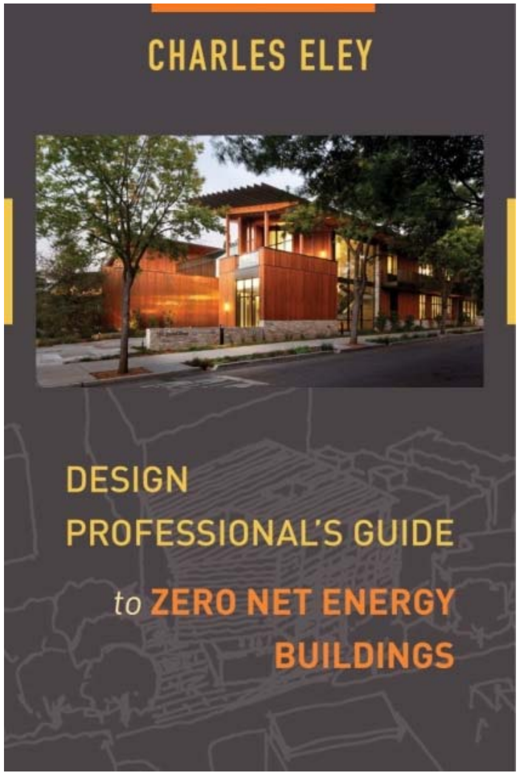

Advanced Designs for Net Zero Buildings

Charles Eley, P.E., Fellow ASHRAE, Fellow AIA, LEED® AP

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Today's Program

EDUCATION PARTNER

Advanced Designs for Net Zero Buildings

By ASHRAE

GBCI cannot guarantee that course sessions will be delivered to you as submitted to GBCI. However, any course found to be in violation of the standards of the program, or otherwise contrary to the mission of GBCI, shall be removed. Your course evaluations will help us uphold these standards.

Course ID: 920015146

Approved for:

3

General CE hours

0

LEED-specific hours

- LEED GREEN ASSOCIATE
- LEED AP BD+C
- LEED AP HOMES
- LEED AP ID+C
- LEED AP ND
- LEED AP O+M

Target Audience

Consulting engineers, Architects, Developers, Owners, Architectural and Engineering Students, Facility managers, Contractors)

This course is for professional engineers and architects who want to expand their practice to include the design, construction and operation of zero net energy buildings. The course will begin with a definition of a ZNE building.

- The first principle of ZNE design is to make the building as energy efficient as possible.
- On-site renewable energy systems will then be added to achieve ZNE.
- If adequate on-site ZNE is not feasible, then options for off-site renewable energy should be explored.
- The test for ZNE is at the energy meter, so proper commissioning and operator training is critical to success.

The ZNE principles outlined above will be presented with case studies and examples showing how other design professionals have met the ZNE goal.

Learning Objectives

At the conclusion of this course, attendees will :

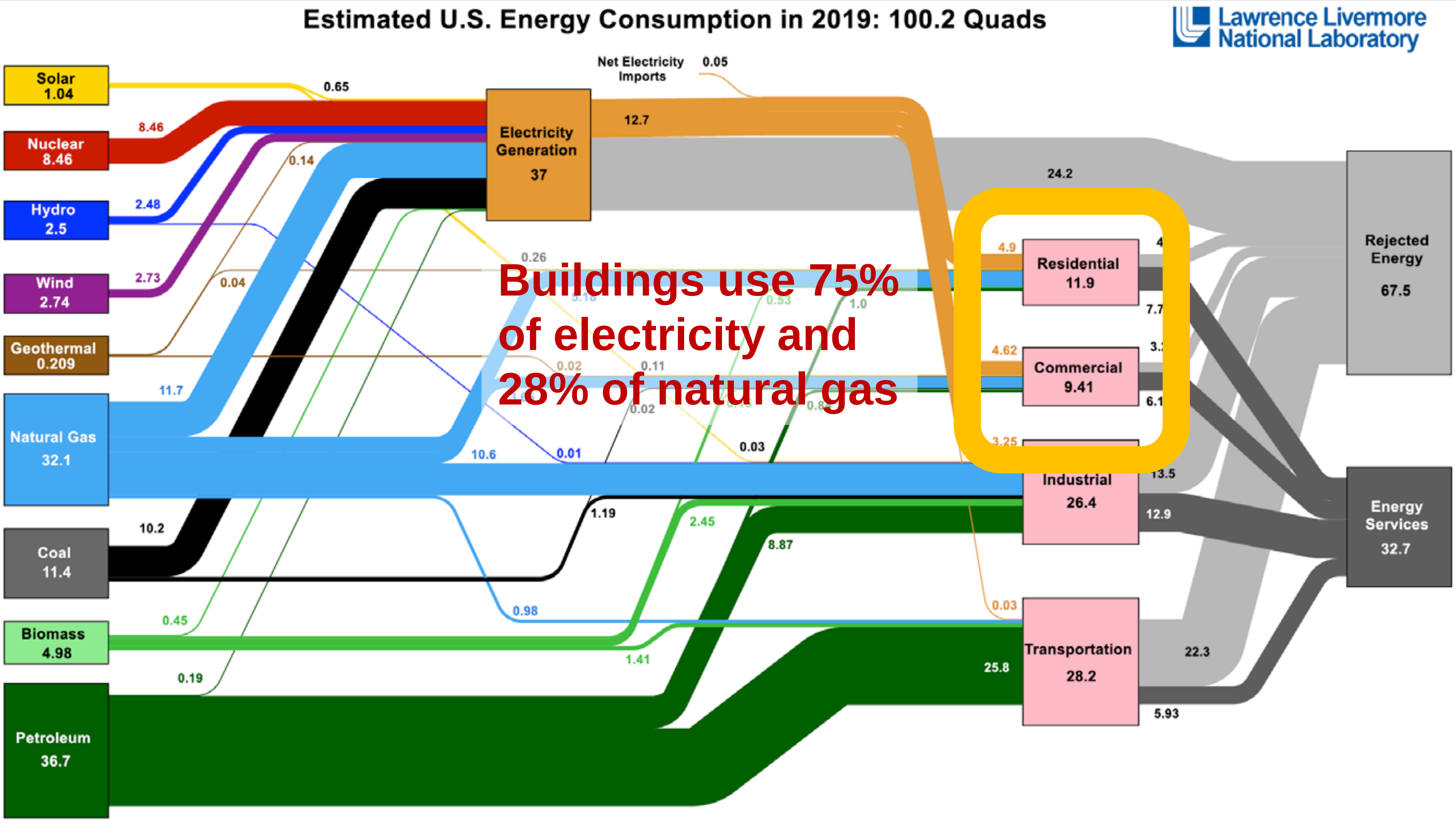
- Understand what a zero-net energy building is.
- Analyze a building's energy components and how these can be reduced to a minimum.
- Show compliance to zero net energy at the design phase.
- Identify system operation that should be measured and verified after construction.
- Provide owner information on how to operate zero net energy buildings and their systems.

Agenda

Topic	Approximate Time
Introduction to Zero Net Energy (ZNE)	**10 minutes**
Source Energy and the California Grid	**15 minutes**
Time Dependent Source (TDS) Energy	**10 minutes**
HVAC and Thermal Comfort	**15 minutes**
Energy Modeling in the Design Process	**10 minutes**
Break	**20 minutes**
EUI Targets and Potential	**10 minutes**
Renewable Energy Systems	**25 minutes**
Making It All Work	**10 minutes**
Practical Examples	**15 minutes**
Closing Comments	**5 minutes**
Wrap-Up	**10 minutes**

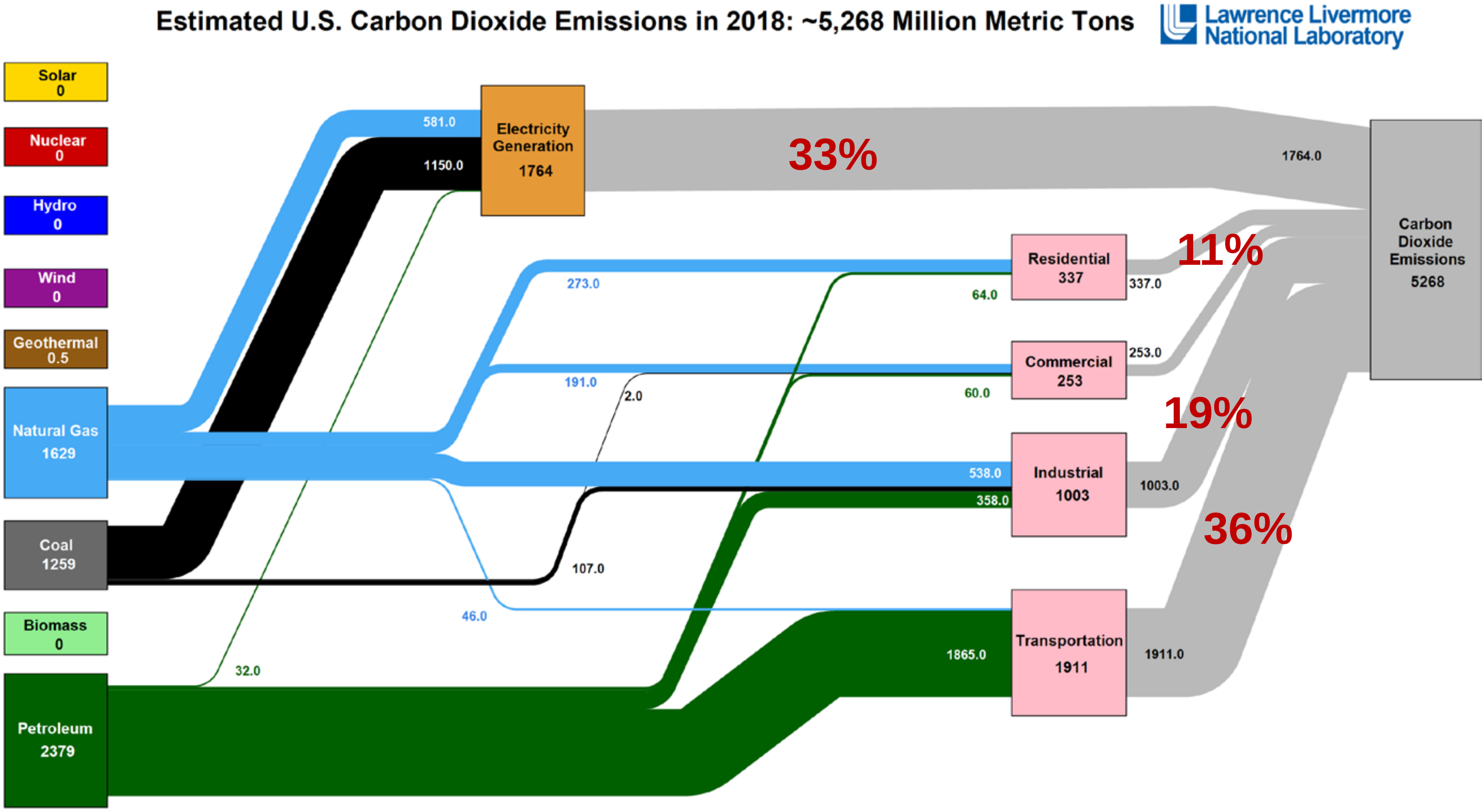
Introduction to Zero Net Energy (ZNE)

United States Energy Flows – 2019



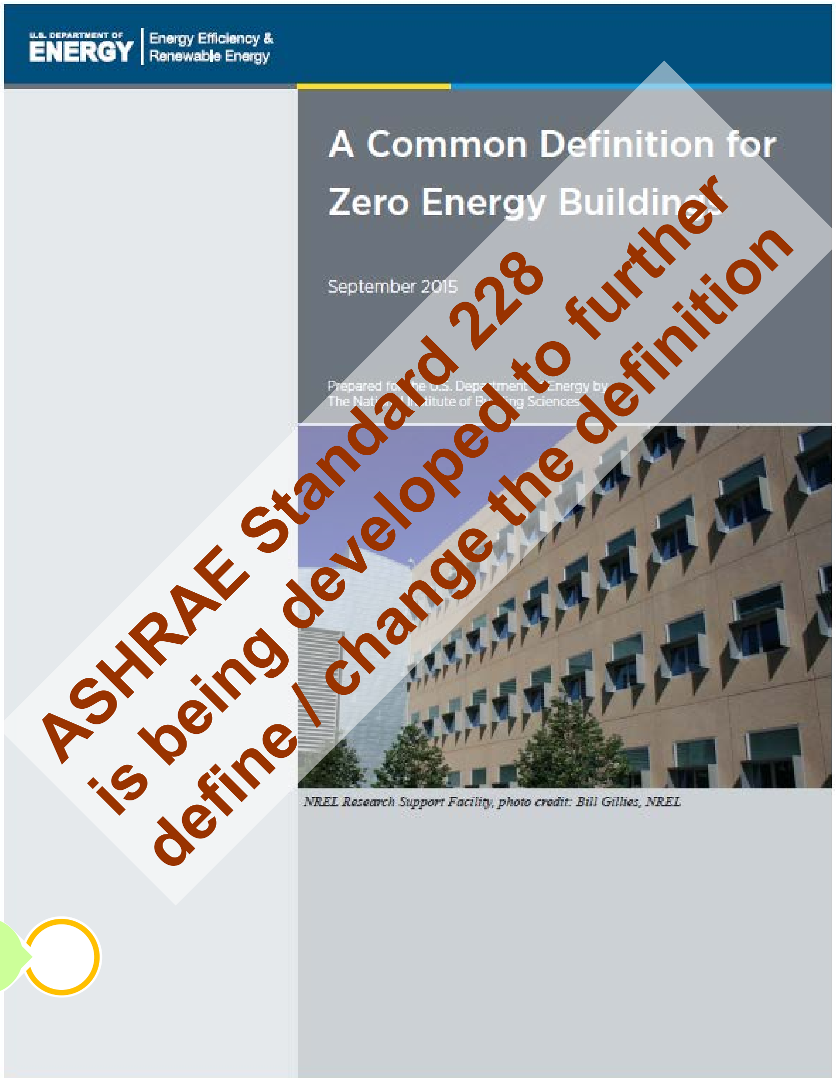
Source: LLNL March, 2020. Data is based on DOE/EIA MER (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Estimated U.S. Carbon Dioxide Emissions in 2018: ~5,268 Million Metric Tons



Source: LLNL July, 2019. Data is based on DOE/EIA MER (2018). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon emissions are attributed to their physical source, and are not allocated to end use for electricity consumption in the residental, commercial, industrial and transportation sectors. Petroleum consumption in the electric power sector includes the non-renewable portion of municipal solid waste. Combustion of biologically derived fuels is assumed to have zero net carbon emissions - the lifecycle emissions associated with producing biofuels are included in commercial and industrial emissions. Totals may not equal sum of components due to indepedent rounding errors. LLNL-MI-410527

DOE Common Definition



ASHRAE Standard 228 is being developed to further define / change the definition

Zero Net Energy
Net Zero Energy
Zero Energy

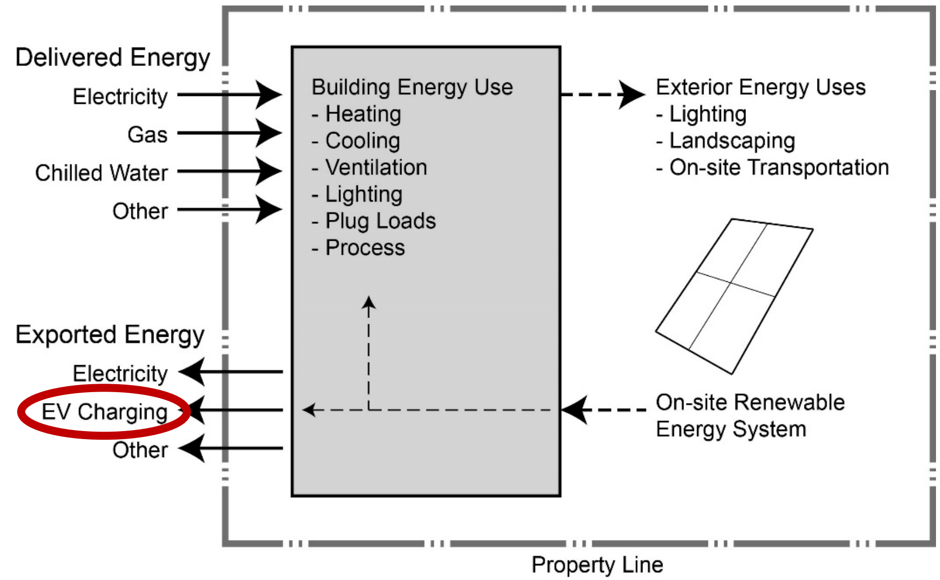
Living Buildings

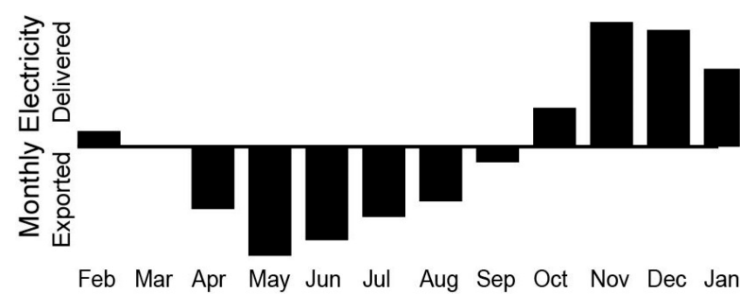
Nearly Zero Energy
Zero Net Ready
Ultra-Low Energy

Zero Electric
Zero Carbon

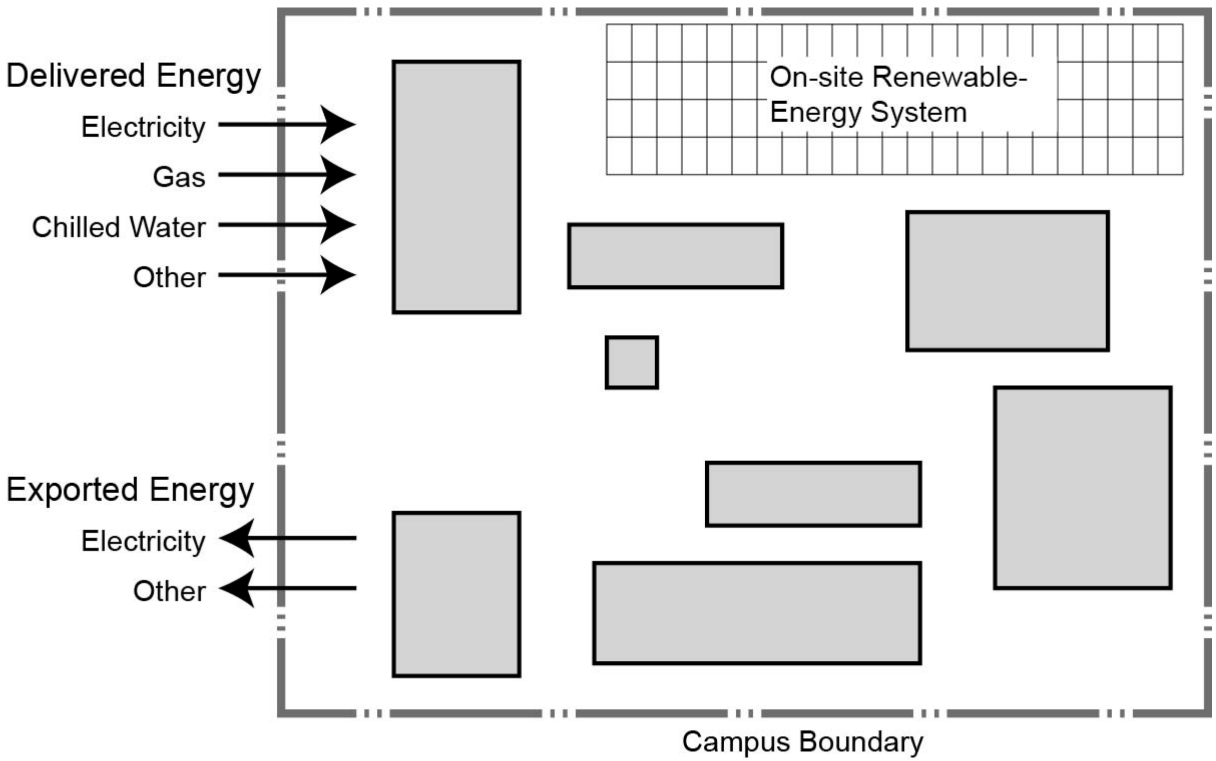
ZNE Definition

- The sum of all **source** energy that is **delivered** to the property line must be less than the energy that is **exported** from the property.
- All energy use is included:
  - Electricity
  - Gas
  - District energy
- EV charging is considered exported energy if the vehicles are used off site.
- No on-site combustion is allowed for International Living Building Institute certified ZNE buildings.





Portfolios, Campuses, and Communities



Contiguous boundary, usually the same owner

Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

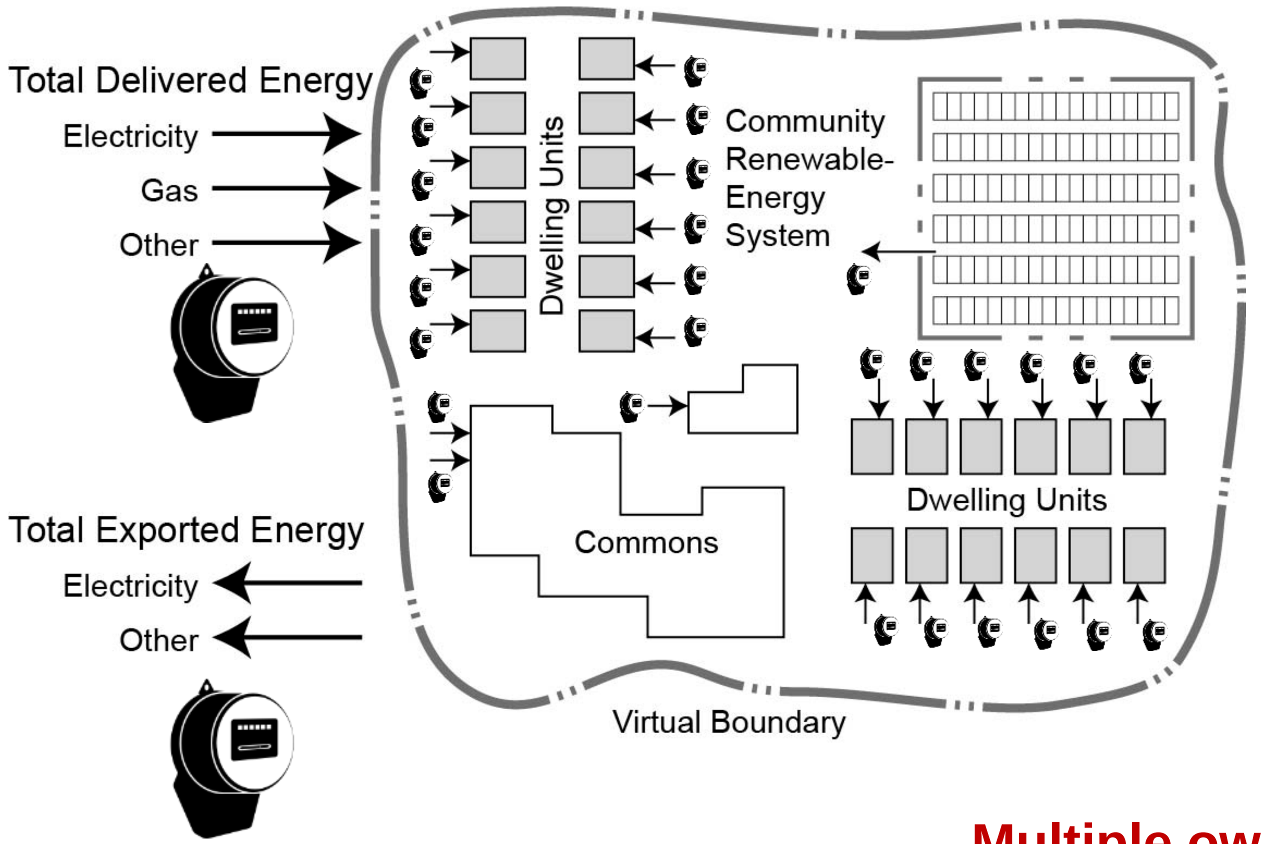
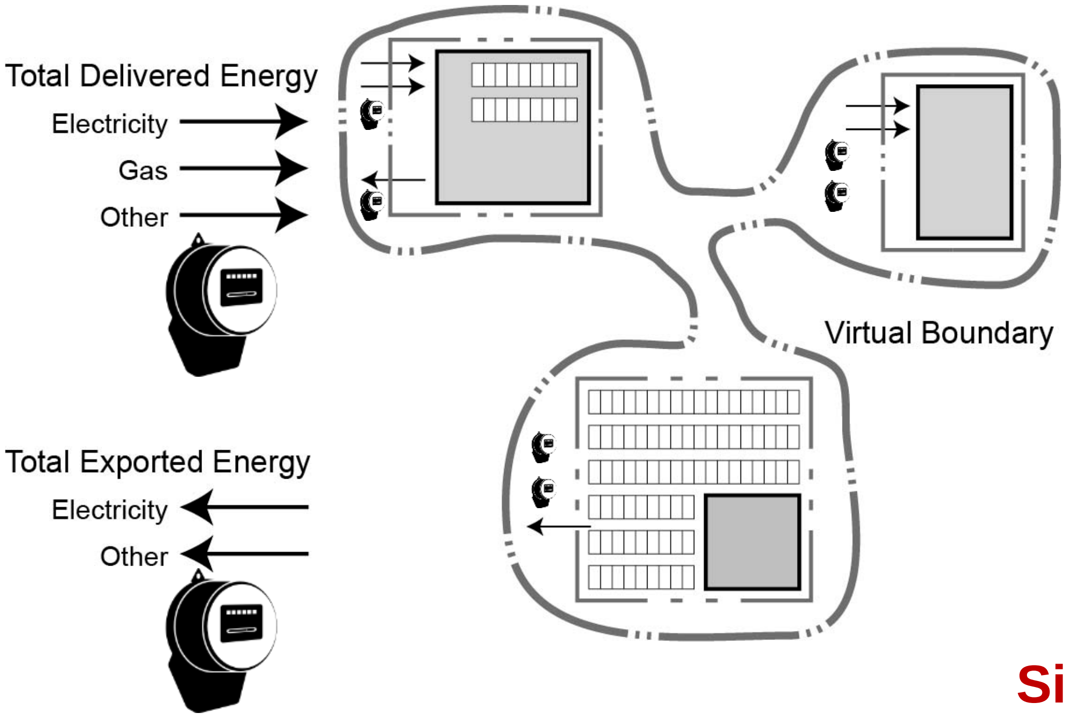


Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

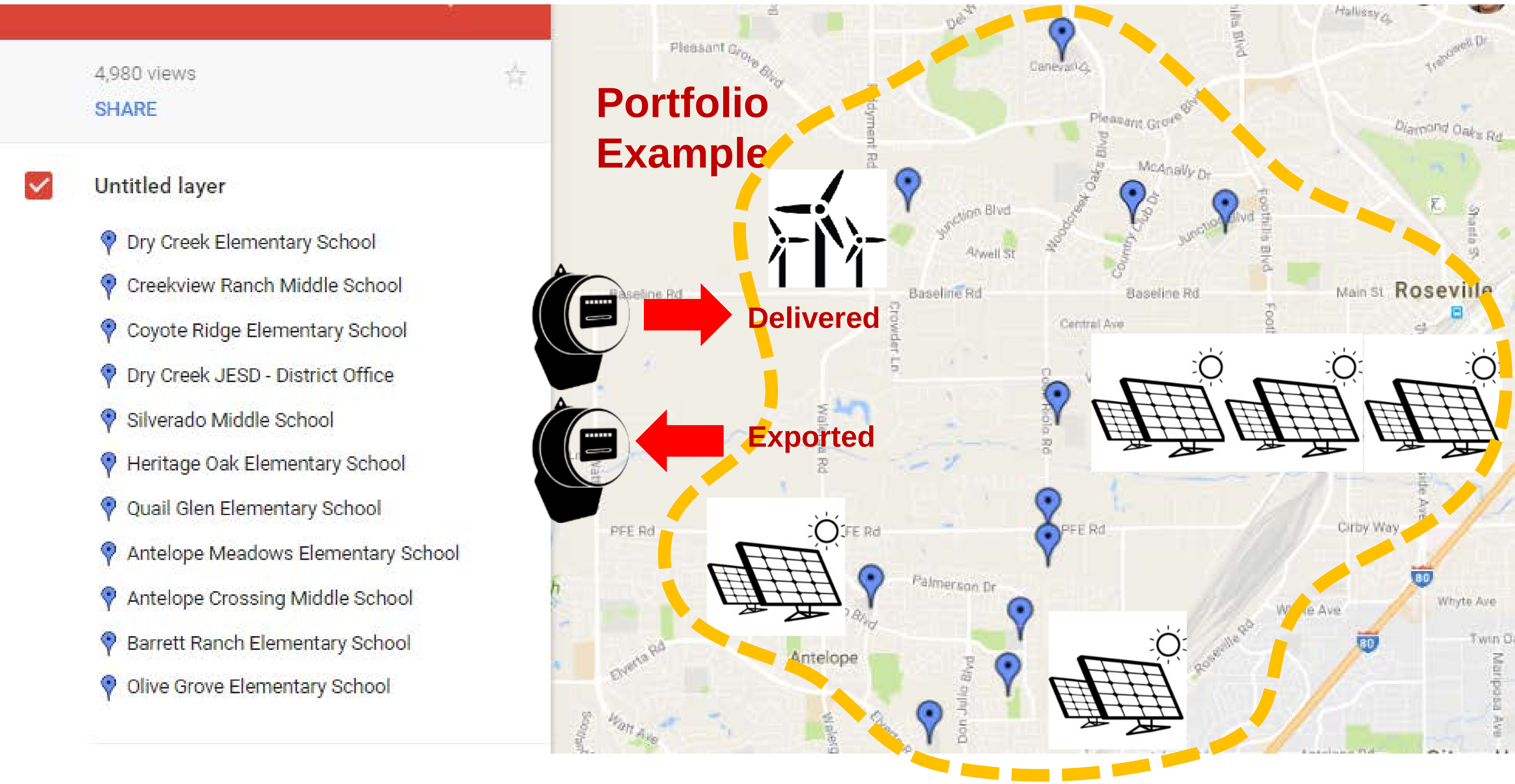
Multiple owners, noncontiguous boundary



Single owner or manager, noncontiguous boundary

Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

Dry Creek Elementary School District



Portfolio Example

Energy Accounting

British Thermal Unit (Btu)		kiloWatt-hour (kWh)		kiloJoule (kJ)
1 Btu	=	.000293 kWh	=	1.055 kJ
3,412 Btu	=	1 kWh	=	3,600 kJ
0.948 Btu	=	.000278 kWh	=	1 kJ

