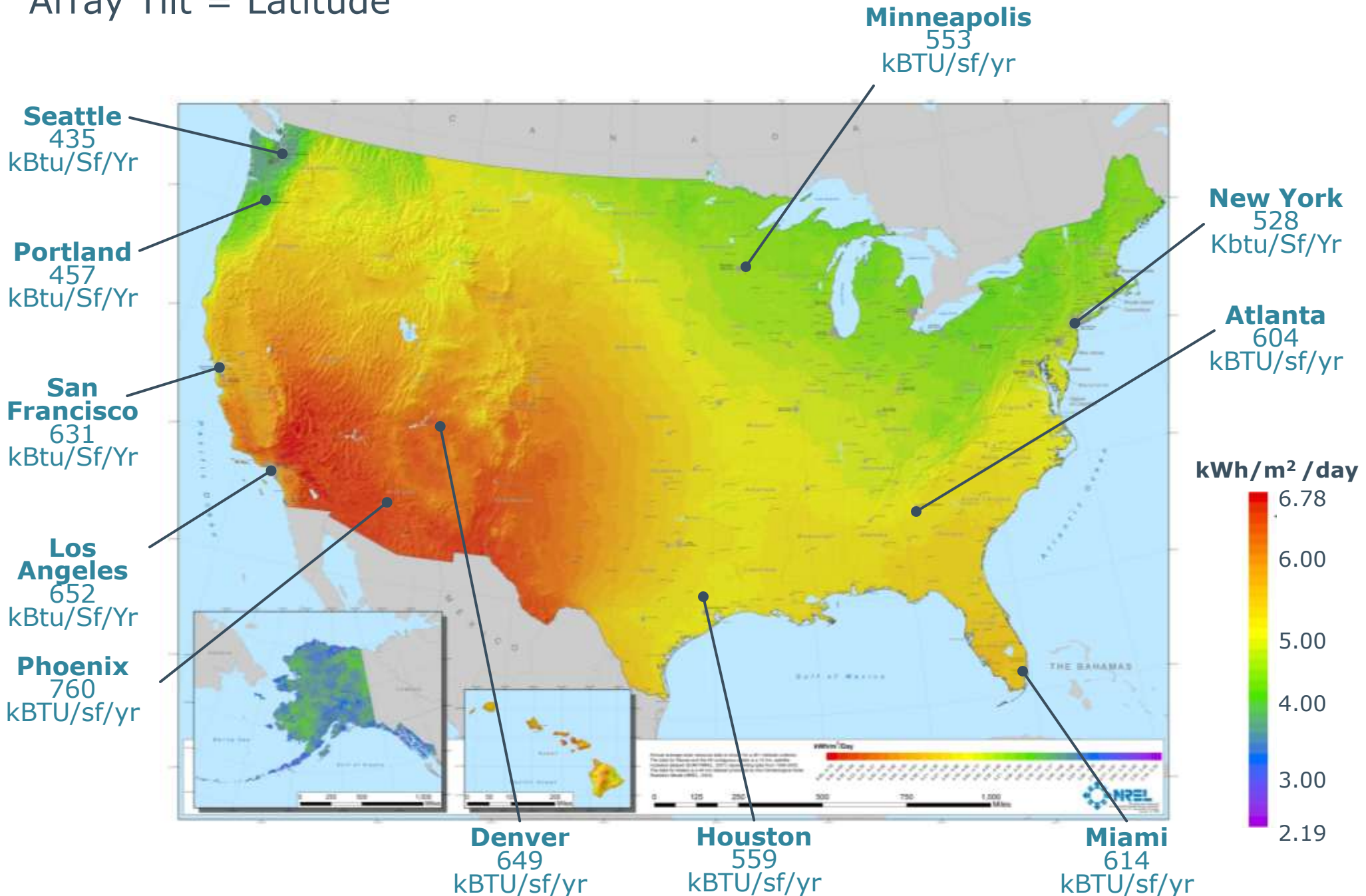
The earth receives more energy from the sun in just one hour than the whole world uses in a year. \*



# Solar Resource

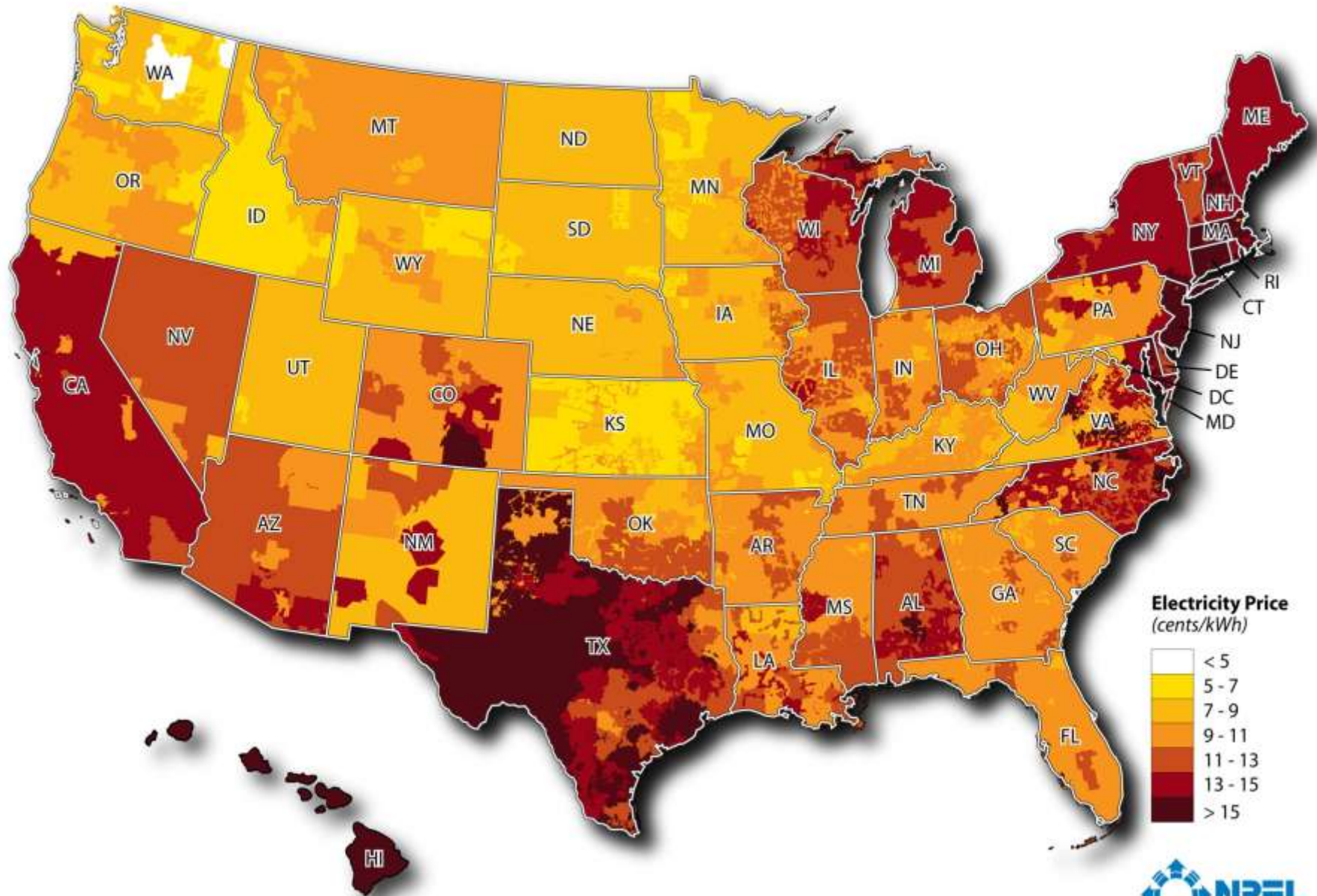


Array Tilt = Latitude



# Electricity

## Costs

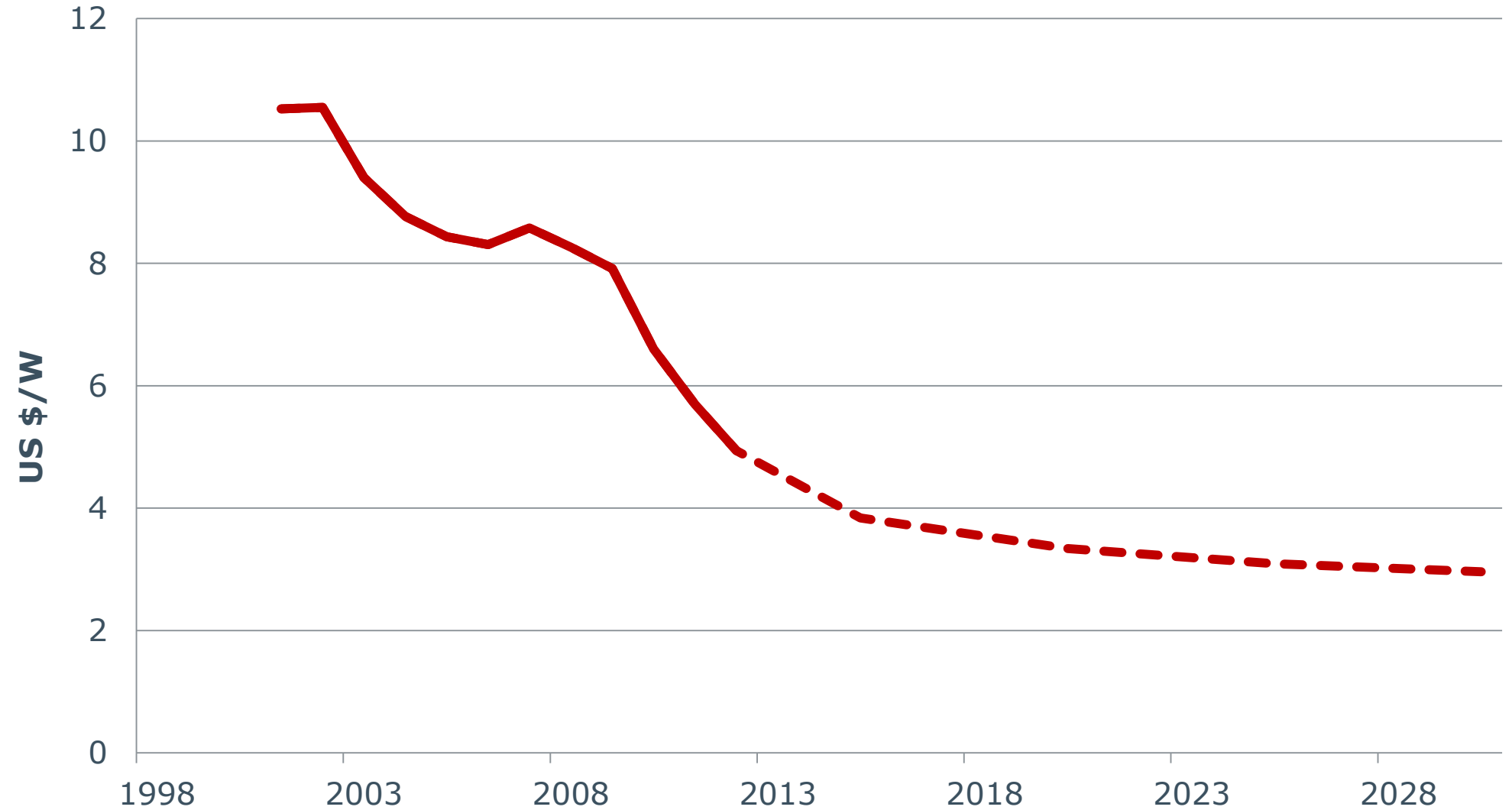


# First Cost Trend



## Average Price of PV

First Cost Trend  
Average Price of PV



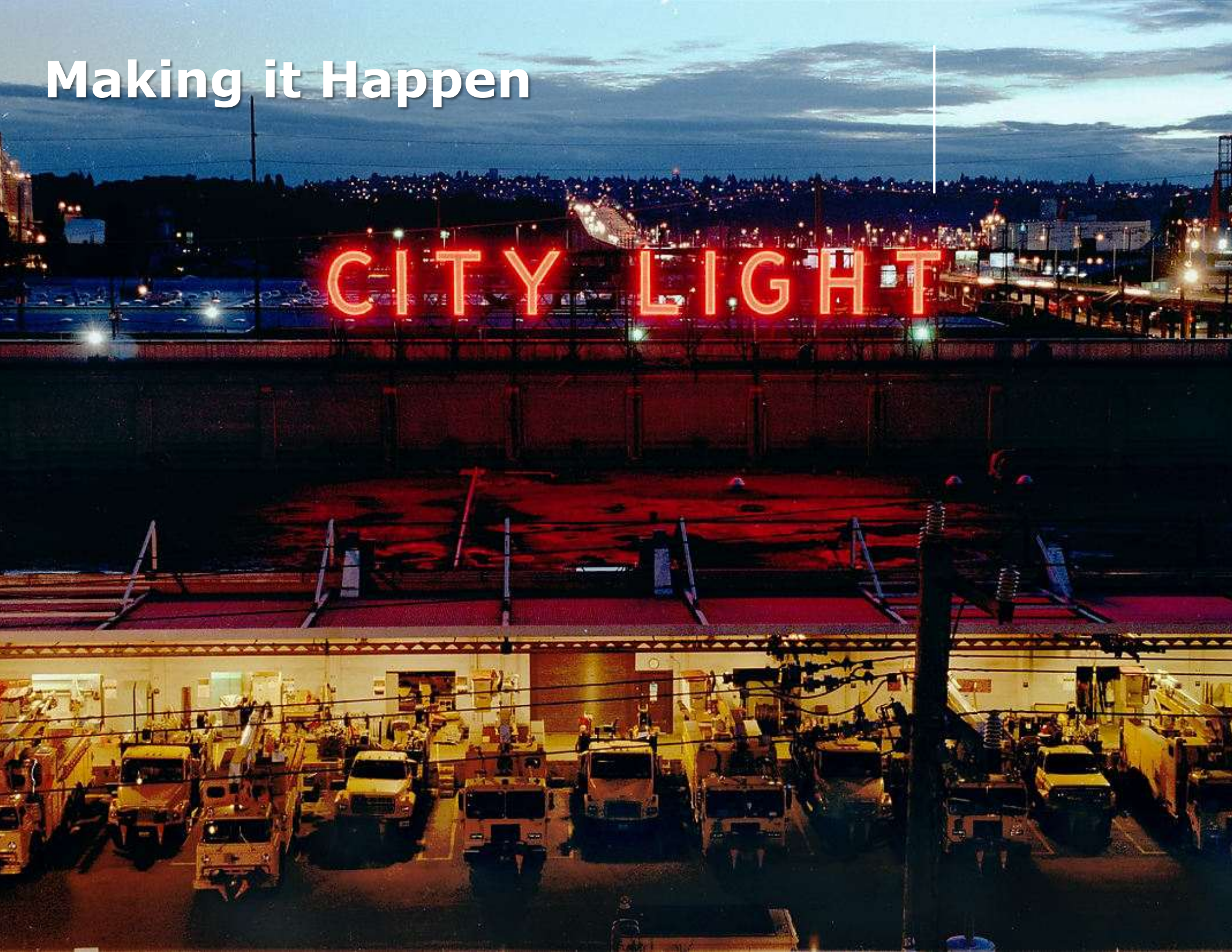
Source: Barbose, Galen L, Darghouth, Naim, Weaver, Samantha, and Wiser, Ryan H. *Tracking the Sun VI: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2012*. Berkeley, 2013.