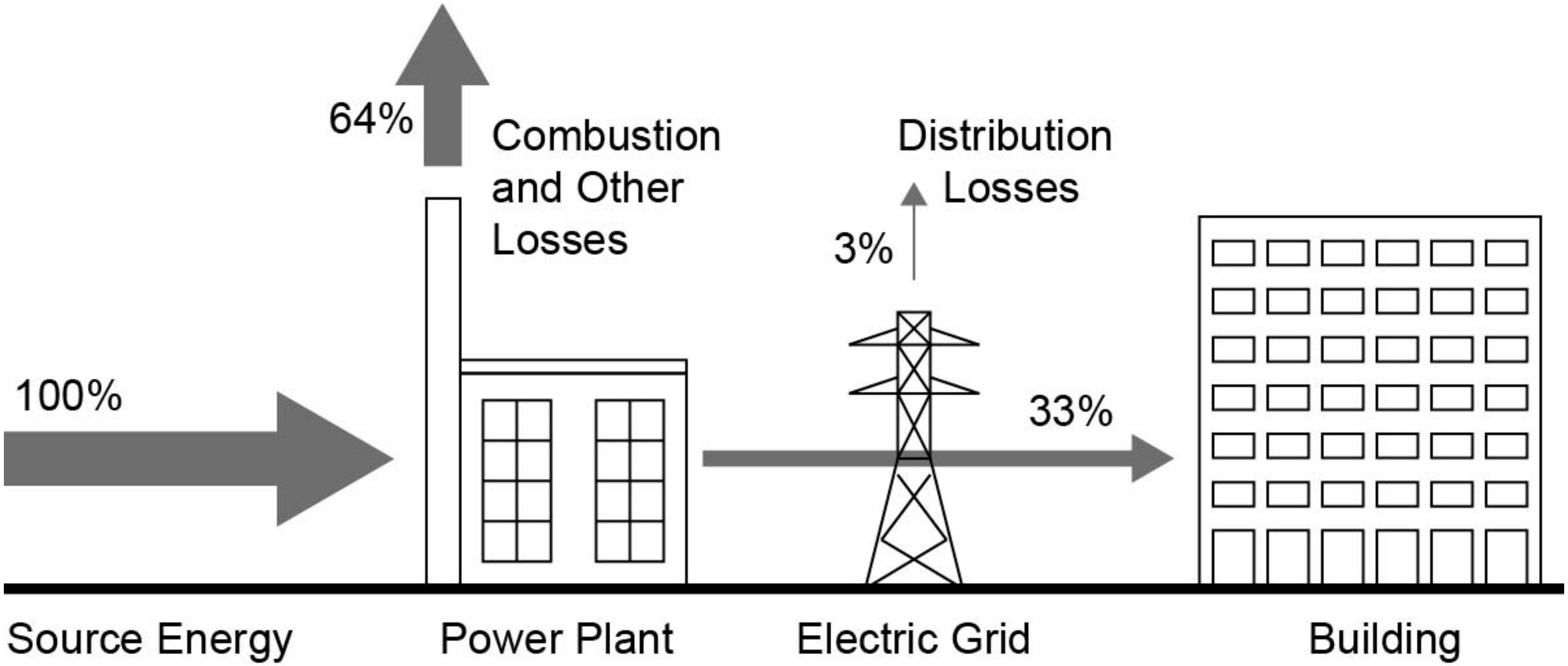
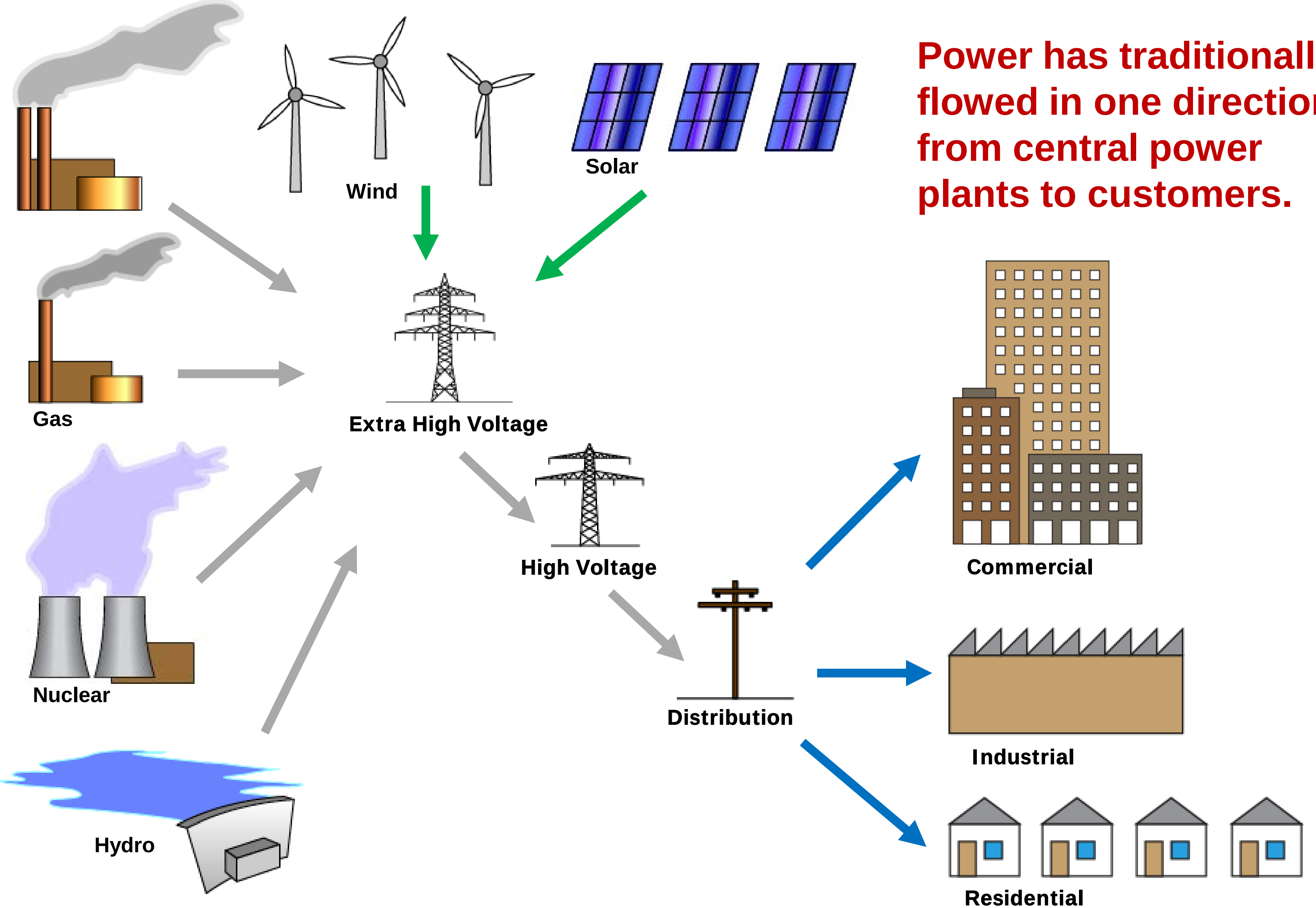


Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

Power has traditionally flowed in one direction, from central power plants to customers.



Energy Accounting

Energy Type	Source Multiplier	Common Energy Units	Site Btu/unit	Source Btu/unit
Imported Electricity	3.15	kWh	3412	10,751
Exported Renewable Electricity	3.15	kWh	3412	10,751
Natural Gas	1.09	Therms	100,000	109,000
Fuel Oil (1,2,4,5,6,Diesel, Kerosene)	1.19	Gallons	138,000	164,220
Propane & Liquid Propane	1.15	Gallons	91,000	104,650
Steam	1.45	lb	1000	1450
Hot Water	1.35	millions Btu	1,000,000	1,350,000
Chilled Water	1.04	millions Btu	1,000,000	1,040,000
Coal or Other	1.05	short ton	19,210,000	20,170,000
Notes: The Btu per lb of steam will vary depending on how much the steam is superheated.				

Revised values published In Standard 189.1-2020

Source: DOE Common Definition and ASHRAE Standard 105

Example calculation for mixed fuel building:
Source Energy (Btu) = kWh × 10,751 + Therms ×109,000

	All Electric Buildings
Site Energy	Equal difficulty in achieving ZNE
Source Energy (recommended)	
Energy Cost (flat rate)	

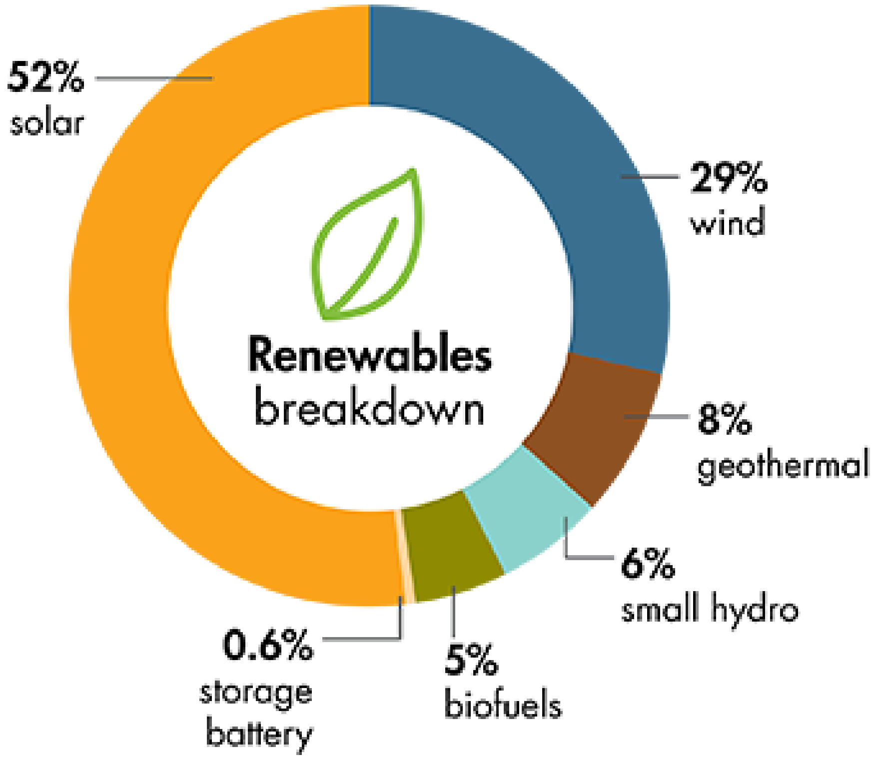
Table: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

Source Energy and the California Grid

California BEES 1975–2005

- For three decades, California used flat source energy multipliers:
  - 3.0 for electricity
    (1 kWh = 10,236 Btu)
  - 1.0 for gas
    (1 therm = 100,000 Btu)
- Replaced by time-dependent valued (TDV) energy in 2005

Source Energy and the California Grid



	Megawatts
Solar	11,439
Wind	6,295
Small hydro	1,238
Geothermal	1,790
Biofuels	997
Storage battery	134*
TOTAL	**21,893**

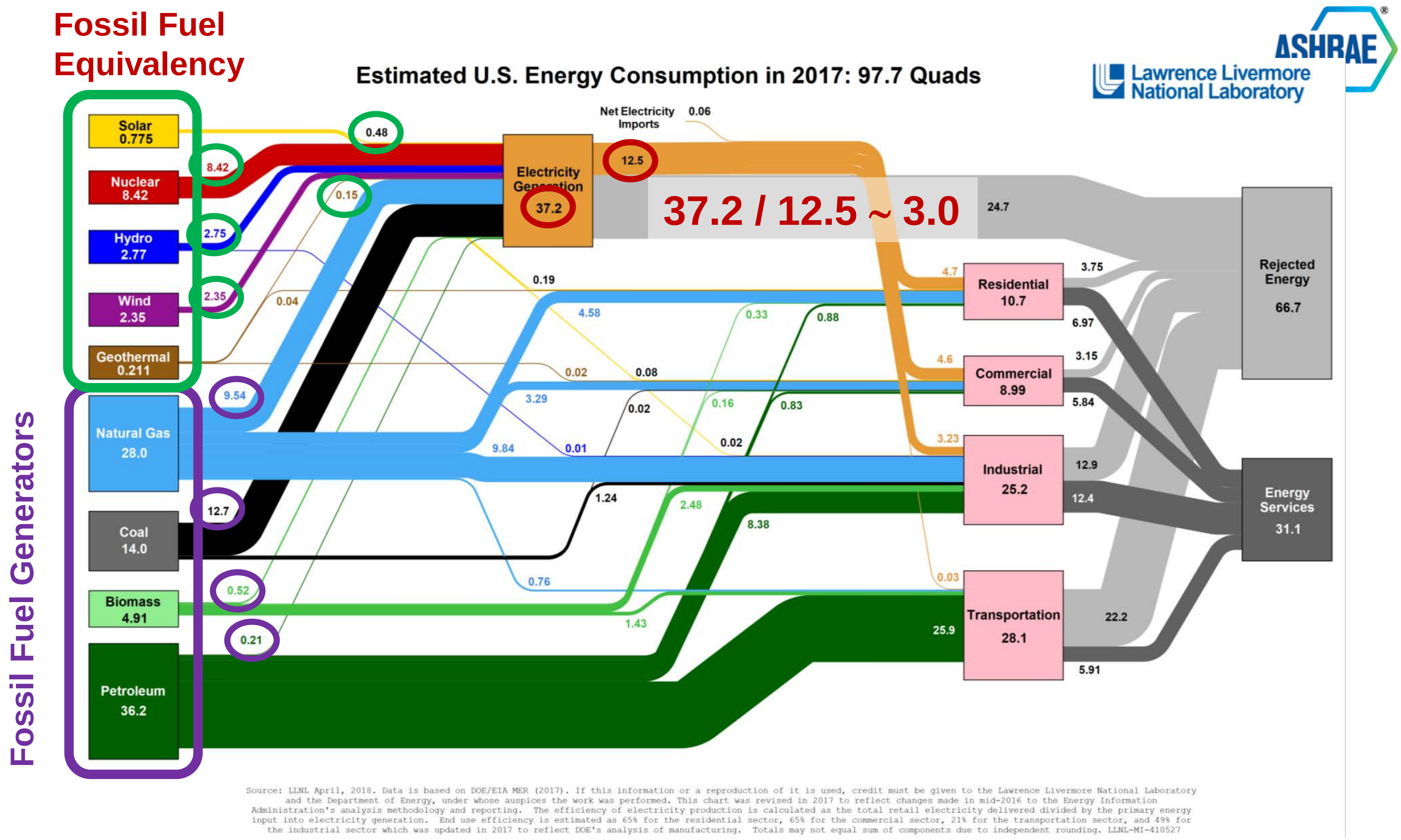
Source: CalSO.com

Fuel Type	California In-State Generation (GWh)	Percent of California In-State Generation	Northwest Imports (GWh)	Southwest Imports (GWh)	California Energy Mix (GWh)	California Power Mix
Coal	302	0.15%	409	11,364	12,075	4.13%
Large Hydro	36,920	17.89%	4,531	1,536	42,987	14.72%
Natural Gas	89,564	43.40%	46	8,705	98,315	33.67%
Nuclear	17,925	8.69%	0	8,594	26,519	9.08%
Oil	33	0.02%	0	0	33	0.01%
Other	409	0.20%	0	0	409	0.14%
Renewables	**61,183**	**29.65%**	**12,502**	**10,999**	**84,684**	**29.00%**
Biomass	5,827	2.82%	1,015	32	6,874	2.35%
Geothermal	11,745	5.69%	23	937	12,705	4.35%
Small Hydro	6,413	3.11%	1,449	5	7,867	2.70%
Solar	24,331	11.79%	0	5,465	29,796	10.20%
Wind	12,867	6.24%	10,015	4,560	27,442	9.40%
Unspecified	N/A	N/A	22,385	4,632	27,017	9.25%
Total	206,336	100.00%	39,873	45,830	292,039	100.00%

Source: http://www.energy.ca.gov/almanac/electricity_data/total_system_power.html

Senate Bill 100
(recently signed by Governor Brown)

33%	50%	60%	100%
2020	2026	2030	2045



Fossil Fuel Equivalency
Fossil Fuel Generators
Estimated U.S. Energy Consumption in 2017: 97.7 Quads
Lawrence Livermore National Laboratory
Solar 0.775
Nuclear 8.42
Hydro 2.77
Wind 2.35
Geothermal 0.211
Natural Gas 28.0
Coal 14.0
Biomass 4.91
Petroleum 36.2
0.48
8.42
0.15
2.75
2.35
0.04
9.54
12.7
0.52
0.21
Net Electricity Imports 0.06
Electricity Generation 37.2
12.5
37.2 / 12.5 ~ 3.0
24.7
0.19
4.58
0.33
0.88
0.02
0.08
3.29
0.02
0.16
0.83
9.84
0.01
0.02
1.24
2.48
8.38
0.76
1.43
4.7
4.6
3.23
0.03
25.9
Residential 10.7
Commercial 8.99
Industrial 25.2
Transportation 28.1
3.75
6.97
3.15
5.84
12.9
12.4
22.2
5.91
Rejected Energy 66.7
Energy Services 31.1
Source: LLNL April, 2018. Data is based on DOE/EIA MER (2017). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2016 to the Energy Information Administration's analysis methodology and reporting. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector, and 49% for the industrial sector which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

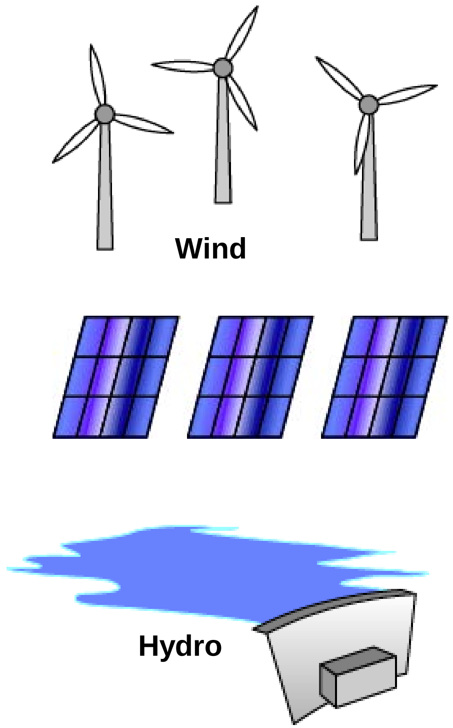
Fossil Fuel Equivalency Approach

Primary Energy | **Electricity Production**

~ 10,000 Btu → 1 kWh

~ 10,000 Btu → 1 kWh

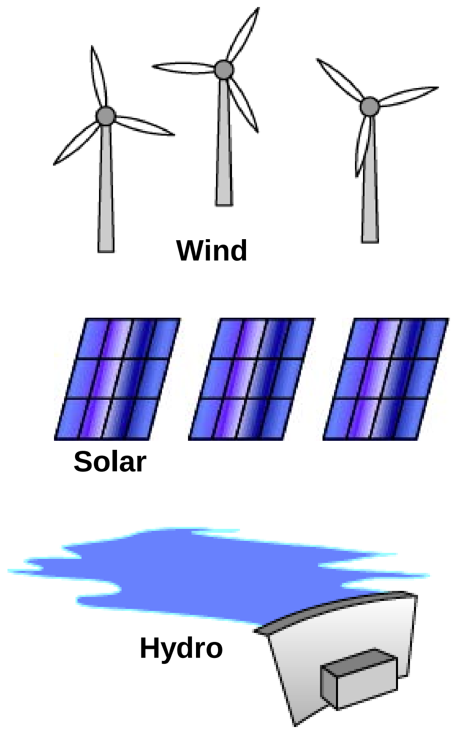
~ 10,000 Btu → 1 kWh



- Source energy is unaffected as more clean generators are added to the grid.
- The source-site multiplier for wind, solar and other renewables is the same as fossil generators.

Primary Energy | **Electricity Production**

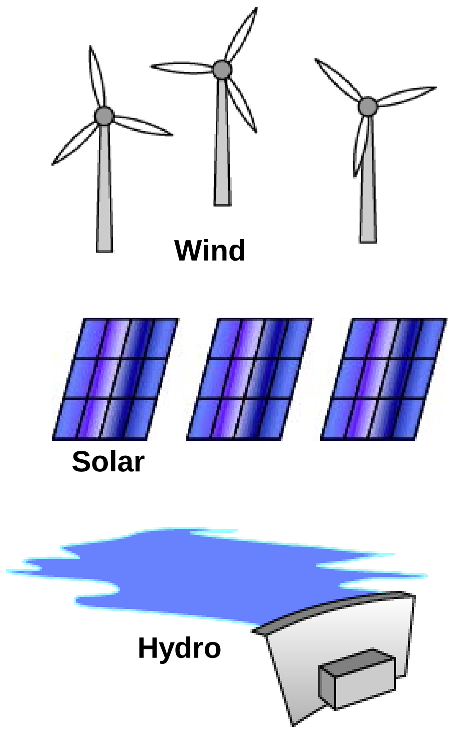
Primary Energy		Electricity Production
3,412 Btu	Wind	1 kWh
3,412 Btu	Solar	1 kWh
3,412 Btu	Hydro	1 kWh



- Recommended by DOE.
- The source-site multiplier for wind, solar and other renewables is 1.0.

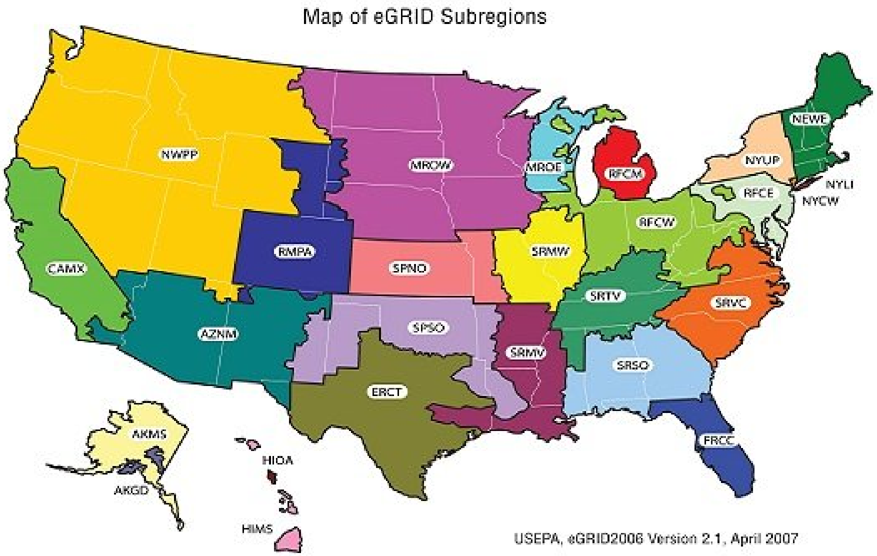
Source Energy and the California Grid

Primary Energy		Electricity Production
ZERO Btu	→	1 kWh
ZERO Btu	→	1 kWh
ZERO Btu	→	1 kWh



- Wind, solar and gravity are free.
- The source-site multiplier for wind, solar and other renewables is ZERO.
- Source energy and carbon emissions track each other exactly.

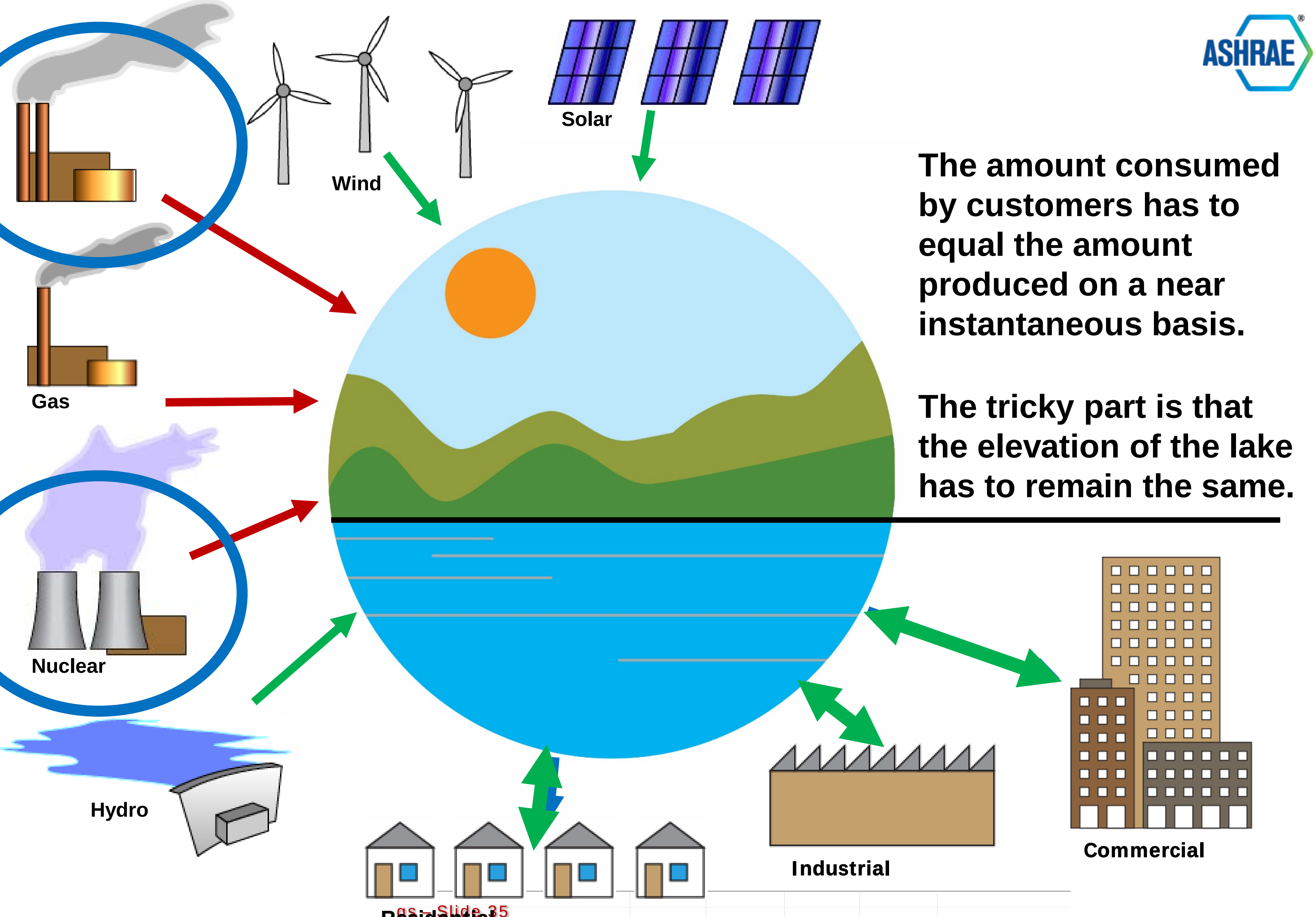
ASCC Alaska Grid	2.52
ASCC Miscellaneous (not a grid, delete)	1.21
WECC Southwest	2.75
WECC California	1.94
ERCOT All	2.58
FRCC All	2.97
HICC Miscellaneous	2.86
HICC Oahu	3.83
MRO East	3.08
MRO West	2.50
NPCC New England	2.87
WECC Northwest	1.39
NPCC NYC/Westchester	2.92
NPCC Long Island	2.90
NPCC Upstate NY	1.97
RFC East	3.05
RFC Michigan	3.06
RFC West	3.14
WECC Rockies	2.33
SPP North	2.67
SPP South	2.46
SERC Mississippi Valley	2.95
SERC Midwest	3.20
SERC South	3.04
SERC Tennessee Valley	3.02
SERC Virginia/Carolina	3.11
United States as a Whole	2.64



Source : Standard 189.1-2020

Assumes zero heat rate for non-combustible renewable energy.