# Energy Storage



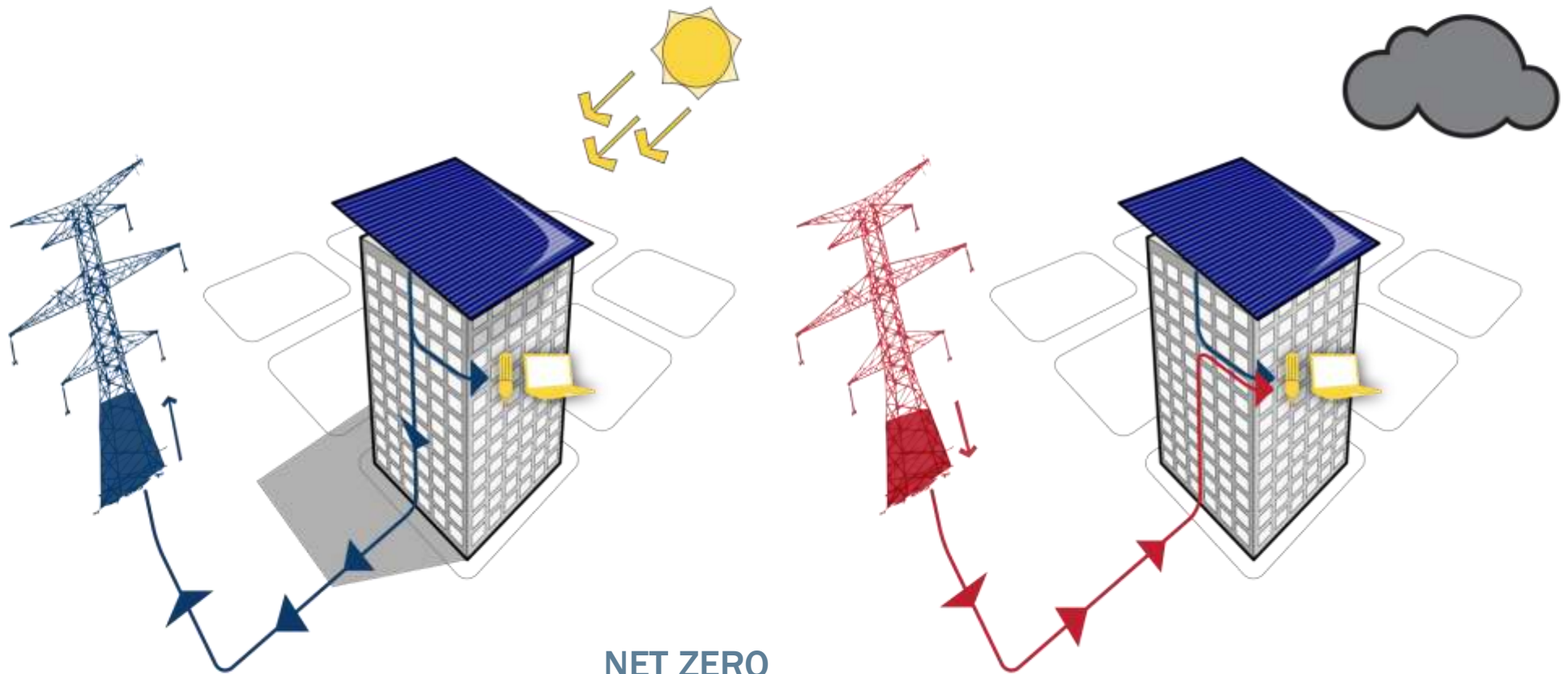
Making it Happen





# Net Zero Energy

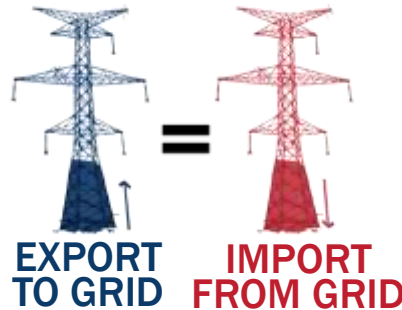
## Using the Grid



ENERGY EXPORT

NET ZERO

ENERGY IMPORT



EXPORT TO GRID

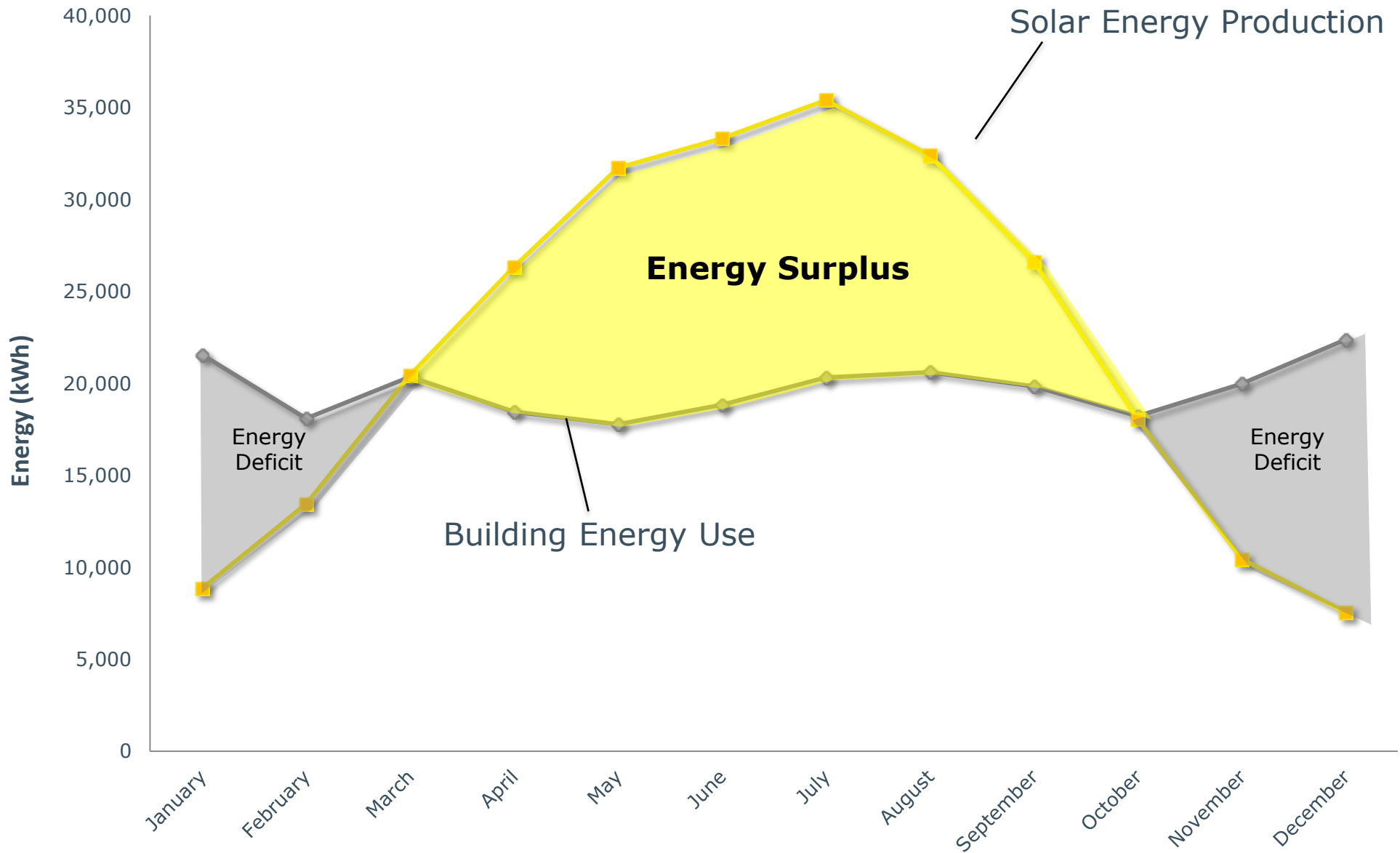
IMPORT FROM GRID



# Net Zero Energy



## Energy Use | Solar Budget



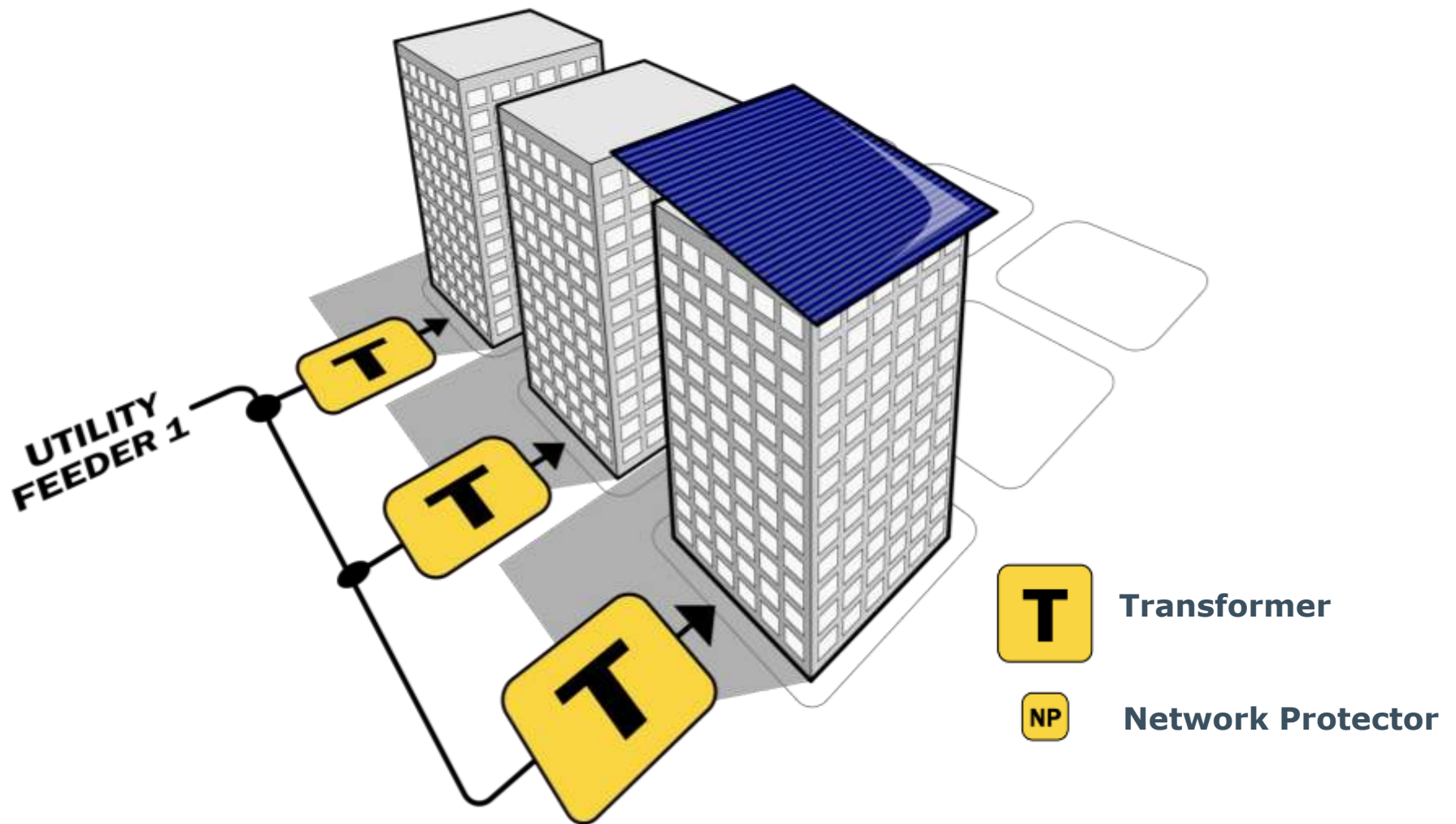
# Utility Grids



KILOWATT  
HOURS

# Grid

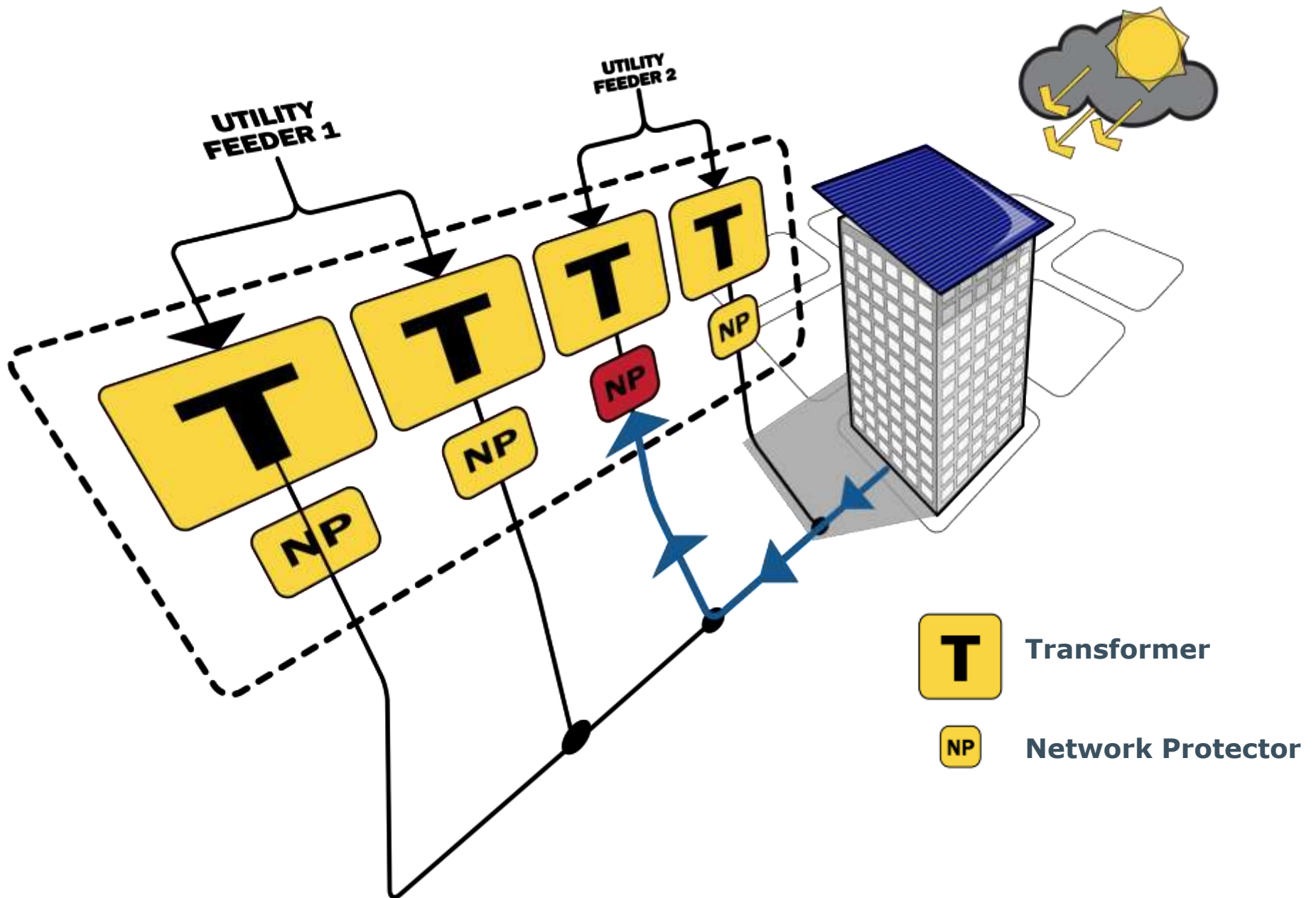
## Radial





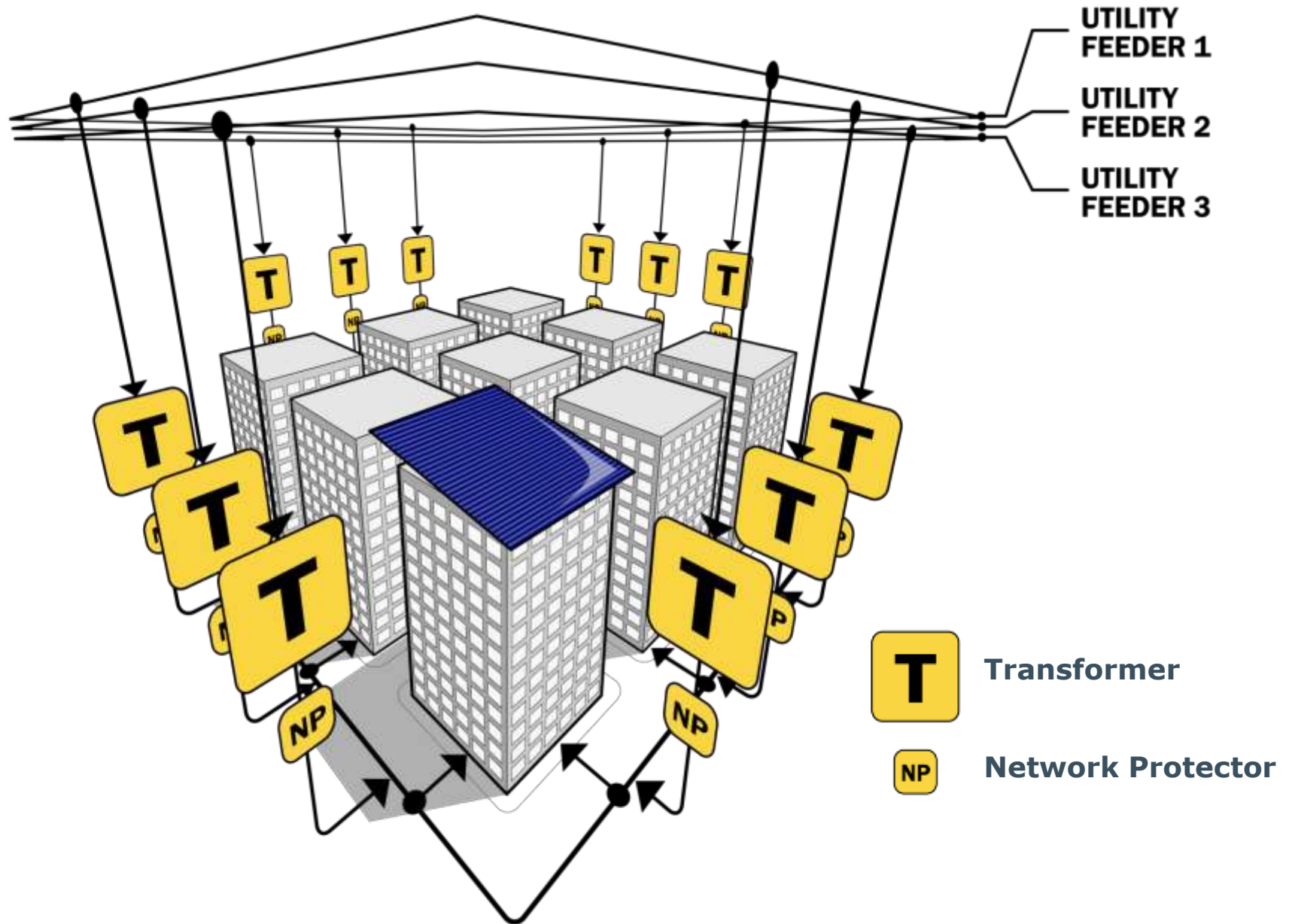
# Grid

## Spot Network



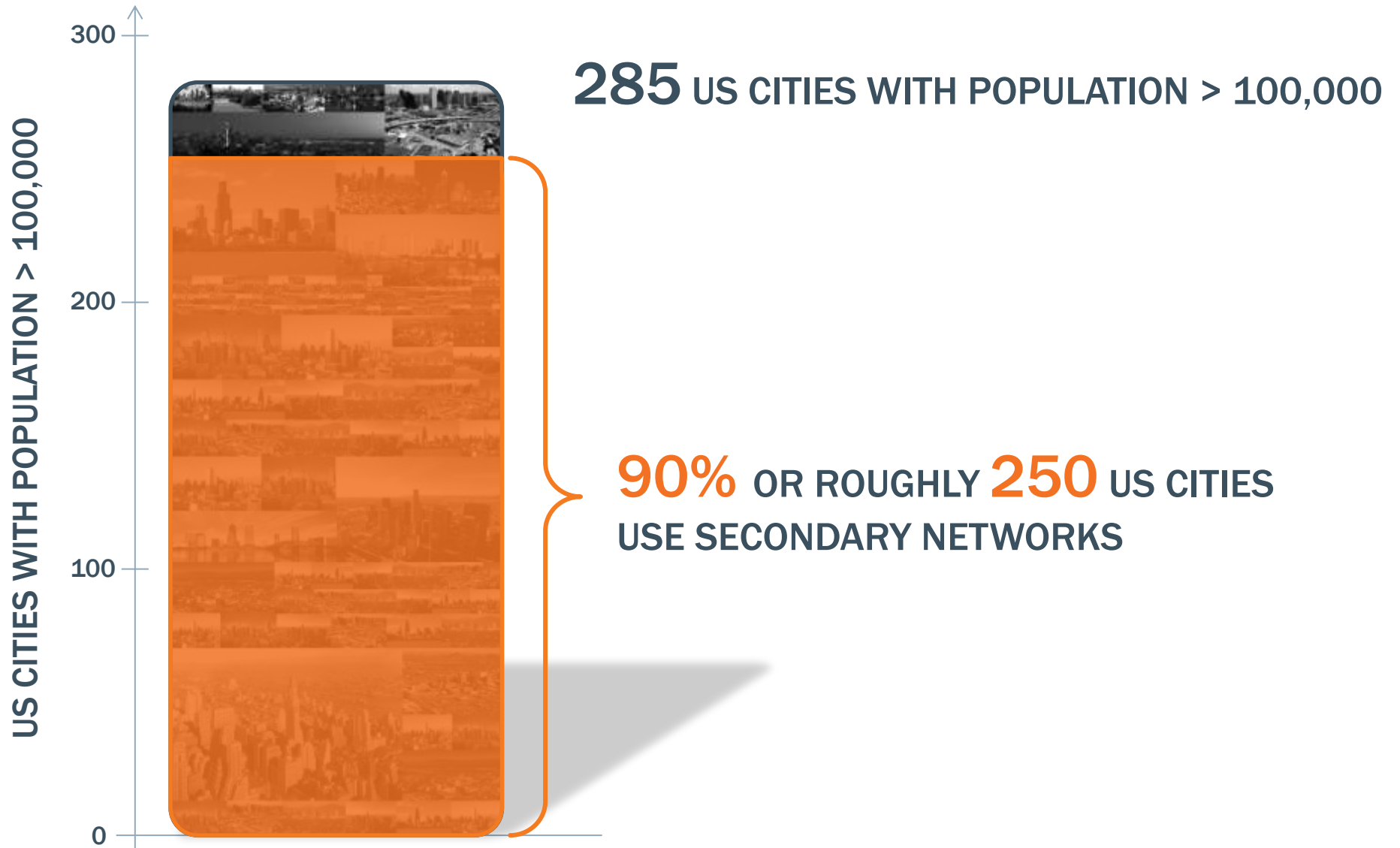
# Grid

## Area Network



# Networks

Are Everywhere





# Portland

## Downtown Network



# Edith Green-Wendell Wyatt





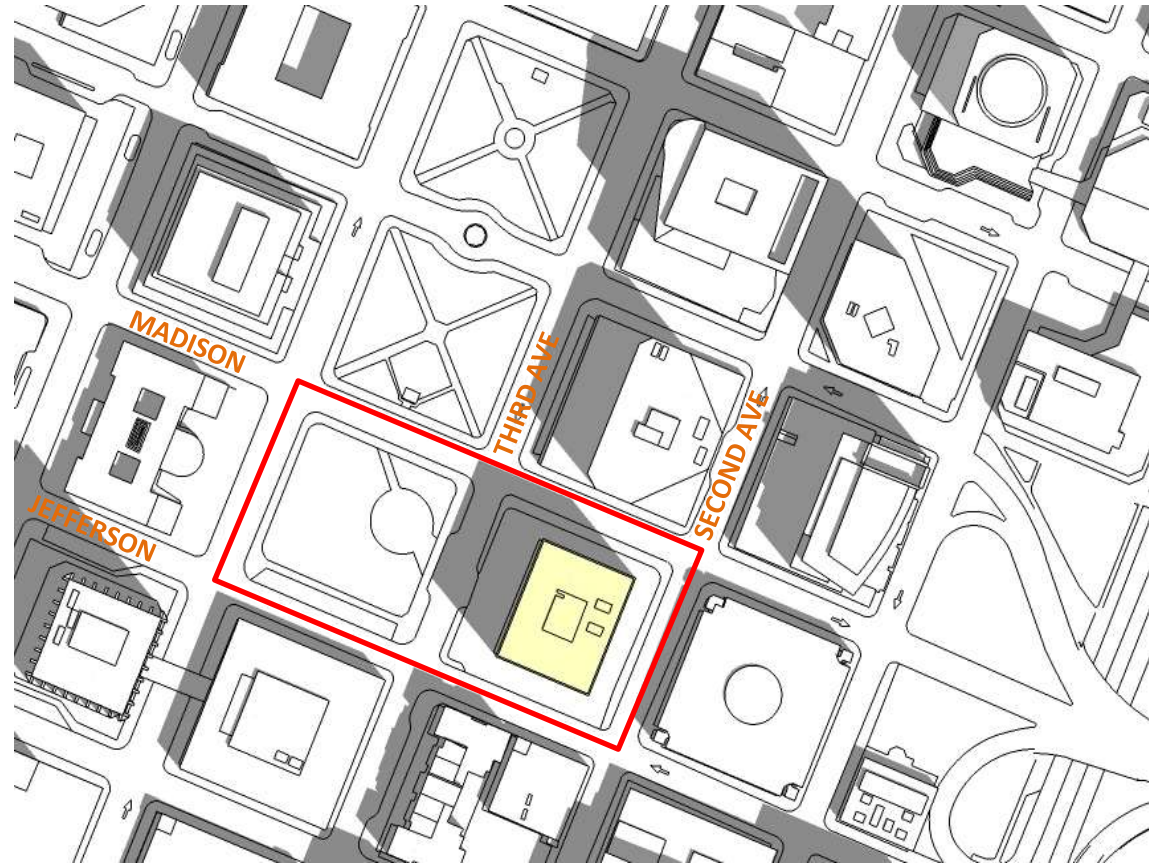
# Edith Green-Wendell Wyatt





# Edith Green-Wendell Wyatt

## Modernization Project



Transform a 512,400 square foot, 18-story, 1974 office building into a LEED Platinum cornerstone of GSA's green building portfolio.

Budget: \$ 141,000,000



# Edith Green-Wendell Wyatt



## Solar PV



**SERA ARCHITECTS**  
Solar Site Analysis Report

Image File ROOF\_NW\_02.JPG

### Solar Obstruction Data

Month	Unshaded % of Ideal Site Azimuth=180 Tilt=45.52	Actual Solar Rad w/ Shading Azimuth=180.0 Tilt=45.52 KWH/m <sup>2</sup> /day
January	71.00%	1.48
February	93.00%	2.40
March	100.00%	3.89
April	100.00%	4.35
May	100.00%	5.29
June	100.00%	5.30
July	100.00%	6.01
August	100.00%	5.55
September	100.00%	5.00
October	100.00%	3.79
November	73.00%	1.48
December	70.00%	1.02
<b>Totals</b>	<b>92.29%</b>	<b>-</b>
Unweighted		Effect: 96.32%
Yearly Avg		Sun Hrs: 3.80

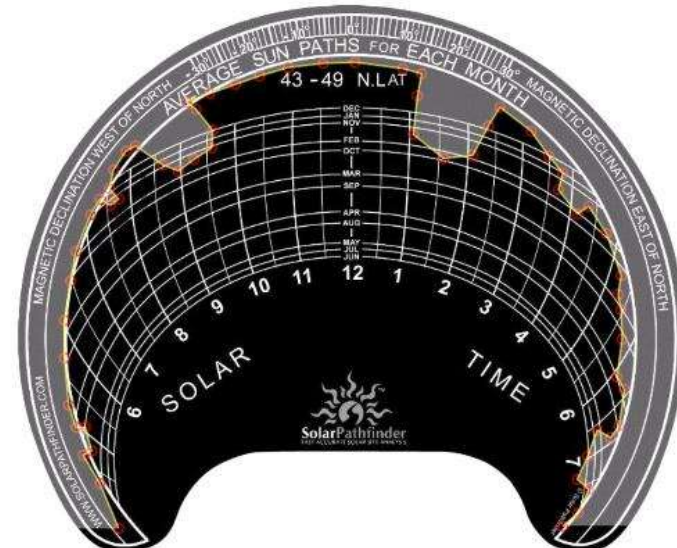
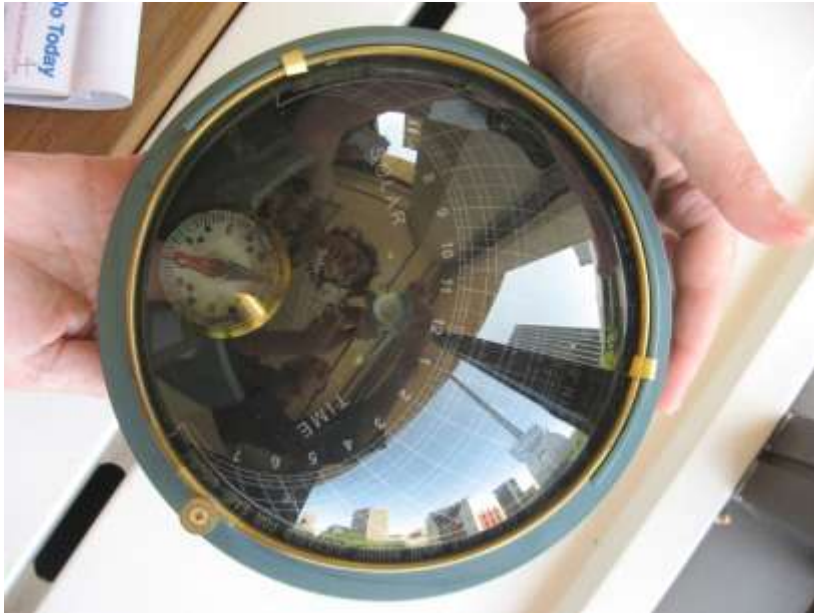
**98% of Available Solar**

### Azimuth/Altitude Data

Azimuth / Altitude (degrees) where North = 180 degrees

-125	0.0	-80	0.0	-35	17.0	10	3.5	55	9.5	100	1.0
<b>-120 (ENE)</b>	<b>0.0</b>	-75	0.0	<b>-30 (SSE)</b>	<b>1.0</b>	15	3.5	<b>60 (WSW)</b>	<b>9.0</b>	105	0.0
-115	0.0	-70	0.0	-25	2.0	20	26.0	65	2.5	110	0.0
-110	1.5	-65	0.0	-20	3.0	25	28.0	70	1.5	115	5.5
-105	0.0	<b>-60 (ESE)</b>	<b>5.0</b>	-15	3.0	<b>30 (SSW)</b>	<b>27.5</b>	75	1.0	<b>120 (WNW)</b>	<b>4.5</b>
-100	0.0	-55	0.0	-10	3.5	35	2.5	80	2.5	125	0.0
-95	0.0	-50	0.0	-5	3.0	40	3.0	85	2.5		
<b>-90 (E)</b>	<b>0.0</b>	<b>-45 (SE)</b>	<b>17.0</b>	<b>0 (S)</b>	<b>3.5</b>	<b>45 (SW)</b>	<b>3.5</b>	<b>90 (W)</b>	<b>3.0</b>		
-85	0.0	-40	18.5	5	3.5	50	5.0	95	3.5		

Notes: ROOF\_NW\_CORNER





# Edith Green-Wendell Wyatt



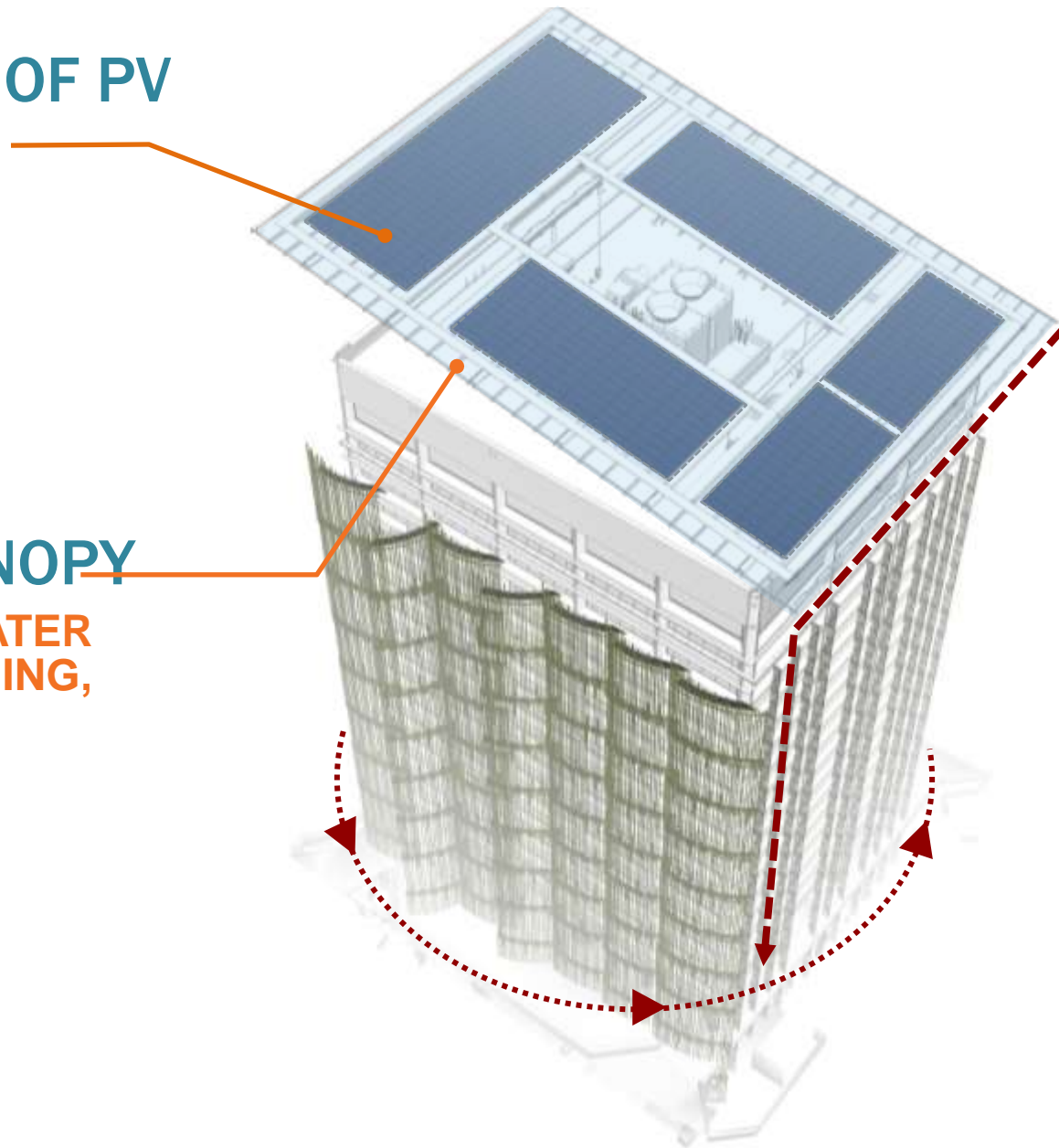
Rooftop PV

**OVER 13,000 SF OF PV**

**180 kW**

**25,000 SF CANOPY**

**COLLECTS RAINWATER  
FOR TOILET FLUSHING,  
IRRIGATION, AND  
COOLING TOWERS**





# PV Array

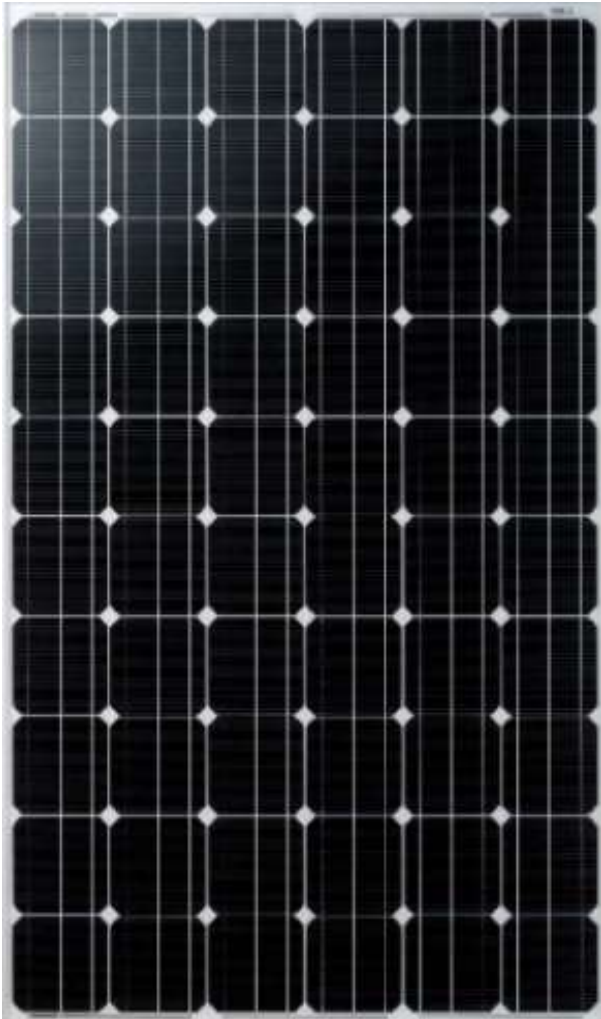
In detail



## Solarworld 250W

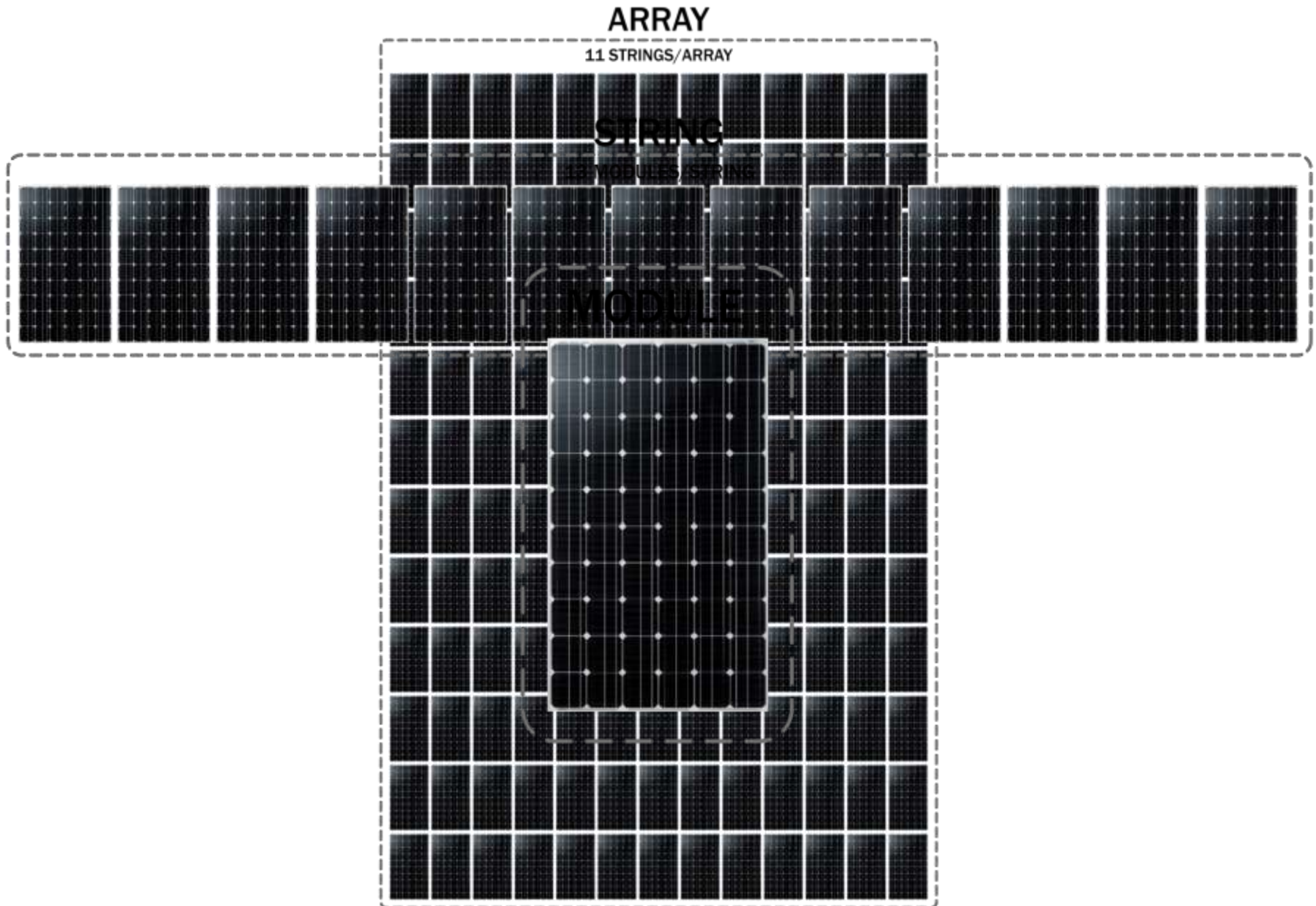
SW 250 mono

Number of modules	715
Unit Nom. Power	250 W
Peak System Output	179 kW
Produced Energy	209,000 kWh/yr
Panel Efficiency (STC)	14.9%
System Efficiency	~13%



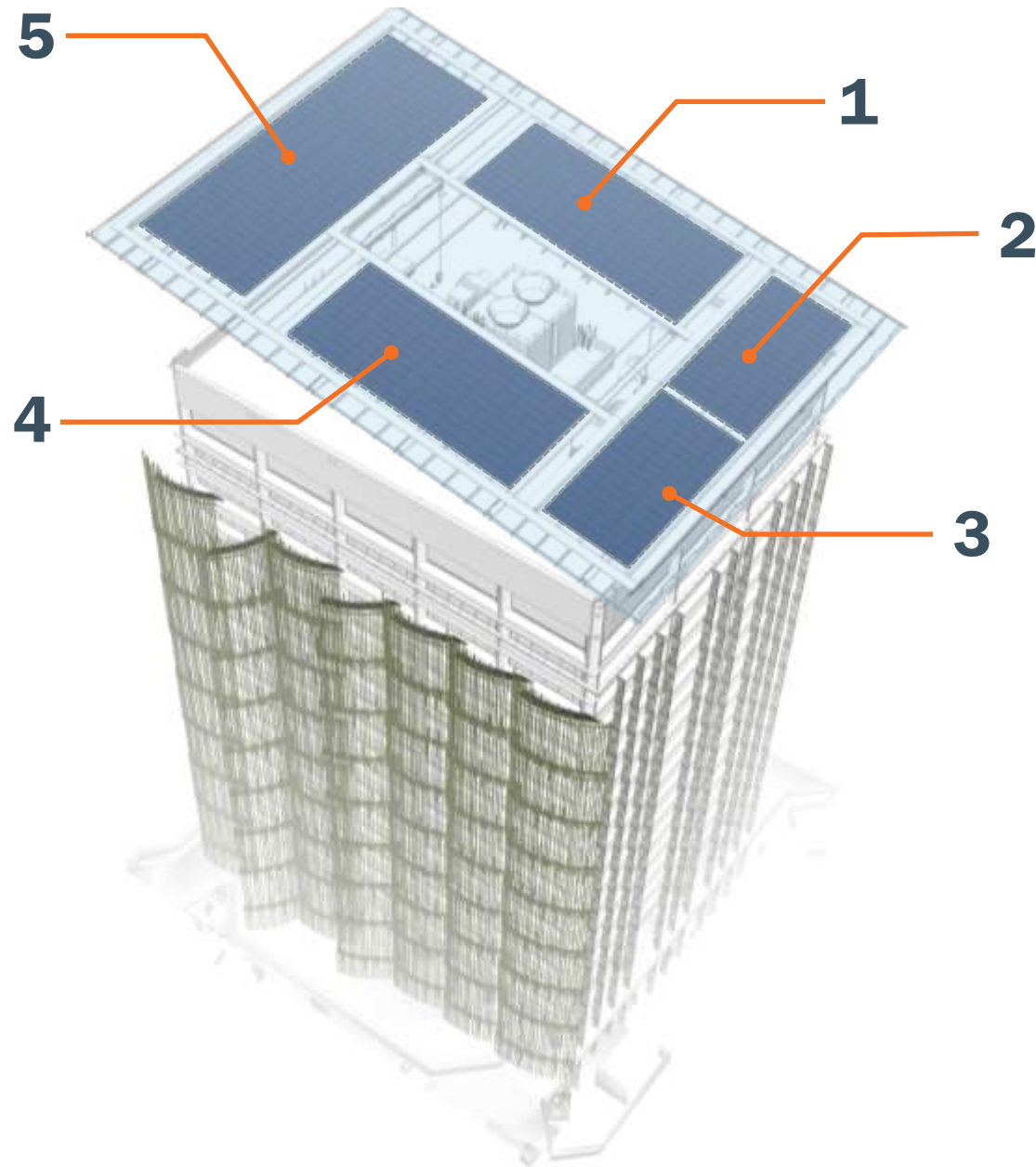
# PV Array

## Components



# PV Array

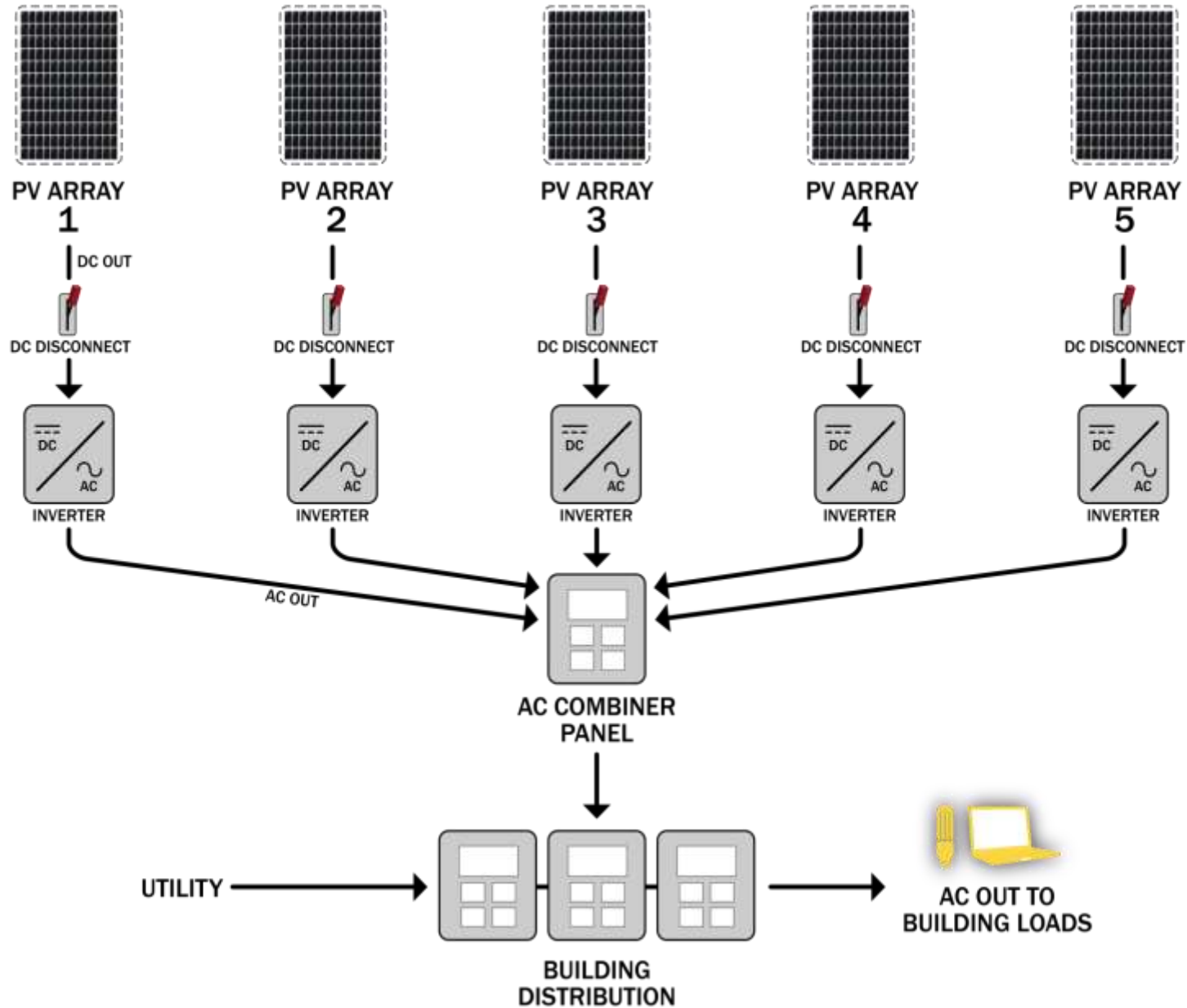
Rooftop

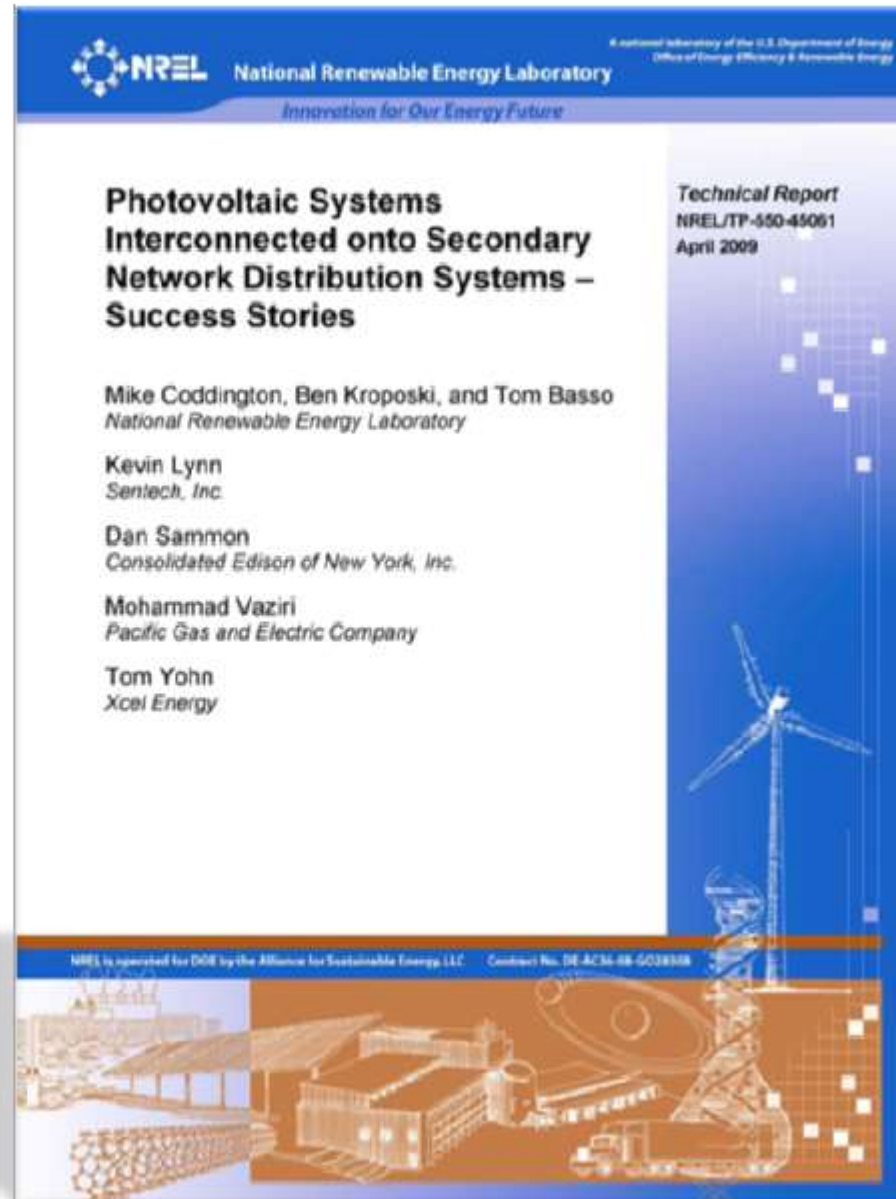




# PV Array

## System Interconnection



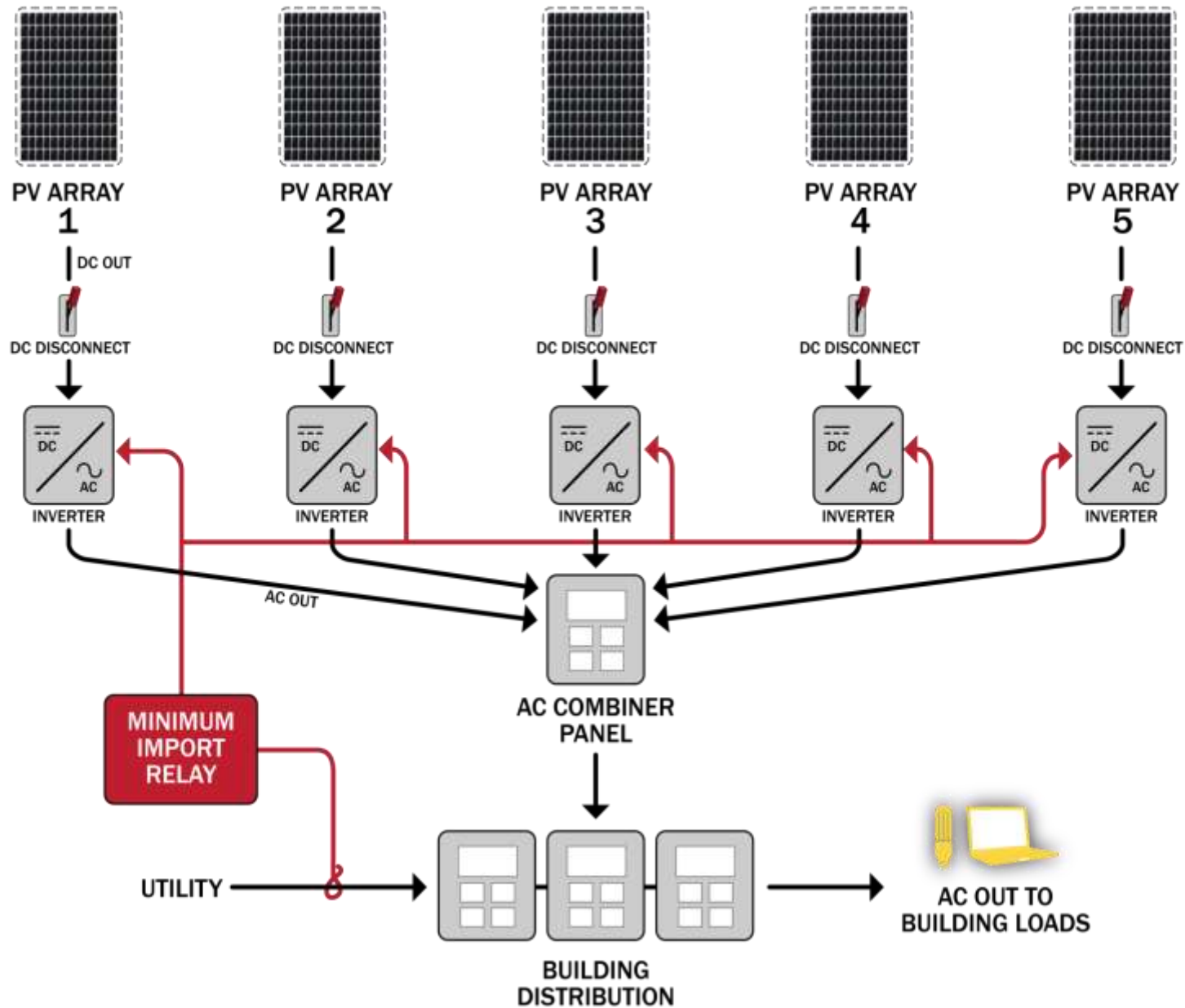




# PV Array



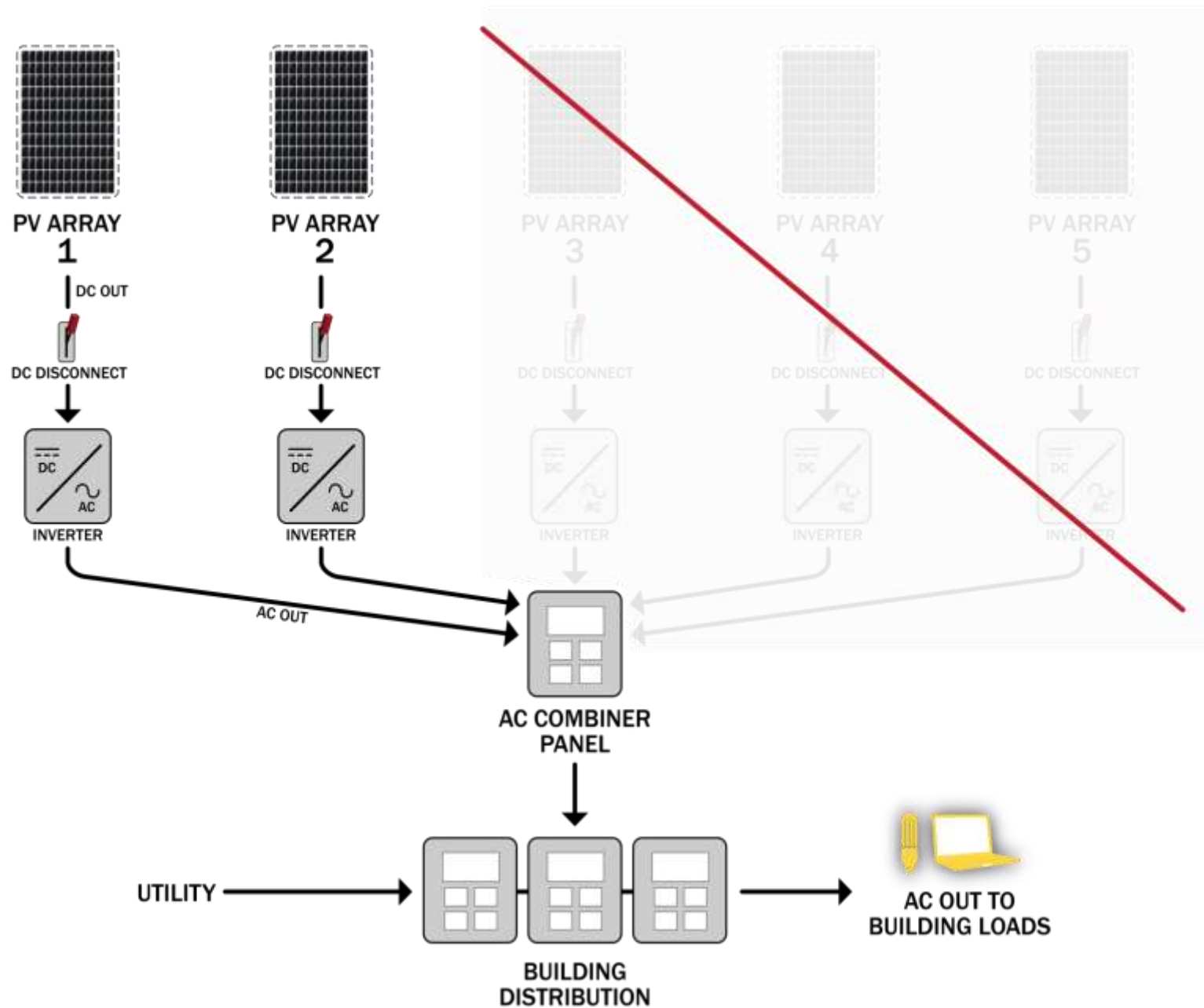
## Minimum Import Relay



# PV Array



## Minimize Array Size

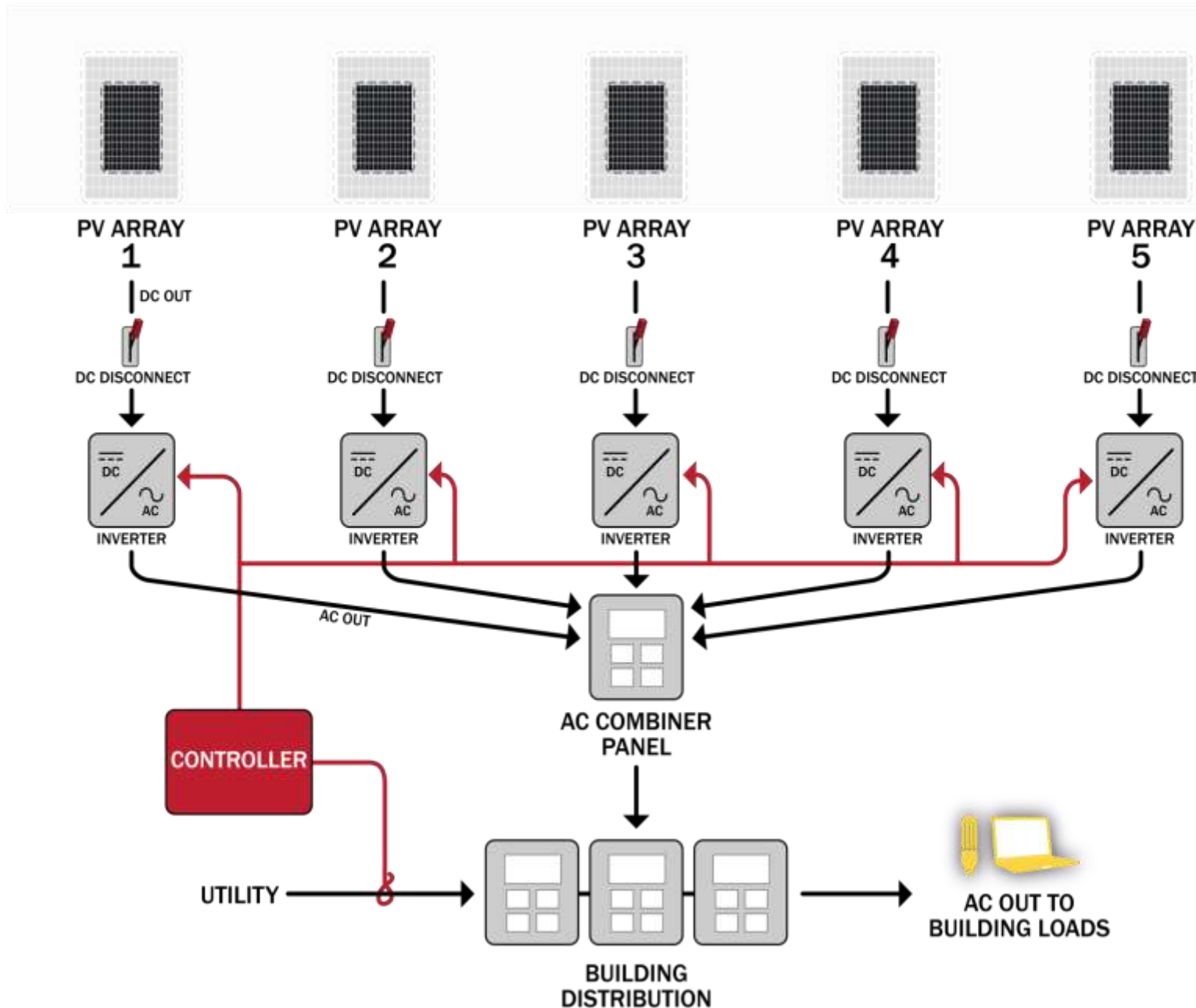




# PV Array



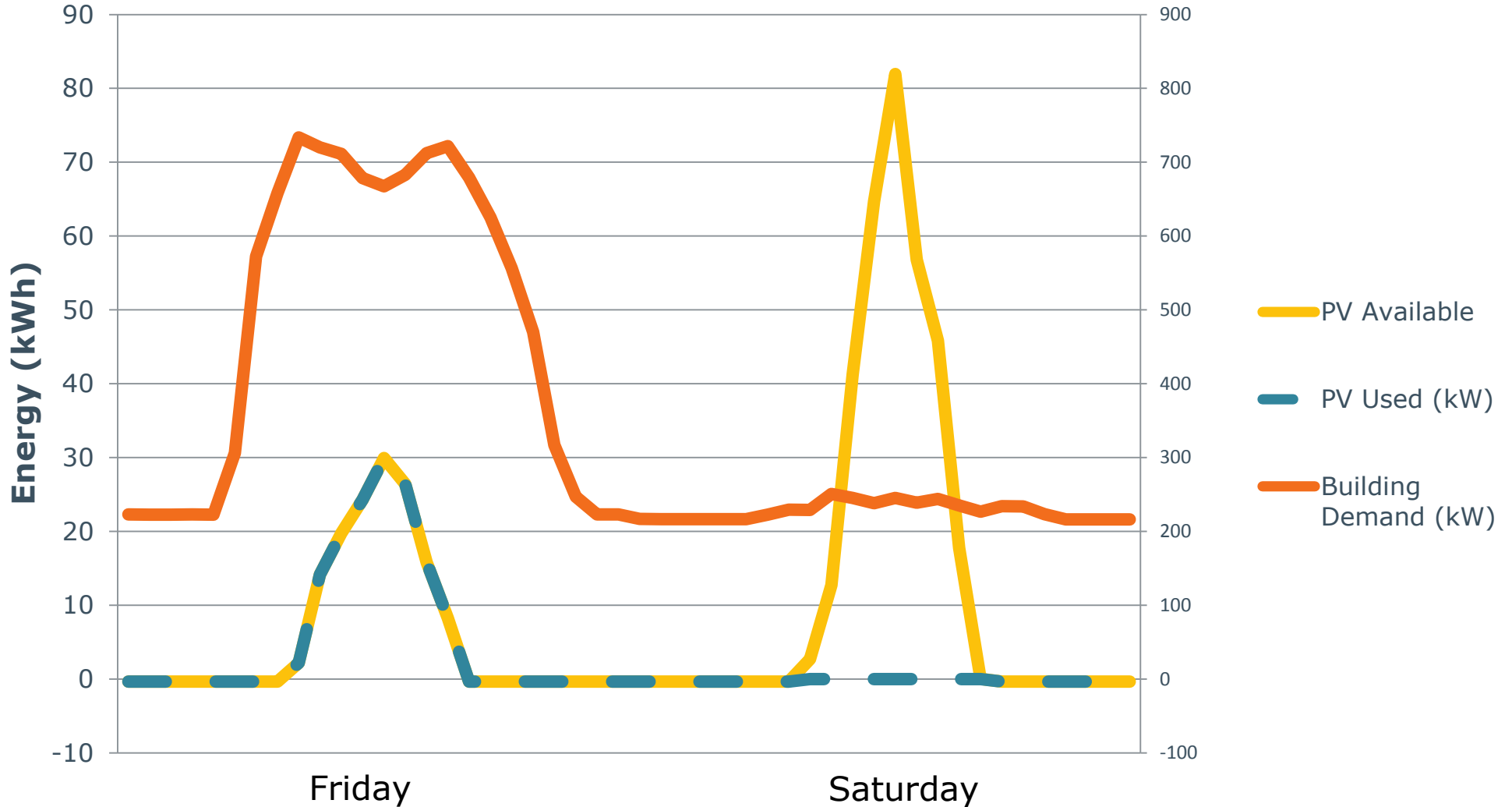
## Dynamically Controlled Inverters



# Net Electricity



Typical Occupied and Unoccupied Days



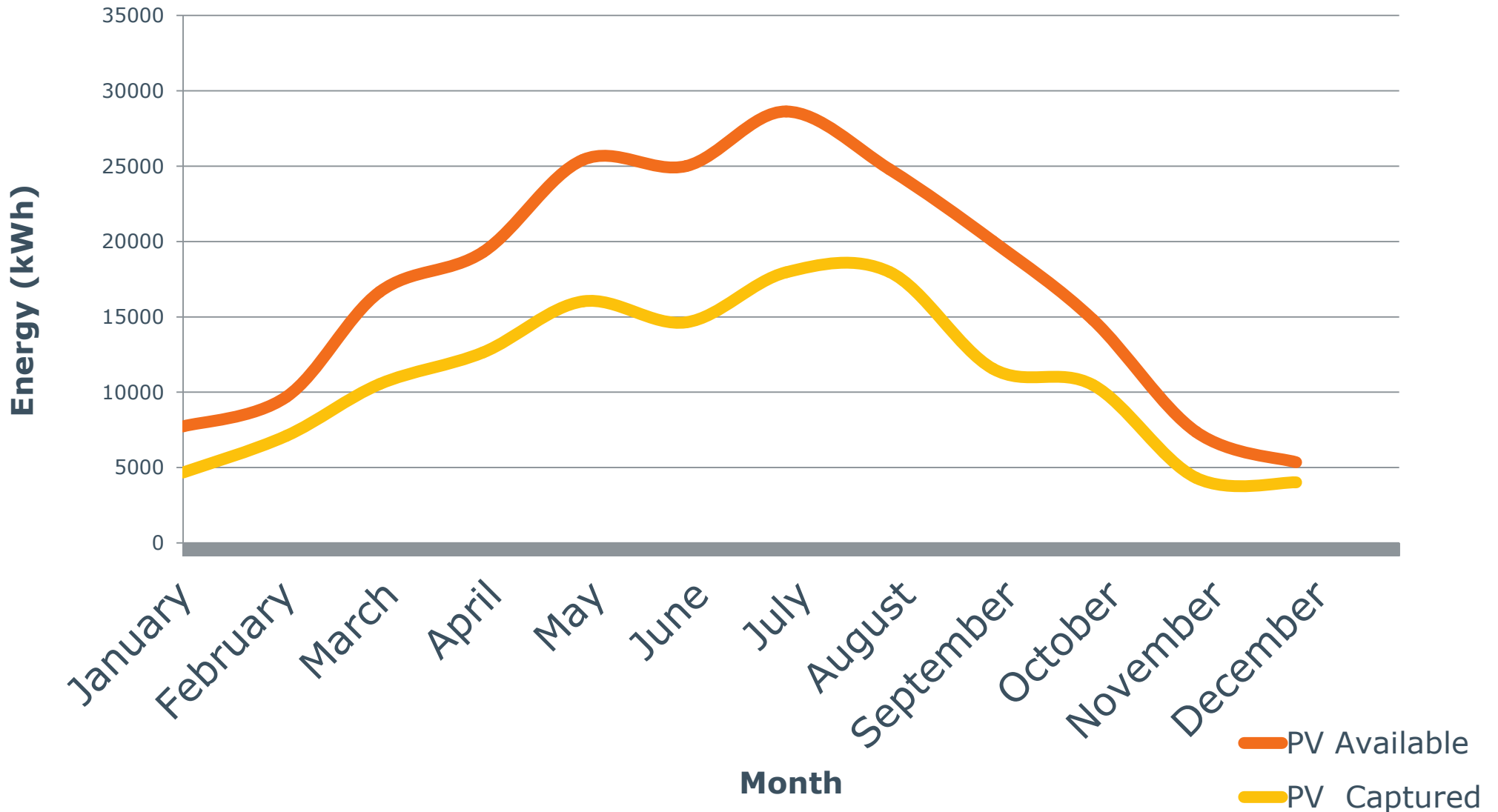


# Opportunity Lost

More Than 35% of Possible Production Lost

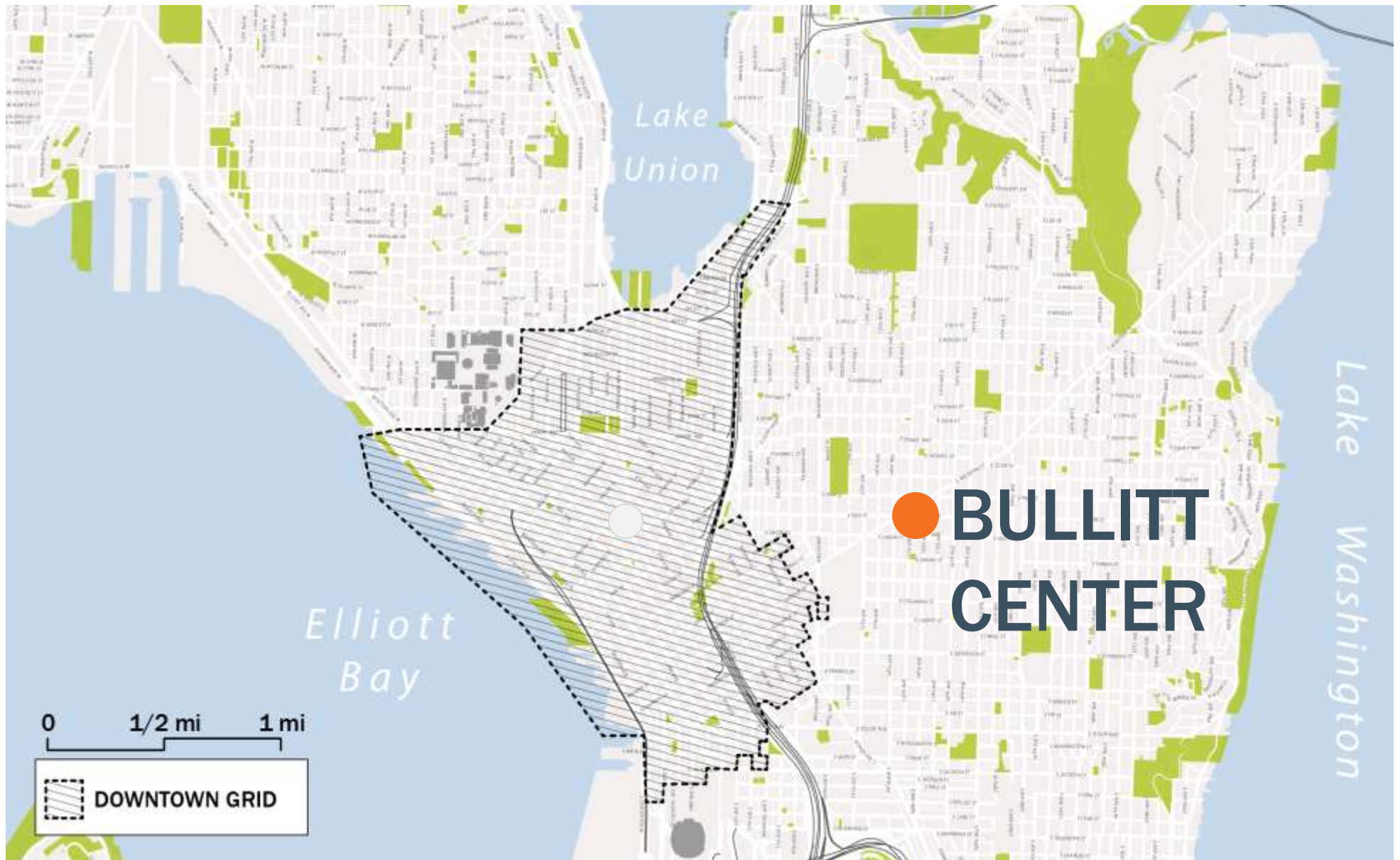


Monthly Estimated PV Available and PV Captured



# Seattle

## Downtown Network



# The Power Plant

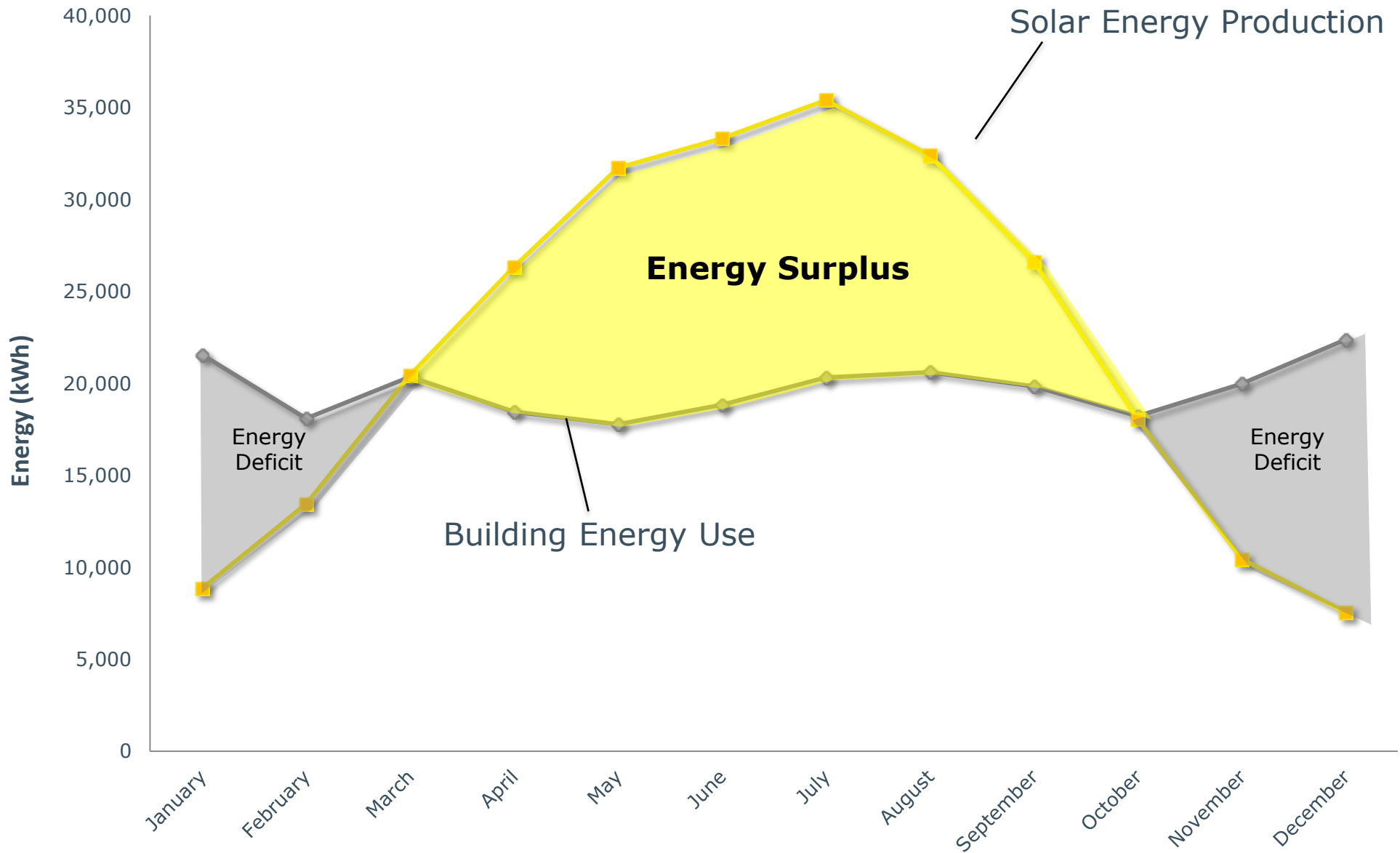




# Net Zero Energy

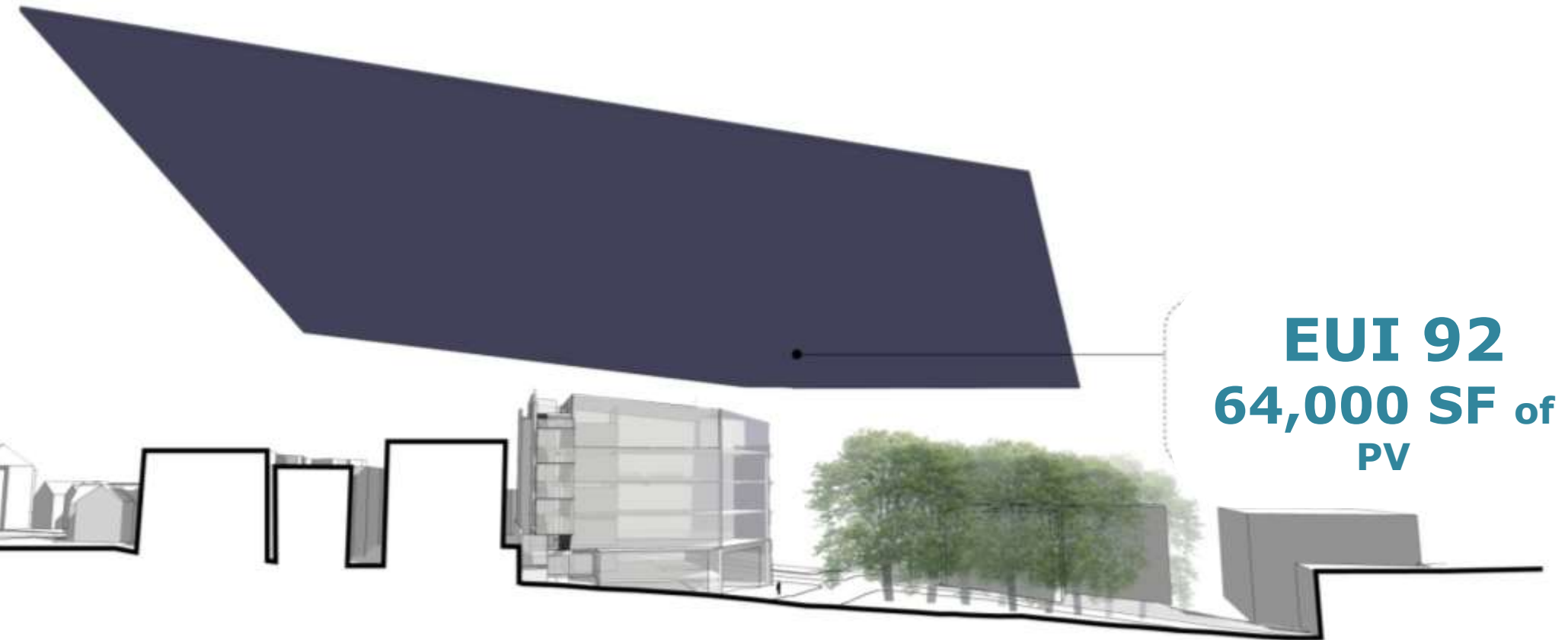


## Energy Use | Solar Budget



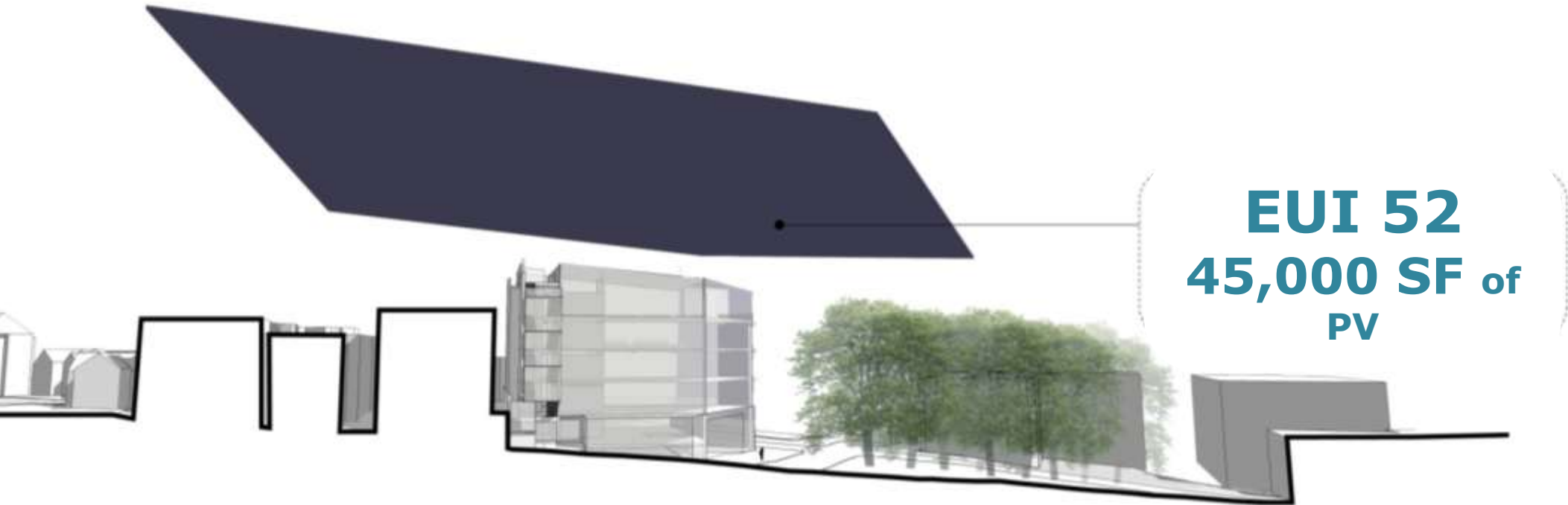