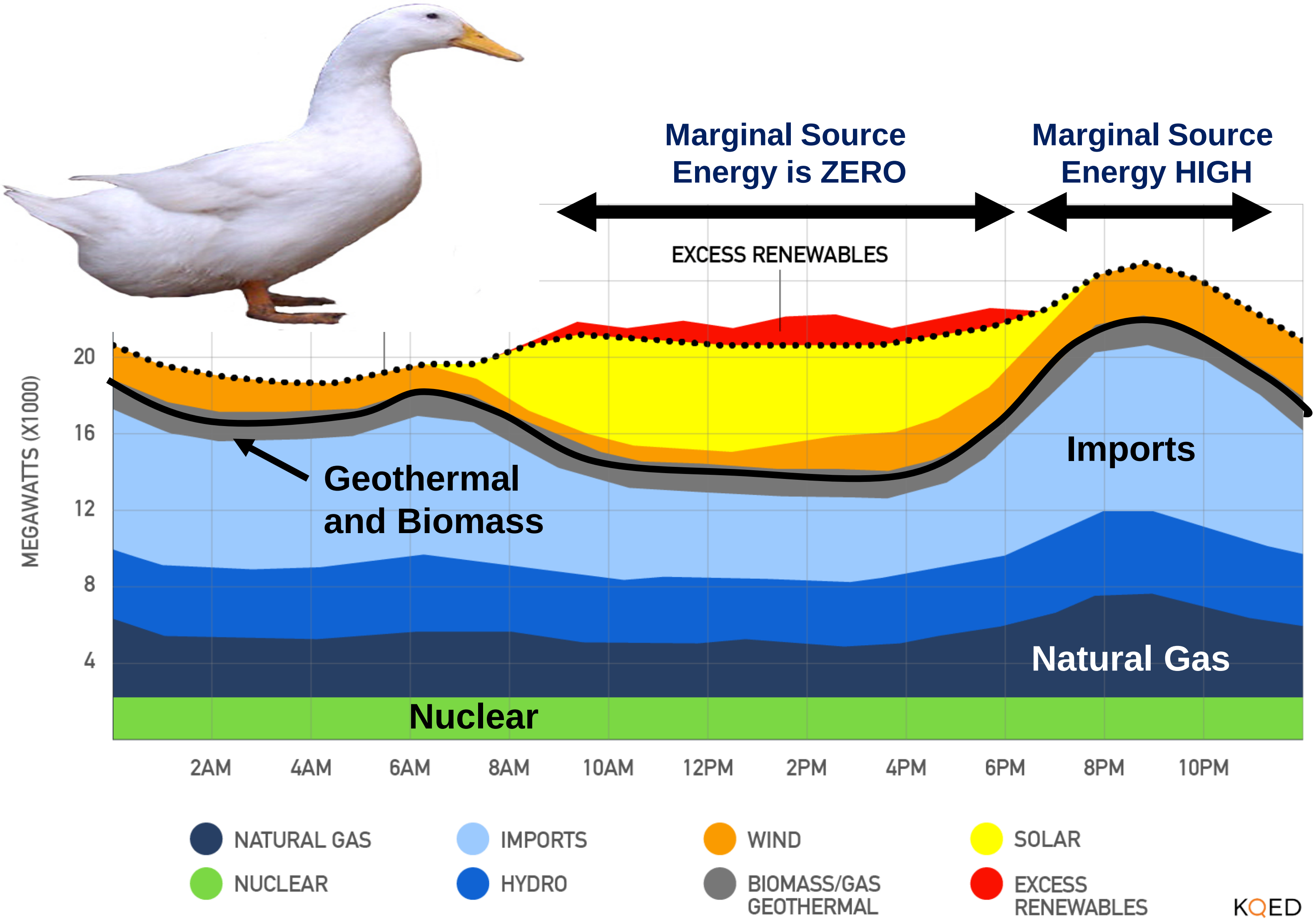
Time Dependent Source (TDS) Energy



The amount consumed by customers has to equal the amount produced on a near instantaneous basis.

The tricky part is that the elevation of the lake has to remain the same.

Time Dependent Source (TDS) Energy

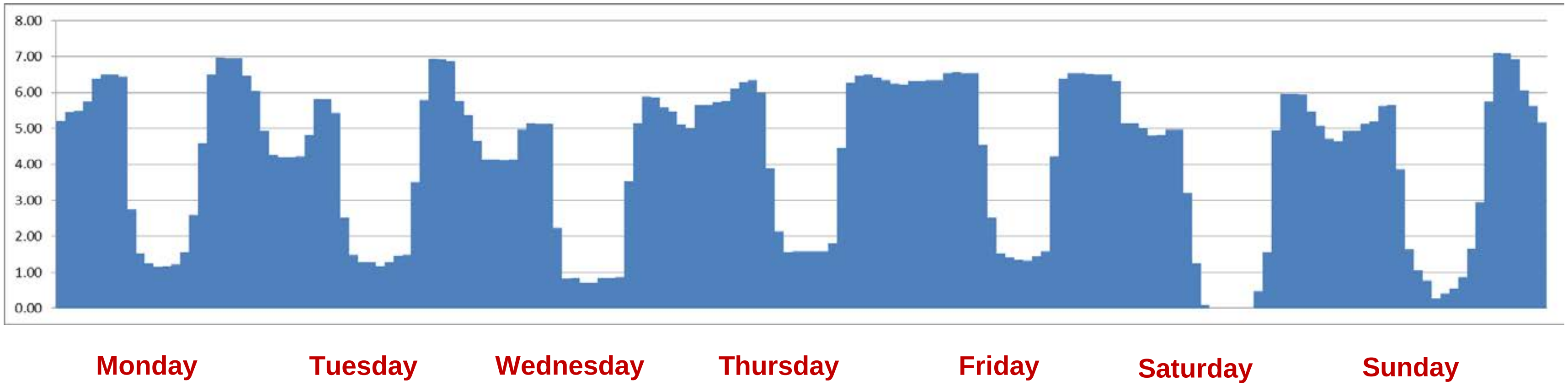


Week Beginning March 23 (on the official weather files)

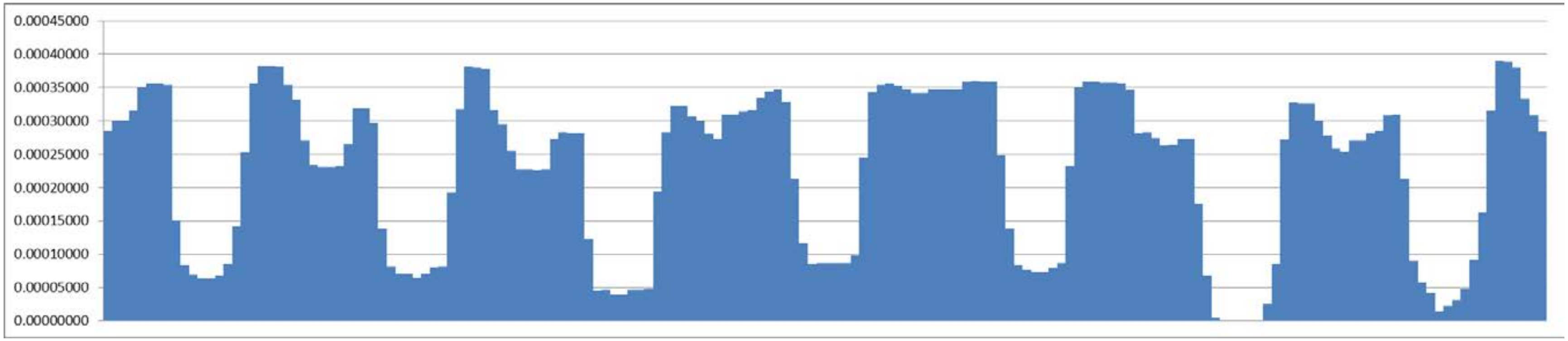
Monday Tuesday Wednesday Thursday Friday Saturday Sunday

Headline:

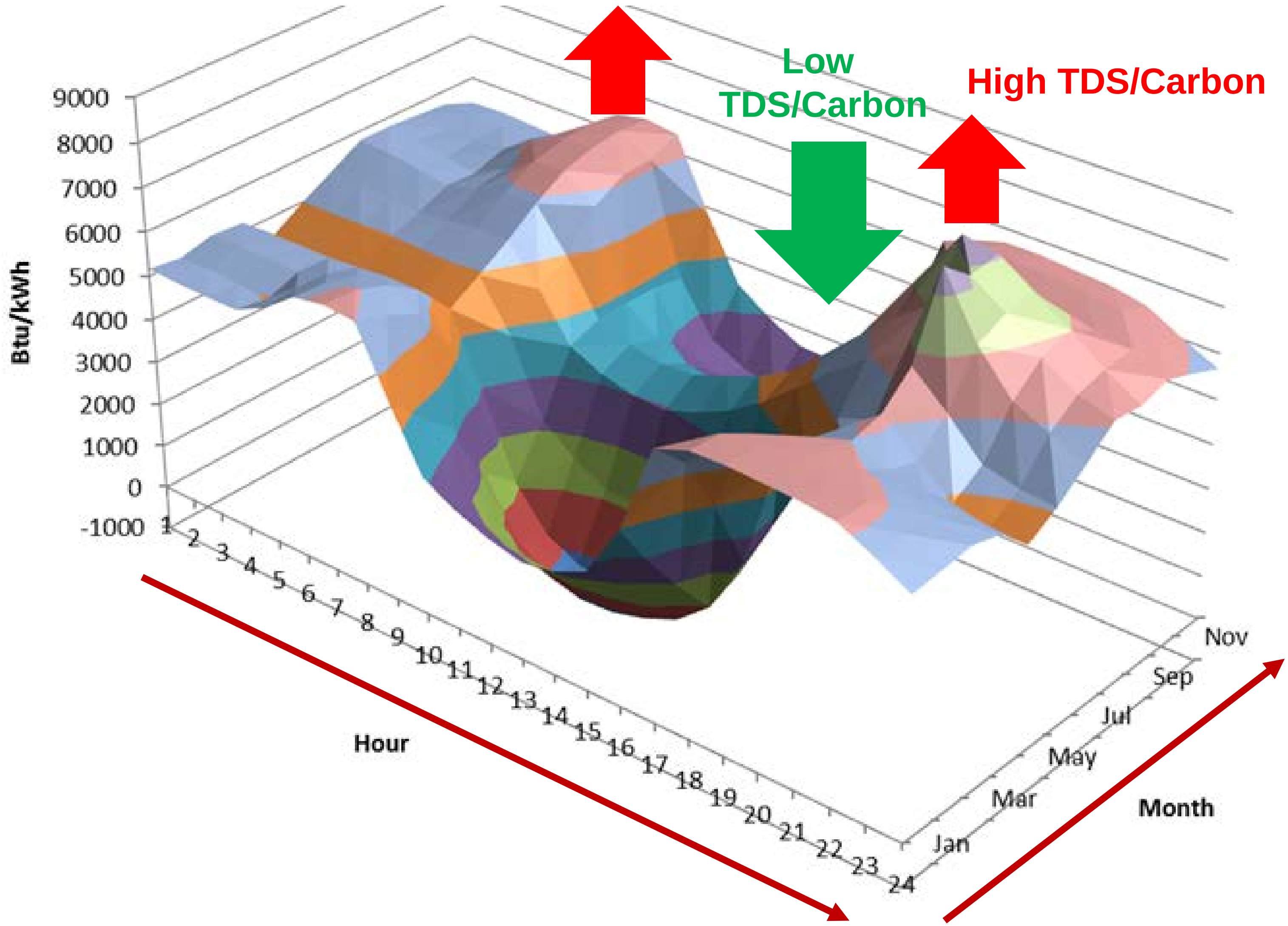
Time-Dependent Source Energy (kBtu/kWh)



Hourly Carbon Emissions (tons/kWh)

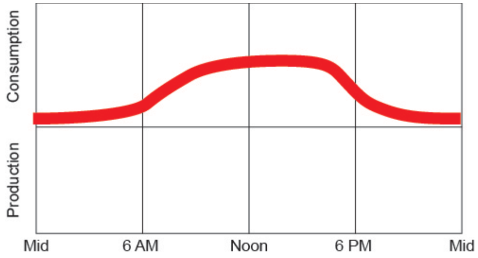


Time Dependent Source (TDS) Energy



Time Dependent Source (TDS) Energy

Building Electricity Load



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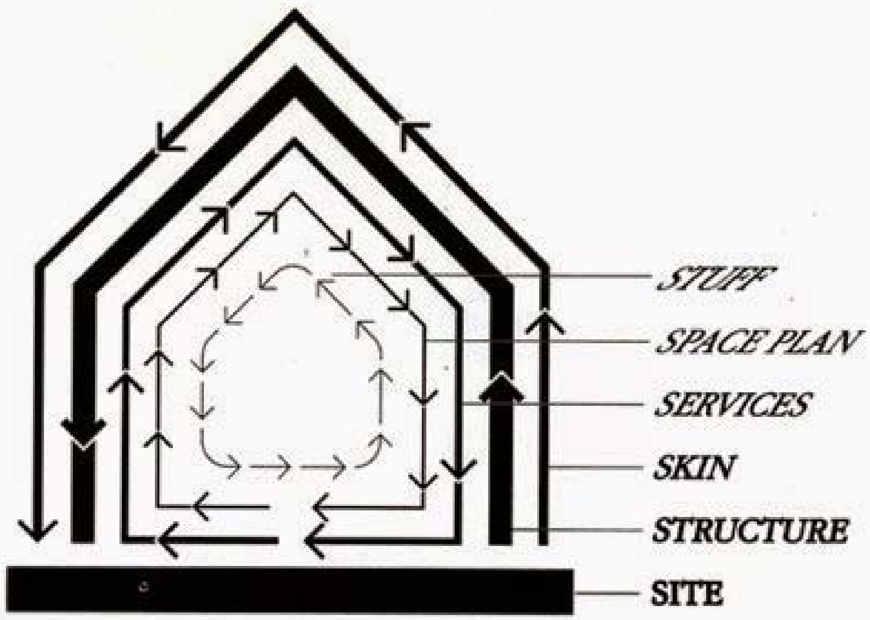
Building Envelope

Building Envelope



SHEARING LAYERS OF CHANGE. Because of the different rates of change of its components, a building is always tearing itself apart.

Building Envelope

Building Envelope

BORA Architects
ARUP

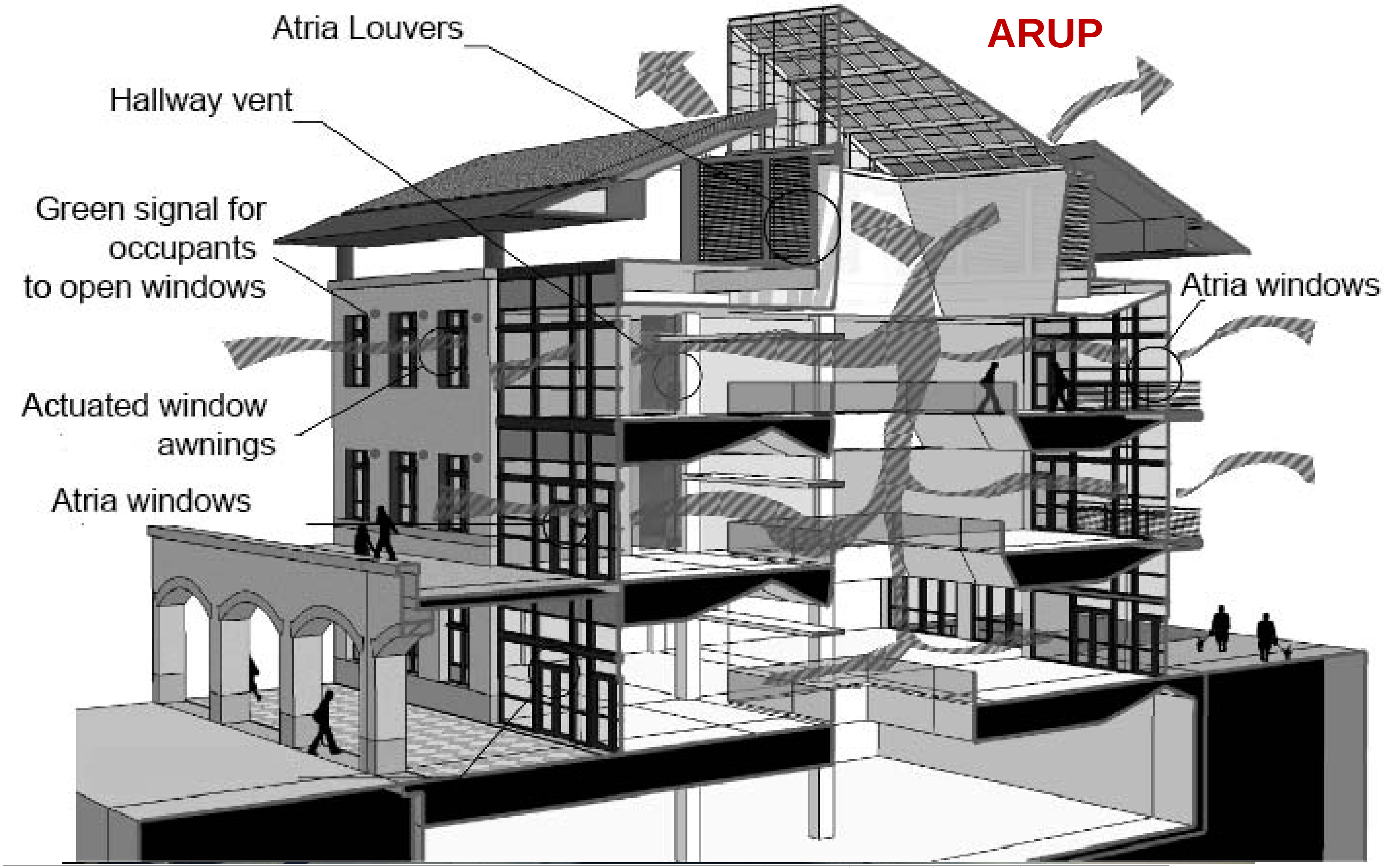
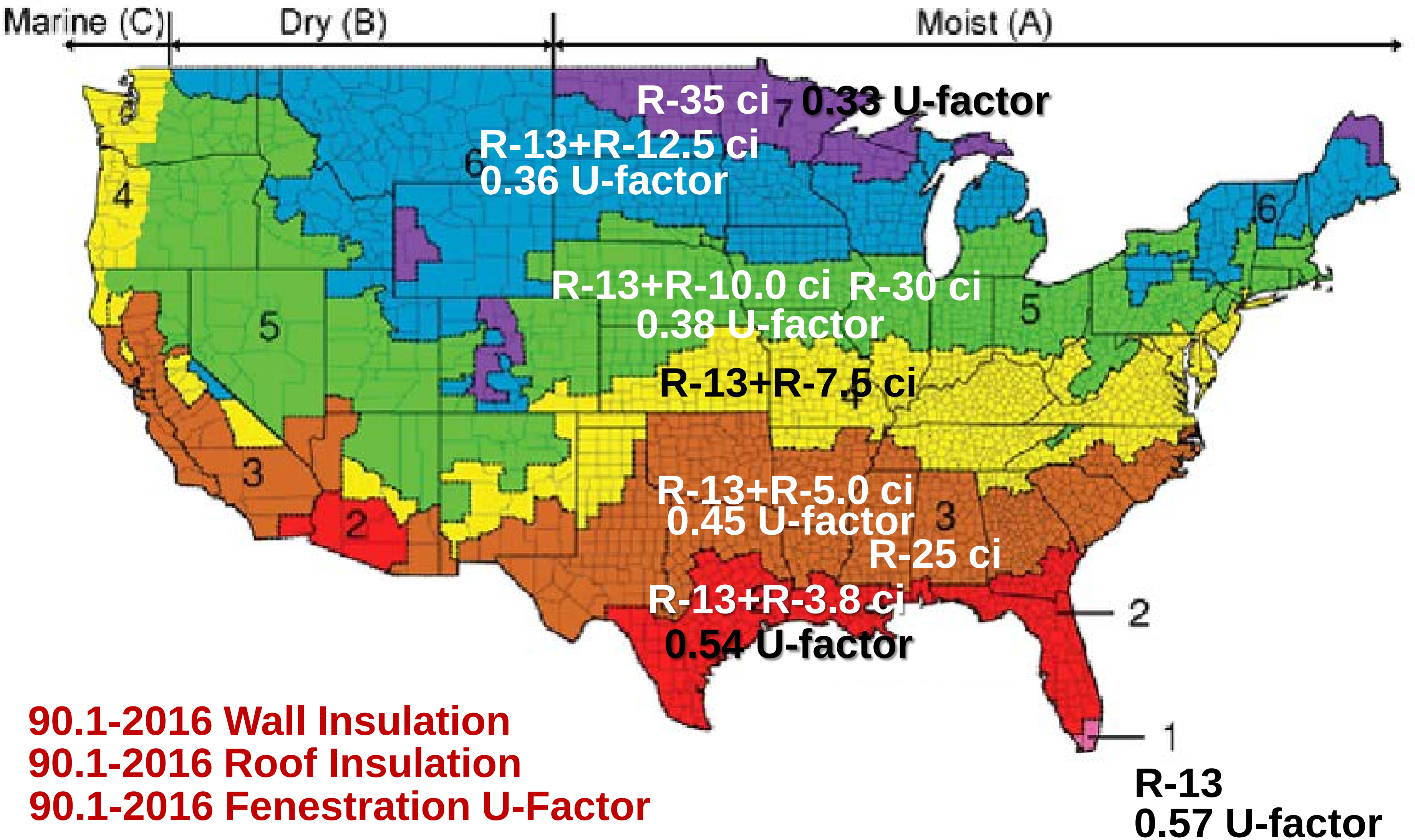


Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.



90.1-2016 Wall Insulation
90.1-2016 Roof Insulation
90.1-2016 Fenestration U-Factor

Two Tabor Center—Denver CO

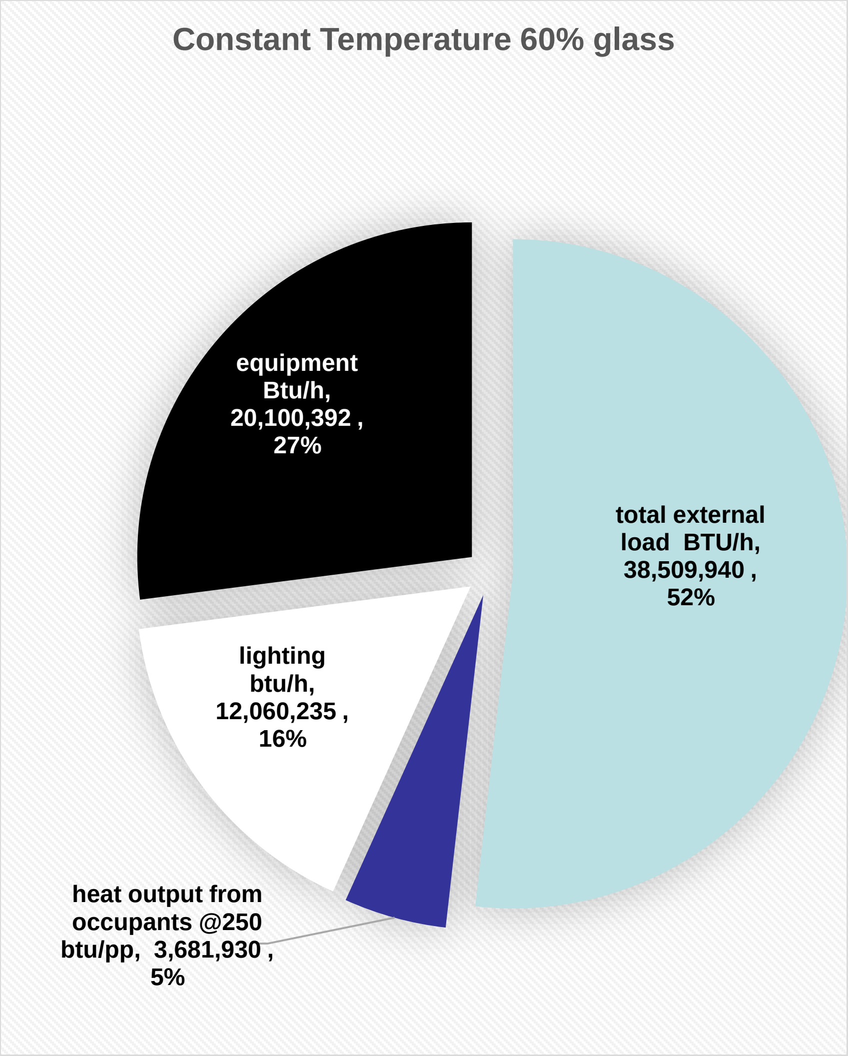
- The new 30- to 33-story Two Tabor Center has been designed with a focus on providing tenants a productive and healthy work environment that is employee-centric and provides easy access to the many amenities of Tabor Center and the 16th Street Mall.
- Two Tabor Center will add approximately 637,000 to 692,000 rentable square feet of class AA office space to Tabor Center, creating one of the largest office complexes in Denver with over 1,217,000 rentable square feet of office space. Retail space occupies the ground level of Two Tabor Center along 17 St. and Larimer Street. Entrances to a 1700-space underground parking garage.

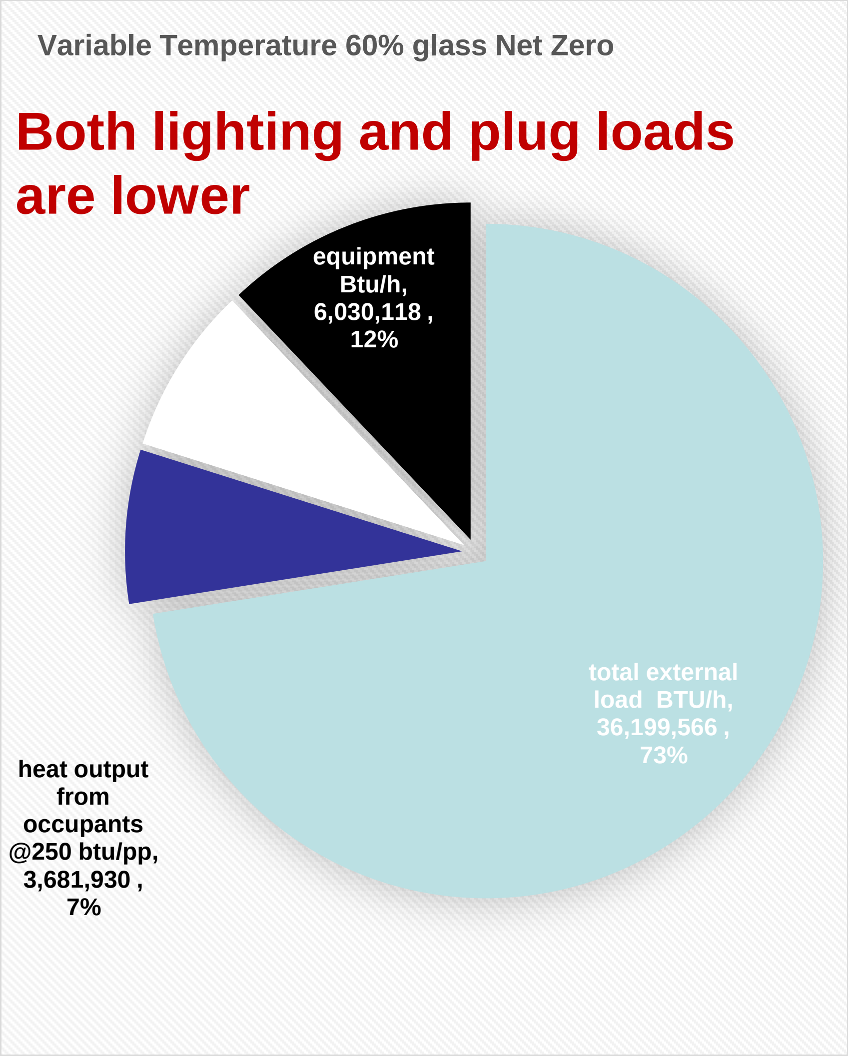
Glazing Comparison

Name	Cavity	U factor	SC	SHGC	Tvis
VNE 1-53	Air (10%)/ Argon (90%)	0.201	0.256	0.223	0.587
VNE 1-53	Air (100%)	0.289	0.264	0.23	0.487
VNE 1-63	Air (10%)/ Argon (90%)	0.209	0.327	0.284	0.619
VP 1-13	Air (10%)/ Argon (90%)	0.404	0.228	0.198	0.128
VRE 1-38	Air (10%)/ Argon (90%)	0.213	0.26	0.226	0.361
VUE 1-30	Air (10%)/ Argon (90%)	0.204	0.195	0.169	0.307
90.1		0.420	0.450	0.400	

Comparison of glass types

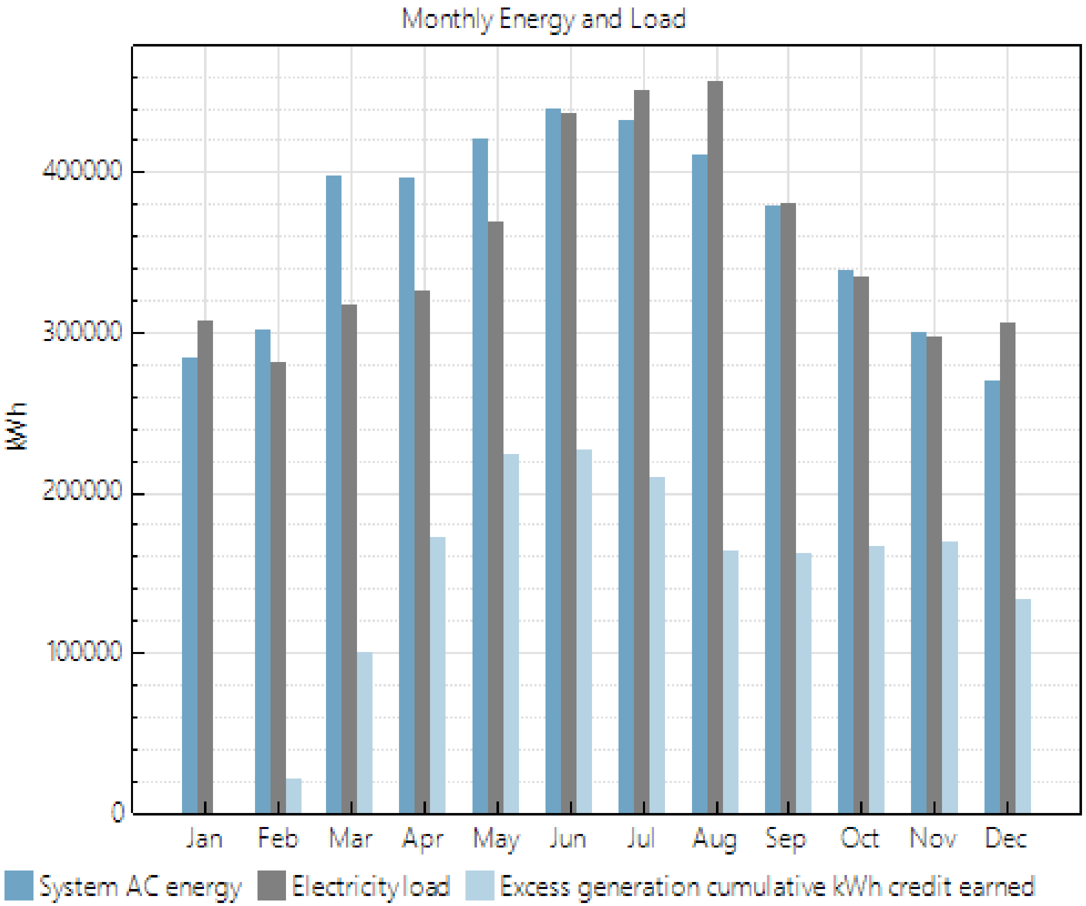
	Cavity	floor area	Solar Radiation (Btu/h)	Transmission (Btu/h)	total	Envelope load per SF floor area (Btuh/sf)
VUE1-30 (40%)	Air(10%)/Argon (90%)	765,272	1,133,853	629,567	1,763,420	2.30
VNE4-53 (40%)	Air(10%)/Argon (90%)	765,272	1,496,149	623,118	2,119,268	2.77
VRE1-38 (40%)	Air(10%)/Argon (90%)	765,272	1,516,277	648,914	2,165,191	2.83
VP1-13 (40%)	Air(10%)/Argon (90%)	765,272	1,328,420	1,059,492	2,387,911	3.12
VNE1-63 (40%)	Air(10%)/Argon (90%)	765,272	1,905,410	640,315	2,545,725	3.33
VUE1-30 (65%)	Air(10%)/Argon (90%)	765,272	1,842,511	824,042	2,666,553	3.48
VNE1-53 (65%)	Air(10%)/Argon (90%)	765,272	2,431,243	788,959	3,220,201	4.21
VNE4-53 (65%)	Air(10%)/Argon (90%)	765,272	2,431,243	813,563	3,244,805	4.24
VRE1-38 (65%)	Air(10%)/Argon (90%)	765,272	2,463,950	855,480	3,319,430	4.34
VP1-13 (65%)	Air(10%)/Argon (90%)	765,272	2,158,682	1,522,669	3,681,351	4.81
ASHRAE 90.1 (40%)	Air(10%)/Argon (90%)	765,272	2,683,676	1,093,886	3,777,561	4.94
VNE1-63 (65%)	Air(10%)/Argon (90%)	765,272	3,096,291	841,508	3,937,799	5.15
ASHRAE 90.1 (65%)		765,272	4,360,973	1,578,560	5,939,533	7.76
VNE1-53 Air (65%)	Air (100%)	765,272	2,507,560	995,206	3,502,765	4.58