# Bullitt Center

PV Area



# Bullitt Center

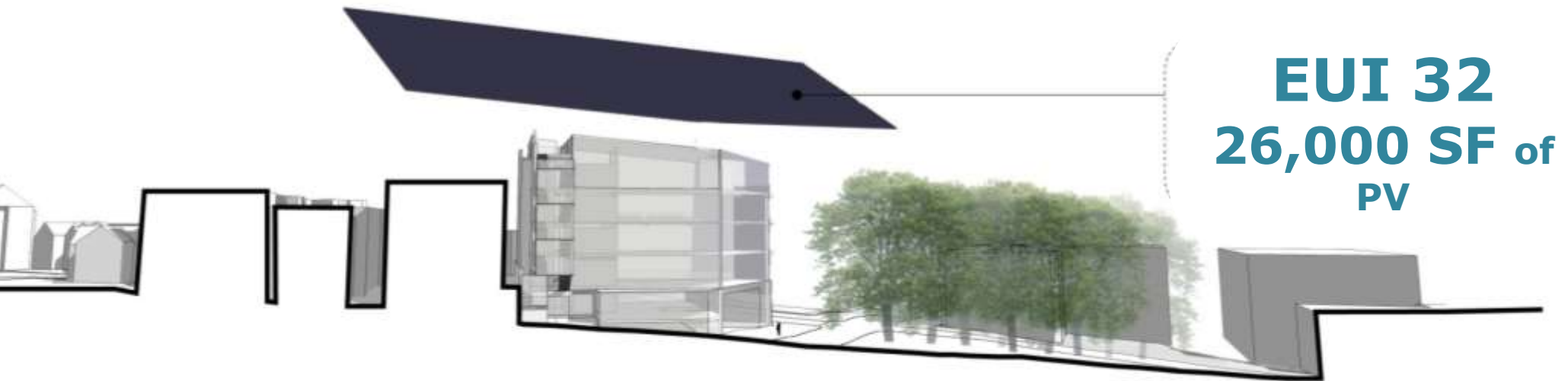
PV Area





# Bullitt Center

PV Area

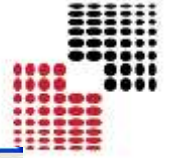


# Bullitt Center

PV Area



# Grasshopper



File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render Help

Choose world view (Top Bottom Left Right Front Back Perspective): \_Top  
Command:

Perspective

Grasshopper - PanelizedOverhang2

File Edit View Arrange Solution Window Help

PanelizedOverhang2

Params Logic Scalar Vector Curve Surface Mesh Intersect XForm

Geometry Primitive Special

64%

Top

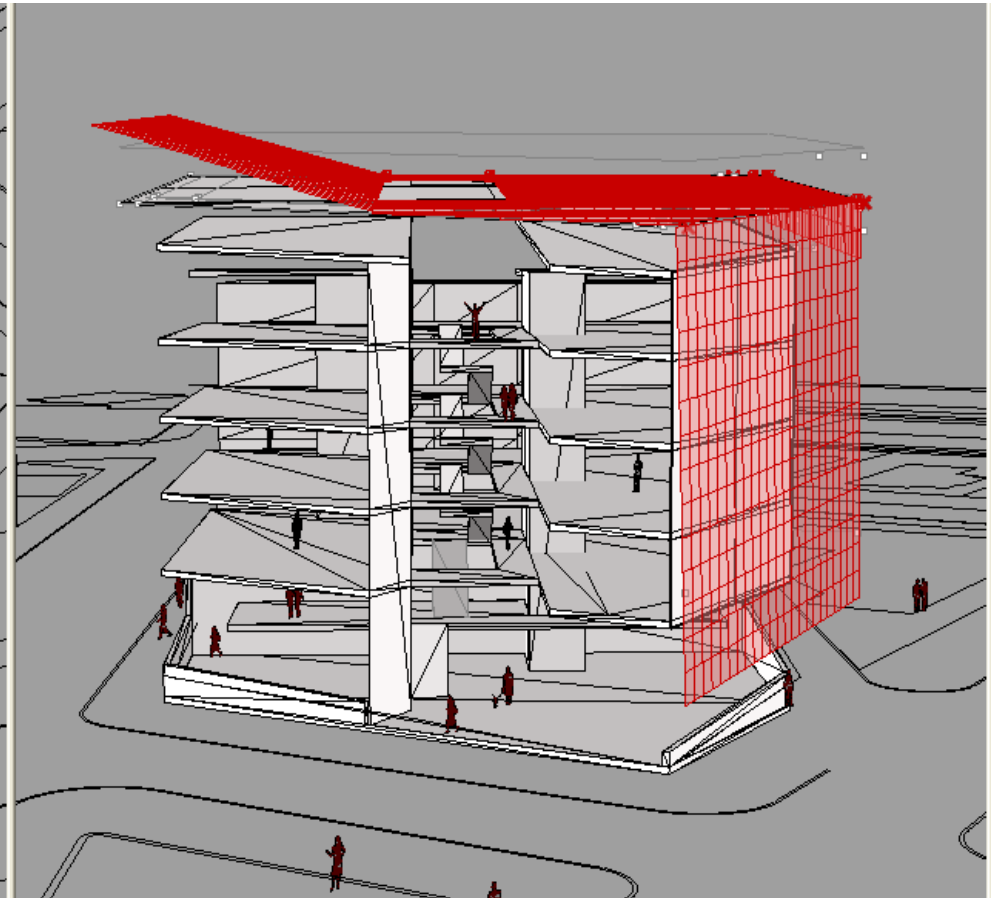
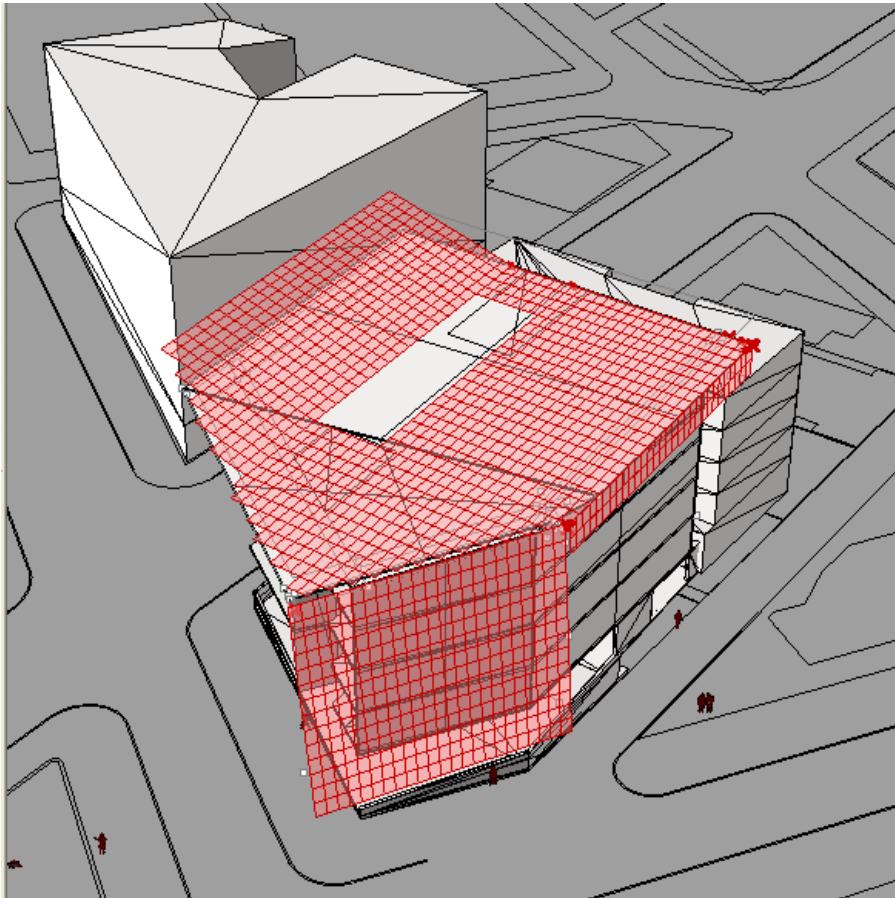
CPlane x 298'-8 7/8" y 222'-5 1/8" z 0" Default Snap Ortho Planar Usnap Record History



# Net Zero Energy - PV



## Scheme II



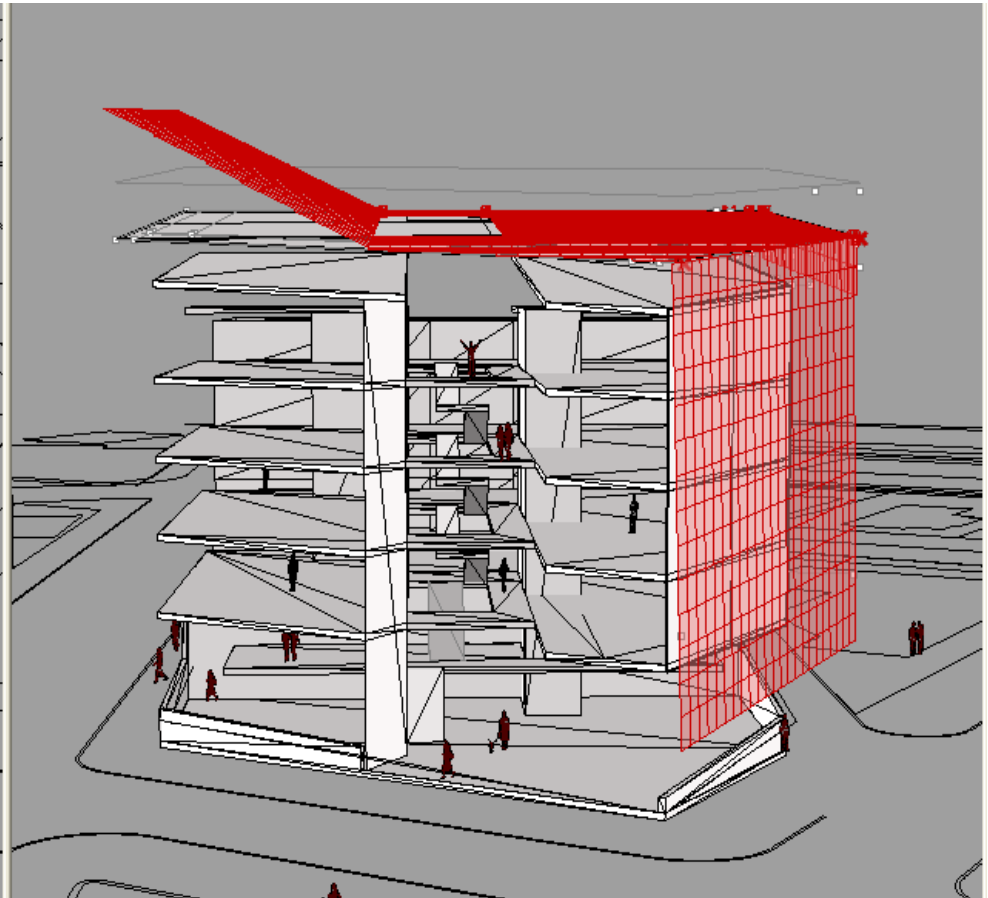
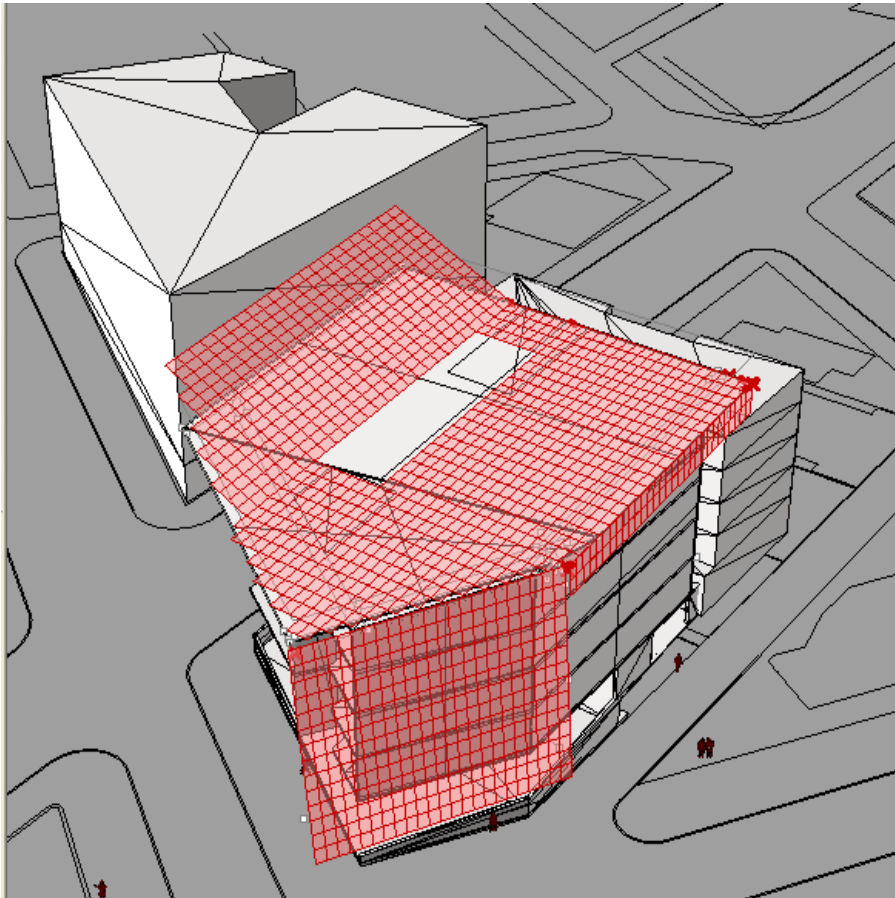
### **Scheme 2 - TILTED ROOF ARRAY (15 deg tilt @ Back):**

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)
		<b>255,000 kWh/yr (+9K v. BASE)</b>