Both lighting and plug loads are lower

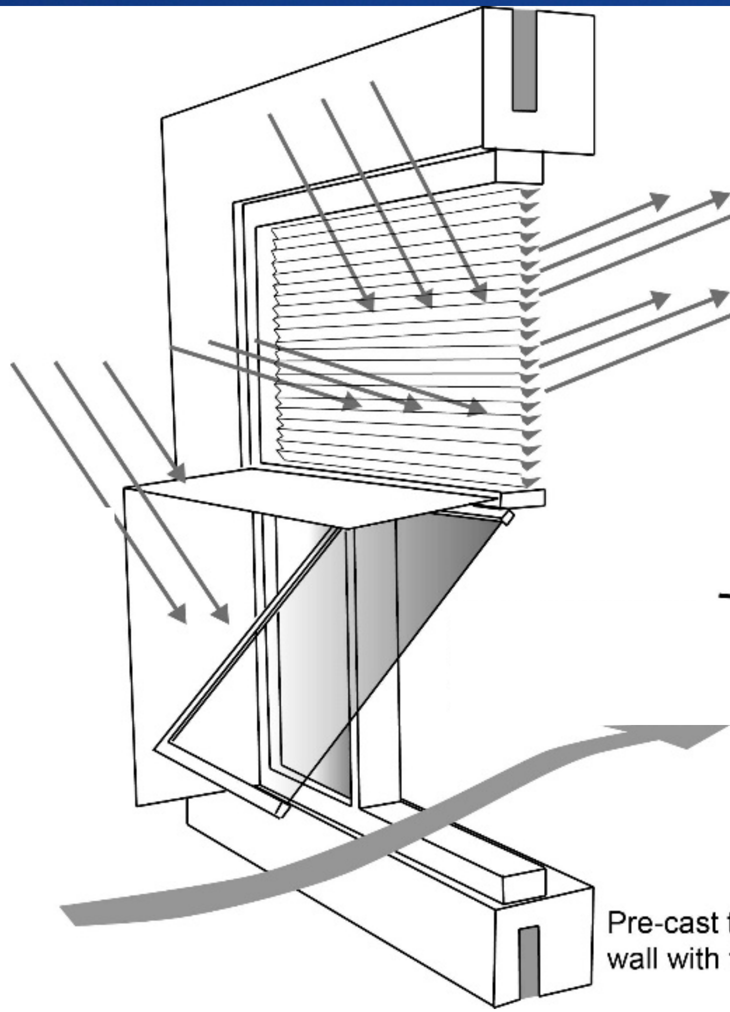
Using Photovoltaics to Take Tabor II to Net Zero

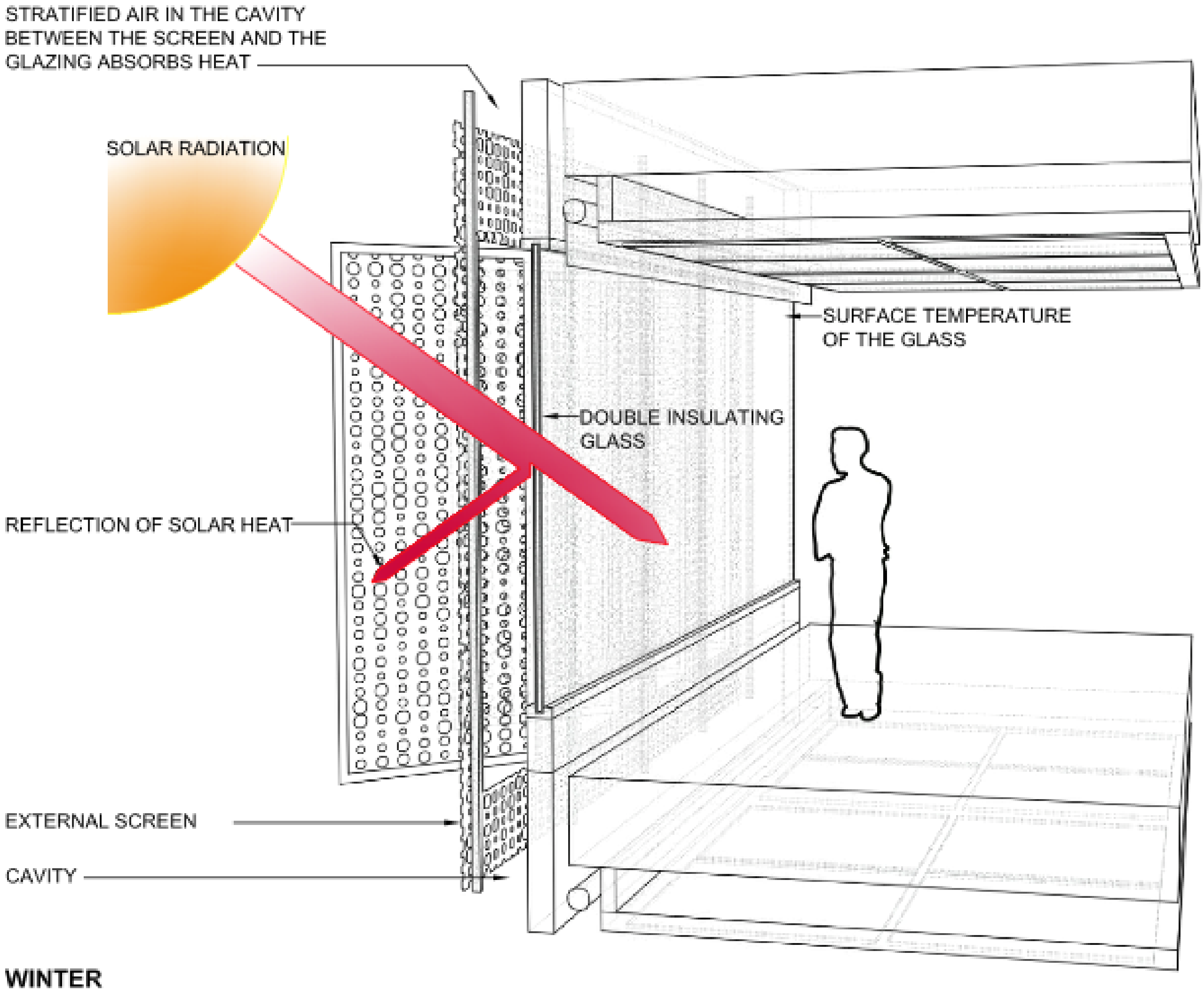


Metric	Value
Annual energy (year 1)	4,369,936 kWh
Capacity factor (year 1)	19.2%
Energy yield (year 1)	1,680 kWh/kW
Performance ratio (year 1)	0.81
Levelized COE (nominal)	6.05 ¢/kWh
Levelized COE (real)	4.83 ¢/kWh
Electricity bill without system (year 1)	$519,583
Electricity bill with system (year 1)	$167,846
Net savings with system (year 1)	$351,738
Net present value	$525,719
Simple payback period	11.9 years
Discounted payback period	NaN
Net capital cost	$4,732,172
Equity	$1,892,869
Debt	$2,839,303

Advanced Building Envelope Concepts

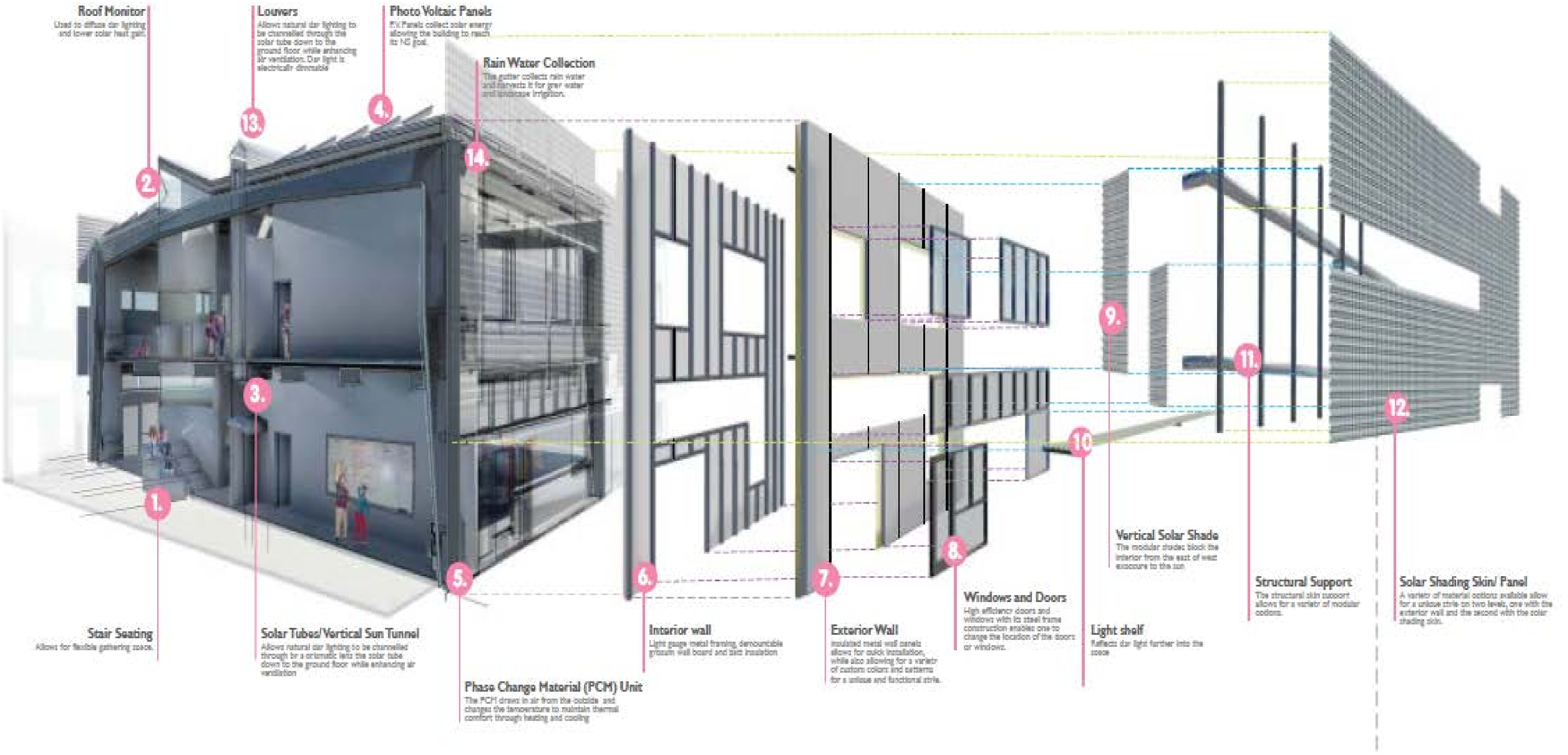
RNL Architects
Stantec





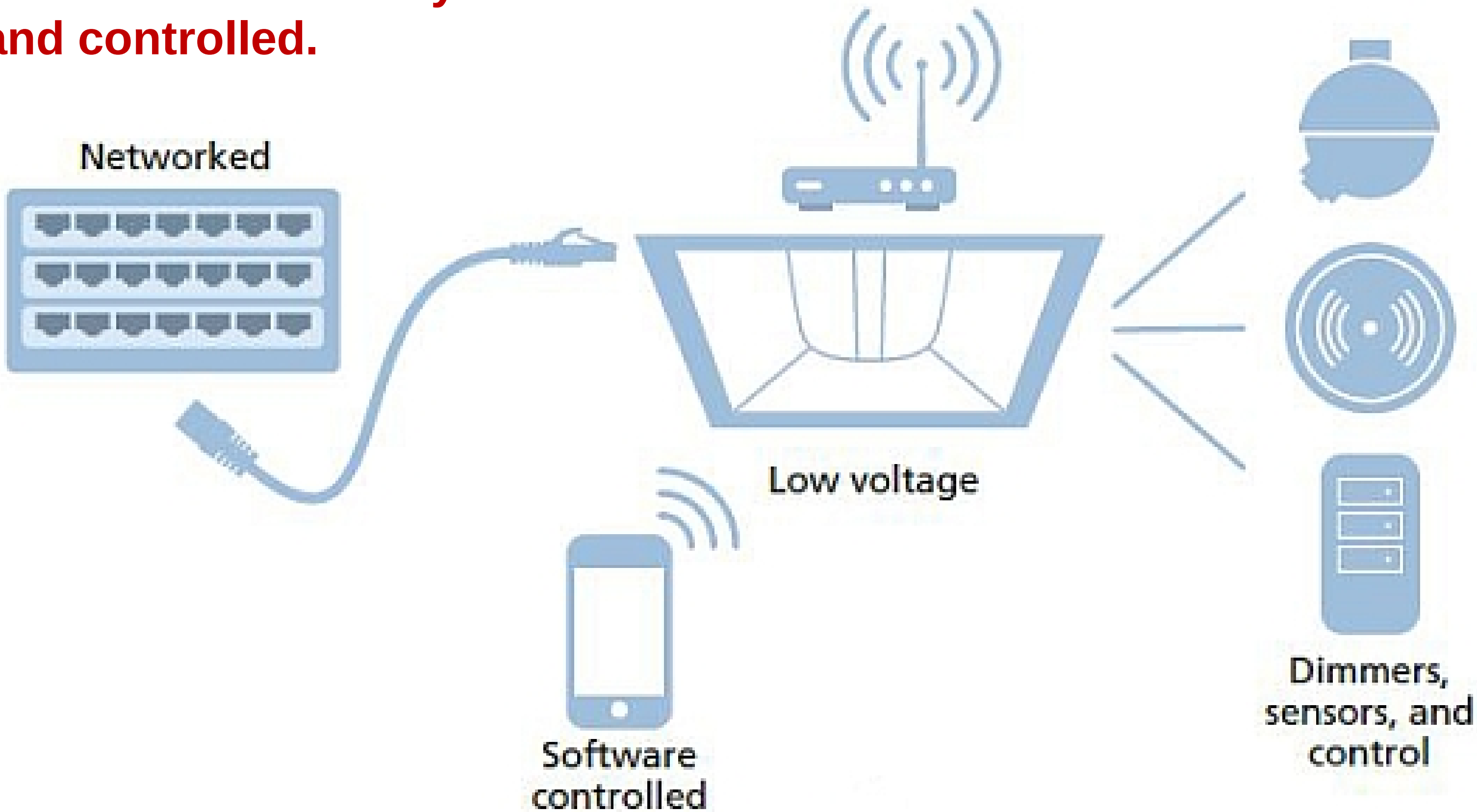
WINTER
OUTSIDE TEMPERATURE = 23°F
SUNNY DAY / OPEN PANEL


THE COOPER UNION


Roof Monitor
Louvers
Photo Voltaic Panels
Rain Water Collection
1.
2.
3.
4.
5.
6.
7.
8.
9.
10
11.
12.
13.
14.
Stair Seating
Solar Tubes/Vertical Sun Tunnel
Phase Change Material (PCM) Unit
Interior wall
Exterior Wall
Windows and Doors
Light shelf
Vertical Solar Shade
Structural Support
Solar Shading Skin/ Panel

Lighting and Daylighting

Power over Ethernet (PoE) allows individual LED lighting fixtures to be directly addressed and controlled.



Source: Maxim Integrated; published in LEDs Magazine, September 2015.

Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

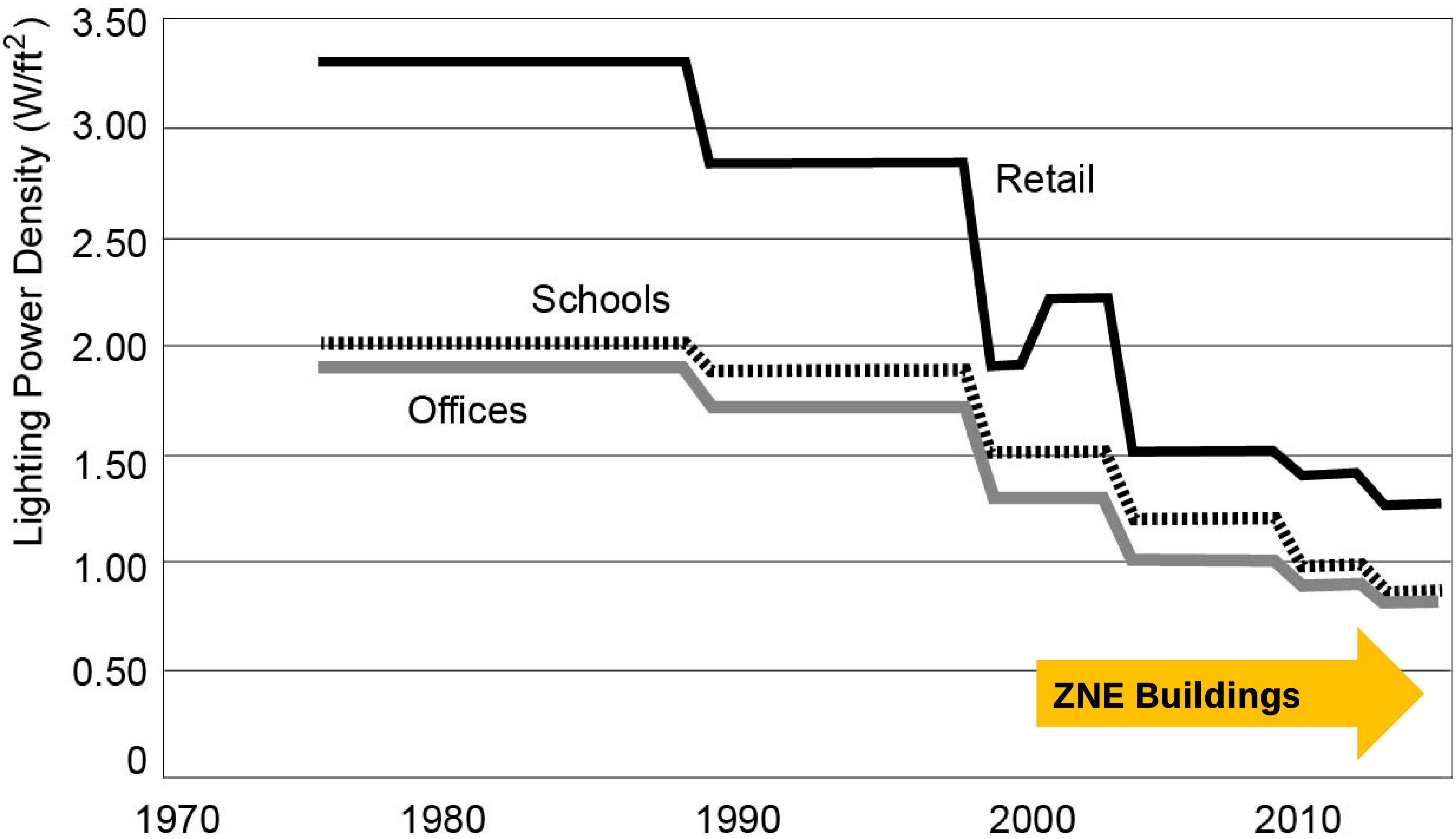
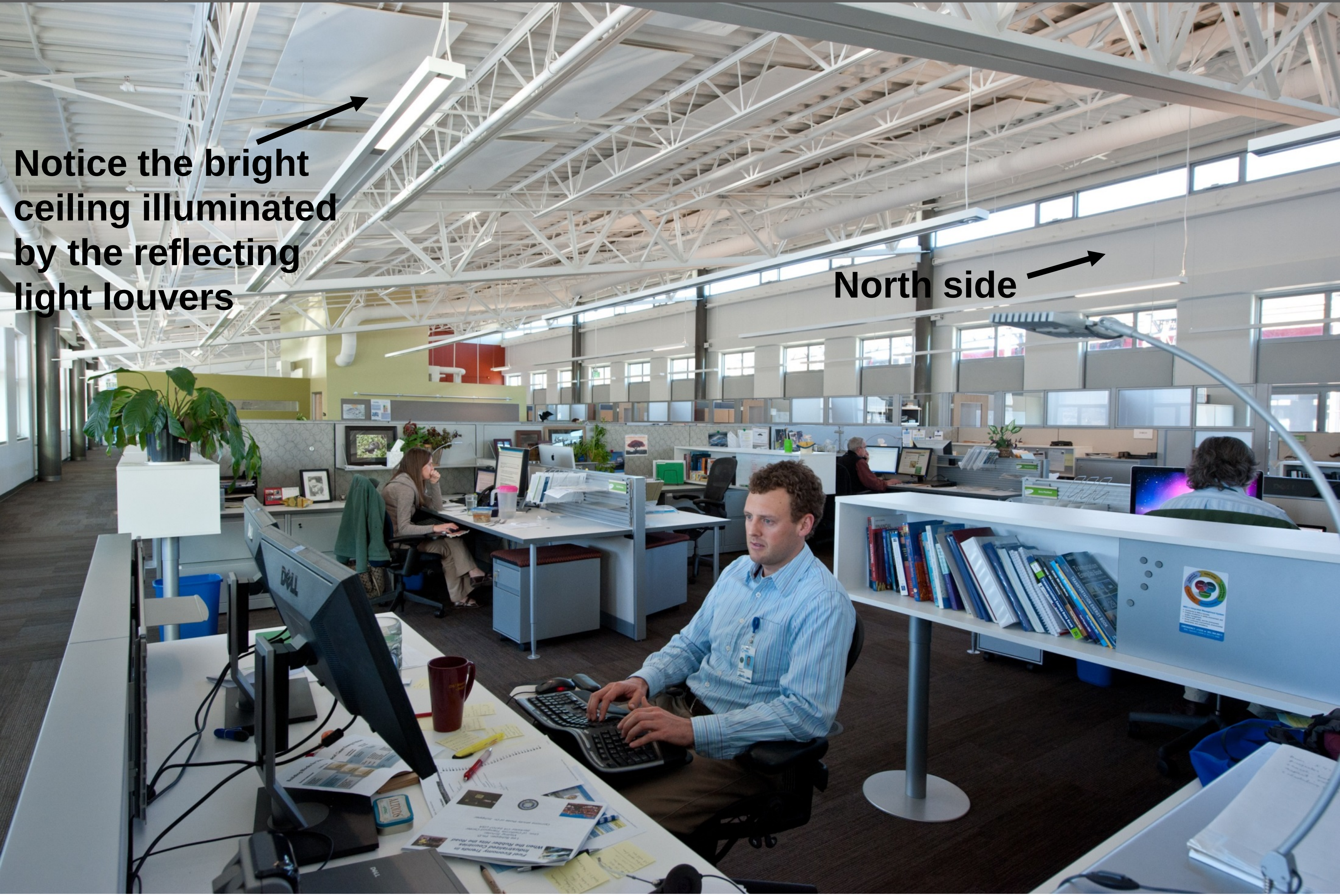


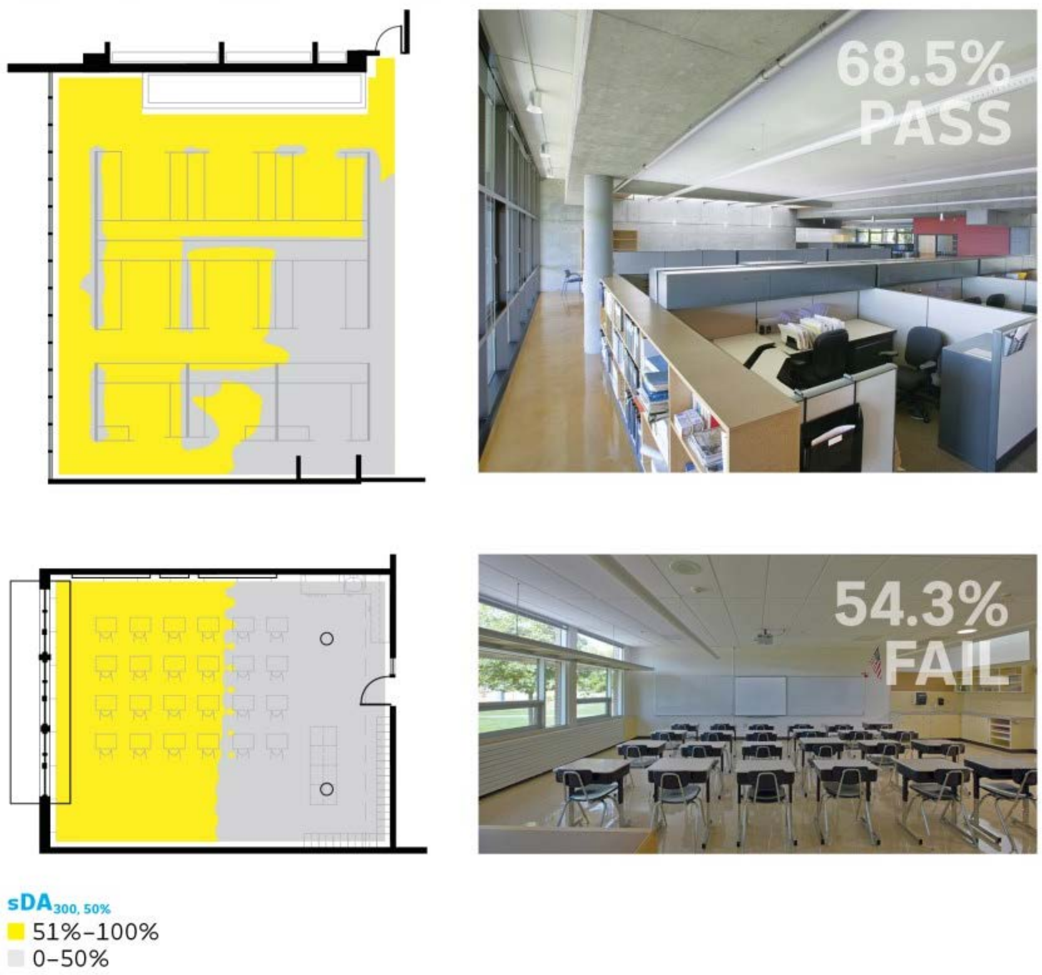
Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.


Notice the bright ceiling illuminated by the reflecting light louvers
North side

Dynamic Daylighting Metrics

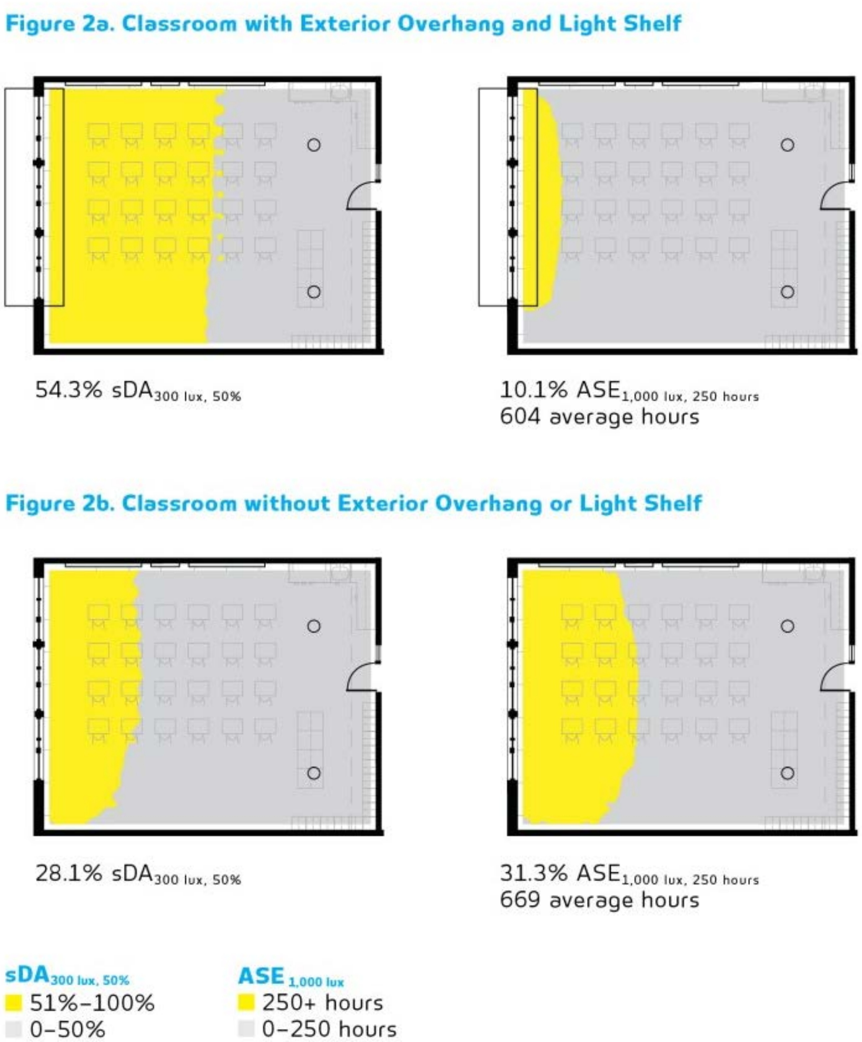
Spatial Daylight Autonomy (sDA)

Figure 1. Spatial Daylight Autonomy (sDA) Evaluation

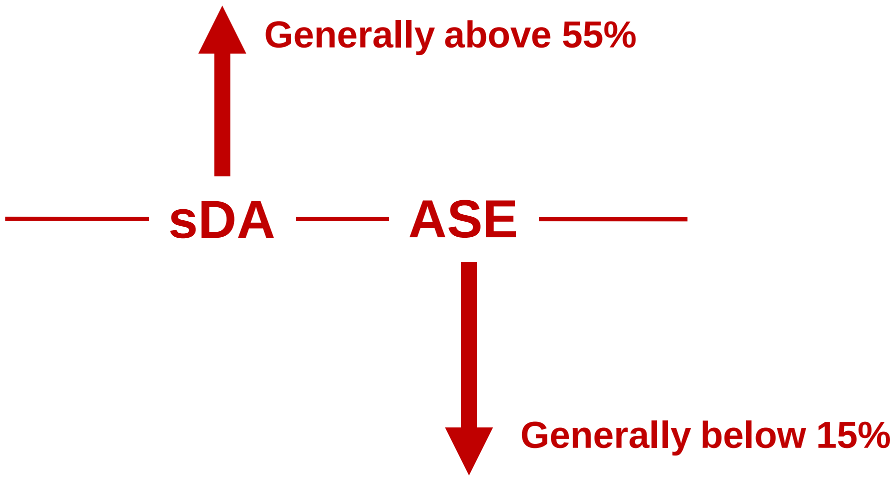


- The percent of the space where daylight illumination is above 300 lux for 50% or more of the time during standard operating hours.
- These pass/fail examples are for attempting to achieve an sDA of 55%.
- See IES LM-83 for more details.