# Net Zero Energy - PV



## Scheme III



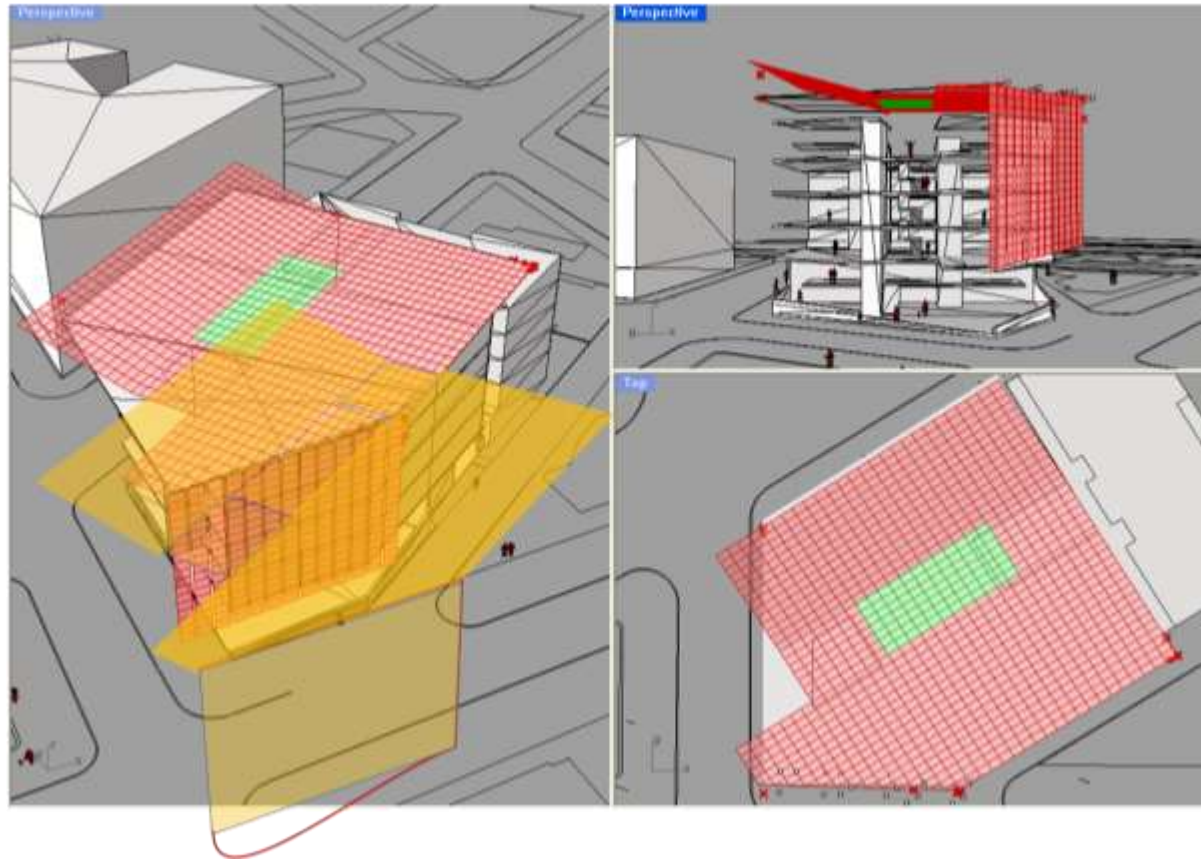
### **Scheme 3 - TILTED ROOF ARRAY (25 deg tilt @ Back):**

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)
		<b>262,000 kWh/yr (+18K v. BASE)</b>

# Net Zero Energy – PV



## Scheme Ia



### Scheme 1a – South Spaced 10.5” (15 deg tilt @ North Roof):

Panel Orientation	Area	Panel #	Sanyo 205	SunPower 315
ROOF SOUTH (5 deg West):	6,272sf =	(503 panels)	101,500 kWh/yr	(110,500 kWh/yr)
ROOF MIDDLE (5 deg West):	611sf =	(49 panels)	10,000 kWh/yr	
	524sf * 70% = 367sf =	(42 panels)	7,000 kWh/yr	
(Sliding roof section)	1,048sf * 75% = 785sf =	(84 panels)	12,000 kWh/yr	
ROOF NORTH (5 deg West & 15 deg SE):	4,539sf =	(364 panels)	78,500 kWh/yr	(85,500 kWh/yr)
SOUTH WALL:	2,918sf =	(234 panels)	36,000 kWh/yr	
		(1276 panels)	<b>245,000 kWh/yr</b>	<b>(261,000 kWh/yr)</b>



# Sunpower 425

SPR-425E-WHT-D



Number of modules	570
Unit Nom. Power	425 W
Peak System Output	227 kW
Produced Energy	242,000 KWH/yr
Panel Efficiency (STC)	19.7%
System Efficiency	~16%



# Building Site



PHOTO: STAMETS



# Overview

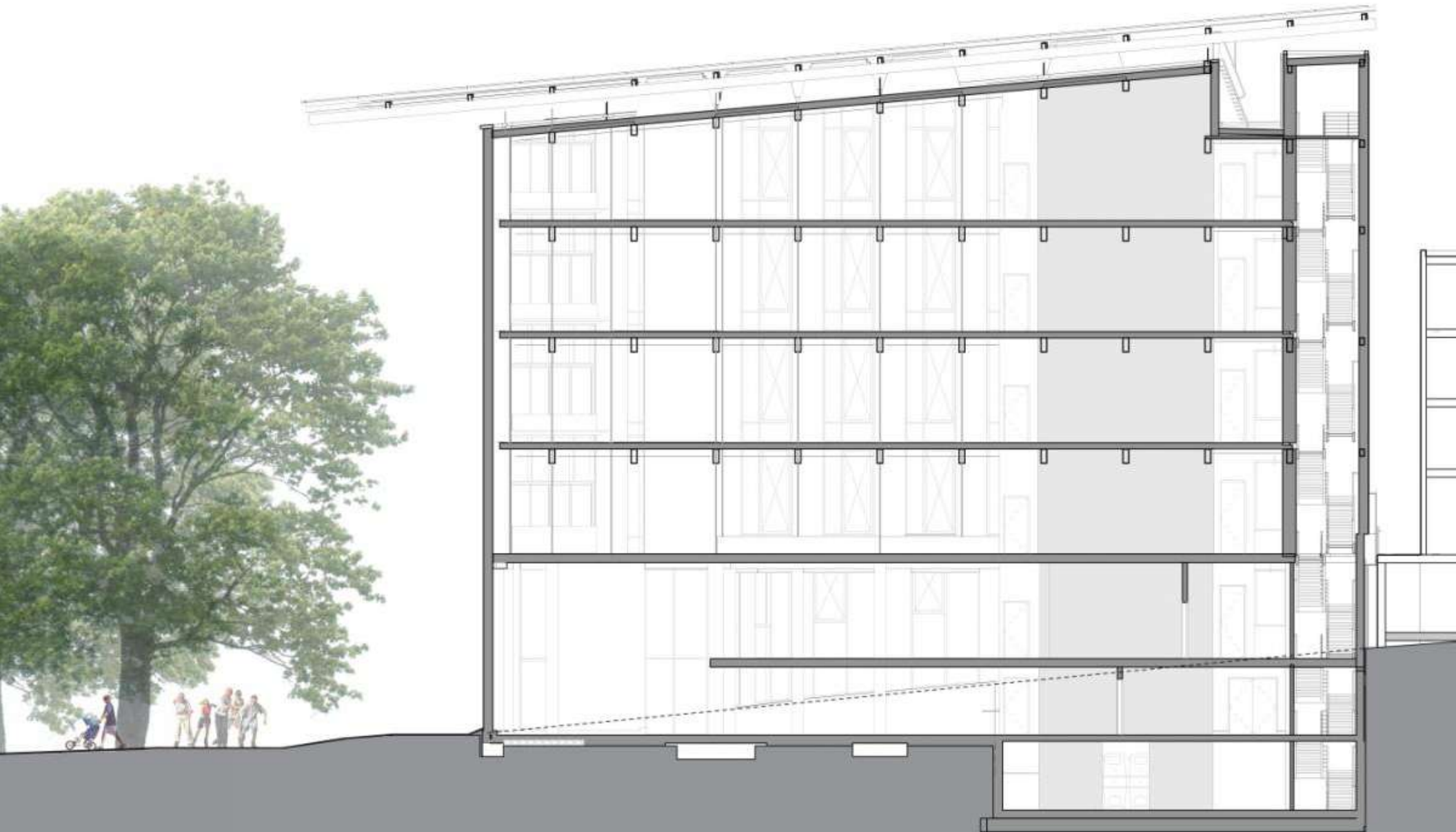




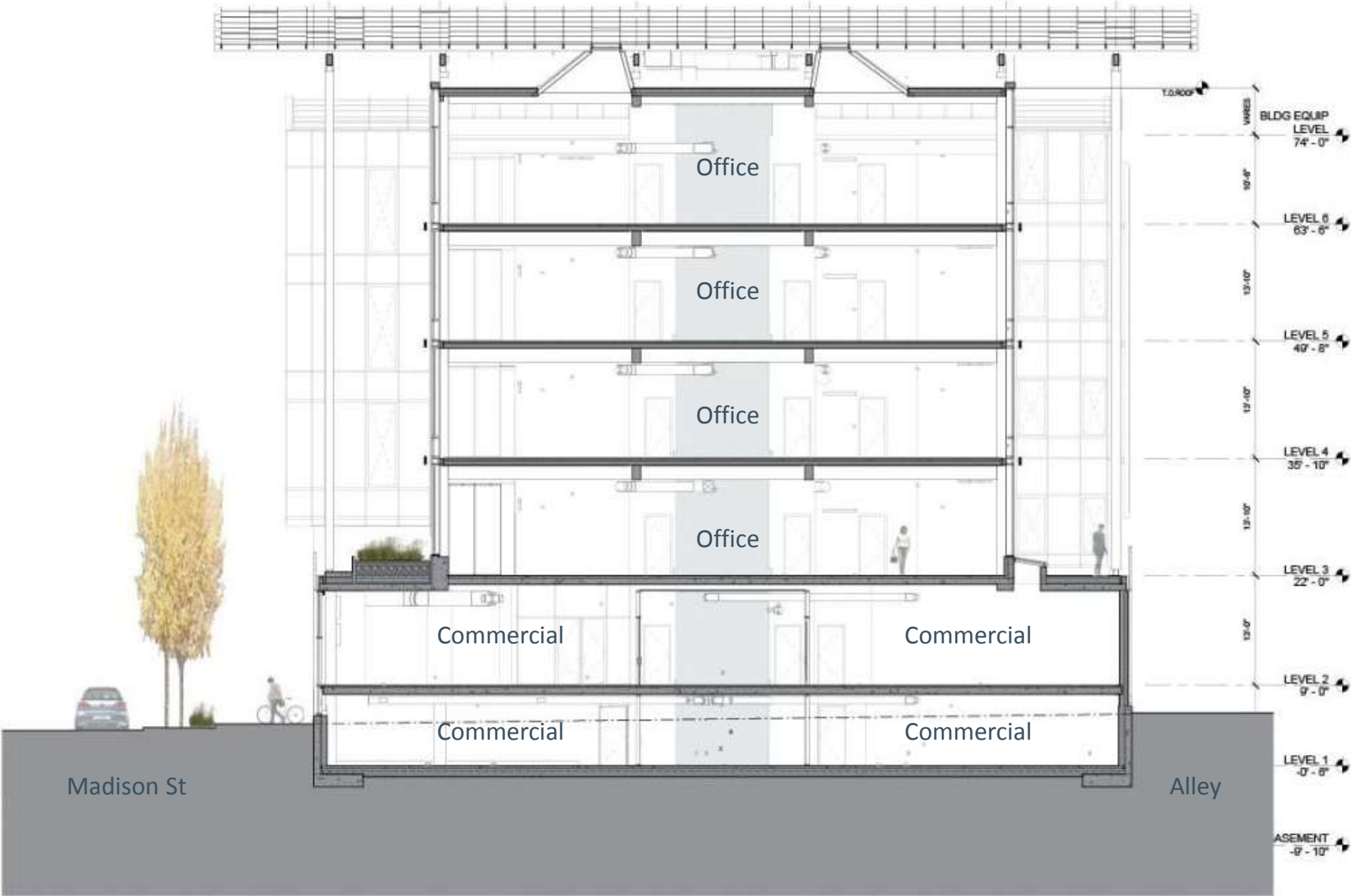
# Typical Tenant Floor



# Section Looking North



# Section Looking East









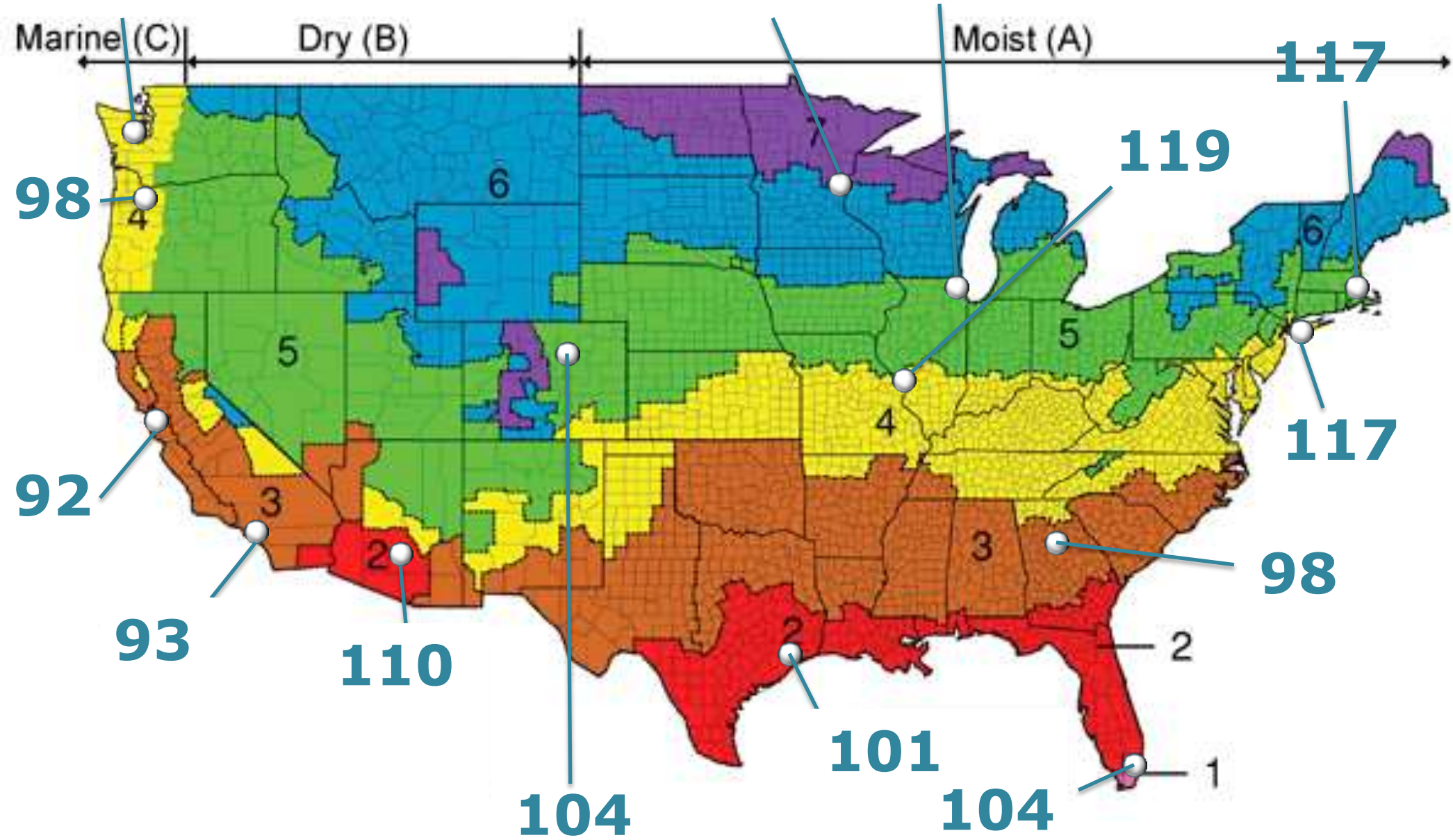
# Average Building Energy Use



EPA Target Finder Score of 50 (Median EUI)

**98**

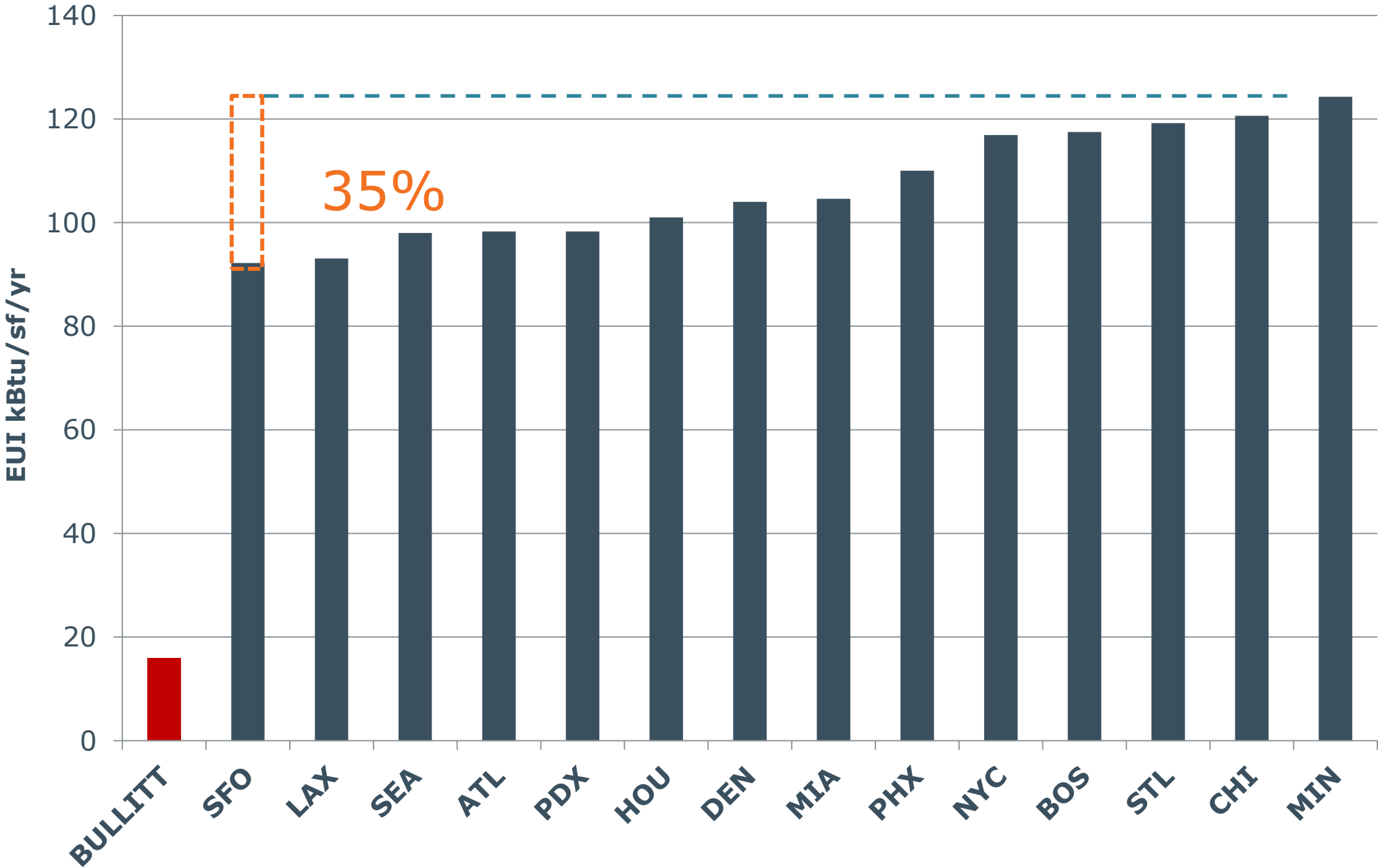
**124 120**



# Average Building Energy Use



EPA Target Finder 50 Score Bldg Energy Use

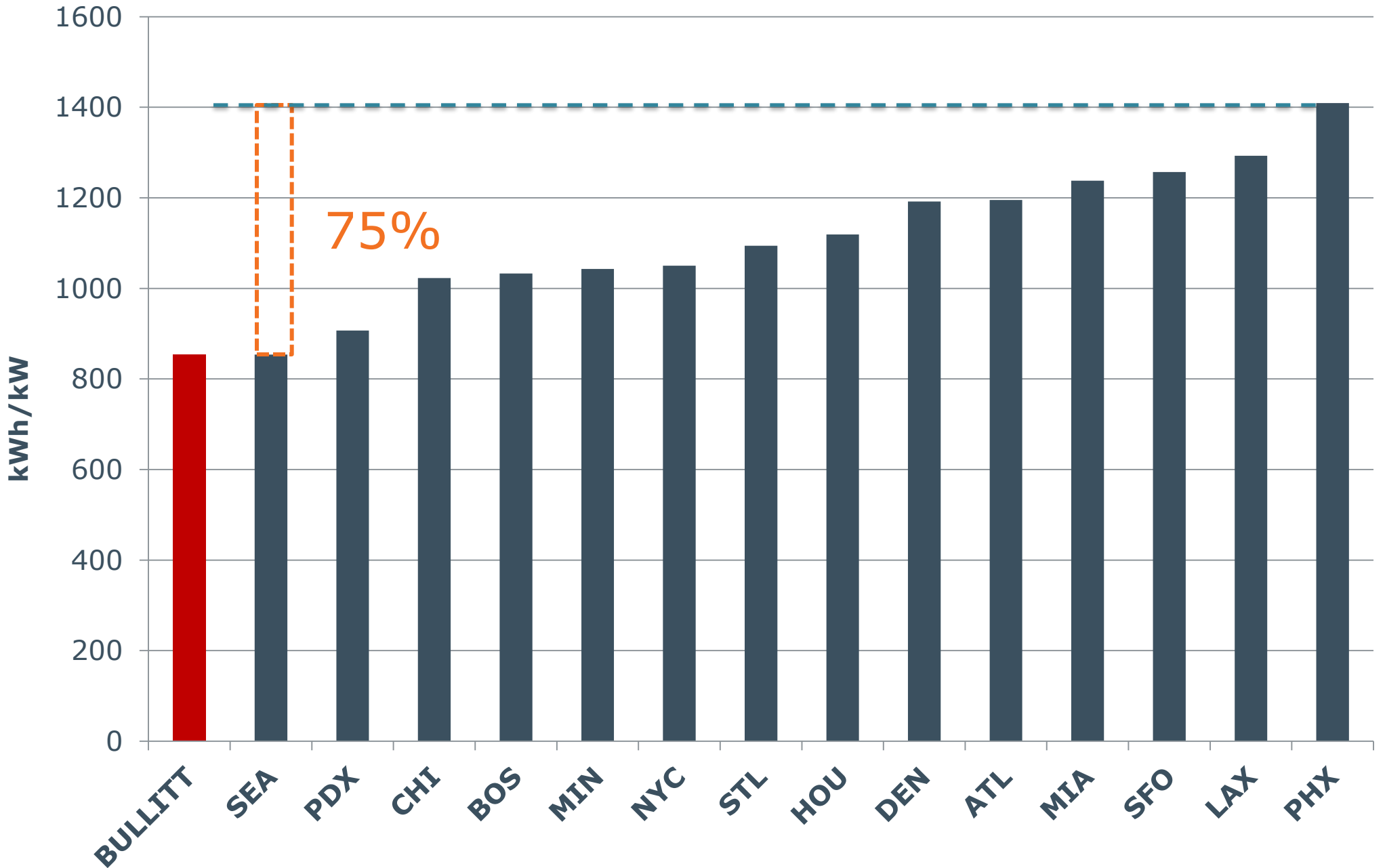




# PV Production by City



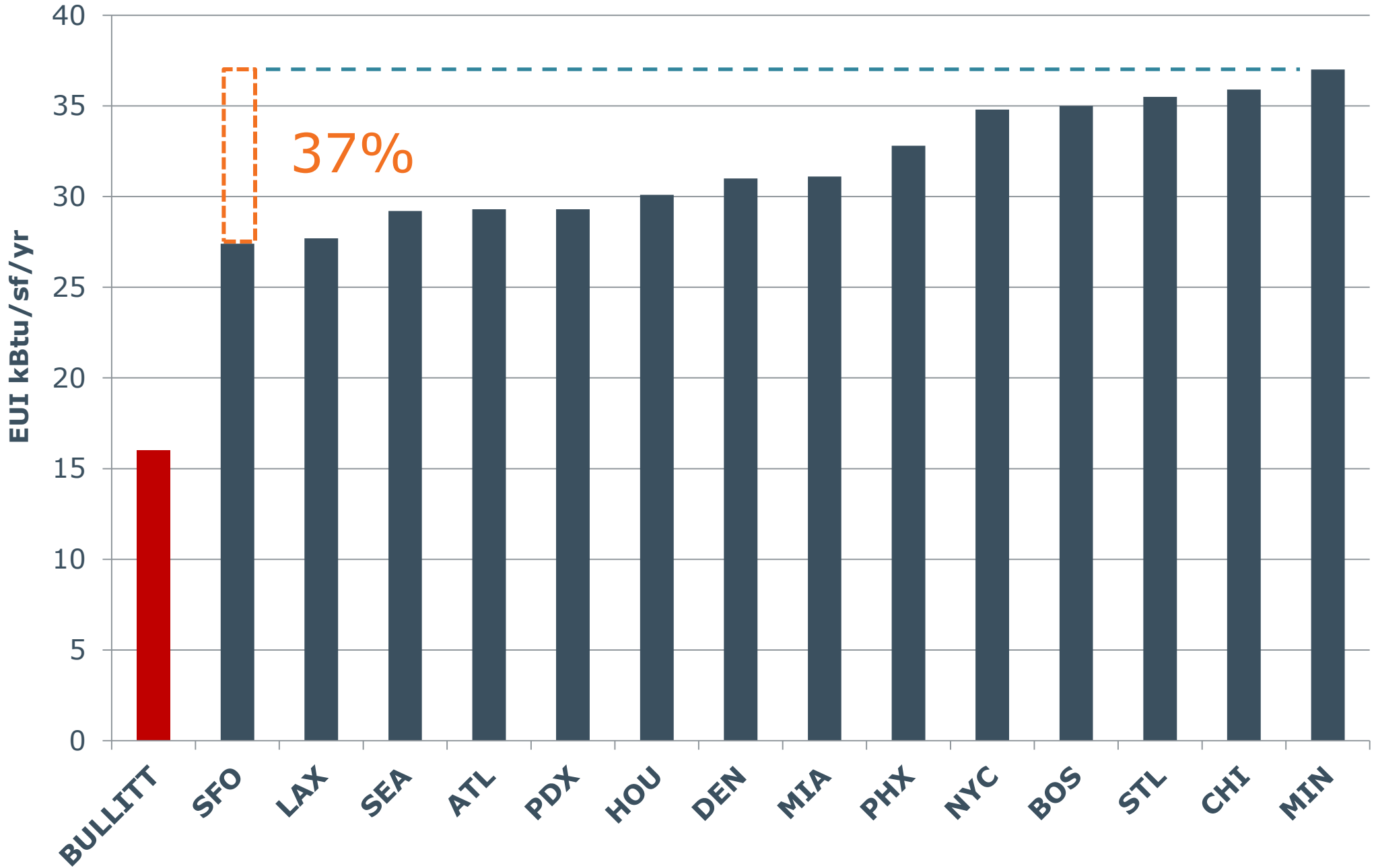
## Solar Power Generation at Horizontal



# "Best" Building Energy Use



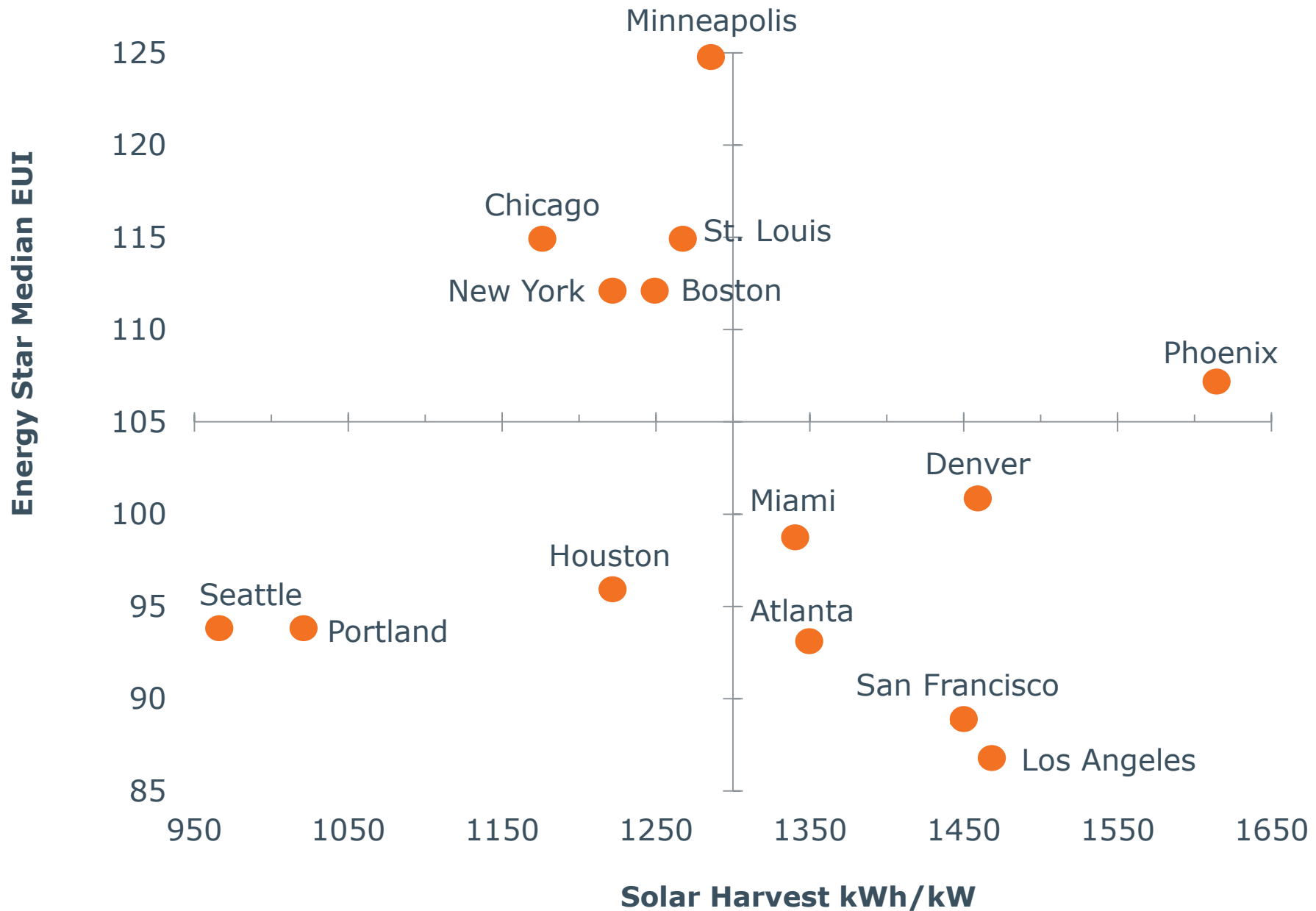
EPA Target Finder 100 Score Bldg Energy Use



# Energy Use & PV Production



## National Solar Harvest vs. Median EUI

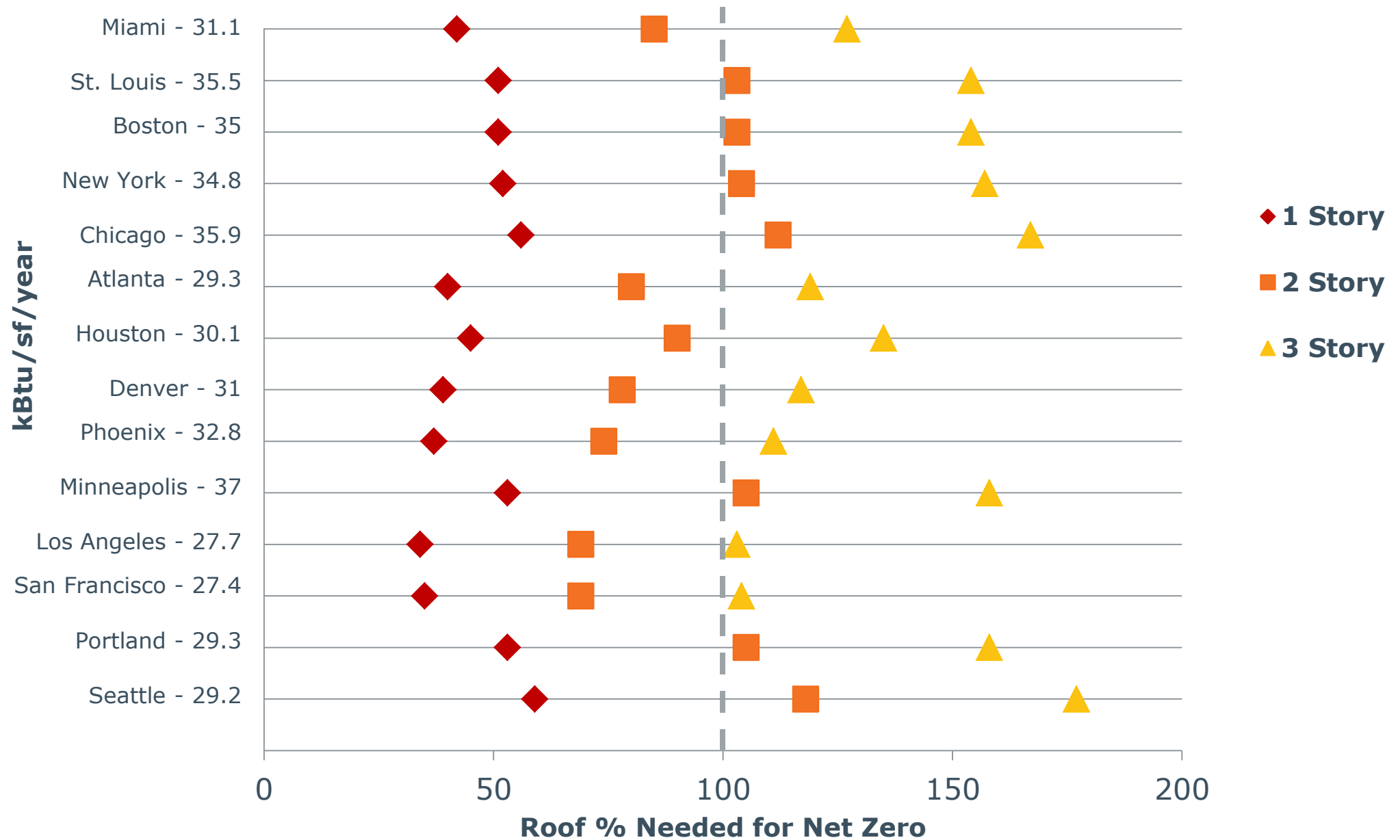




# Target Finder Score of 100



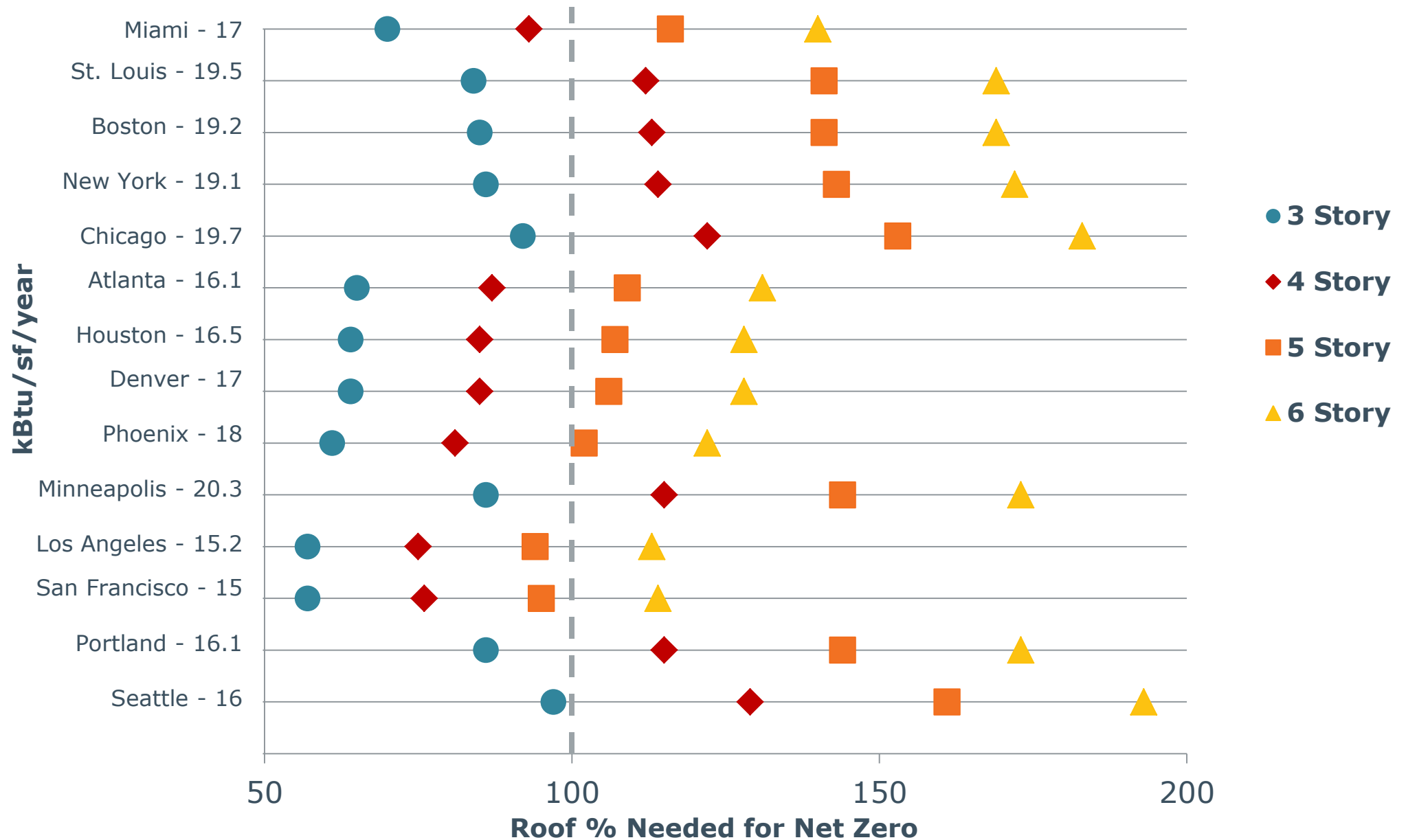
## % of Roof Area to Achieve Net Zero



# Bullitt Center Equivalent Buildings



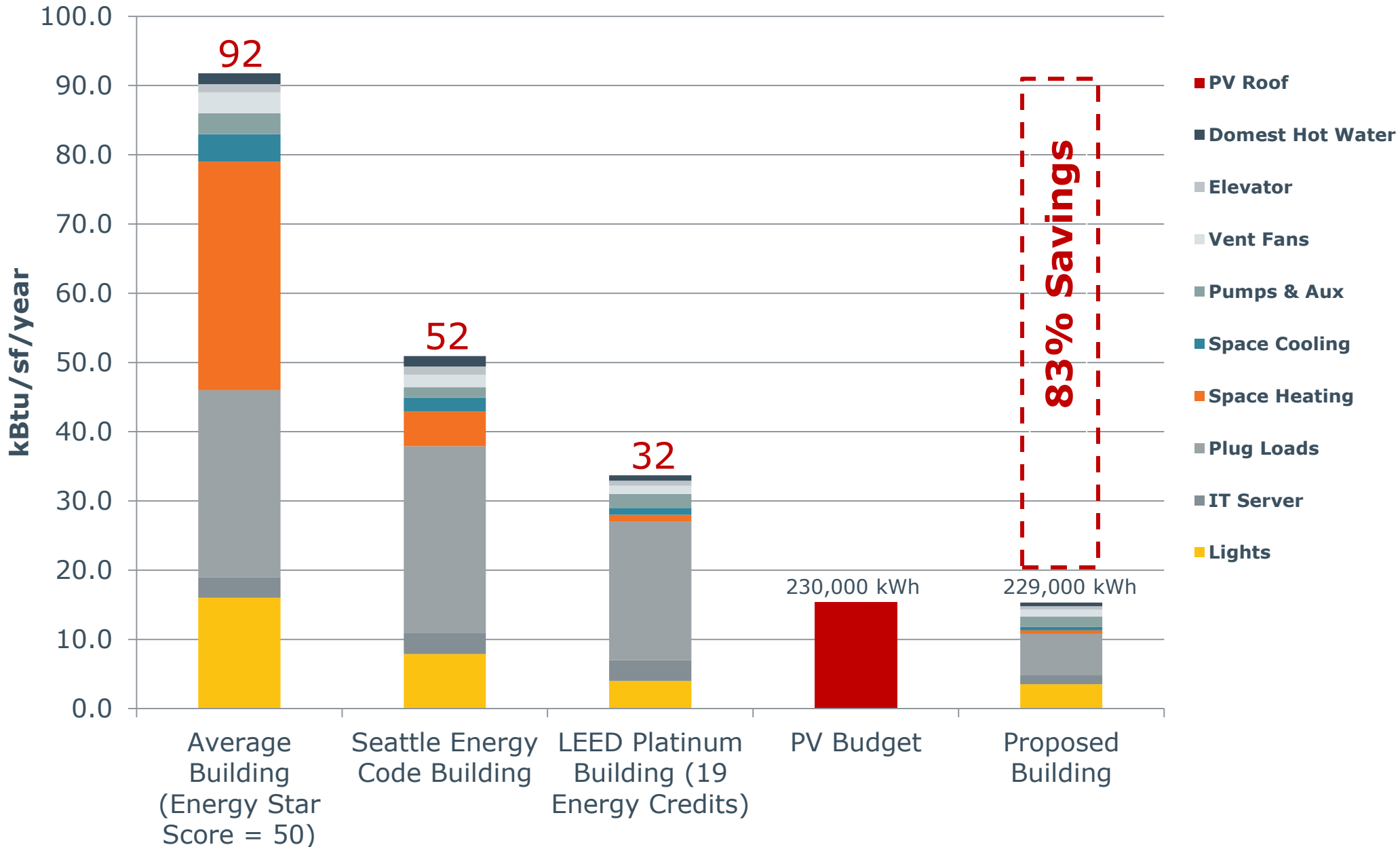
## % of Roof Area to Achieve Net Zero



# Net Zero Energy in Seattle



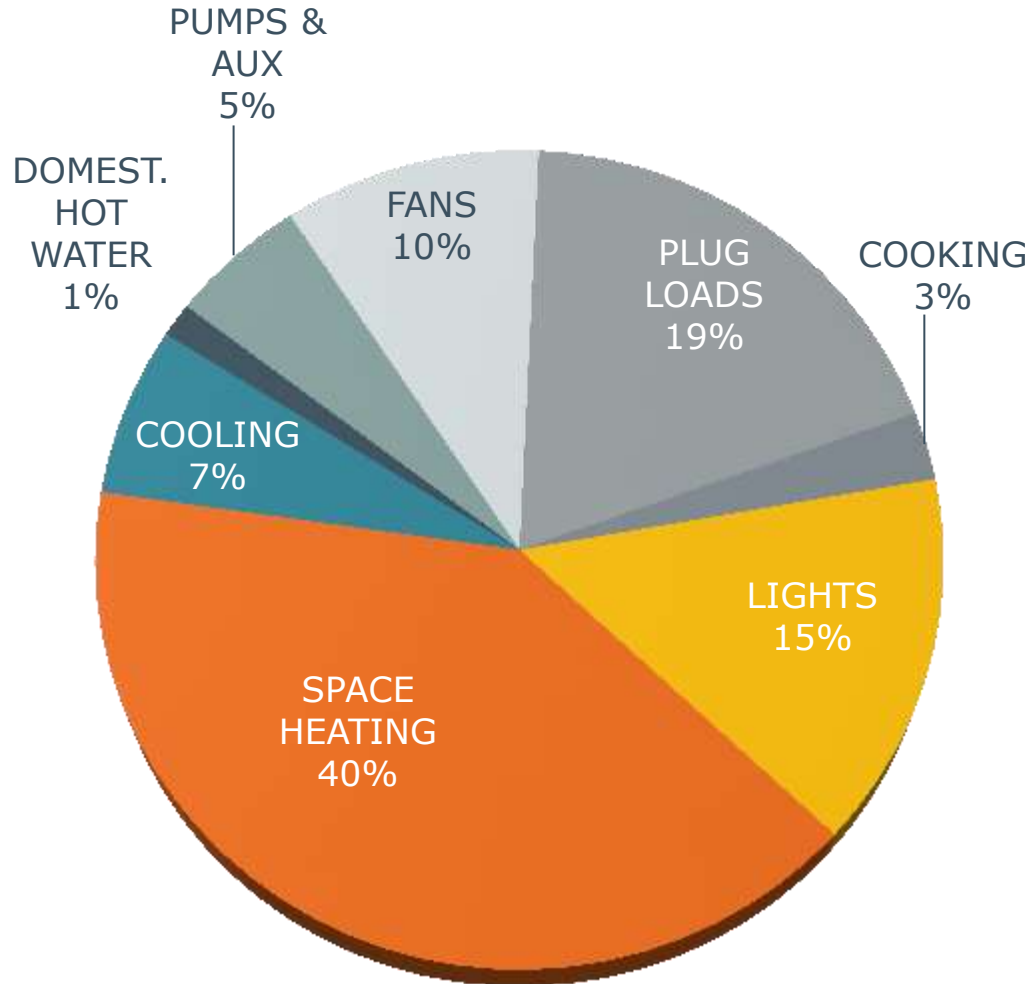
## Energy Use + Solar Budget



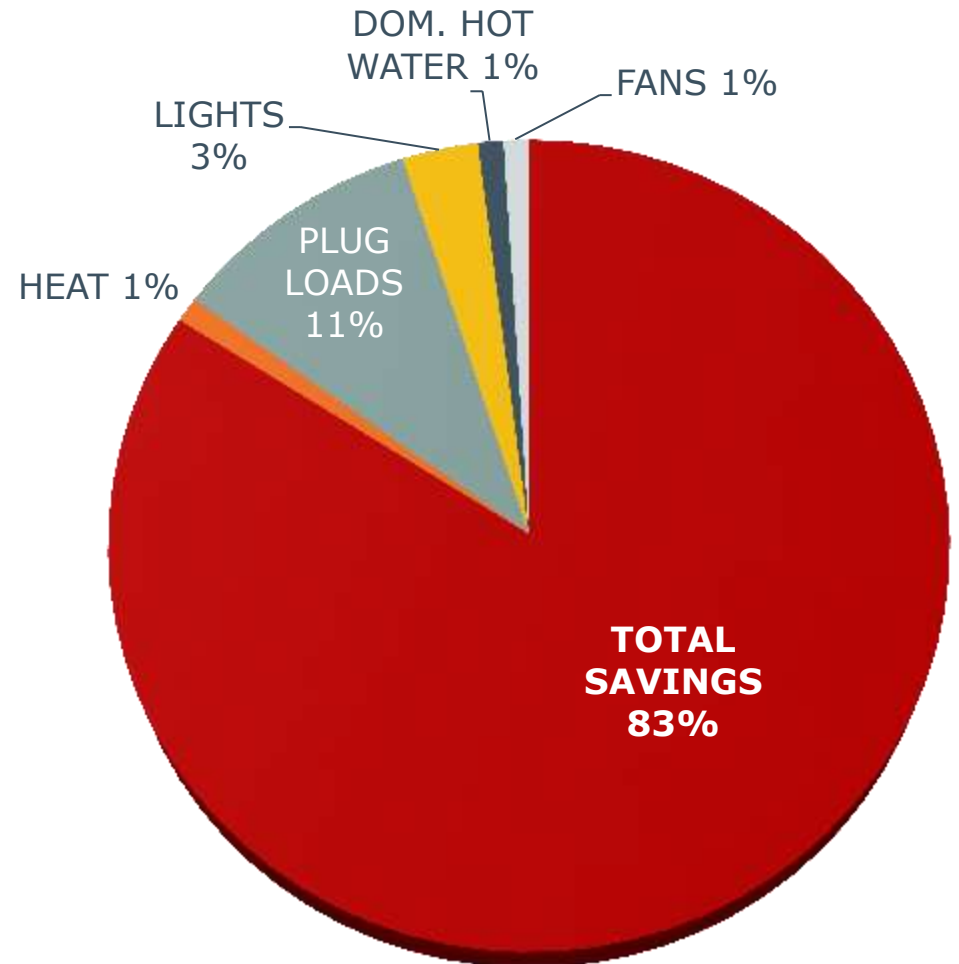


# Net Zero Energy

## Energy Consumption

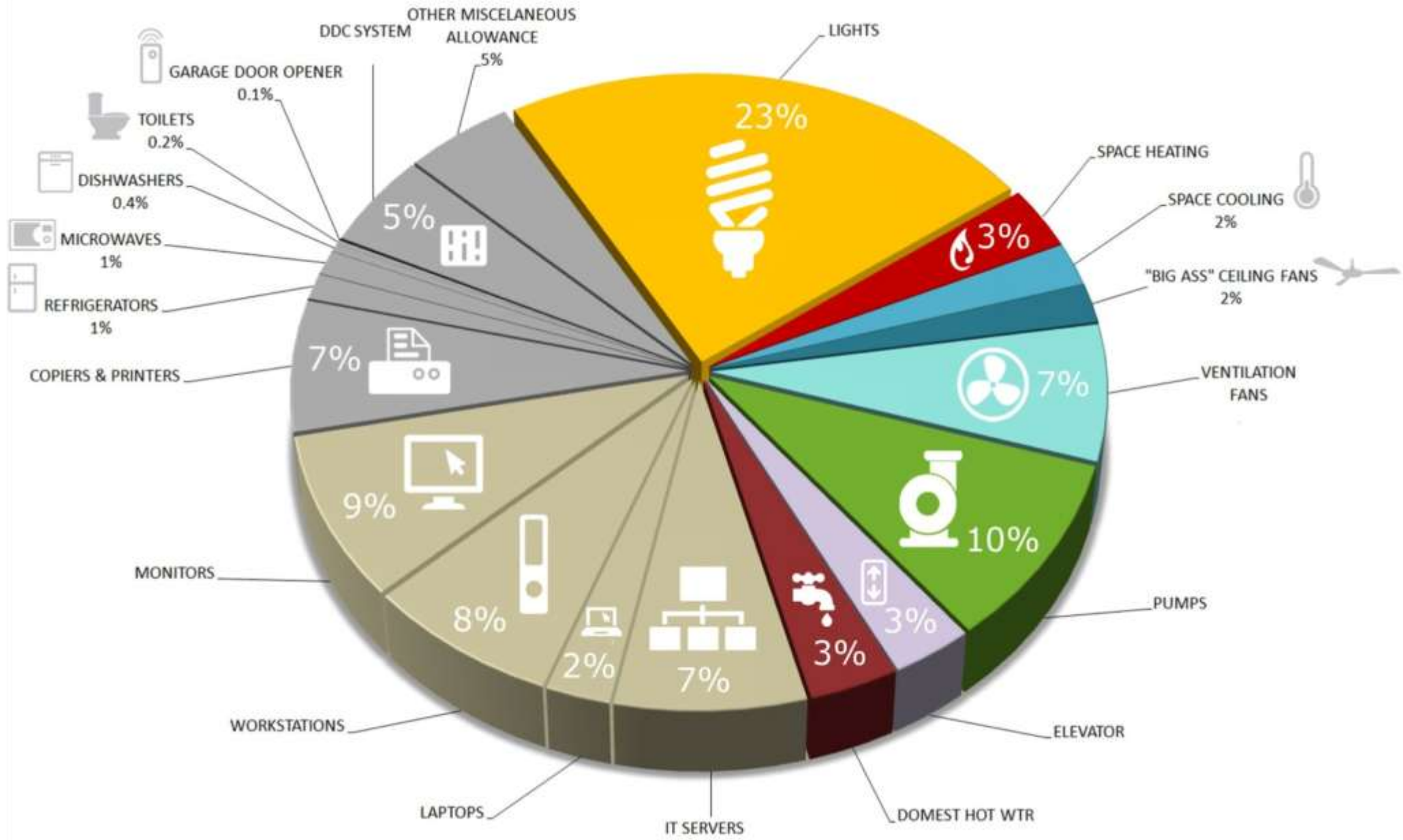


*Typical Building*



*Proposed Building*

# Proposed Building Energy Use



# Building Envelope



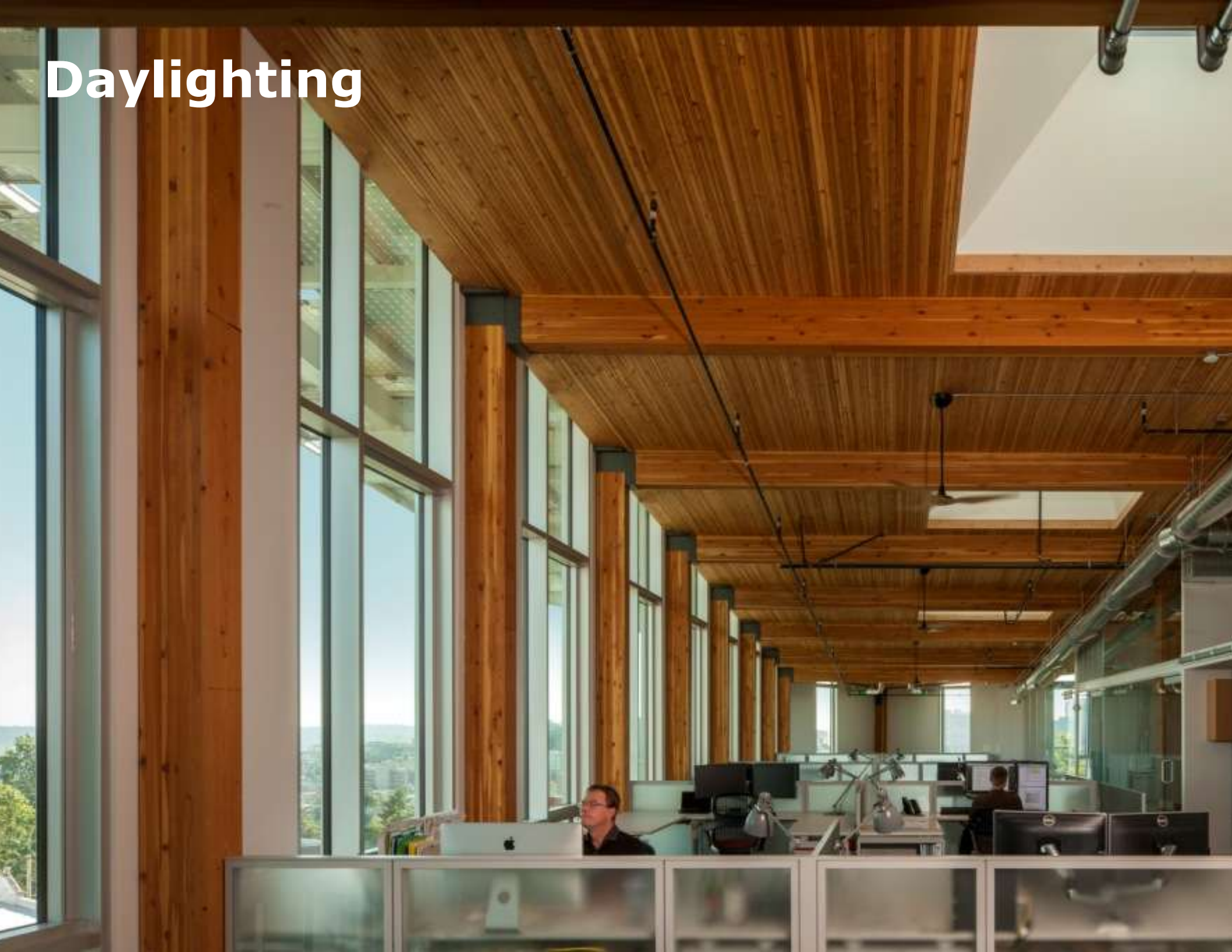


# Goals

Envelope + Lighting (watts/sf)

Envelope	2012 Seattle Code	Bullitt Center
Roof	R-38	R-38
Wall	R-19	R-21.4
Glazing	R-2.5	R-4 VT = 0.53
Infiltration	0.40 cfm/sf (New)	.24 cfm/sf