Annual Sunlight Exposure (ASE)



- Represents the percent of the space when illumination exceeds 1000 lux for more than 250 hours per year.
- Recommended criteria for regularly occupied spaces is from 15% to 25%.
- ASE is a proxy for glare and overheating
- See IES LM-83 for more details.



IES LM-83 Recommendations

	Minimum $sDA_{300,50\%}$	Maximum $ASE_{1000,250}$
Classrooms	75%	15%
Gymnasiums/Multipurpose Rooms	55%	25%
Library Reading Area	55%	25%
Administrative Offices	55%	15%

https://patternguide.advancedbuildings.net

Daylighting Pattern Guide

Home | Patterns | Using this Guide | About | DPG+E Development

Pattern 2: Window Area (Window Spacing)

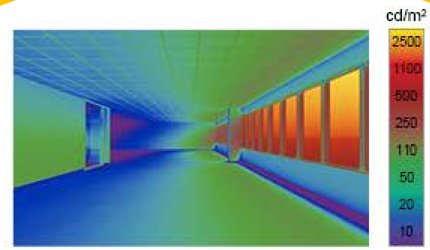
50% Glazing Area

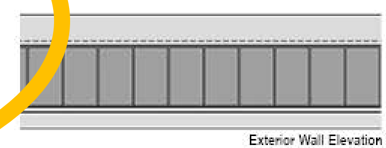
5 of 5

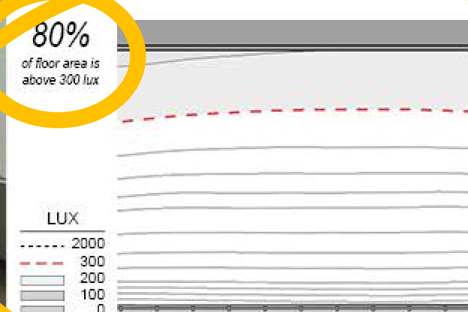
Slideshow

◀ To Overview

Vertical windows comprising 50 percent of the wall area provide daylight illumination that meets or exceeds commonly accepted minimum daylight illumination criteria at approximately 80 percent of the adjacent 26'-0" section. Some contrast remains between the interior surfaces and the glazing, though the "back" wall (at left) shows a substantial increase in surface brightness to balance the luminosity across the section. Note that at this window to wall ratio, the vertical windows are geometrically equivalent to the horizontal band when bounded by a 2'-6" sill and a 9'-6" head height.







HVAC and Thermal Comfort

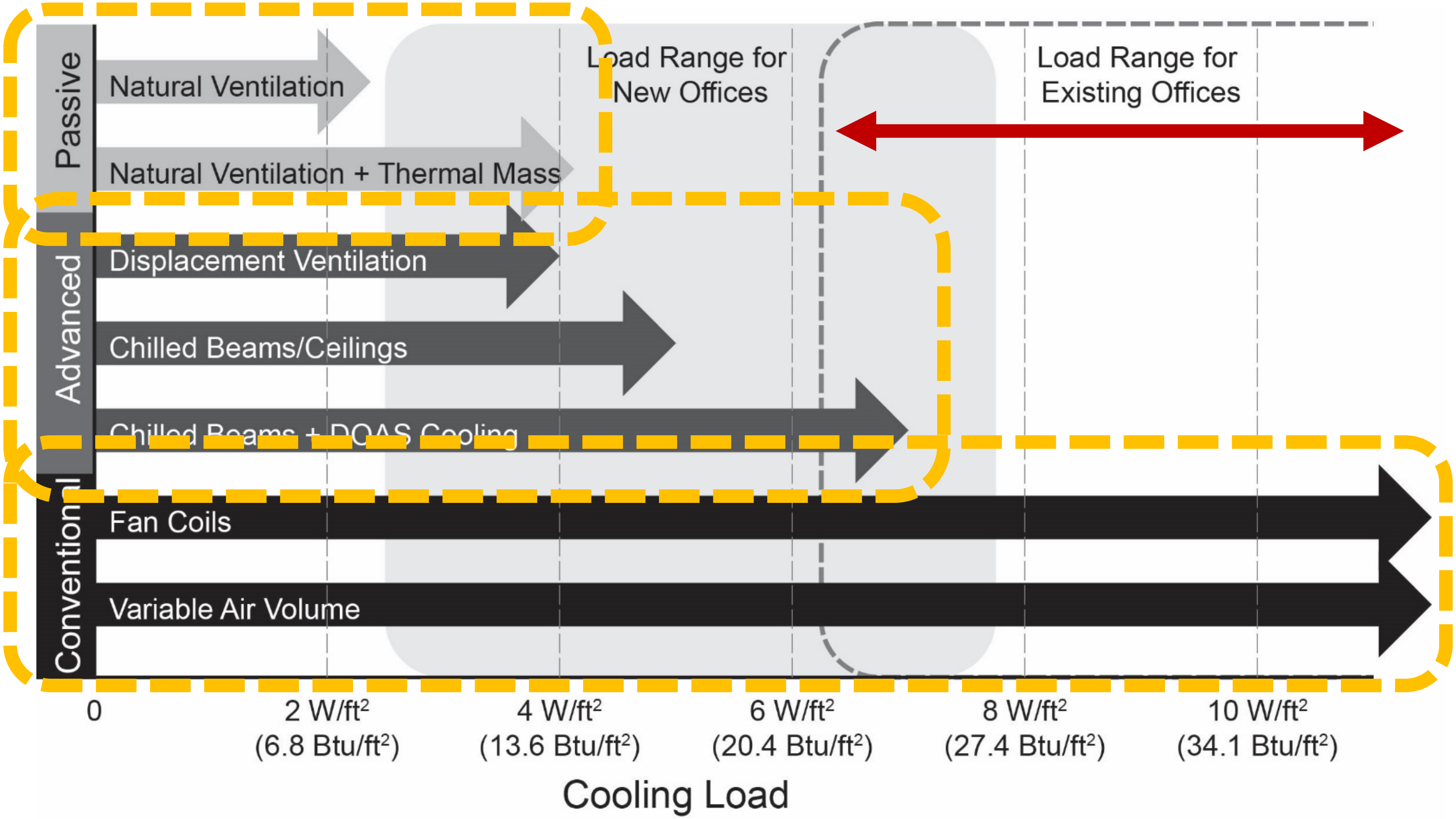


Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

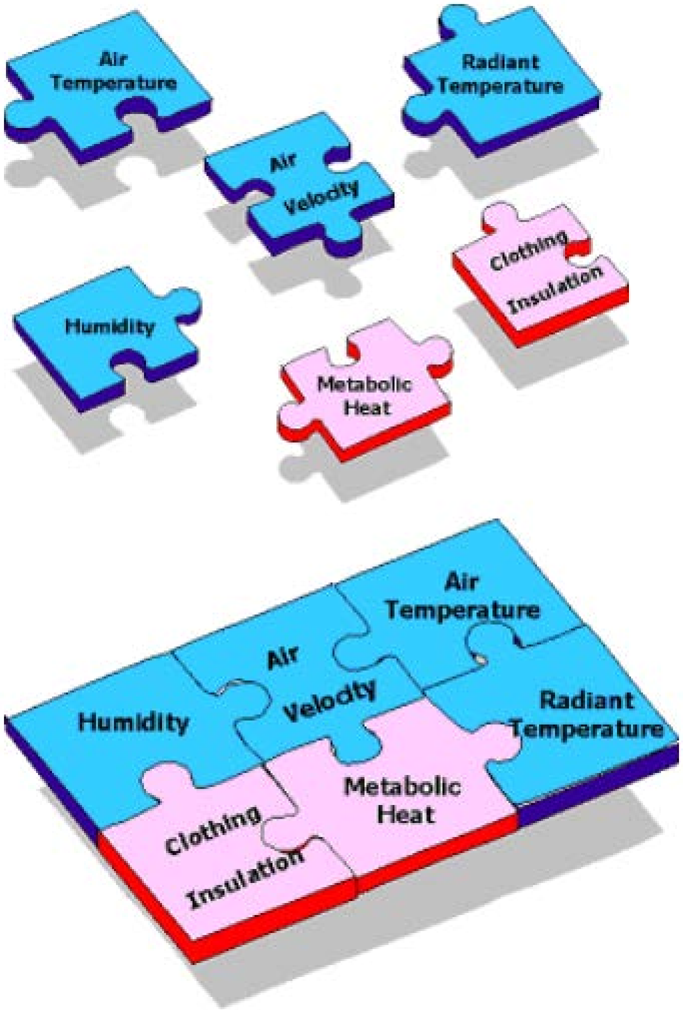
A comparisons of systems for New York and Los Angeles Locations

Annual Electric Energy by End Use		Annual Source Energy		Annual Site Energy		Lighting	HVAC Energy			Peak	
Los Angeles		**total**	**EUI**	**Electric**	**Nat Gas**	**Electric**	**Electric**	**Nat Gas**	**total**	**Electric**	**Cooling**
Annual Energy Use (kWh)		**MBtu**	**kBtu/sf/yr**	**kWh**	**Therms**	**kWh**	**kWh**	**Therms**	**MBtu**	**kW**	**tons**
0	Base Design - VAV	29,779	**165**	2,679,658	23,422	599,160	796,725	124	2732	938	391
1	0+Fan Coils	31,813	**177**	2,879,748	23,276	599,160	996,816	7	3403	948	389
2	0+Radiant Ceiling	26,668	**148**	2,376,977	23,301	599,160	494,044	35	1690	795	330
3	0+Active Beams	26,824	**149**	2,392,191	23,309	599,160	509,257	37	1742	818	346
New York											
0	Base Design - VAV	29,992	**167**	2,594,809	34,236	599,160	711,876	8412	3271	1025	456
1	0+Fan Coils	31,795	**177**	2,814,940	29,727	599,160	932,006	3924	3573	1031	513
2	0+Radiant Ceiling	27,349	**152**	2,336,119	34,295	599,160	453,185	8482	2395	862	426
3	0+Active Beams	27,564	**153**	2,356,092	34,400	599,160	473,158	8585	2473	873	461

What is Thermal Comfort

- Space dry-bulb temperature
- Space humidity content
- Space air movement
- Space mean radiant temperature (MRT)
- Occupants are seated
- Clothing may vary

- Percent persons dissatisfied (PPD)
- Predicted mean vote (PMV)



Natural Ventilation Points

- Natural ventilation can be used under certain conditions
- Natural ventilation air movement is dependent upon buoyancy, wind, or buoyancy and wind driven air outside air.
- There are presently no limitations on space humidity when utilizing natural ventilation; however, space humidity limits must be taken into account.
- The occurrence of natural ventilation is not predictable.
- If the openings are manual, then natural ventilation could be operated outside of recommended conditions.
- In a mixed-mode system there is a chance of surface condensation when switching from conditioning the space to naturally ventilating the space.

Energy Modeling in the Design Process

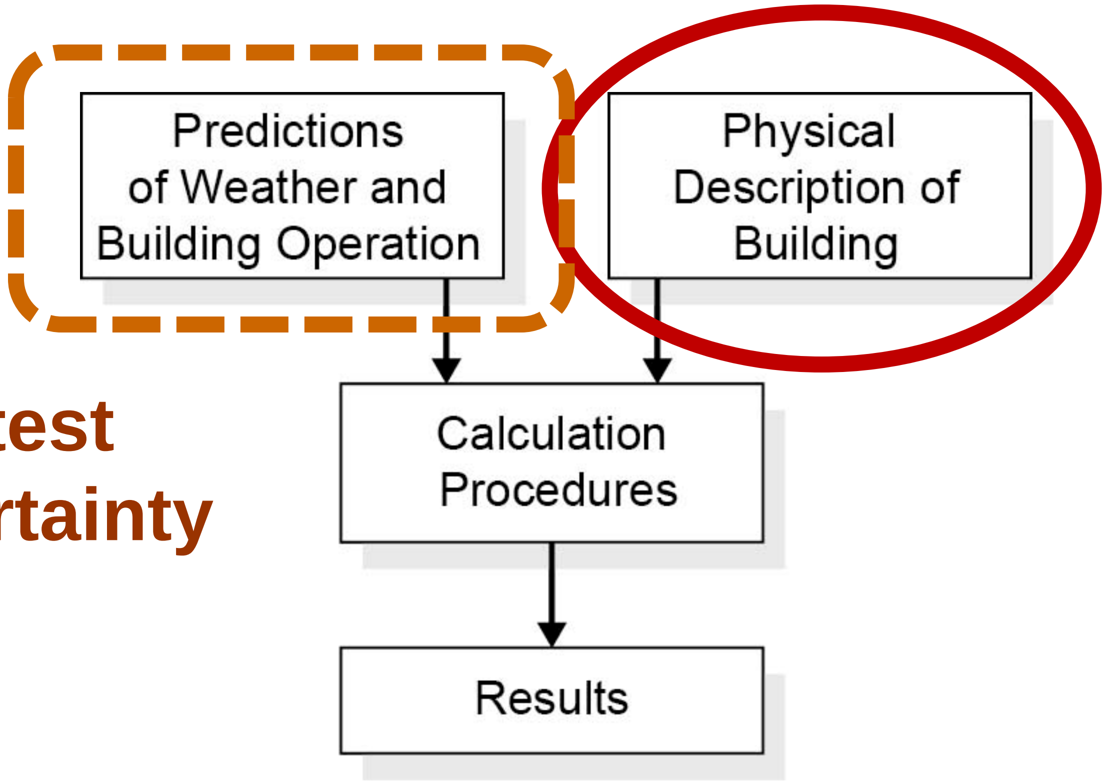
Methods of Assessing ZNE

Operational Assessment

- Based on utility bills
- Actual building operation
- Based on actual weather

Asset Assessment

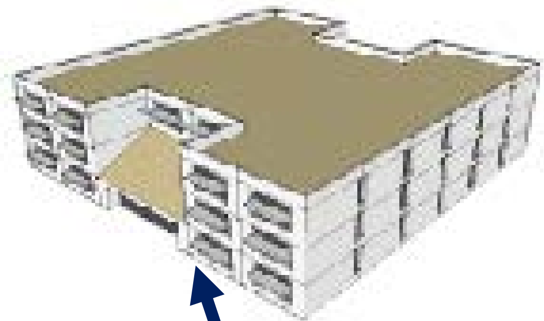
- Based on energy model
- Standard modeling assumptions
- Standard weather file



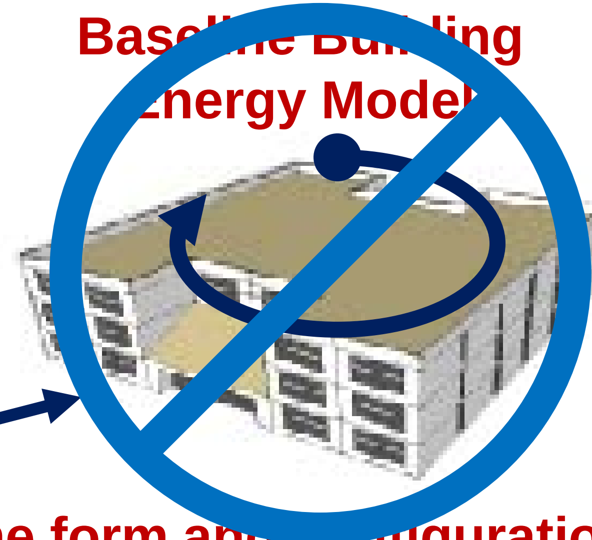
Greatest uncertainty

Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

Proposed Design Energy Model



Baseline Building Energy Model



Both models use the same:

- Energy simulation software
- Temperature set points
- Hours of operation
- Plug loads
- Occupants
- etc.

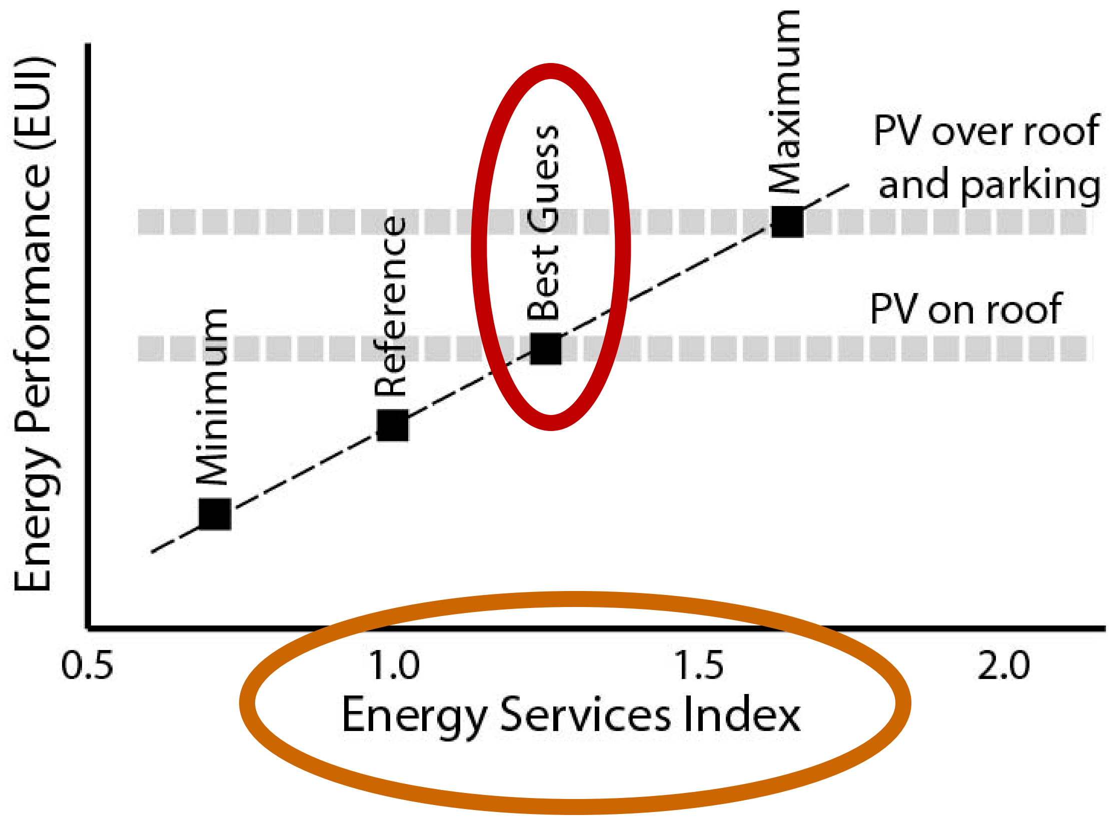
Energy (Source)
Energy (Cost)

≤ ZERO

Same form and configuration but upgraded or downgraded to meet roughly Standard 90.1-2004

- Insulation U-factors
- Fenestration area, SHGC, and U-factor
- Lighting power and controls
- Standard HVAC system and equipment efficiencies

PCI = Performance Cost Index



Accurately estimating building operation and weather is critically important when the target is ZNE.

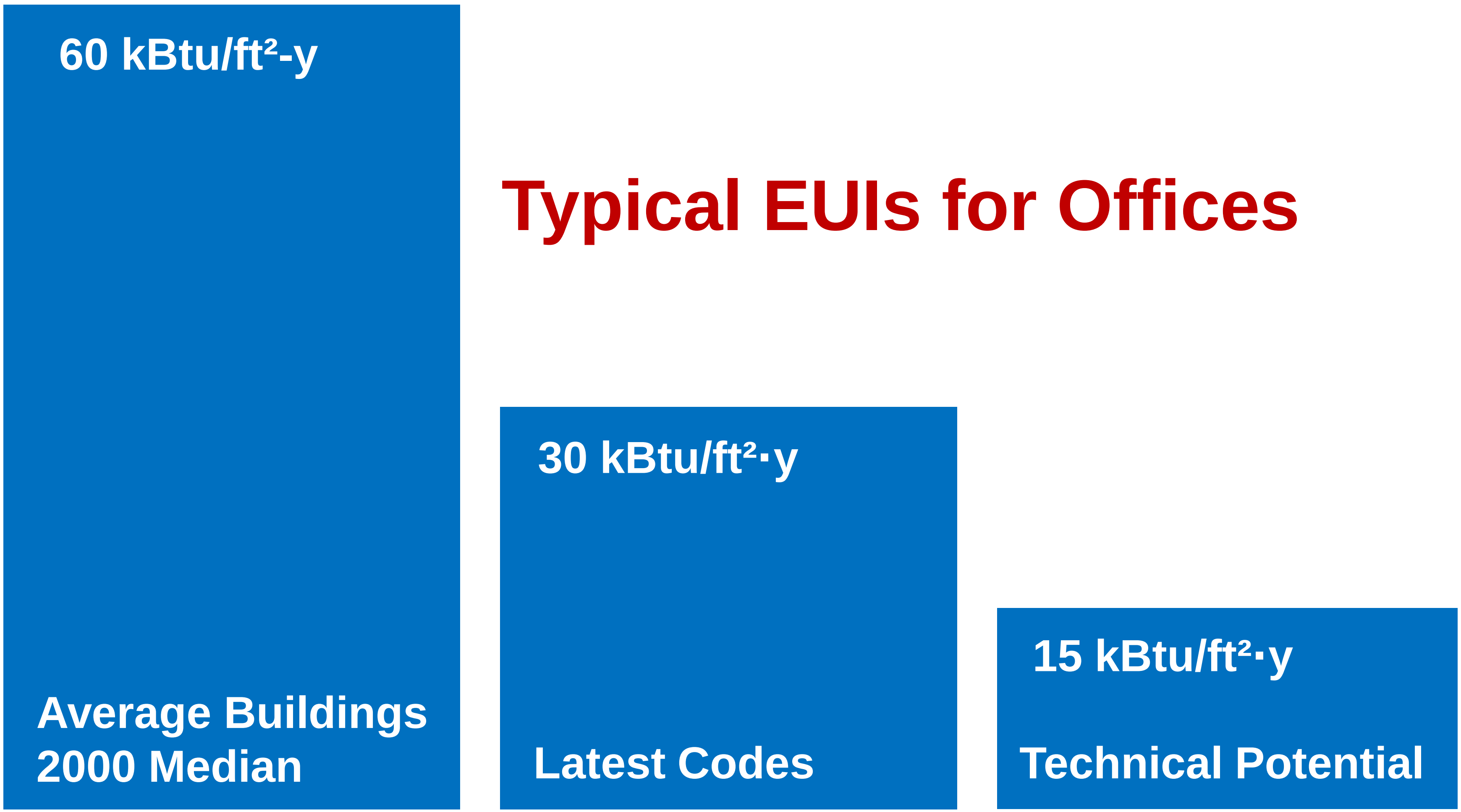
Goldstein, David, and Charles Eley. A Classification of Building Energy Performance Indices, *Energy Efficiency*, Volume 7, Issue 1, February 2014. See Eley.com.

Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

Break

EUI Targets and Potential

Typical EUIs for Offices



EUI Targets and Potential

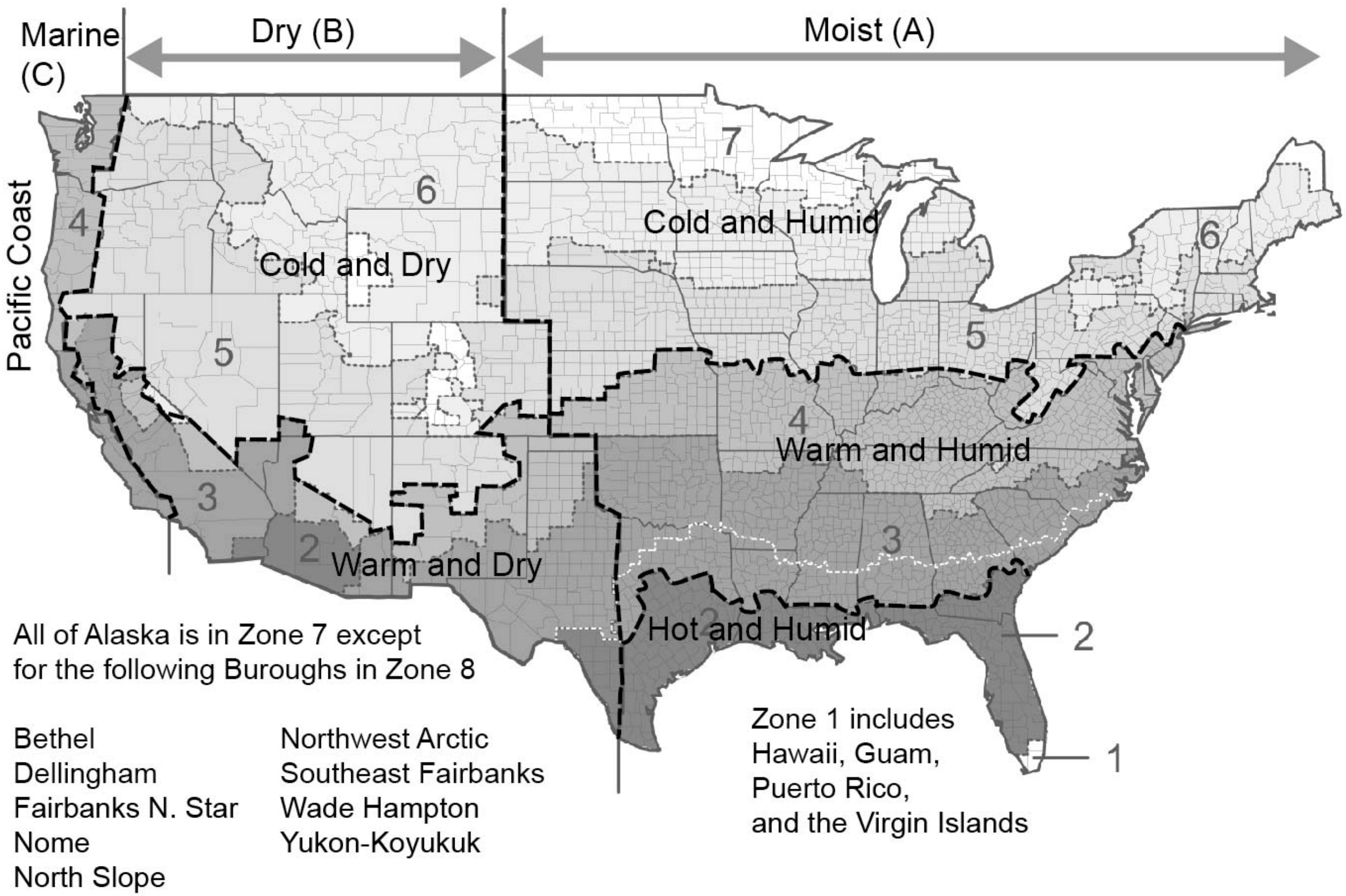


Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

EUI Targets and Potential

	Pacific Coast	Warm and Dry	Hot and Humid	Warm and Humid	Cold and Dry	Cold and Humid	Artic
CZ->	(3c, 4c)	(2b, 3b, 4b)	(1a, 2a)	(3a, 4a)	(5b, 6b)	(5a, 6a, 7)	(8)
Warehouses	34	20	23	40	53	65	161
Offices	58	62	69	69	69	77	126
Retail	101	86	99	114	122	142	249
Schools	70	59	71	78	77	91	165
Apartments	62	42	52	69	73	86	153
Hotels	122	99	119	126	126	134	151
Healthcare	232	202	232	242	218	238	281
Restaurants	558	497	522	569	598	660	965

Source: EnergyPlus simulations of prototype buildings modified to match characteristics of pre-2000 buildings, NREL.

From: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

CA Title 24 is similar

	Pacific Coast	Warm and Dry	Hot and Humid	Warm and Humid	Cold and Dry	Cold and Humid	Artic
	(3c, 4c)	(2b, 3b, 4b)	(1a, 2a)	(3a, 4a)	(5b, 6b)	(5a, 6a, 7)	(8)
Warehouses	16	15	12	17	20	26	33
Offices	22	31	33	32	31	34	41
Retail	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Schools	35	46	49	47	48	50	68
Apartments	35	48	48	51	53	61	76
Office w/ Data Center	62	69	71	70	72	77	88
Hotels	57	75	80	78	77	83	100
Healthcare	101	108	117	116	111	120	140
Restaurants	360	431	414	471	513	574	759

Source: EnergyPlus simulations of prototype buildings in minimum compliance with Standard 90.1-2013, PNNL.