# Daylighting



# Reducing Plug Loads

2007



20" CFL-LCD



75  
watts

20" CFL-LCD



75  
watts



100  
watts

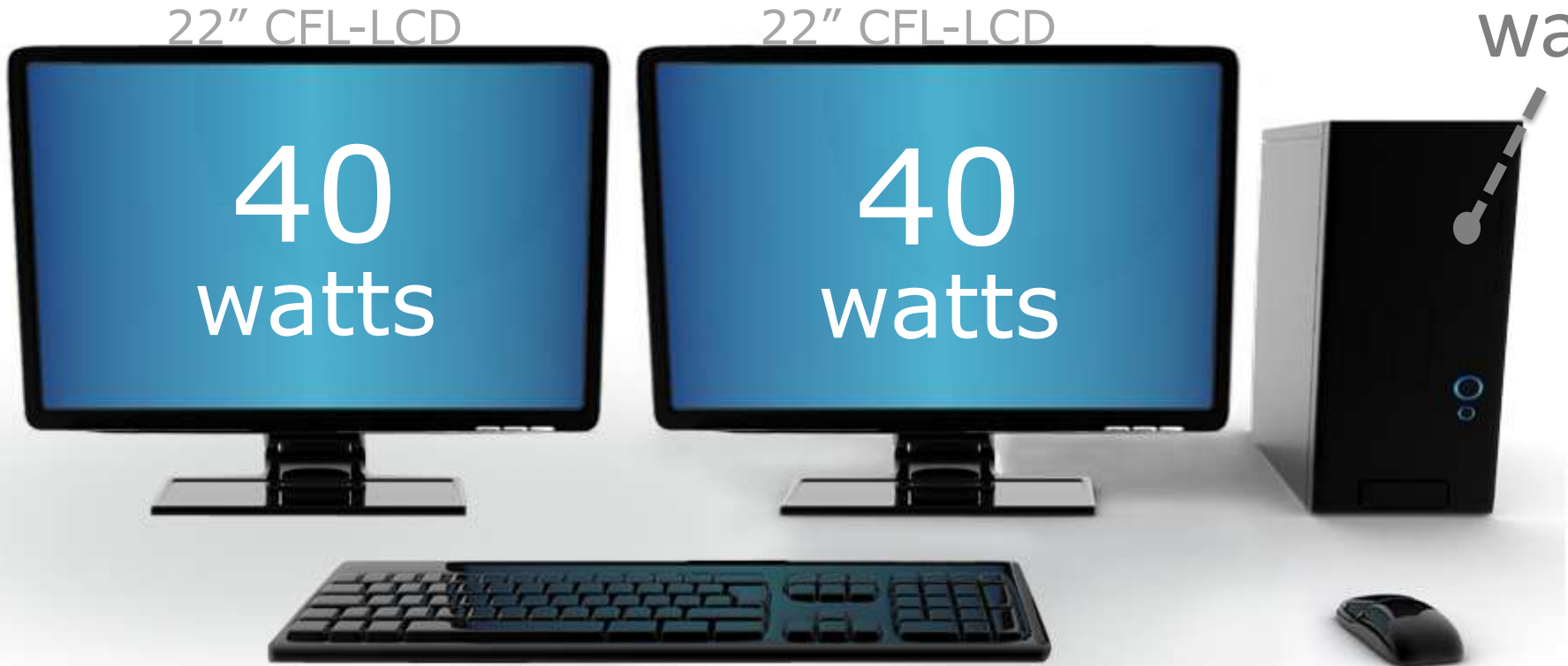


250 watts



# 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**



# Product Inventory

2013

BUDGET	
Daily kWh	0.3
Annual kWh	<b>84016</b>
Budget	<b>84768</b>
STATUS	
APPROVED	



	QTY	W/ea	HRS / DAY	ENERGY (kWh/Day)		Days/yr	kWh/yr
<b>Collocated Server</b>							
IT Equipment	1	2212	24.00	53		365	19,379
<b>Kitchen</b>							
Refrigerator	6.5	200	12	16		365	5,694
Microwave	6.5	1000	1.56	10		252	2,555
Coffee Pot	6.5	1000	3	20		252	4,914
Dishwasher	6.5	500	2	7		252	1,638
<b>Open Office</b>							
Laptop Computer	35	40	8	11		252	2,822
PC	112	51	8	46		252	11,515
Thin Client	26	20	8	4		252	1,048
Monitor	286	25	8	57		252	14,414
Personal Misc (per person)	173	15	6.1	16		252	3,989
<b>Conference Room</b>							
TV display or projector	15.0	110	8	13		252	3,326
<b>Copy Room</b>							
Copier	8.6	1100	3.91	37		252	9,321
<b>Misc. Equipment</b>							
Ceiling Fan	31	290	1.5	13		252	3,398
							<b>84,016</b>

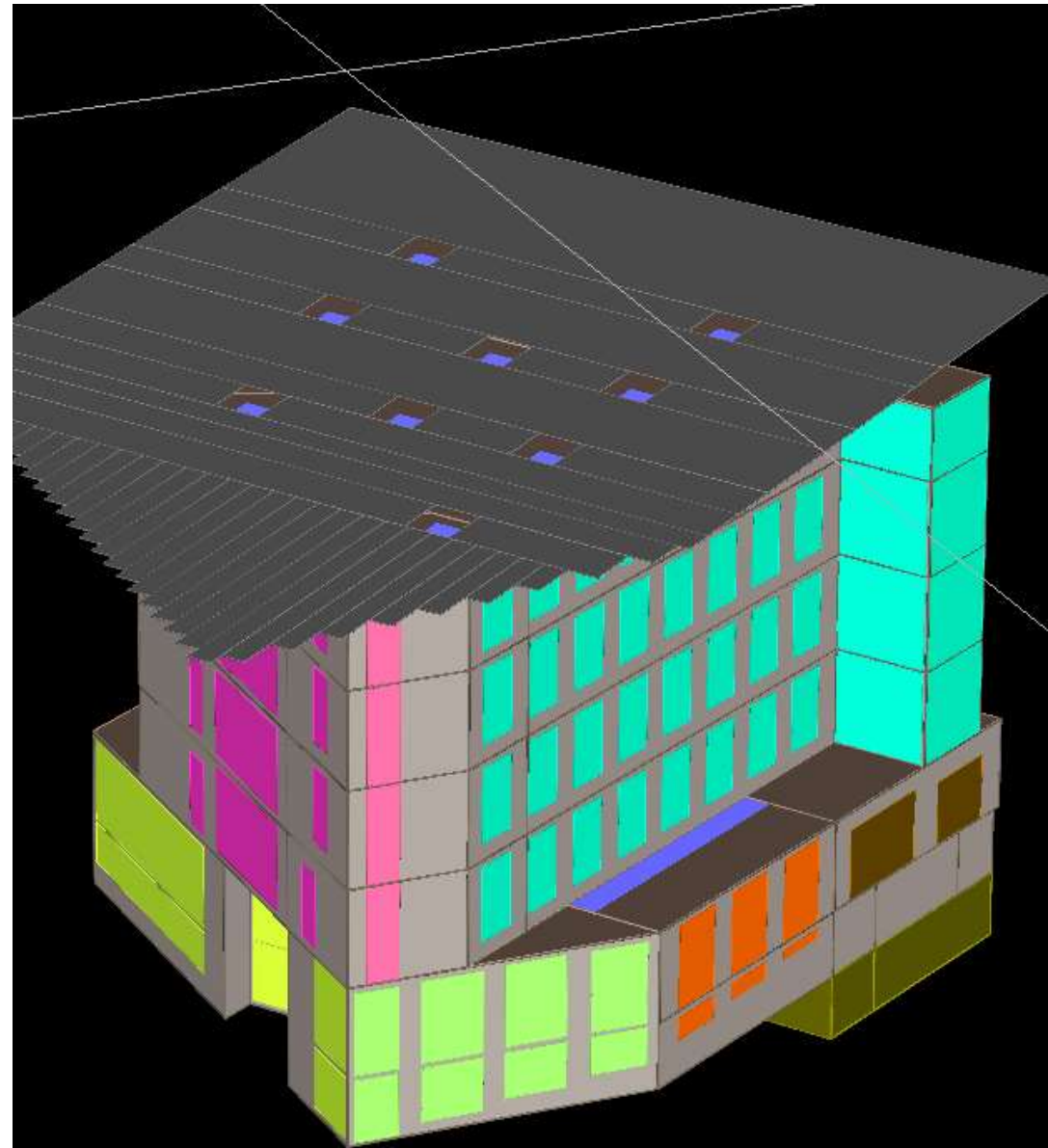
# Comfort Analysis

Tool: Bentley Tas



## Hourly natural ventilation analysis

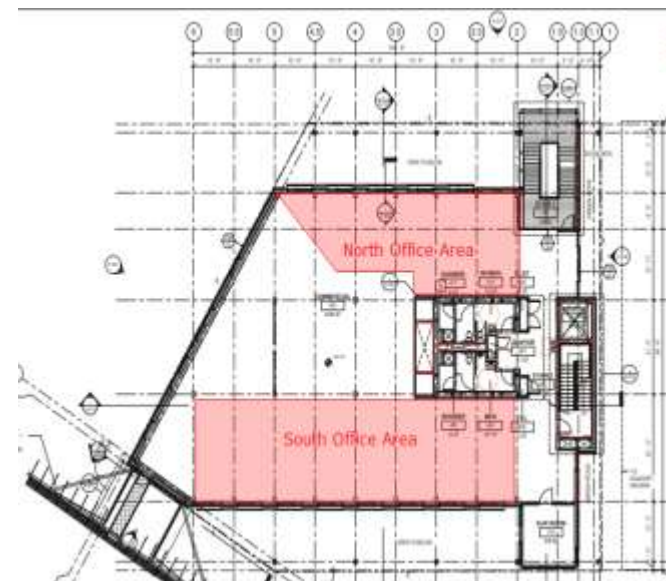
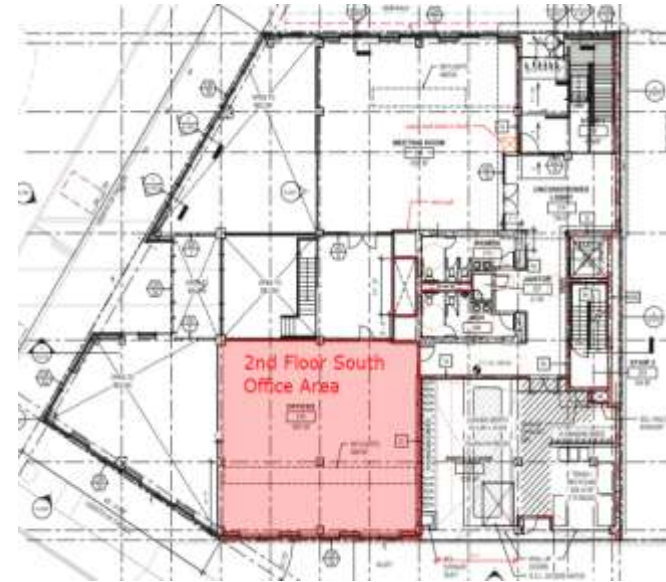
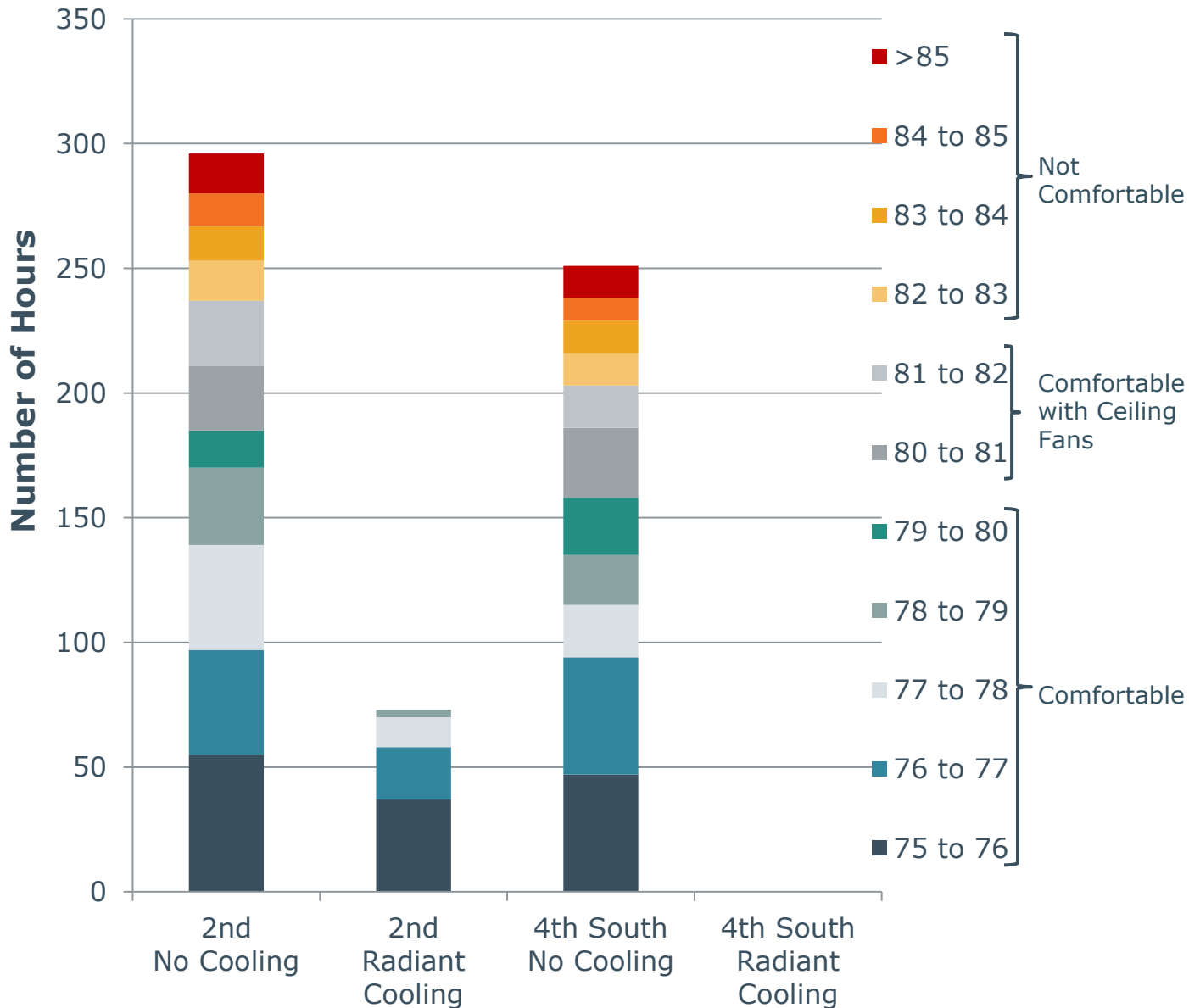
- Multi-zone
- Single-sided, cross-flow, stack-drive ventilation
- Accounts for thermal mass effects
- "Operates" building openings based on user inputs



# Bullitt Center Comfort Study



## Total Hour Space Temperature Falls in 1°F Bins

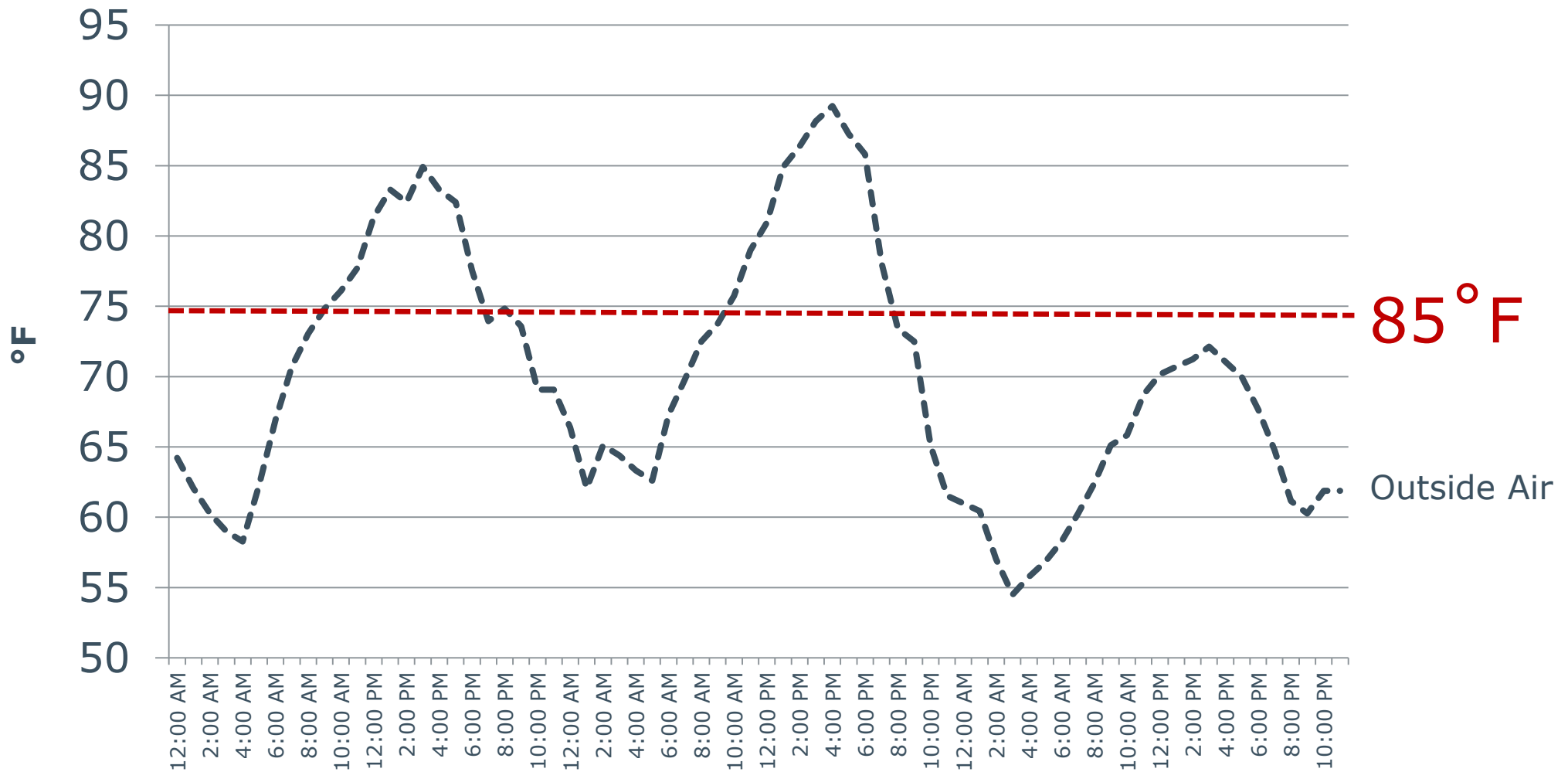




# Passive Cooling



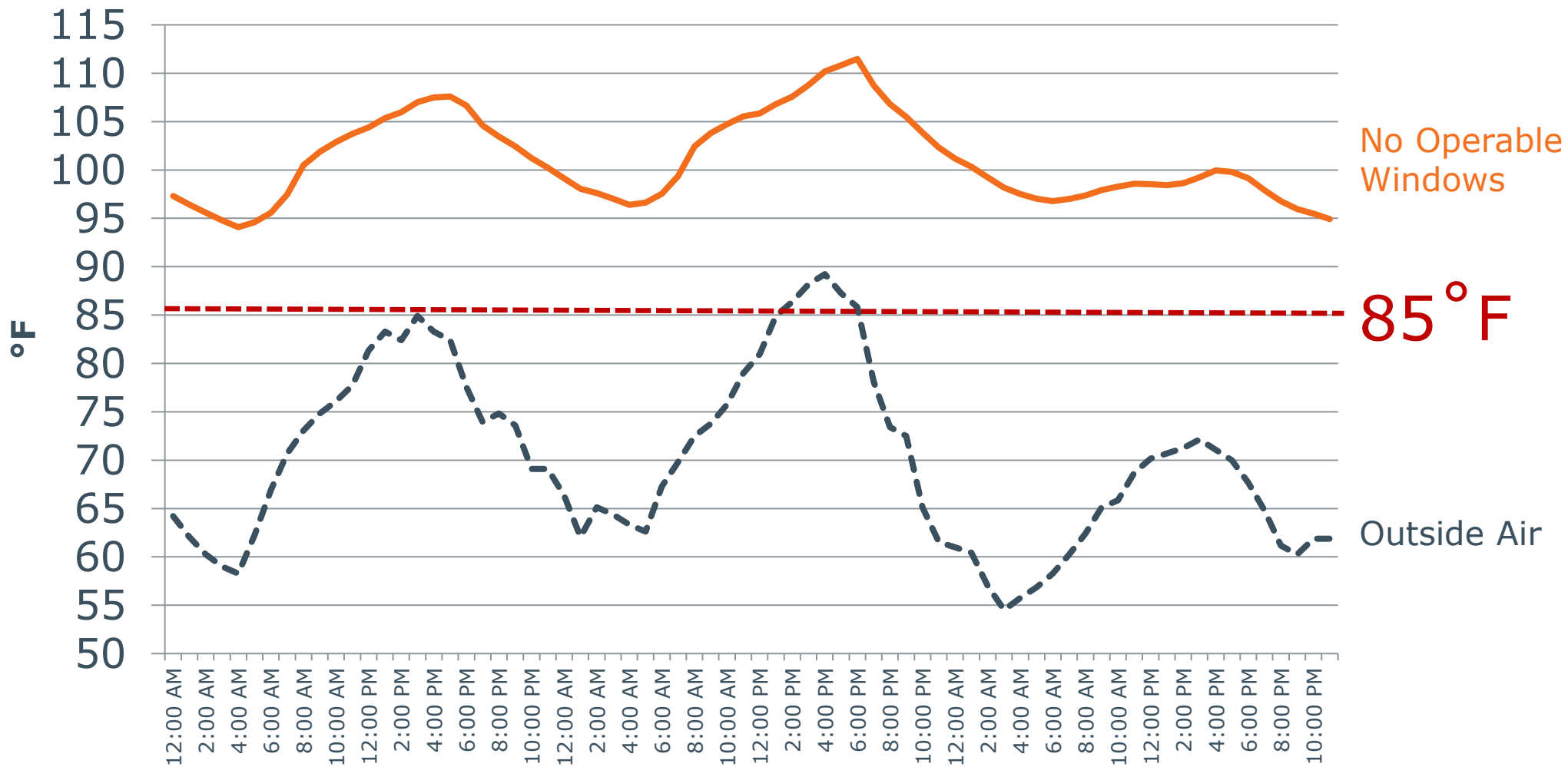
Zone Temperature for South Office Space w/o Mechanical Cooling  
August 9th-11th (Thurs-Sat)



# Passive Cooling



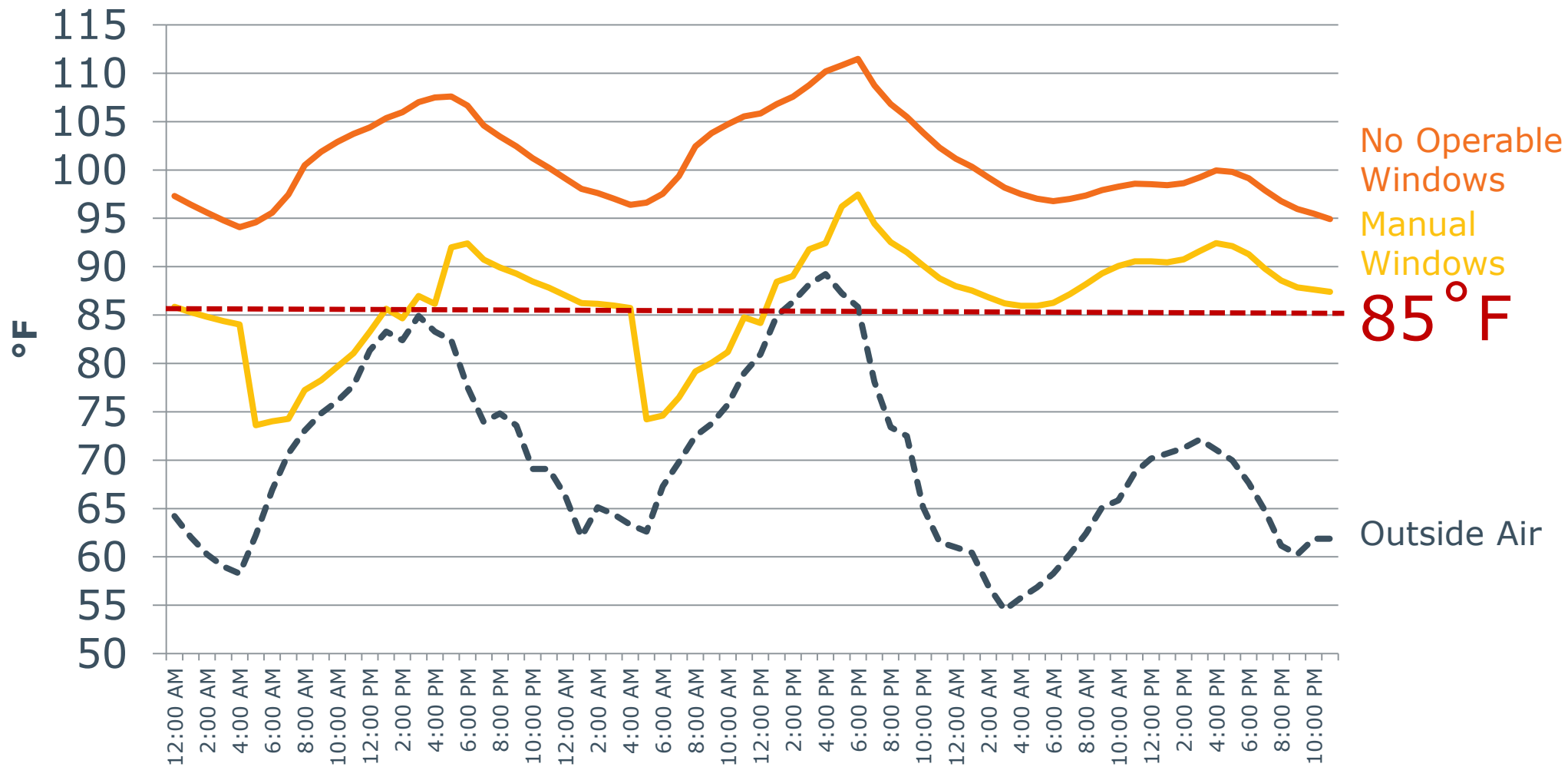
Zone Temperature for South Office Space w/o Mechanical Cooling  
August 9th-11th (Thurs-Sat)



# Passive Cooling



Zone Temperature for South Office Space w/o Mechanical Cooling  
August 9th-11th (Thurs-Sat)