Source: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

	Pacific Coast	Warm and Dry	Hot and Humid	Warm and Humid	Cold and Dry	Cold and Humid	Artic
	(3c, 4c)	(2b, 3b, 4b)	(1a, 2a)	(3a, 4a)	(5b, 6b)	(5a, 6a, 7)	(8)
Warehouses	6	6	5	6	7	8	7
Offices	8	10	11	11	11	11	12
Retail	13	18	18	17	18	19	27
Schools	16	21	23	22	21	23	26
Apartments	24	30	29	31	32	34	35
Offices/Data Center	43	47	47	44	47	46	47
Hotels	40	49	49	51	51	54	58
Healthcare	[illegible]	64	[illegible]	67	[illegible]	[illegible]	72
Restaurants	265	323	324	336	343	353	377

Study did not look at comprehensive measures to reduce cooking and refrigeration energy.

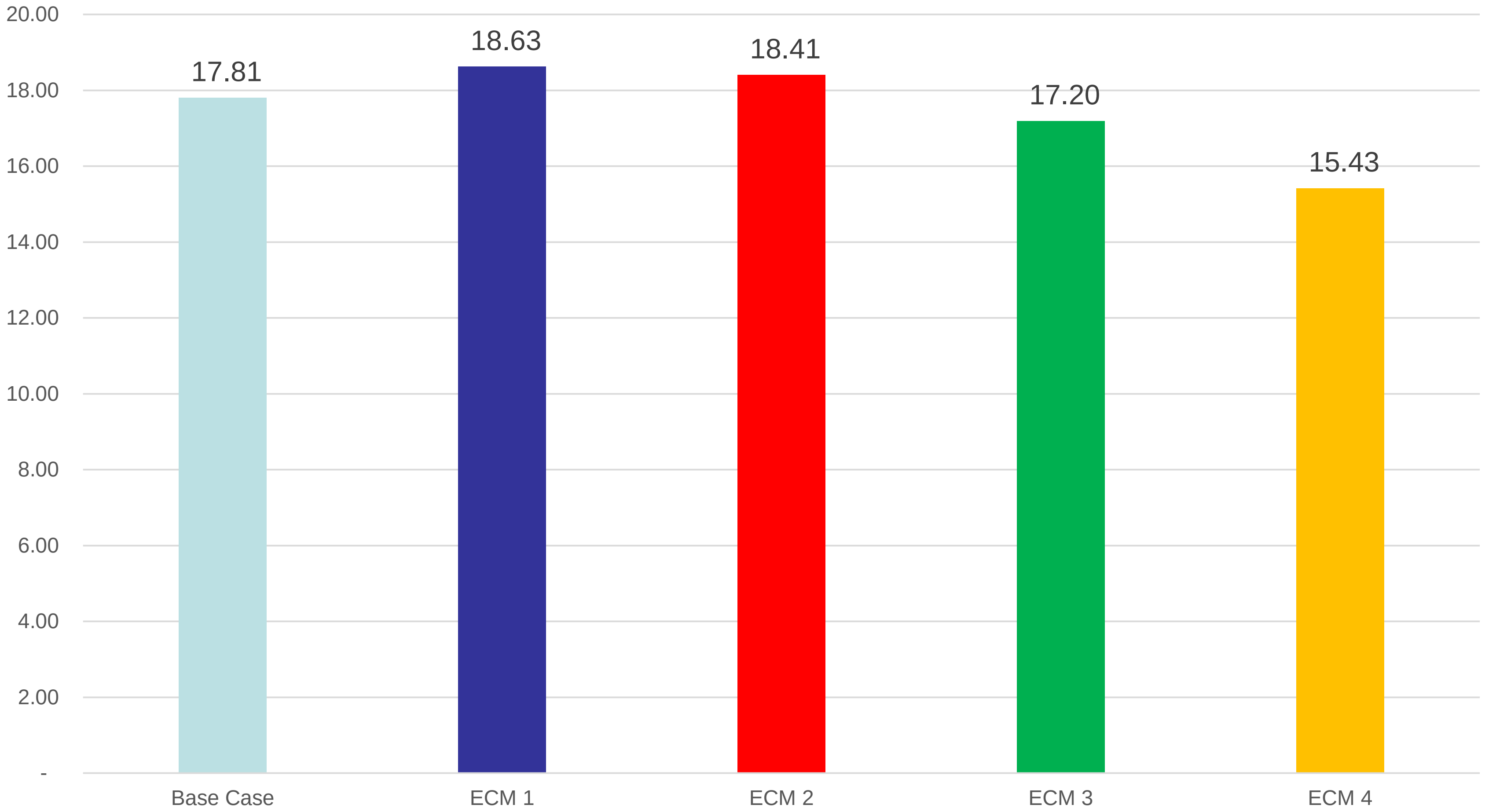
Source: ASHRAE Research Project 1651-RP, Glazer.

From: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

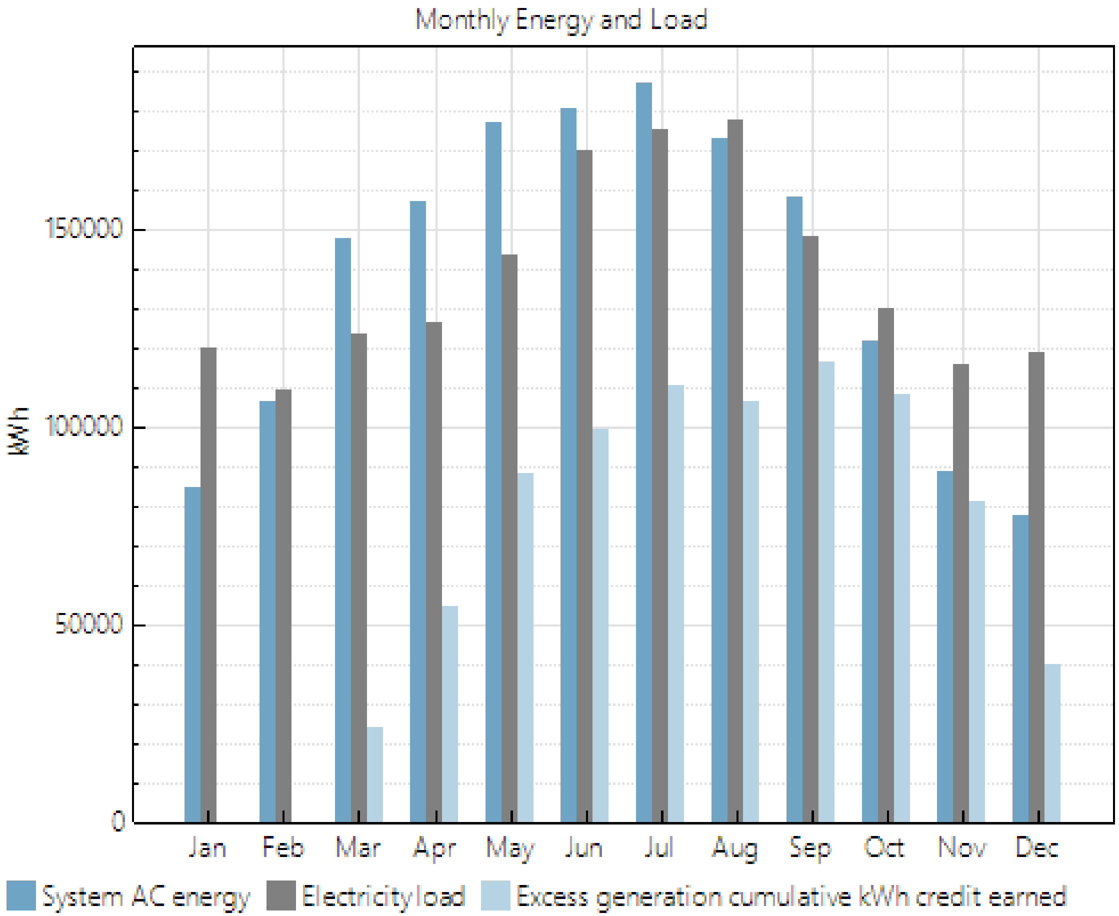
EUI Examples

EUI Examples

EUI Examples



Taking Will County Courthouse to Net Zero

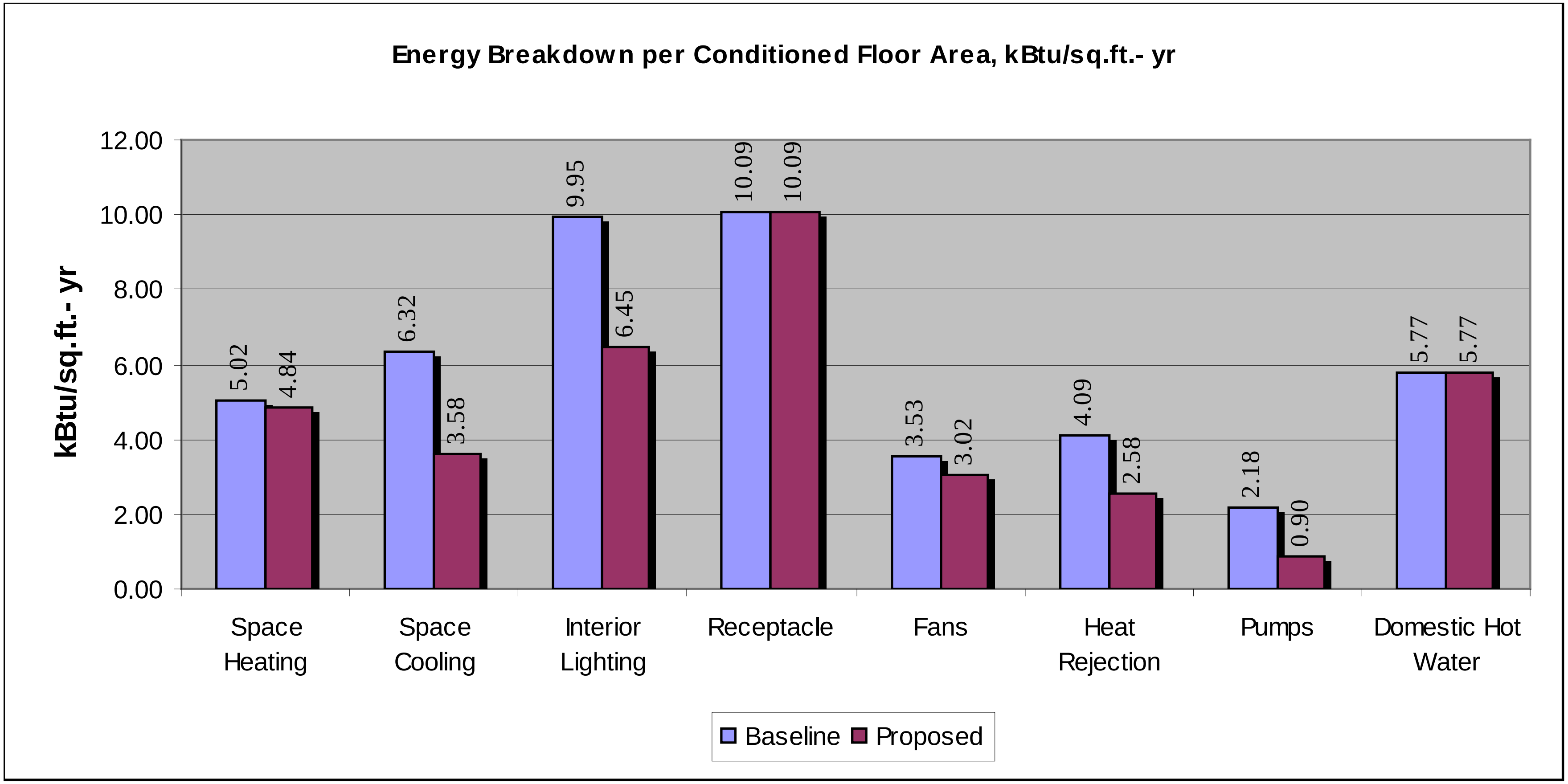


Metric	Value
Annual energy (year 1)	1,661,297 kWh
Capacity factor (year 1)	15.8%
Energy yield (year 1)	1,386 kWh/kW
Performance ratio (year 1)	0.83
Levelized COE (nominal)	7.34 ¢/kWh
Levelized COE (real)	5.86 ¢/kWh
Electricity bill without system (year 1)	$202,787
Electricity bill with system (year 1)	$68,061
Net savings with system (year 1)	$134,726
Net present value	$4,616
Simple payback period	15.5 years
Discounted payback period	NaN
Net capital cost	$2,179,913
Equity	$871,965
Debt	$1,307,948

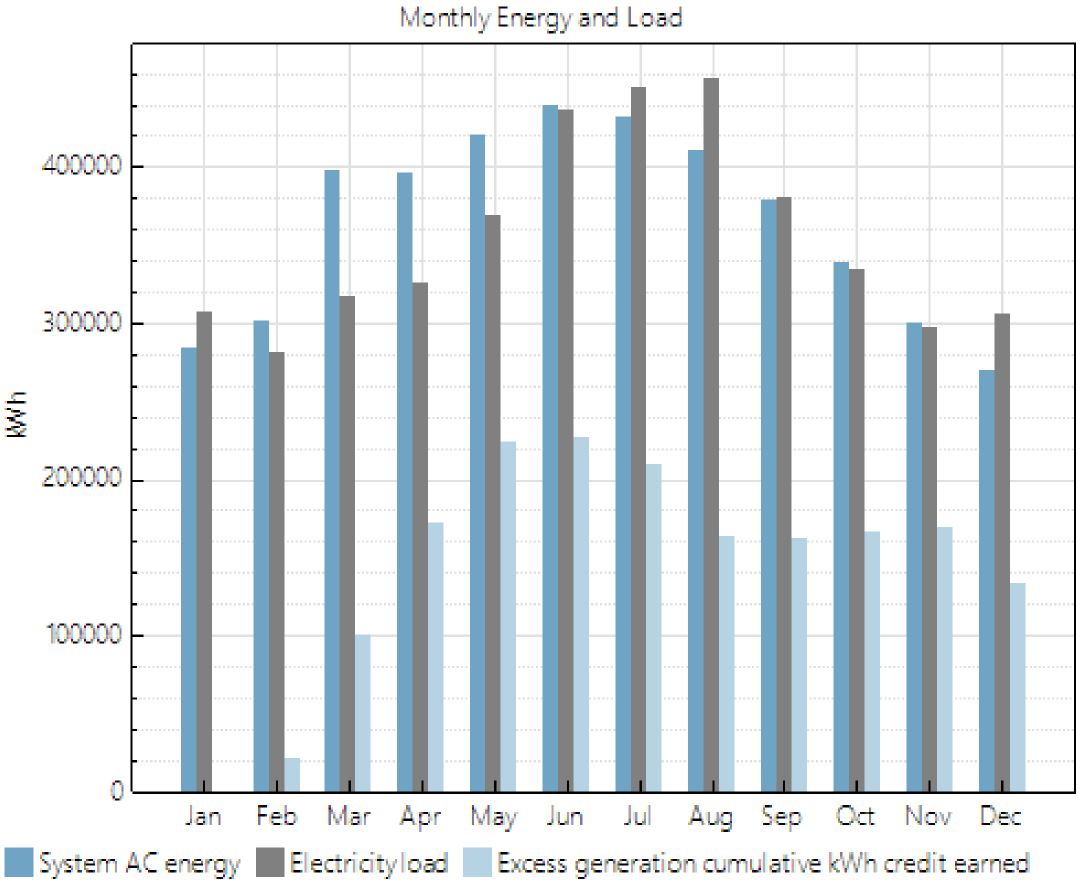
EUI Examples

EUI Examples

	Description	Energy Breakdown per Conditioned Floor Area, kBtu/sq.ft.-yr									
		Space Heating	Space Cooling	Interior Lighting	Receptacle	Fans	Heat Rejection	Pumps	Domestic Hot Water	**Total**	% better
Baseline	2008 Title-24 Standard System Type 4, Overhead VAV w/ Reheat	5.02	6.32	9.95	10.09	3.53	4.09	2.18	5.77	**46.95**	N/A
Proposed	Overhead VAV w/ Reheat, Thermal Storage	4.84	3.58	6.45	10.09	3.02	2.58	0.90	5.77	**37.23**	20.7%


Energy Breakdown per Conditioned Floor Area, kBtu/sq.ft.- yr
kBtu/sq.ft.- yr
12.00
10.00
8.00
6.00
4.00
2.00
0.00
5.02
4.84
6.32
3.58
9.95
6.45
10.09
10.09
3.53
3.02
4.09
2.58
2.18
0.90
5.77
5.77
Space Heating
Space Cooling
Interior Lighting
Receptacle
Fans
Heat Rejection
Pumps
Domestic Hot Water
Baseline
Proposed

Taking San Bernardino Courthouse to Net Zero



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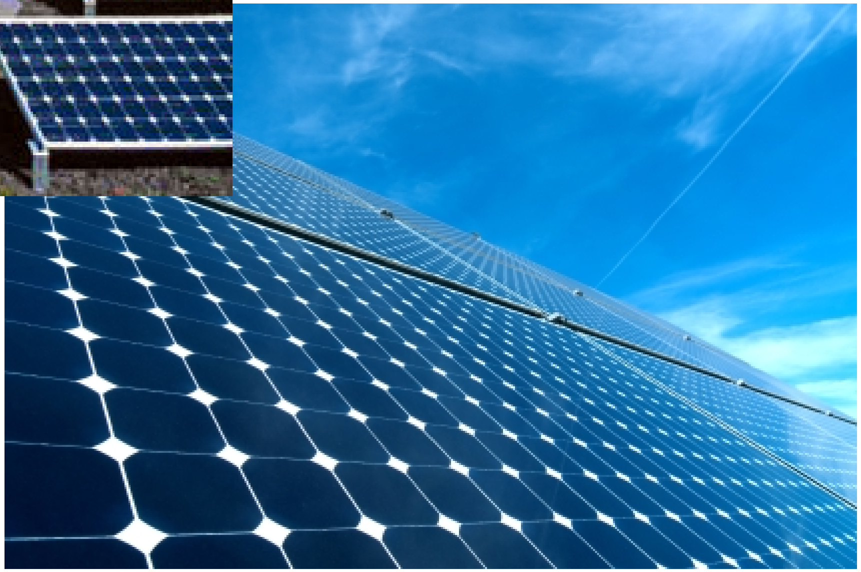
Debt	$2,839,303

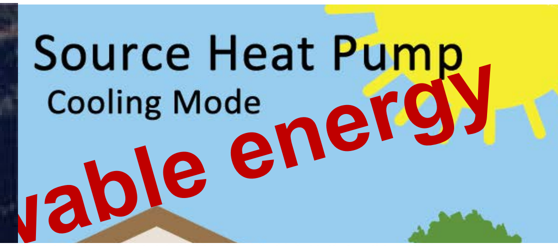
Renewable Energy Systems

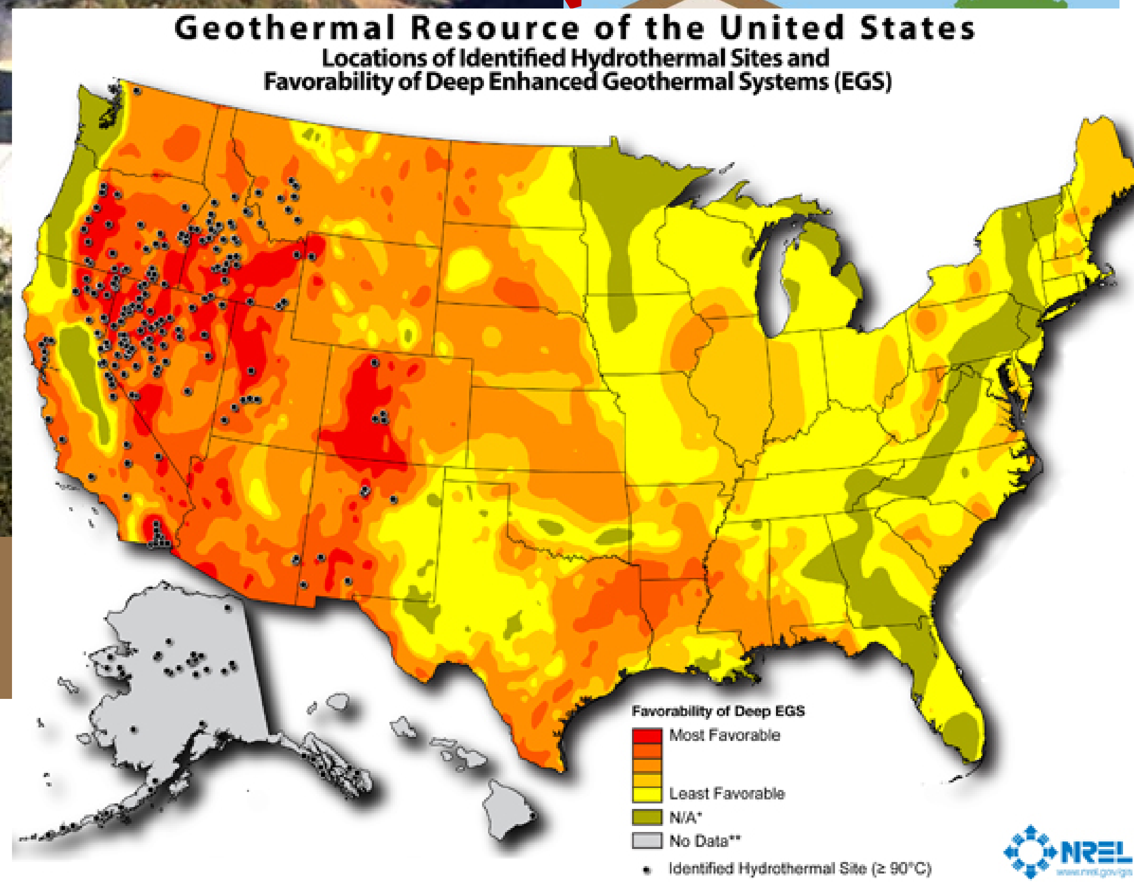
Primary source of on-site renewable energy for ZNE buildings



- Limited on-site potential for ZNE buildings
- More potential is at the utility scale


Limited or no on-site renewable energy potential
Simon Pierce, Quechee, Vermont





Limited or no on-site renewable energy potential

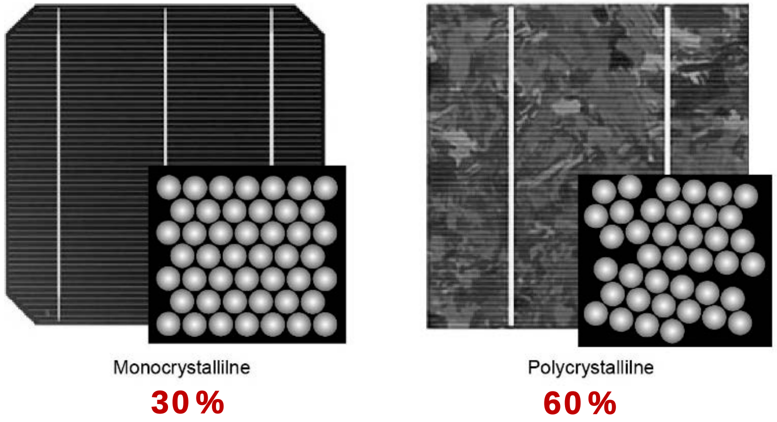
Regenerative but not renewable in the same sense as wind and solar.

SCIENTIFIC AMERICAN.

Congress Says Biomass Is Carbon-Neutral, but Scientists Disagree

Using wood as fuel source could actually increase CO2 emissions

By Chelsea Harvey, Niina Heikkinen, E&E News on March 23, 2018



Costs are less than $4/W before tax credits or incentives

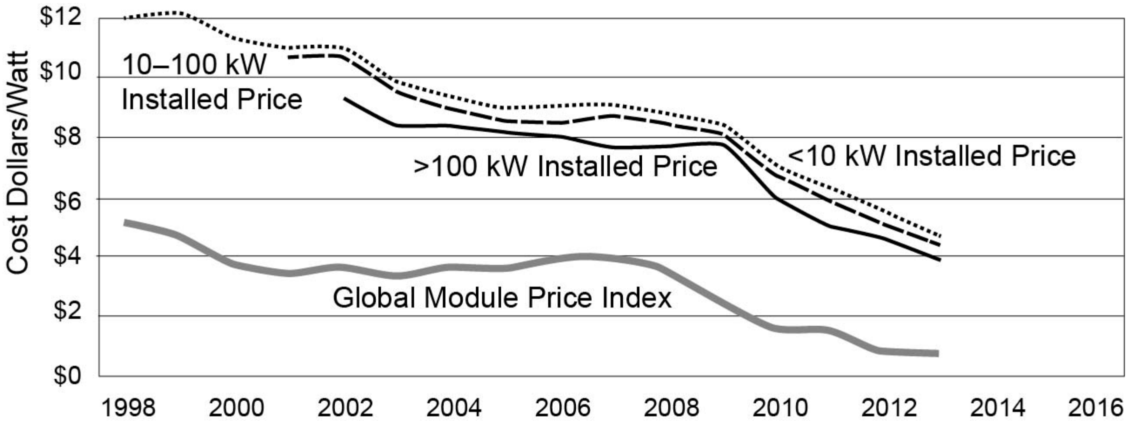
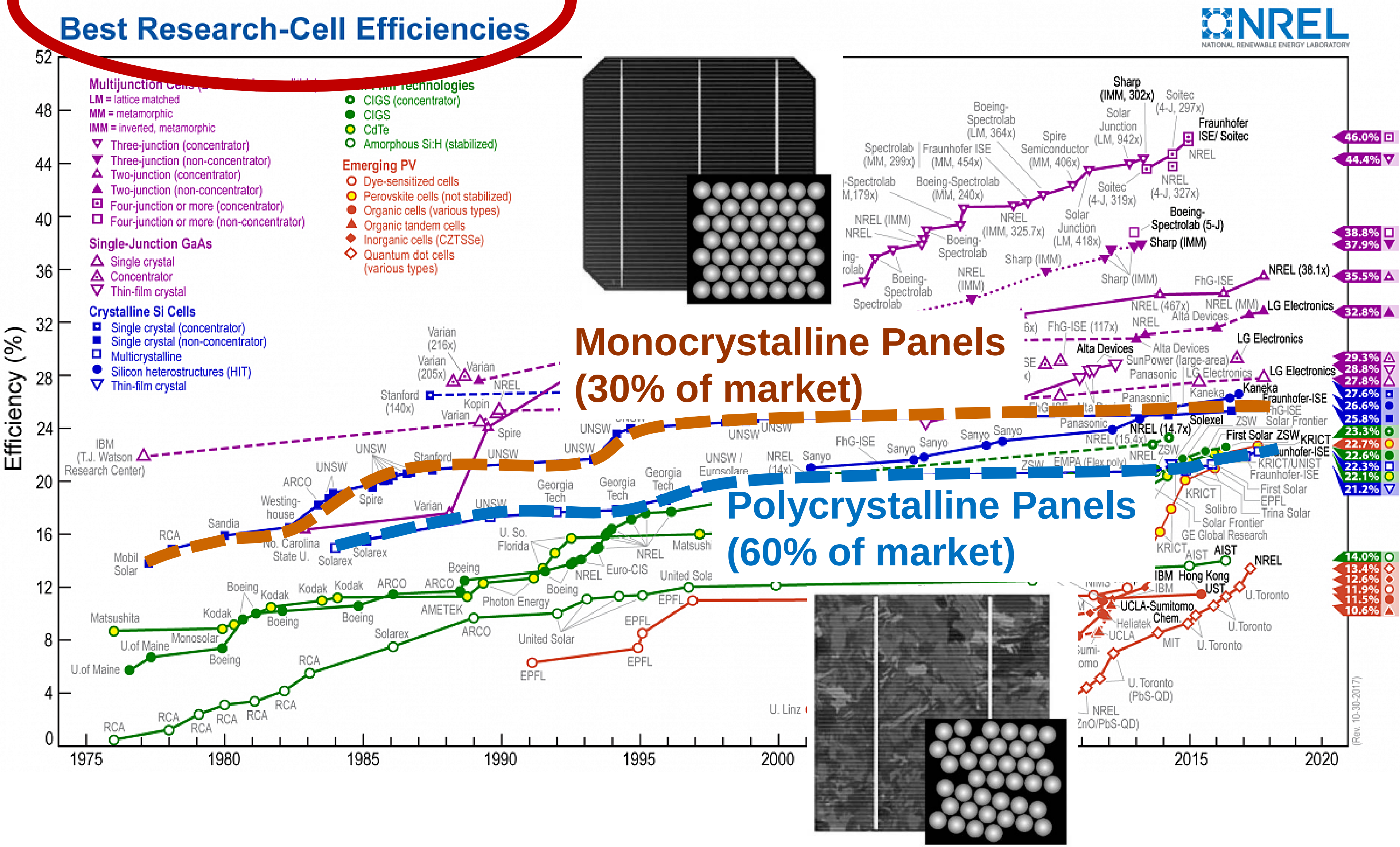
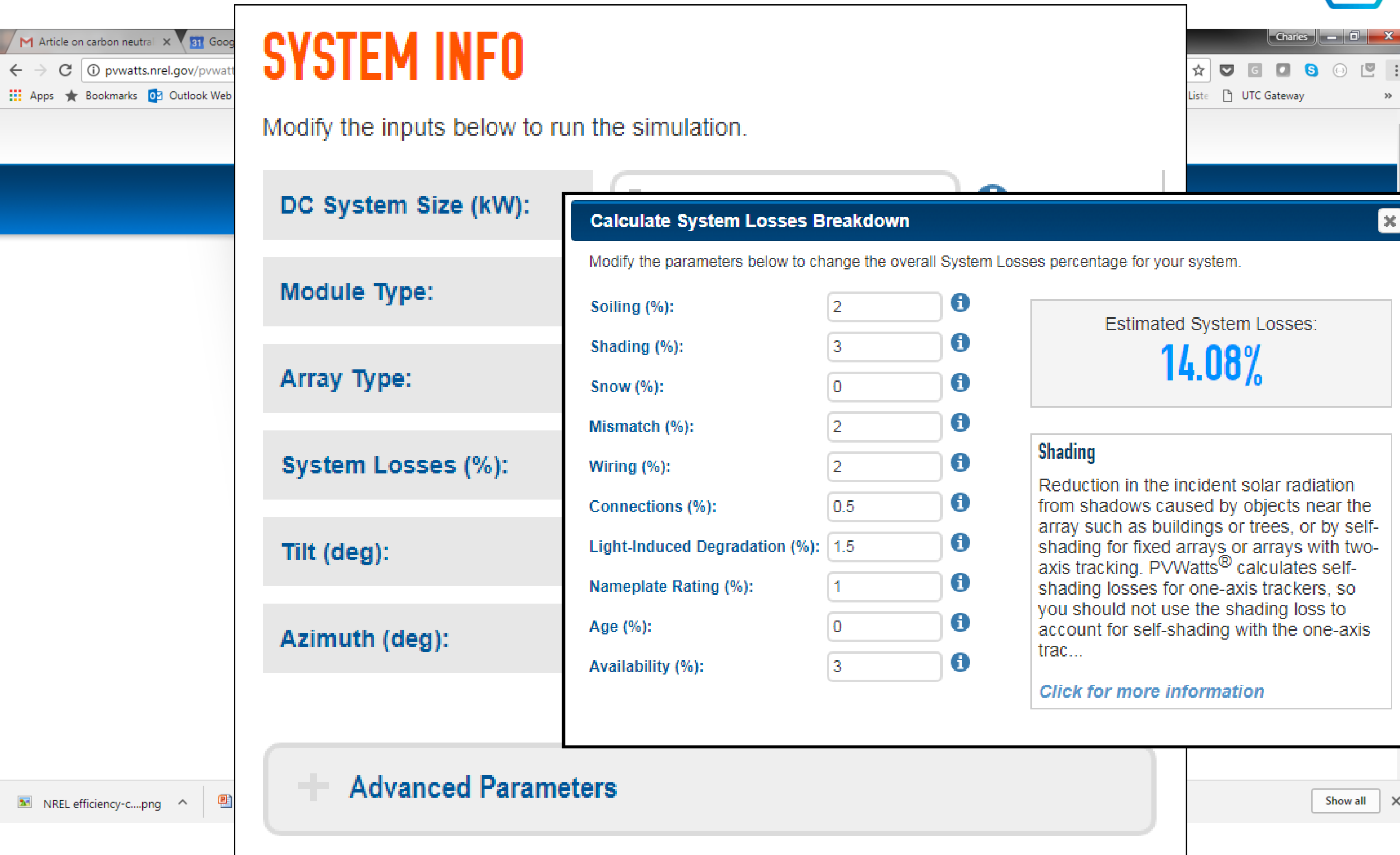


Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016



Best Research-Cell Efficiencies
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
Efficiency (%)
Multijunction Cells
LM = lattice matched
MM = metamorphic
IMM = inverted, metamorphic
Three-junction (concentrator)
Three-junction (non-concentrator)
Two-junction (concentrator)
Two-junction (non-concentrator)
Four-junction or more (concentrator)
Four-junction or more (non-concentrator)
Single-Junction GaAs
Single crystal
Concentrator
Thin-film crystal
Crystalline Si Cells
Single crystal (concentrator)
Single crystal (non-concentrator)
Multicrystalline
Silicon heterostructures (HIT)
Thin-film crystal
Thin-Film Technologies
CIGS (concentrator)
CIGS
CdTe
Amorphous Si:H (stabilized)
Emerging PV
Dye-sensitized cells
Perovskite cells (not stabilized)
Organic cells (various types)
Organic tandem cells
Inorganic cells (CZTSSe)
Quantum dot cells (various types)
Monocrystalline Panels (30% of market)
Polycrystalline Panels (60% of market)
46.0%
44.4%
38.8%
37.9%
35.5%
32.8%
29.3%
28.8%
27.8%
27.6%
26.6%
25.8%
23.3%
22.7%
22.6%
22.3%
22.1%
21.2%
14.0%
13.4%
12.6%
11.9%
11.5%
10.6%
1975
1980
1985
1990
1995
2000
2015
2020

Renewable Energy Systems



Article on carbon neutral | Google Calendar - Week | solar panel efficiency site | System Advisor Model (S

Secure | https://sam.nrel.gov

Apps | Bookmarks | Outlook Web App | WebAccess | Teaming | Site off-line | Charles | Enlighten | CHPS | Sustainability Diction | About | AIA IgCC | COMNET Standing C | Pandora Radio - Liste | UTC Gateway

NREL NATIONAL RENEWABLE ENERGY LABORATORY

System Advisor Model (SAM)

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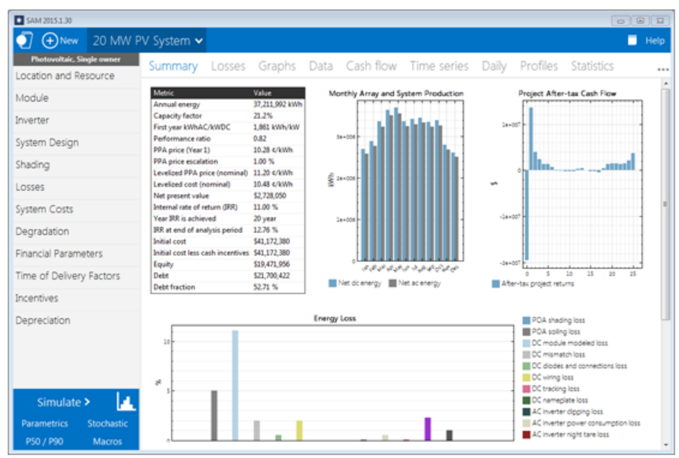
Welcome to SAM

published by admin on Mon, 2010-04-05 16:58

The System Advisor Model (SAM) is a performance and financial model designed to facilitate decision making for people involved in the renewable energy industry:

- Project managers and engineers
- Policy analysts
- Technology developers
- Researchers

Download a published description of SAM 2014.1.14 (PDF 1.6 MB)



SAM's results summary table and graphs.

https://sam.nrel.gov/about

NREL efficiency-c....png | 040318_ZERO Co....pptx | WG07DA89_rene....docx | WG07DA89_rene....docx | GoToMeeting Ope....exe | Show all

SAM includes performance models for the following technologies

- Photovoltaic systems (flat-plate and concentrating)
- Battery storage model for photovoltaic systems
- Parabolic trough concentrating solar power
- Power tower concentrating solar power (molten salt and direct steam)
- Linear Fresnel concentrating solar power
- Dish-Stirling concentrating solar power
- Process heat parabolic trough and linear direct steam
- A simple "generic model" for conventional thermal
- Solar water heating for residential or commercial buildings
- Wind power (large and small)
- Geothermal power and geothermal co-production
- ~~Biomass power~~

Climate	*Orientation*	*0° Tilt*	*10° Tilt*	*20° Tilt*	*30° Tilt*	*40° Tilt*	*50° Tilt*	*60° Tilt*
Warm and Dry	East	1,414	1,385	1,336	1,269	1,191	1,105	1,013
(Los Angeles)	Southeast	1,414	1,470	1,493	1,486	1,450	1,383	1,292
	South	1,414	1,518	1,581	1,605	1,594	1,540	1,451
	Southwest	1,414	[illegible]	1,545	1,560	1,537	1,483	1,399
	West	1,414	1,425	1,409	1,368	1,310	1,236	1,149
Pacific Coast	East	1,378	1,353	1,304	1,244	1,172	1,092	1,010
(San Francisco)	Southeast	1,378	1,437	1,467	1,466	1,434	1,373	1,289
	South	1,378	1,485	1,553	1,582	1,571	1,523	1,436
	Southwest	1,378	1,464	1,518	1,534	1,518	1,466	1,389
	West	1,378	1,389	1,372	1,336	1,282	1,213	1,132

Source: PV Watt Calculations.

Source: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

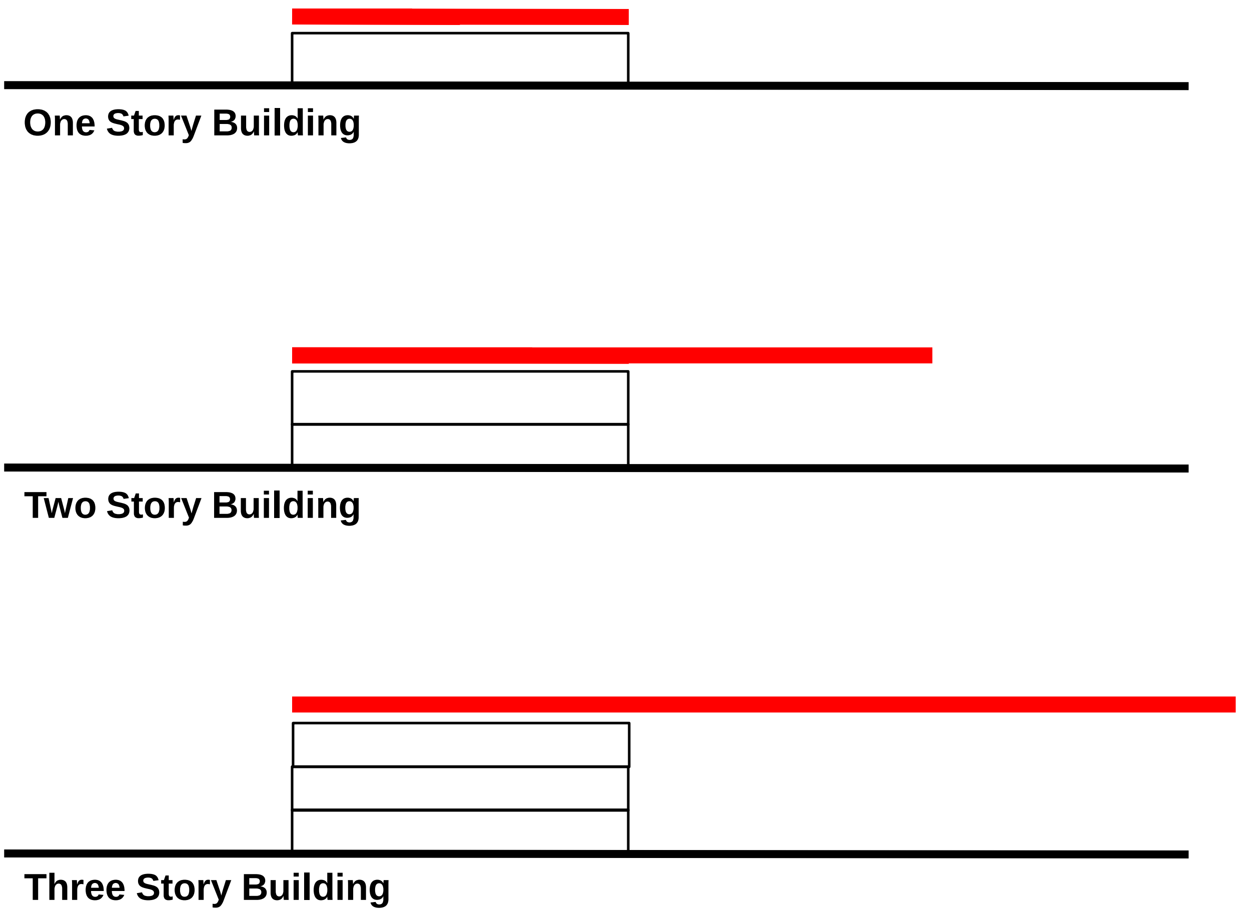
Renewable Energy Systems

	Pacific Coast	Warm and Dry	Hot and Humid	Warm and Humid	Cold and Dry	Cold and Humid	Artic
	(3c, 4c)	(2b, 3b, 4b)	(1a, 2a)	(3a, 4a)	(5b, 6b)	(5a, 6a, 7)	(8)
Horizontal Production (kWh/y)/kW (stc)	1,378	1,414	1,359	1,316	1,311	1,138	748
Horizontal Production (kBtu/y)/kW (stc)	4,702	4,825	4,637	4,490	4,473	3,883	2,552
kBtu/ft²-y of Collector Area	72	74	71	69	69	60	39

Maximum site EUI to achieve ZNE for a one-story building with the roof covered with PVs.

Source: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.

Challenging Building Types and Climates


One Story Building
Two Story Building
Three Story Building

1.00

	Pacific Coast	Warm and Dry	Hot and Humid	Warm and Humid	Cold and Dry	Cold and Humid	Artic
Warehouses	0.08	0.08	0.07	0.09	0.10	0.13	0.19
Offices	0.11	0.14	0.15	0.15	0.15	0.18	0.30
Retail	0.18	0.24	0.25	0.25	0.26	0.32	0.67
Schools	0.22	0.28	0.32	0.32	0.31	0.38	0.66
Apartments	0.33	0.40	0.41	0.44	0.47	0.57	0.90
Off/Data Center	0.59	0.63	0.66	0.64	0.68	0.77	1.19
Hotels	0.55	0.66	0.69	0.74	0.75	0.90	1.48
Healthcare	0.87	0.86	0.96	0.96	0.95	1.15	1.83
Restaurants	3.66	4.35	4.53	4.87	4.99	5.91	9.61

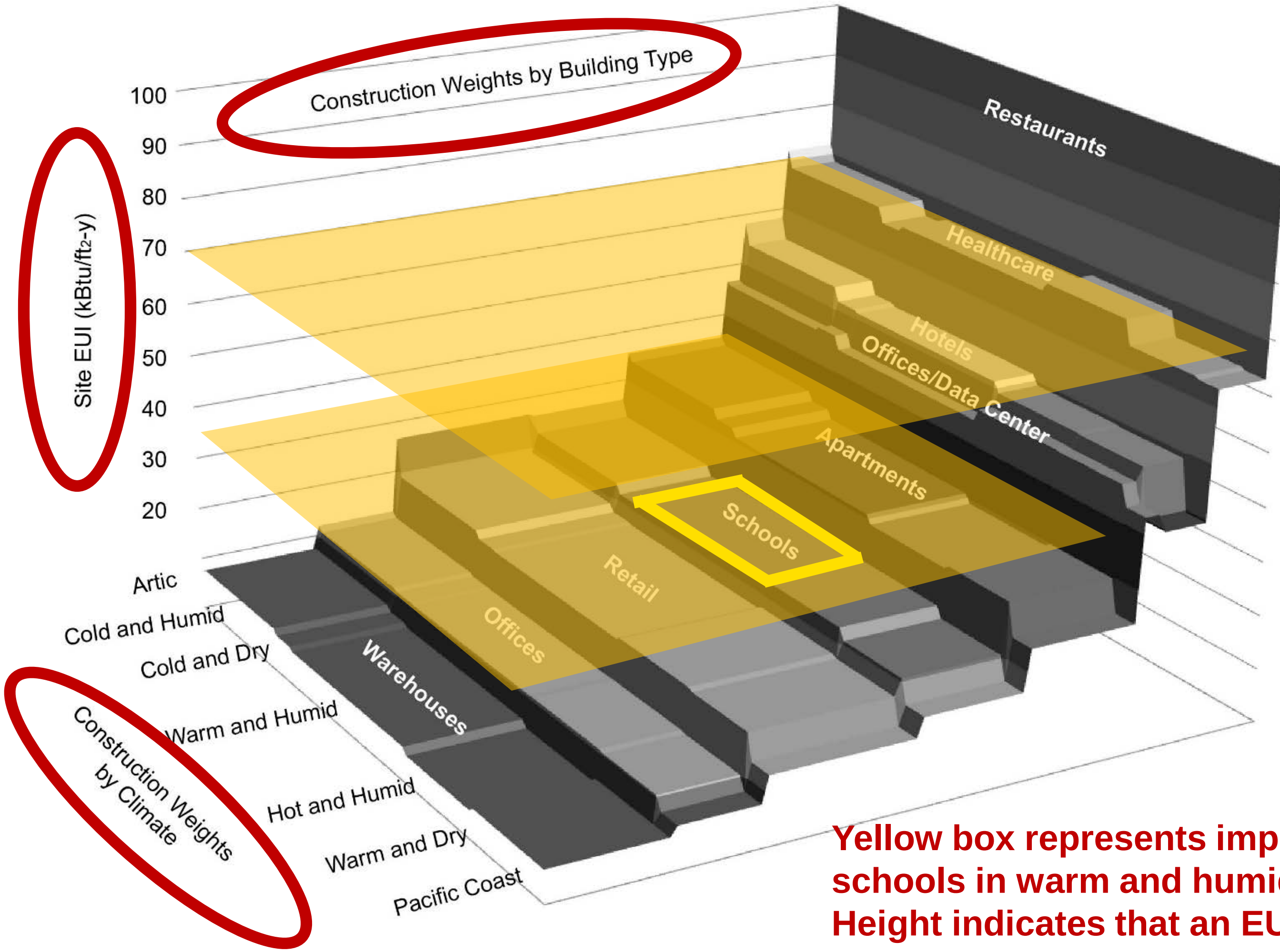
ZNE feasible for four stories or more

ZNE feasible for two-story buildings

ZNE feasible for one-story buildings

PV on roof not enough

Source: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016.



ZNE feasible for one-story buildings

ZNE feasible for two-story buildings

Yellow box represents importance of schools in warm and humid climate. Height indicates that an EUI of 23 kBtu/ft²·y is technically achievable.

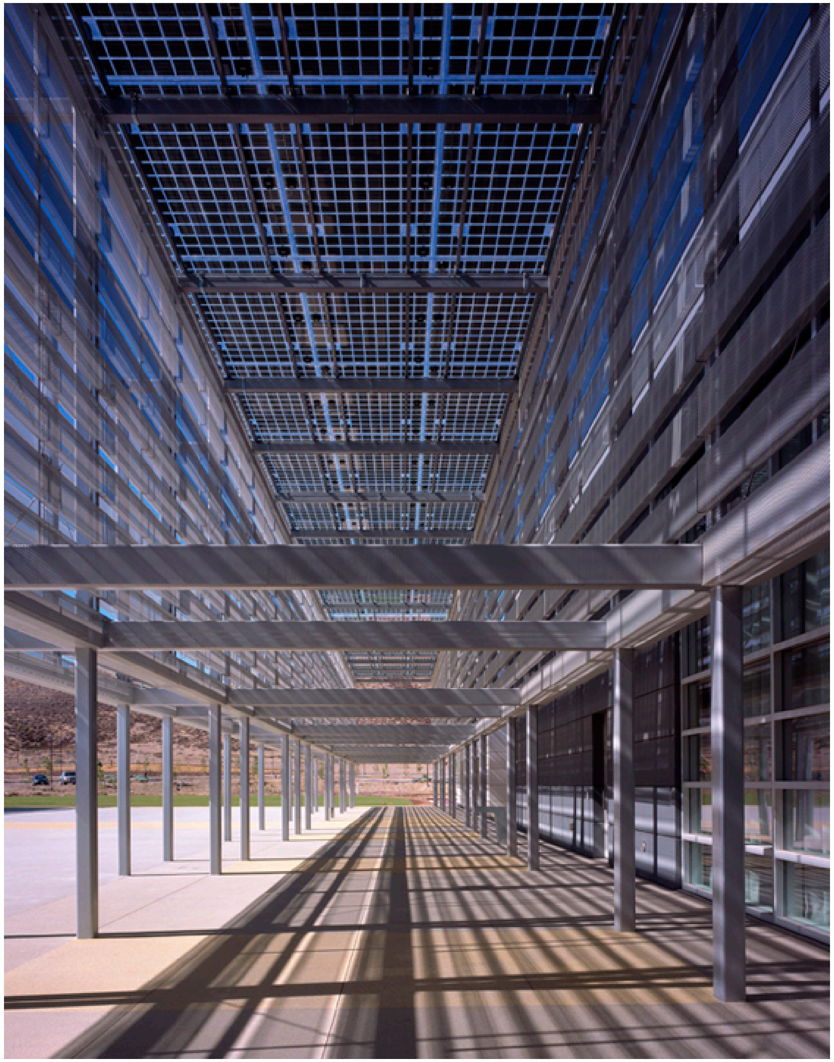
Image from Design Professionals Guide to Zero Net Energy Buildings.

PV Examples

Water and Life Museum, Hemet

- 50,000 ft^2 PV panels
- Daily production 2550 kWh (based on 5.5 hour/day FTE)
- Power consumed by building in 12 hours (3729 kWh)
- 68% solar power contribution

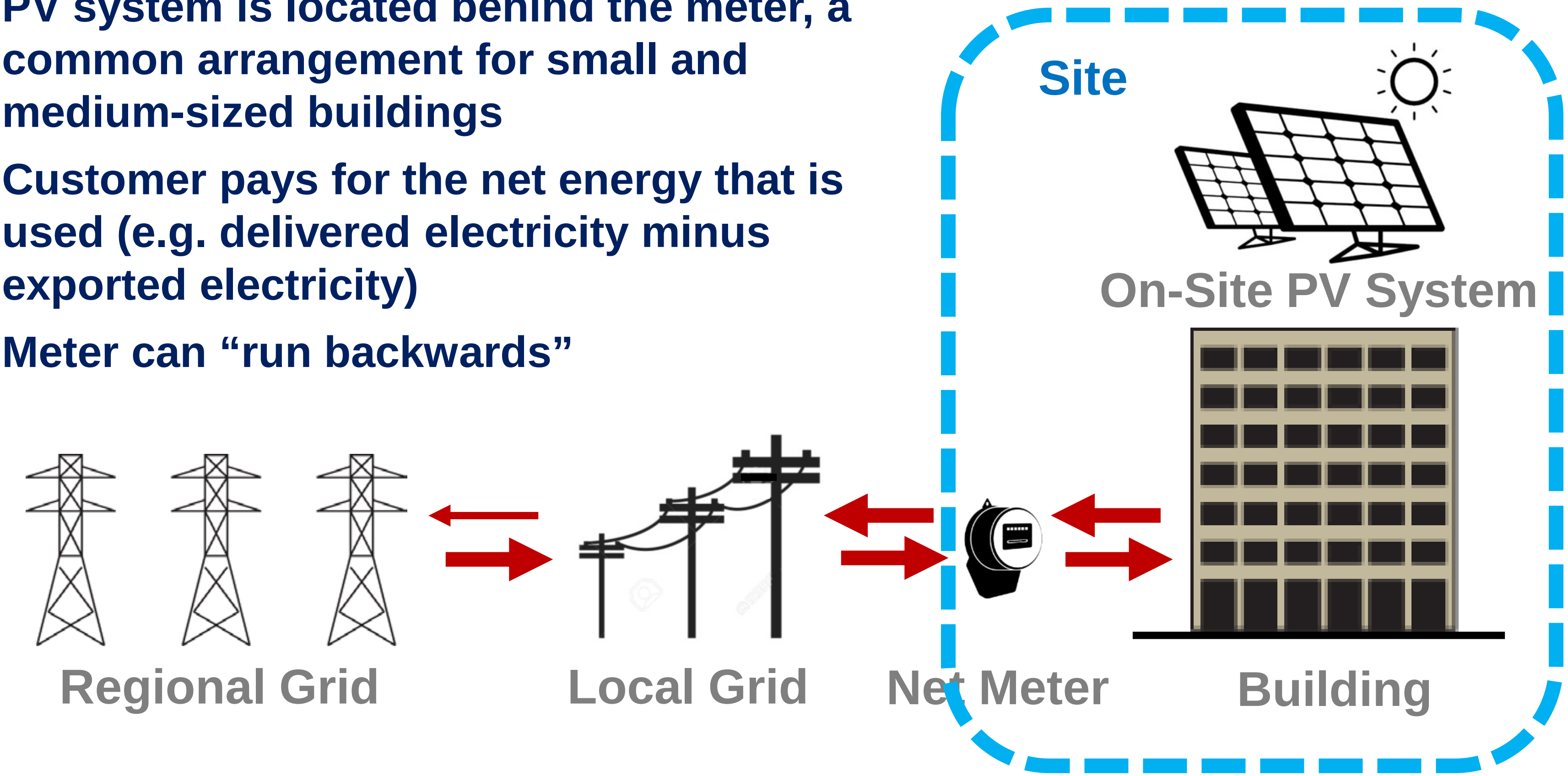
PV Examples



PV Examples

Meter Configurations and Off-Site

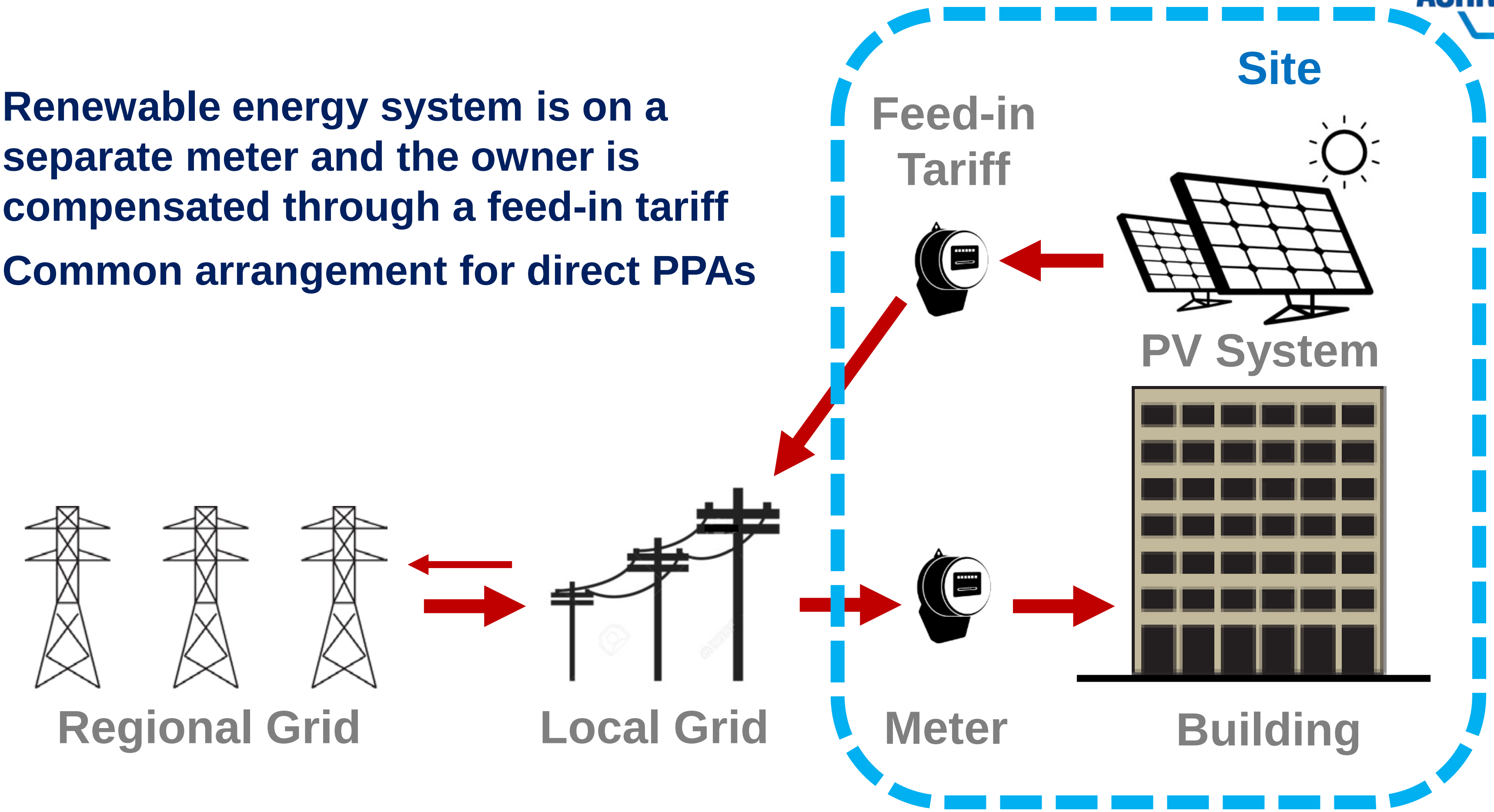
- PV system is located behind the meter, a common arrangement for small and medium-sized buildings
- Customer pays for the net energy that is used (e.g. delivered electricity minus exported electricity)
- Meter can "run backwards"



Content From ZERO Code

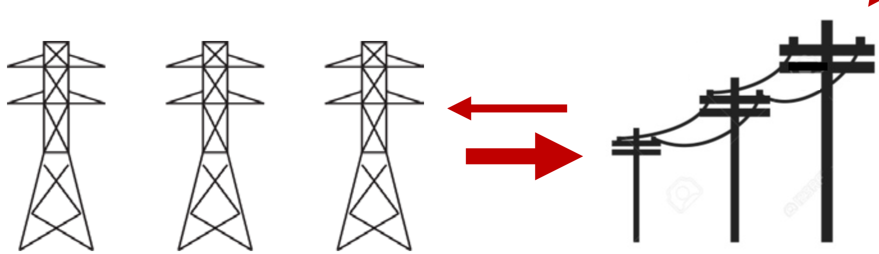
Renewable energy system is on a separate meter and the owner is compensated through a feed-in tariff

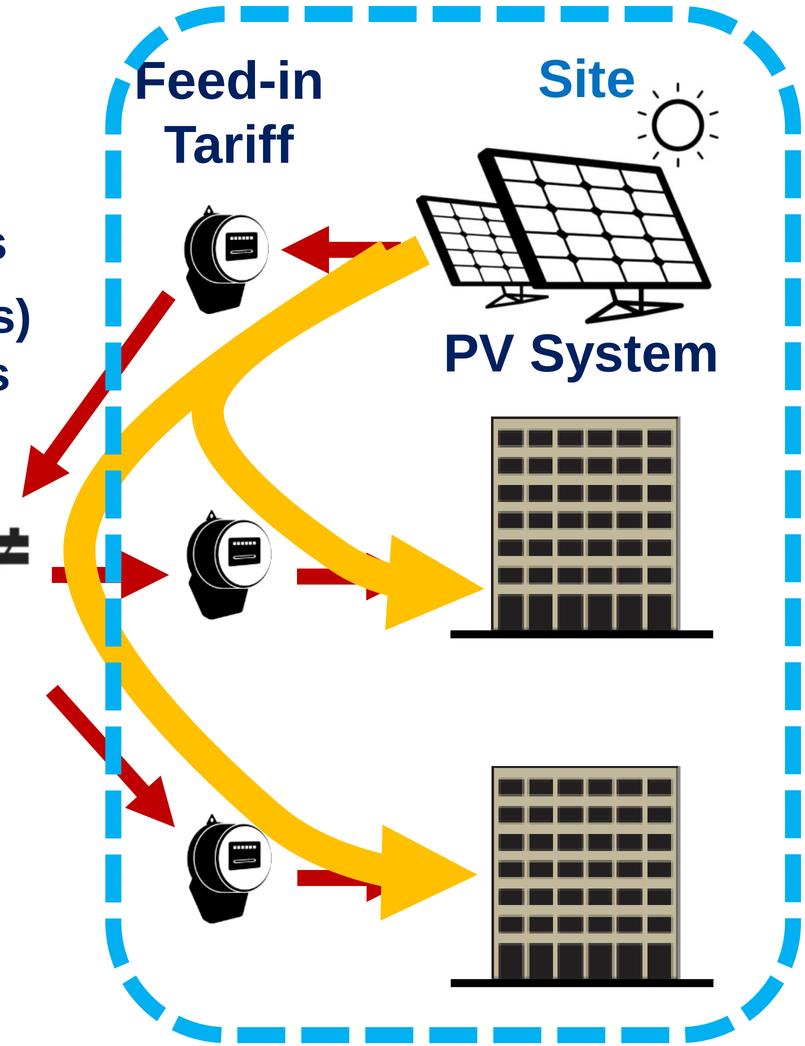
Common arrangement for direct PPAs



Content From ZERO Code

- Renewable energy system is on a separate meter and the owner is compensated through a feed-in tariff
- Common arrangement for direct PPAs
- A certain amount of energy (and RECs) are allocated to one or more buildings on the campus