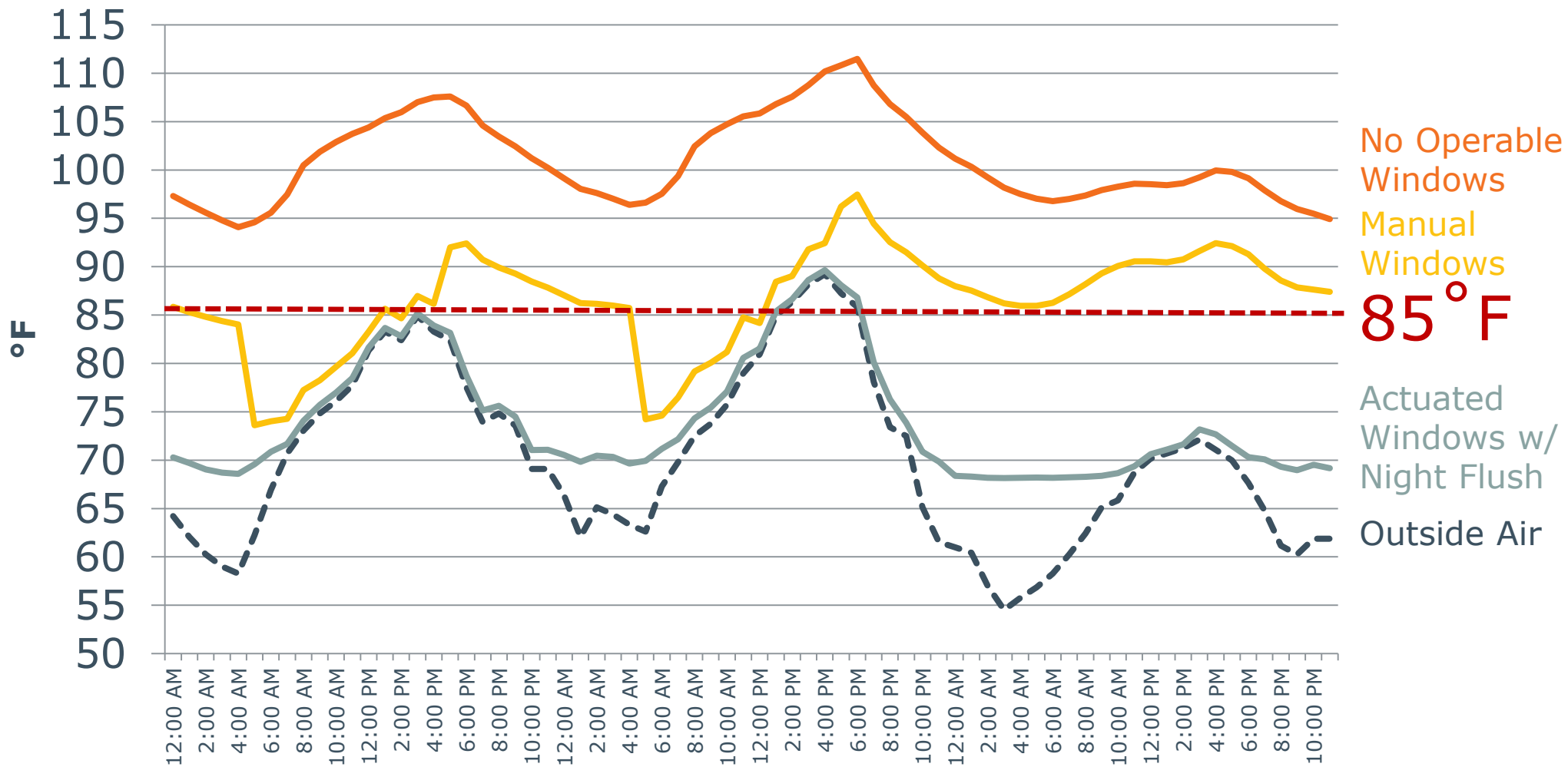




# Passive Cooling

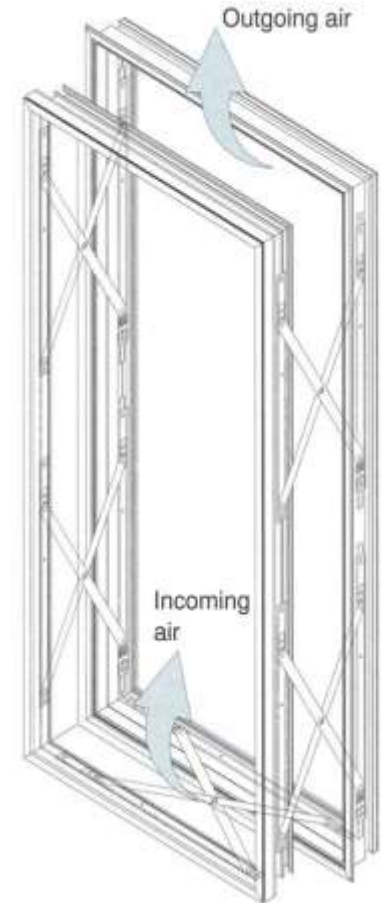
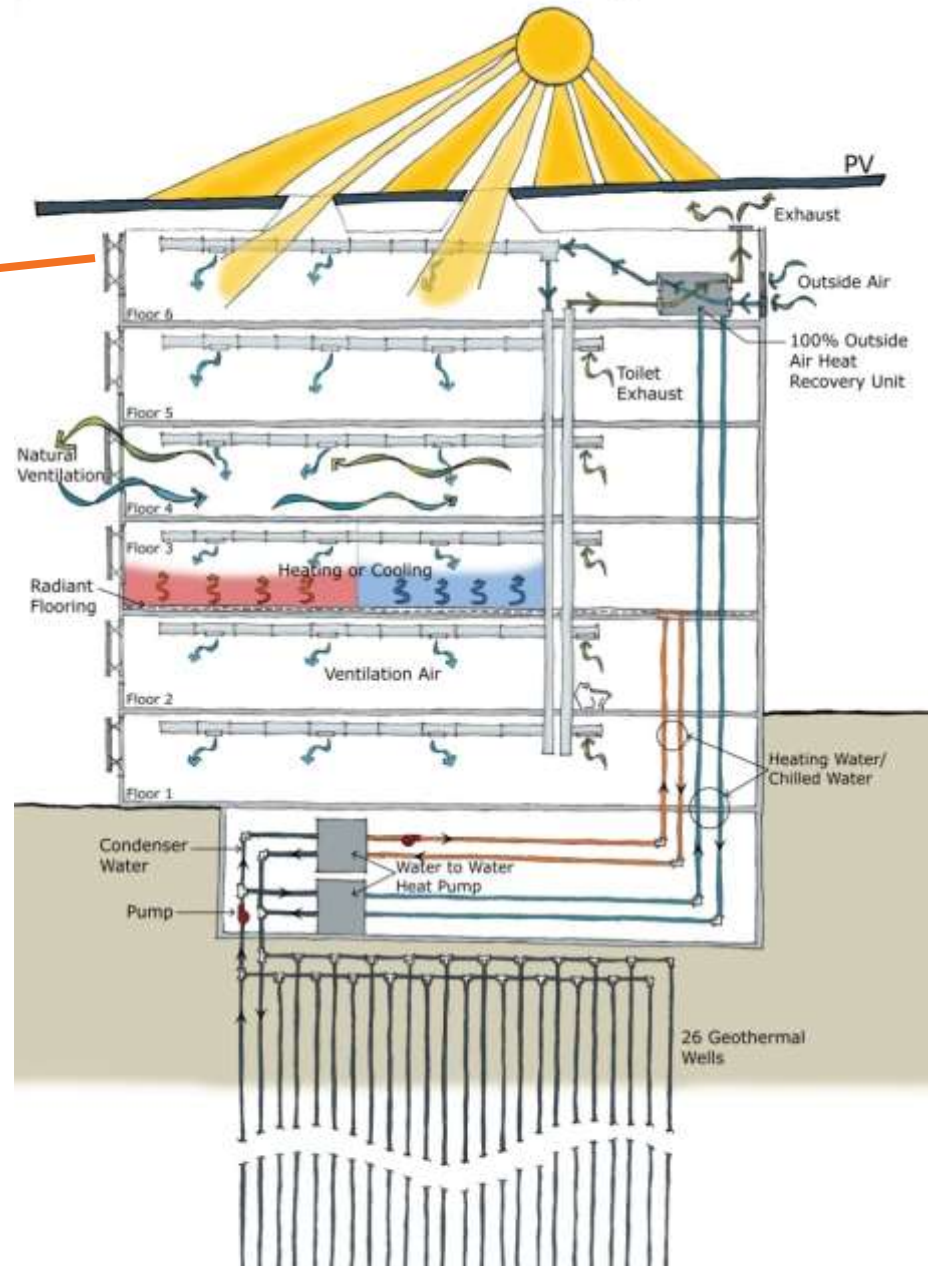


Zone Temperature for South Office Space w/o Mechanical Cooling  
August 9th-11th (Thurs-Sat)



# Bullitt Center

## HVAC System Overview

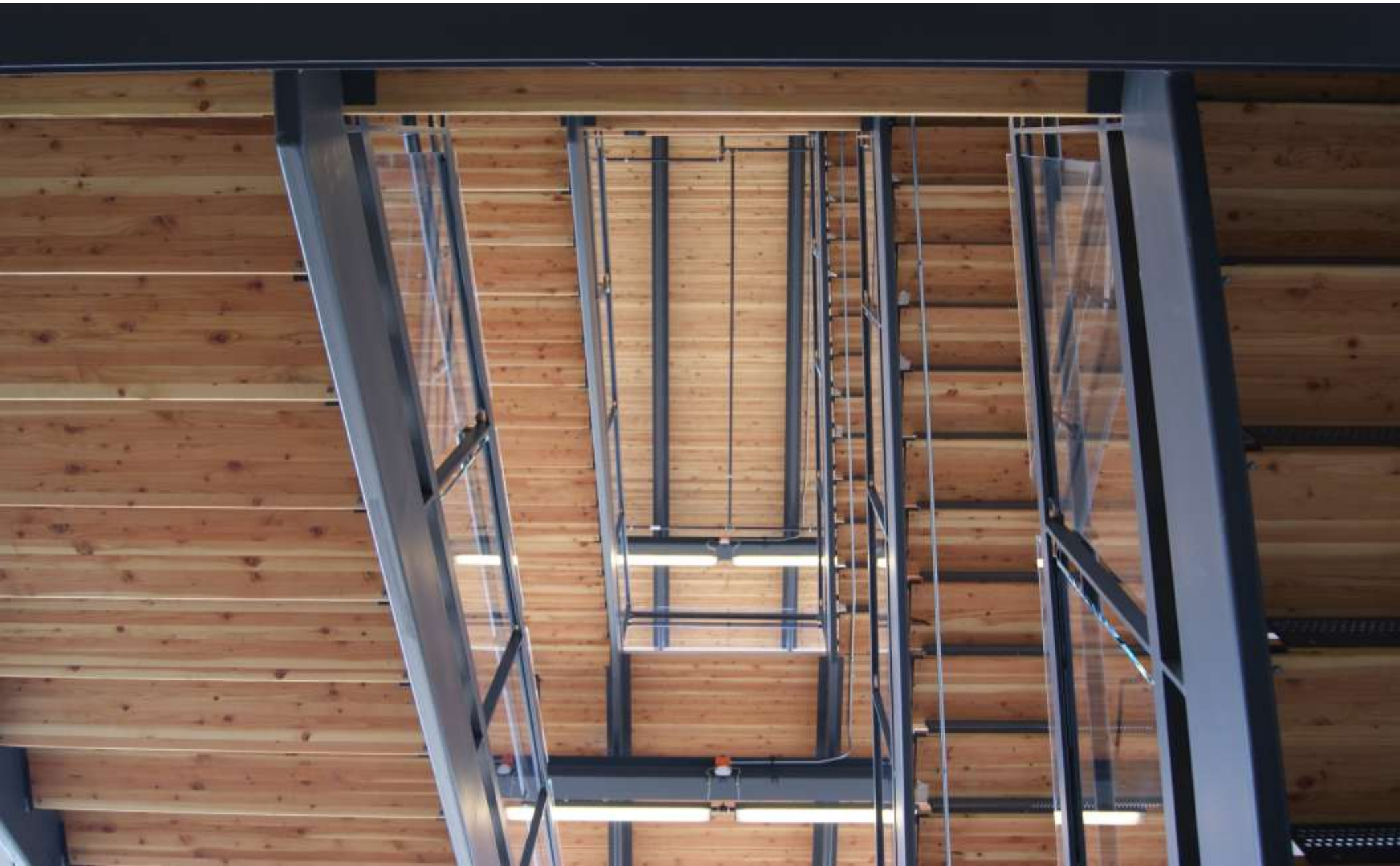


# Radiant Floor

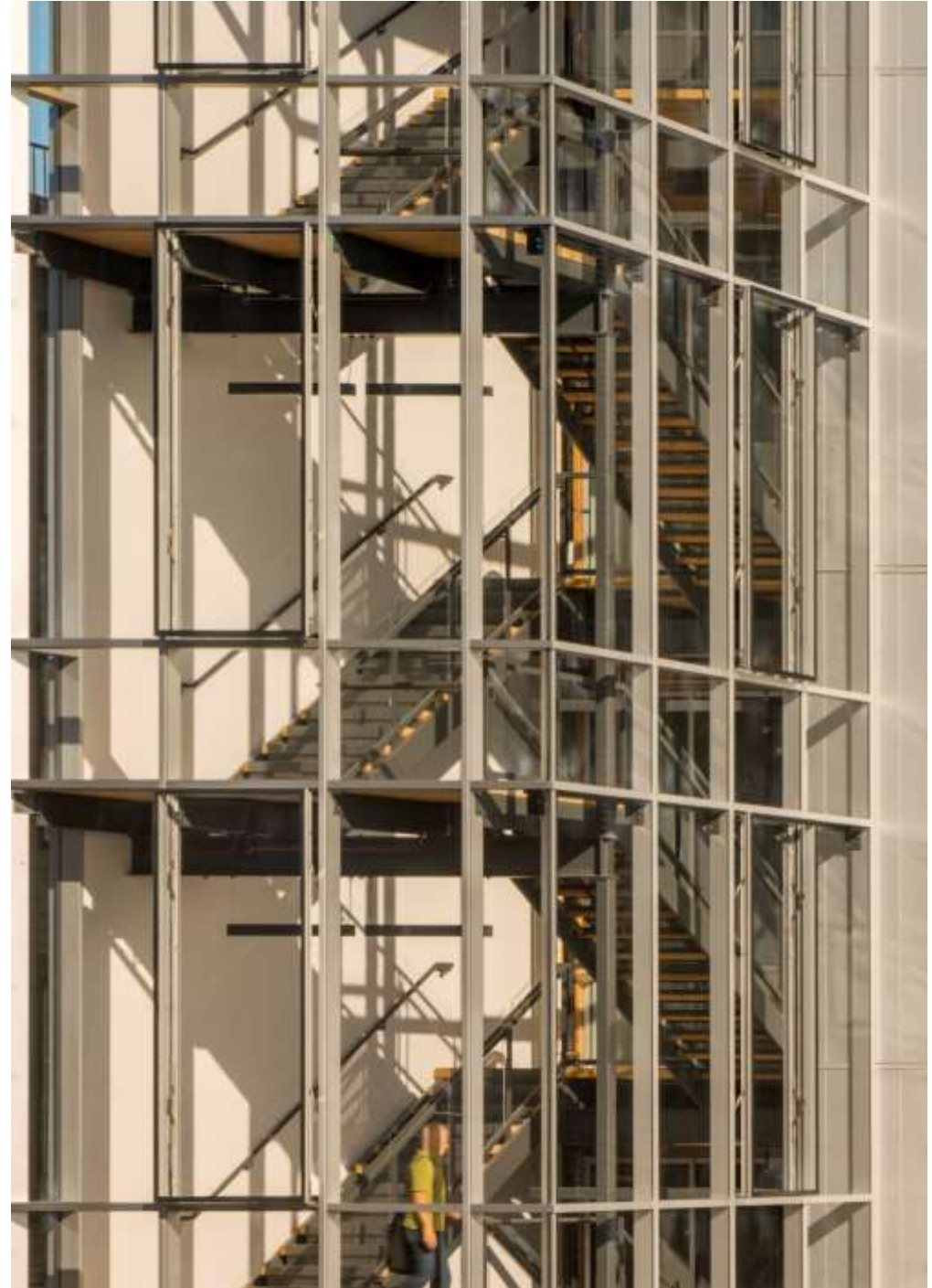




# Irresistible Stair



# Irresistible Stair





# 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

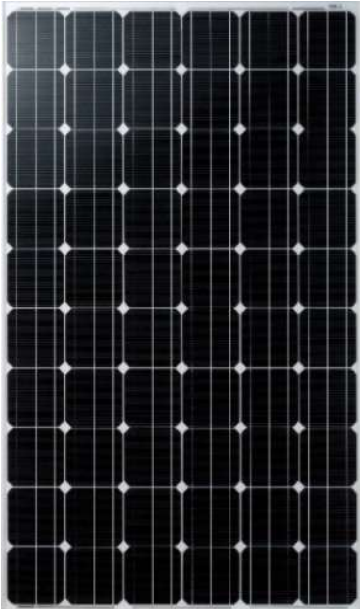
**\$350 / SF**


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%**  more than predicted



Building energy use **10%**  less than predicted

# 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

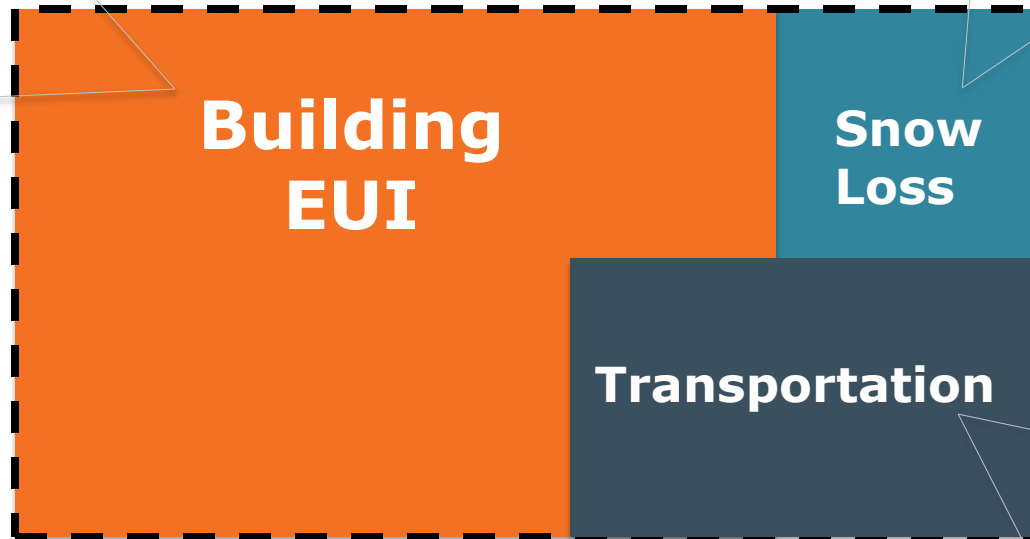
### Term Permit

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



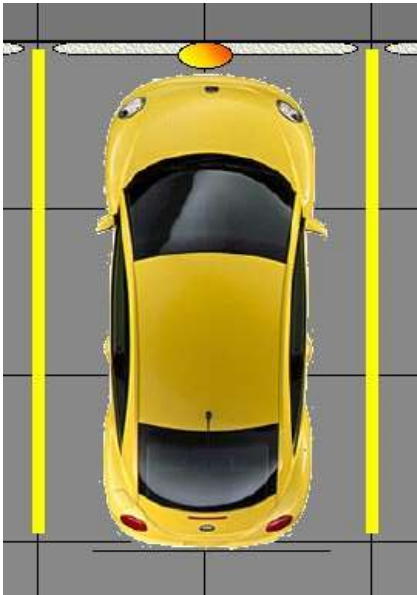
# Beyond Net Zero

Rocky Mountain Institute Headquarters



# Beyond Net Zero

In the Rocky Mountains



1 Parking Space  
9x18'



PV Production  
1.6 kW



EV Travel  
30 miles/day

# Conclusion



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*inspire interpret integrate*



# Bike Rack



# What's Next



how do you measure  
health?

phytoremediation

biophilia

modular  
construction /  
fabrication

pizeoelectrics

buildings that give back

gaming to reduce energy

food waste to  
energy

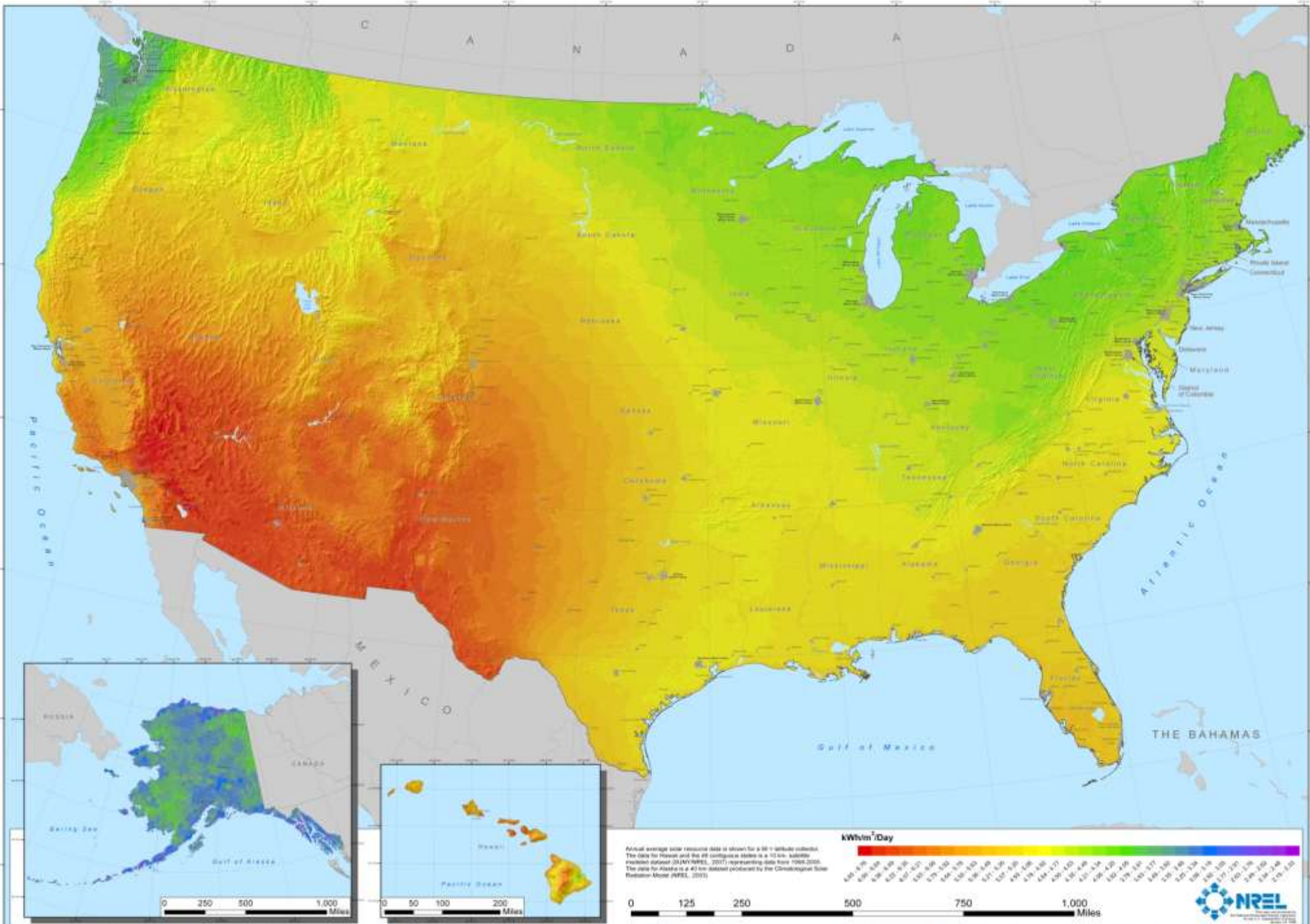
# Gaming to Reduce Energy



# Phase Changing Materials

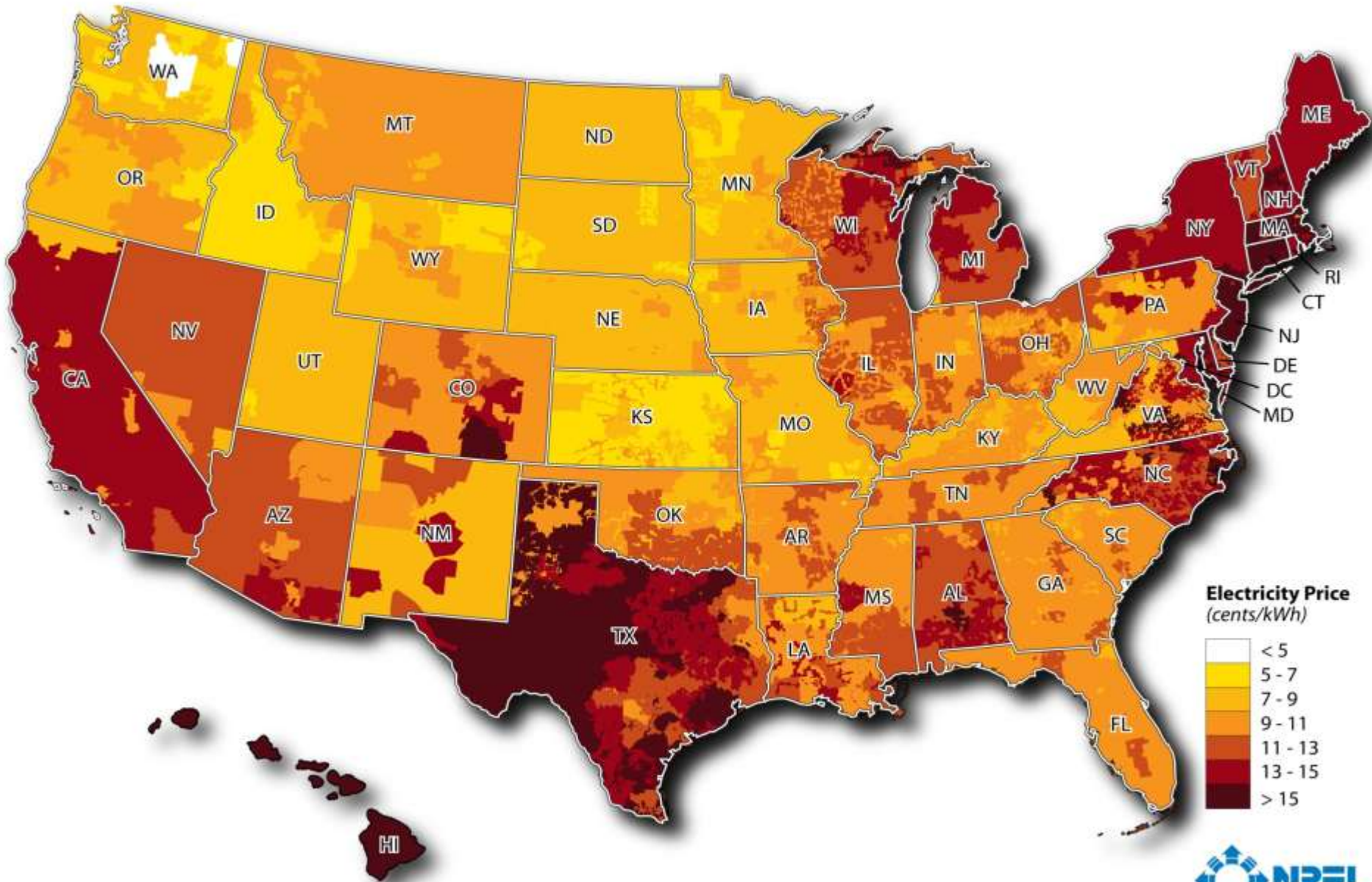


# US Photovoltaic Solar Resource





# Electricity Price by Region



# Reducing Plug Loads

2010



22" LED-LCD



22" LED-LCD



32  
watts



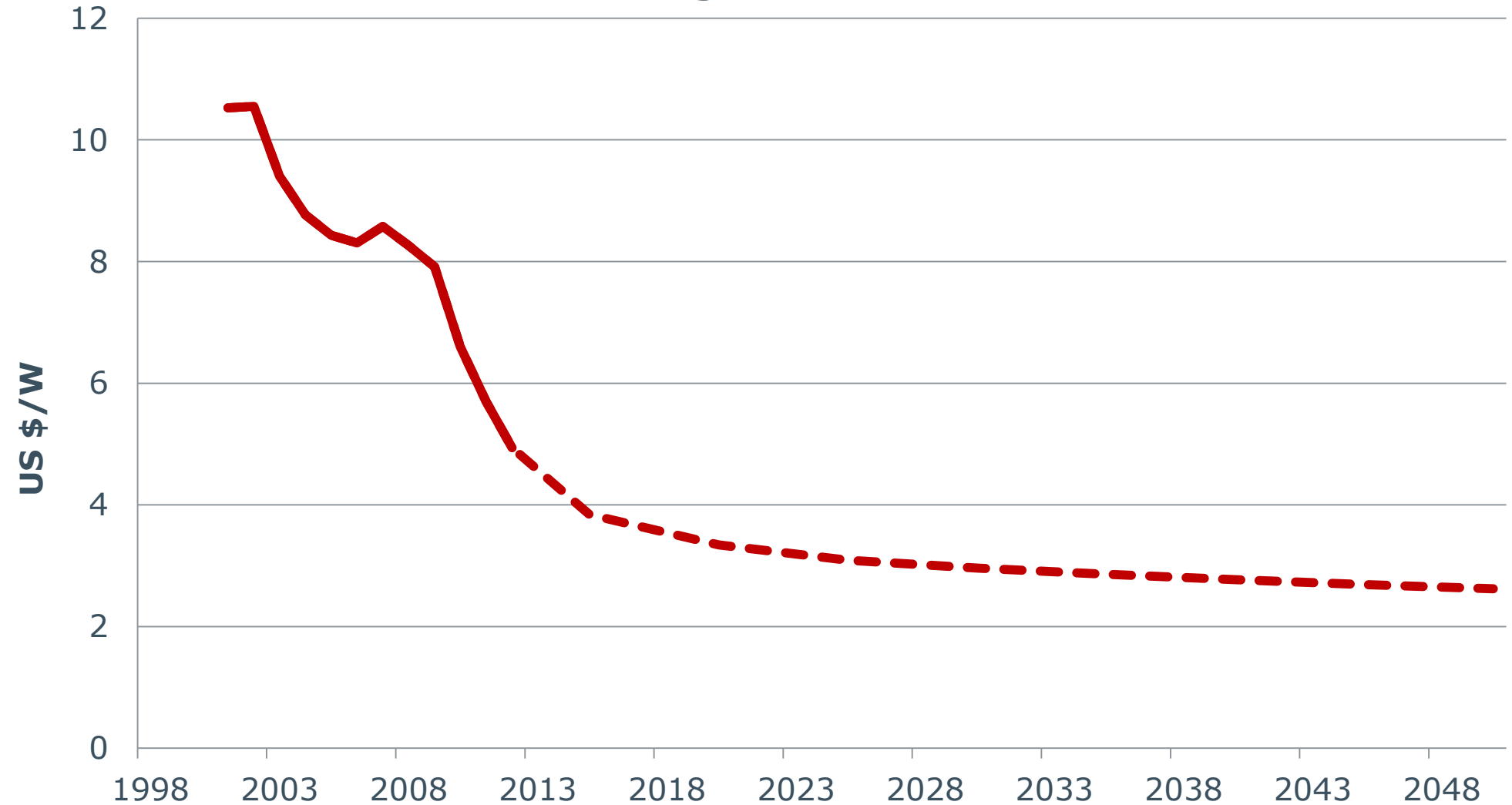
60 watts

# First Cost Trend



## Average Price of PV

First Cost Trend  
Average Price of PV



Source: Barbose, Galen L, Darghouth, Naim, Weaver, Samantha, and Wiser, Ryan H. *Tracking the Sun VI: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2012*. Berkeley, 2013.