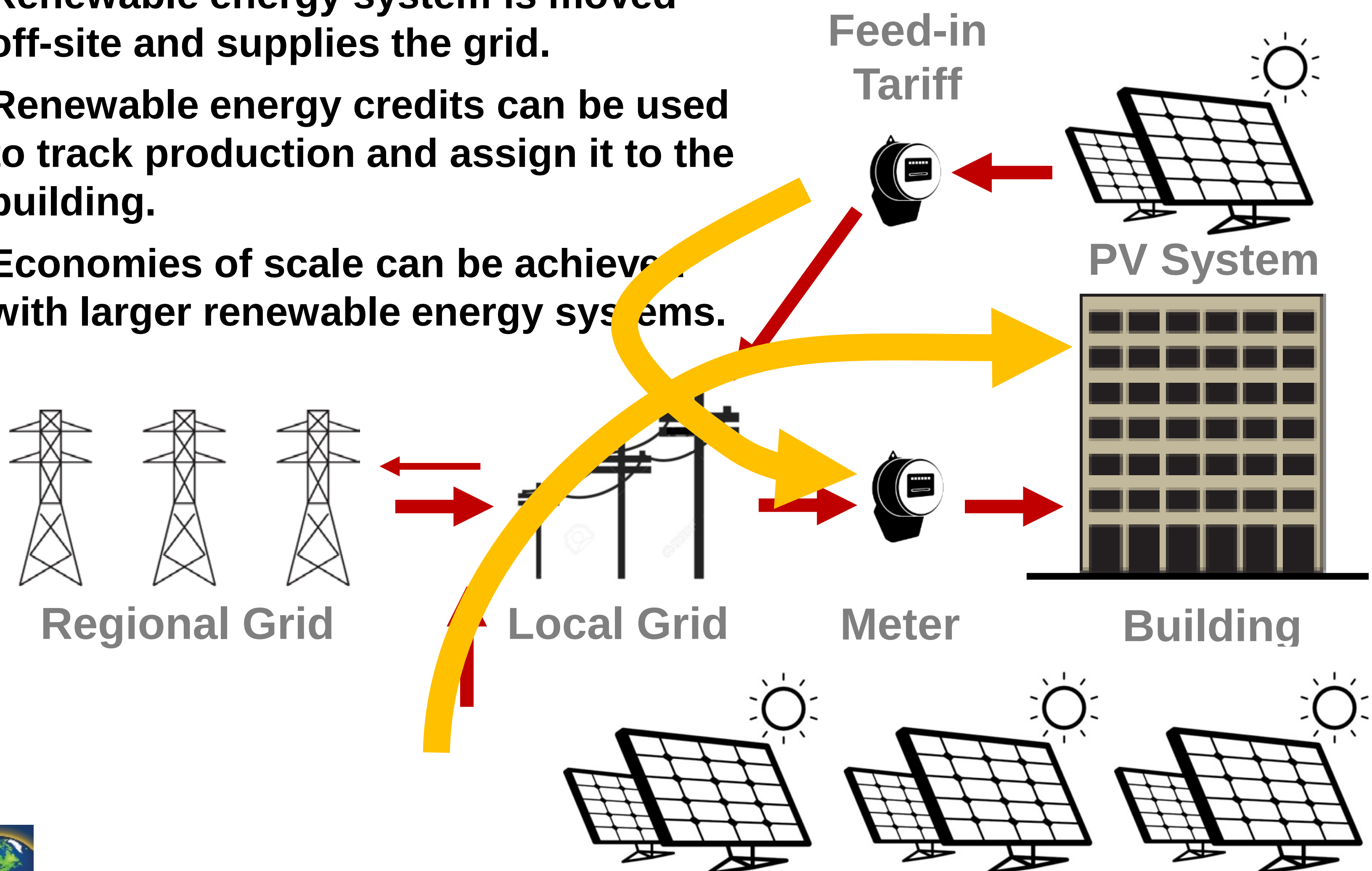
Content From ZERO Code

Meter Configurations and Off-Site

Renewable energy system is moved off-site and supplies the grid.

Renewable energy credits can be used to track production and assign it to the building.

Economies of scale can be achieved with larger renewable energy systems.



Content From ZERO Code

Off-Site Renewable Energy Procurement Options

Class One

- Self Owned
- Community Solar
- Virtual PPA
- Renewable Energy Investment Trust

- ❑ High probability of additionality
- ❑ Long-term commitment

Class Two

- Direct Access to Wholesale Market
- Green Tariffs

- ❑ Medium probability of additionality
- ❑ Customers can easily opt out

Class Three

- Unbundled RECs

- ❑ Little chance of additionality
- ❑ Least desirable option

See zero-code.org for more details.

Meter Configurations and Off-Site

73 MW Solar System in California Desert

Palo Alto Campus

Not the actual site

DECEMBER 3, 2018

Stanford to go 100 percent solar by 2021

A second solar-generating plant, to be built in the next three years, will complete the university's transition to clean power and further shrink campus greenhouse gas emissions.

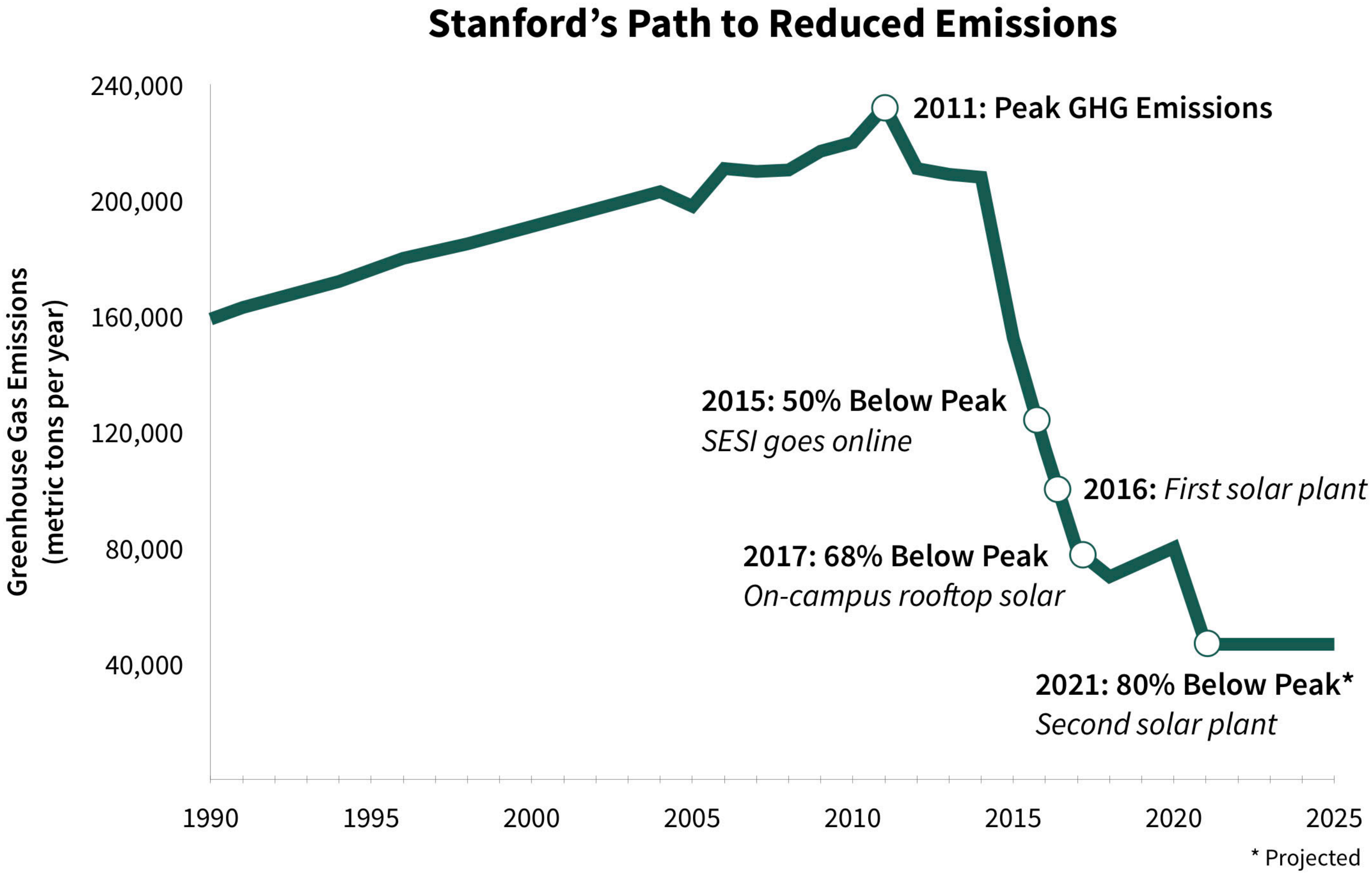
BY CHRIS PEACOCK

Stanford's solar future is growing even brighter.

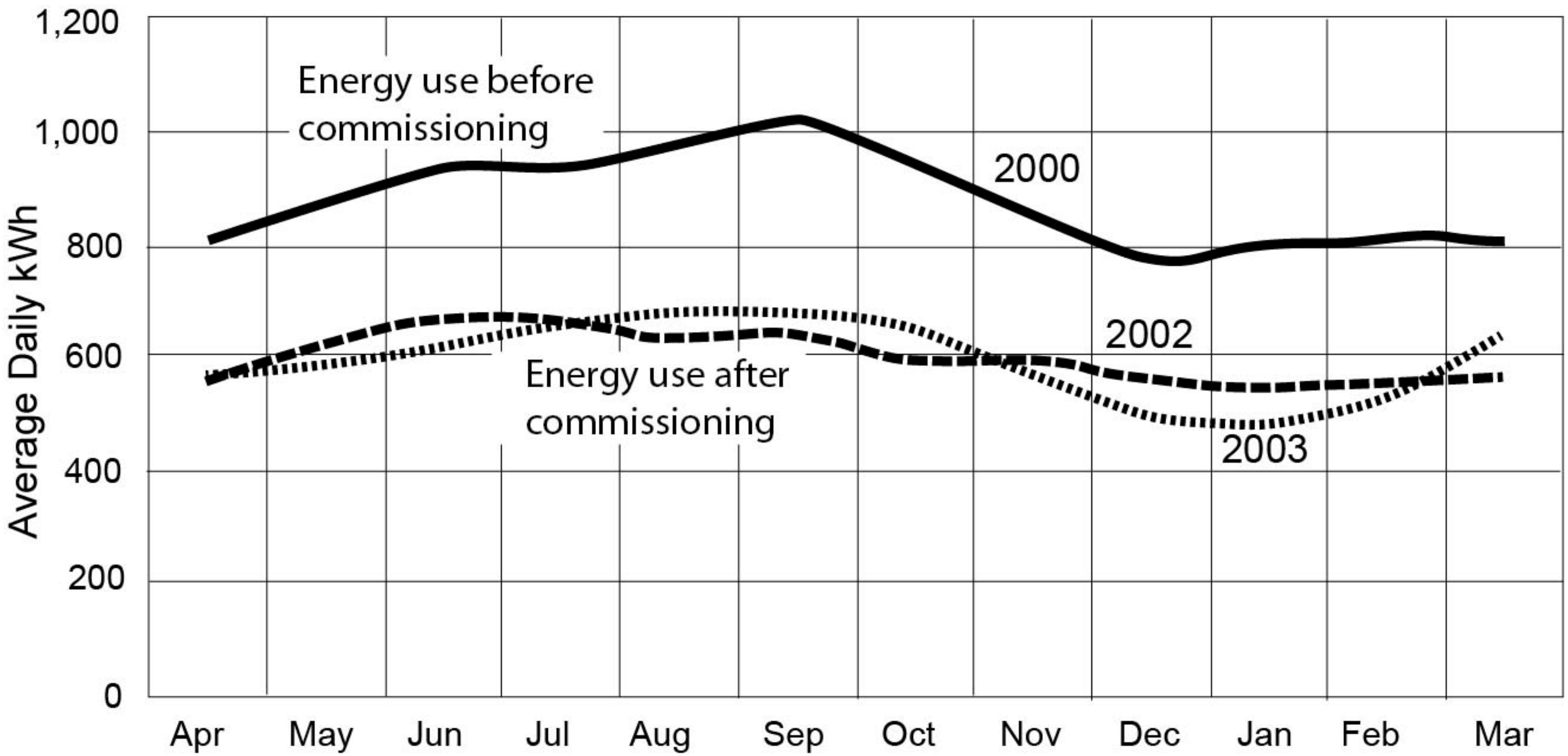
A new solar generating plant – Stanford's second – announced today, will enable the university to use 100 percent renewable electricity in three years, more than two decades ahead of California's goal of a carbon-free grid by 2045.

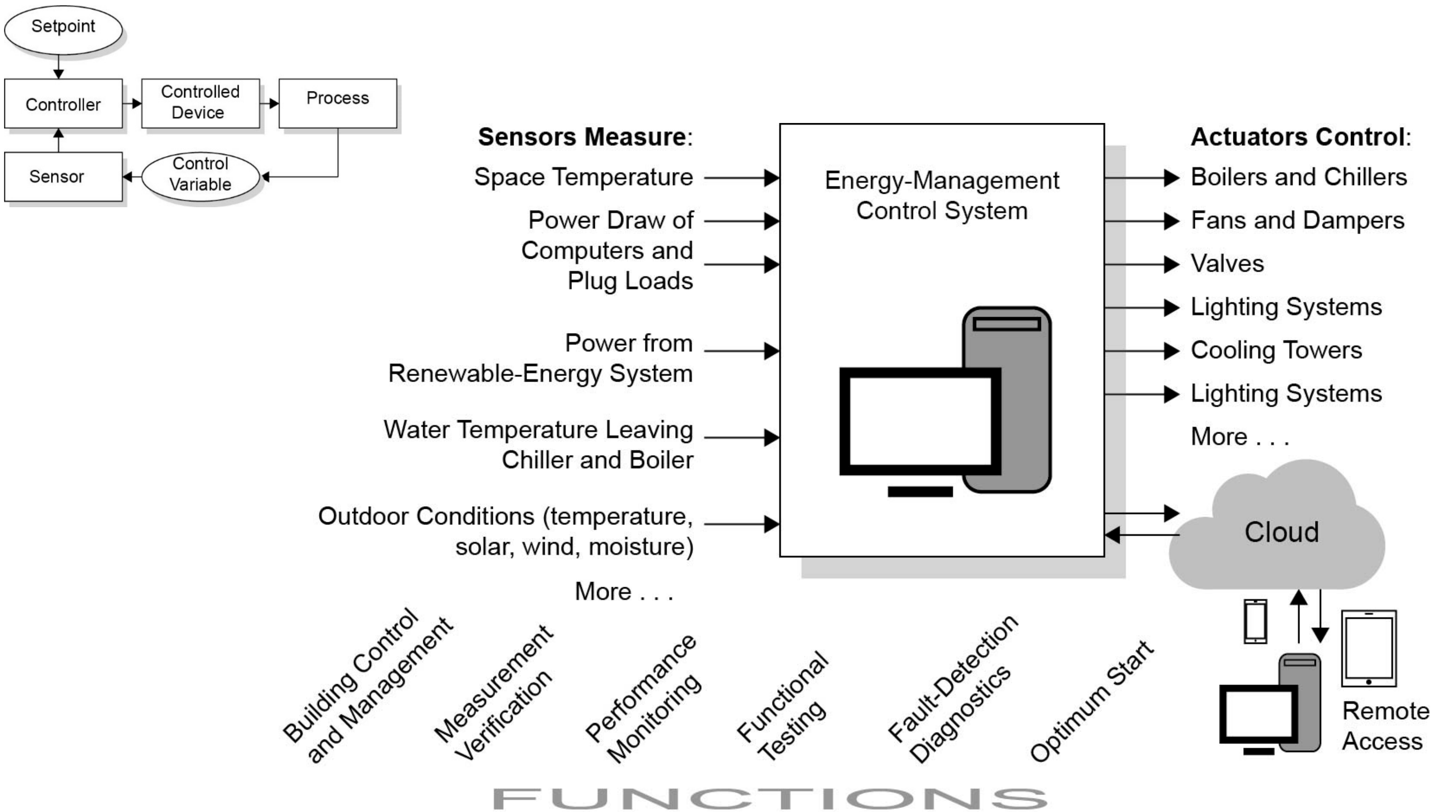
Completing the university's transition to clean power, Stanford finalized an agreement to collaborate with Recurrent Energy on an 88-megawatt solar photovoltaic plant to be constructed in central California, near Lemoore. The plant is scheduled to go online

On-campus rooftop solar power and two solar generating stations together will produce enough clean renewable electricity each year to equal the university's annual electricity consumption. *(Image credit: M. Scott Gould)*


Stanford's Path to Reduced Emissions
240,000
200,000
160,000
120,000
80,000
40,000
Greenhouse Gas Emissions
(metric tons per year)
2011: Peak GHG Emissions
2015: 50% Below Peak
SESI goes online
2016: First solar plant
2017: 68% Below Peak
On-campus rooftop solar
2021: 80% Below Peak*
Second solar plant
1990
1995
2000
2005
2010
2015
2020
2025
* Projected

Making It All Work


1,200
1,000
800
600
400
200
0
Average Daily kWh
Energy use before commissioning
2000
2002
Energy use after commissioning
2003
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar


Setpoint
Controller
Controlled Device
Process
Sensor
Control Variable
Sensors Measure:
Space Temperature
Power Draw of Computers and Plug Loads
Power from Renewable-Energy System
Water Temperature Leaving Chiller and Boiler
Outdoor Conditions (temperature, solar, wind, moisture)
More . . .
Energy-Management Control System
Actuators Control:
Boilers and Chillers
Fans and Dampers
Valves
Lighting Systems
Cooling Towers
Lighting Systems
More . . .
Cloud
Remote Access
Building Control and Management
Measurement Verification
Performance Monitoring
Functional Testing
Fault-Detection Diagnostics
Optimum Start
FUNCTIONS


10:08
companion
10:35


Your Current Zone
Northwest Conference Room
74°F
COOLING
Berkeley, CA 85°
Warm My Space
I am Comfy
Cool My Space

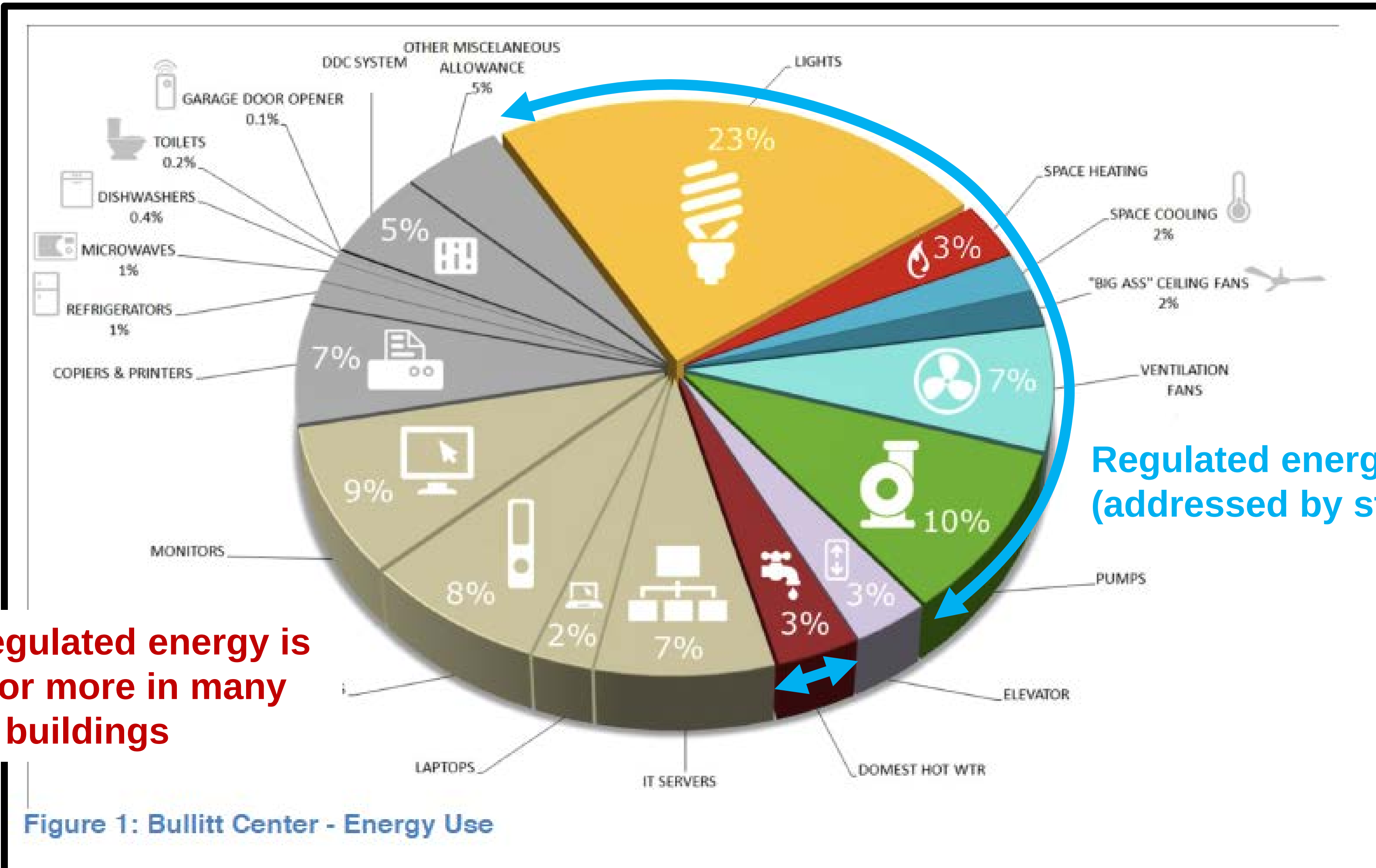
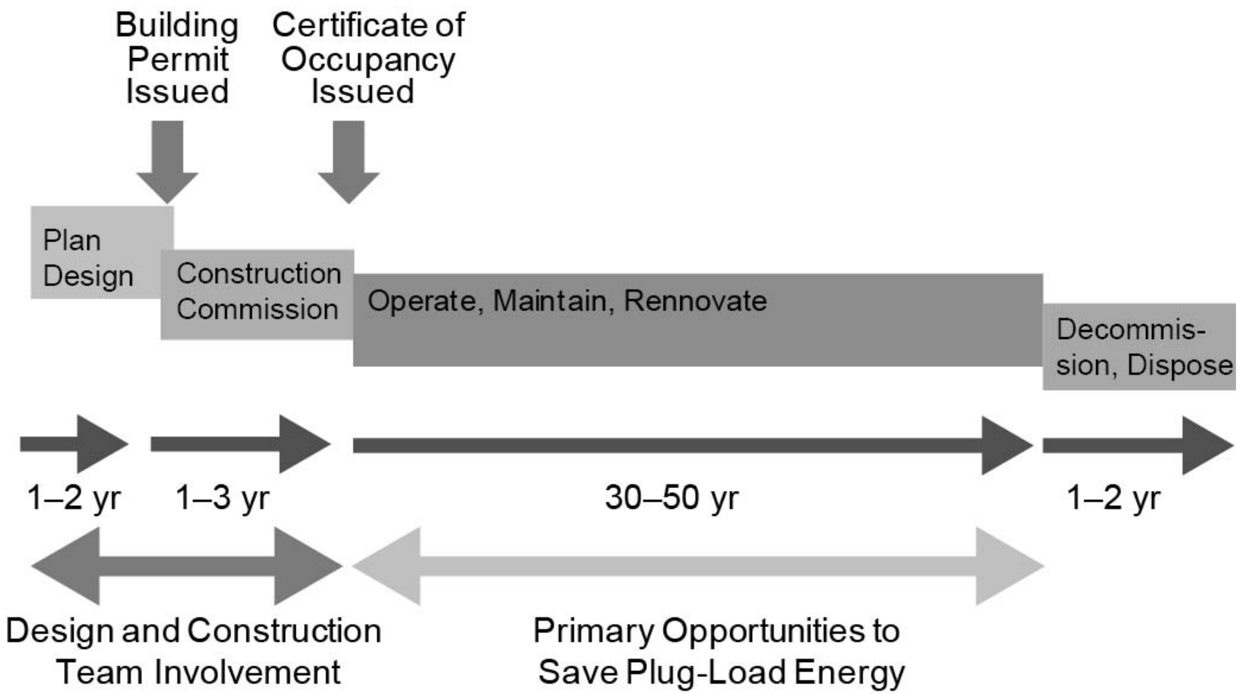


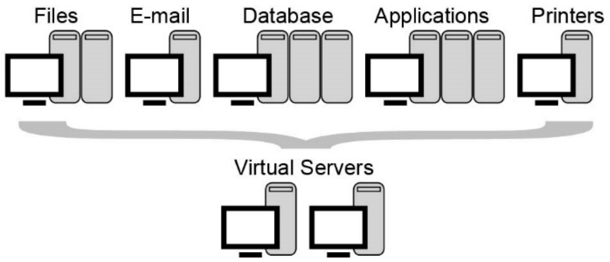
Figure 1: Bullitt Center - Energy Use

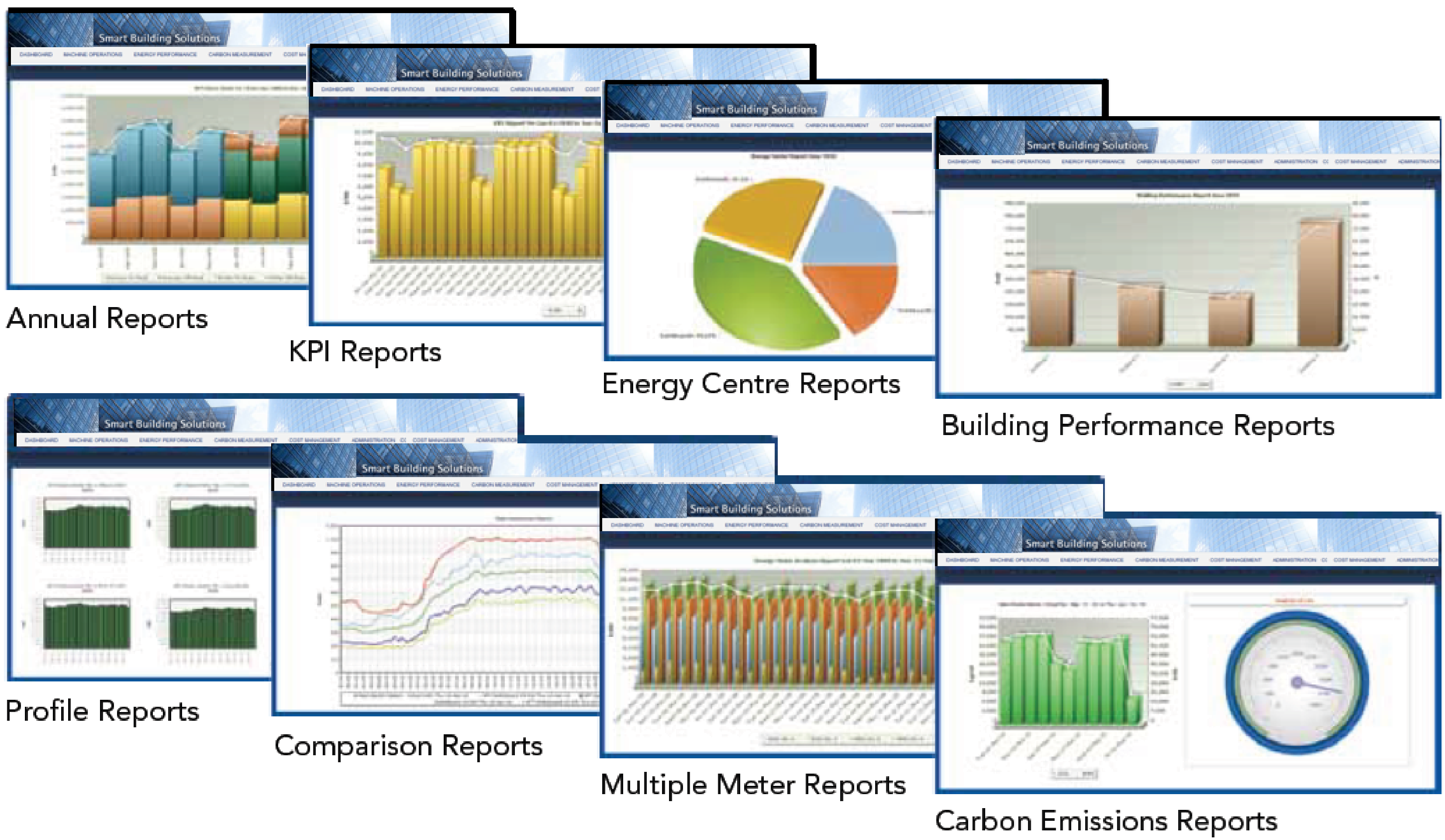
Regulated energy (addressed by standards)

Unregulated energy is half or more in many ZNE buildings

http://greentechadvocates.com/2013/05/07/plug-loads-a-growing-concern/

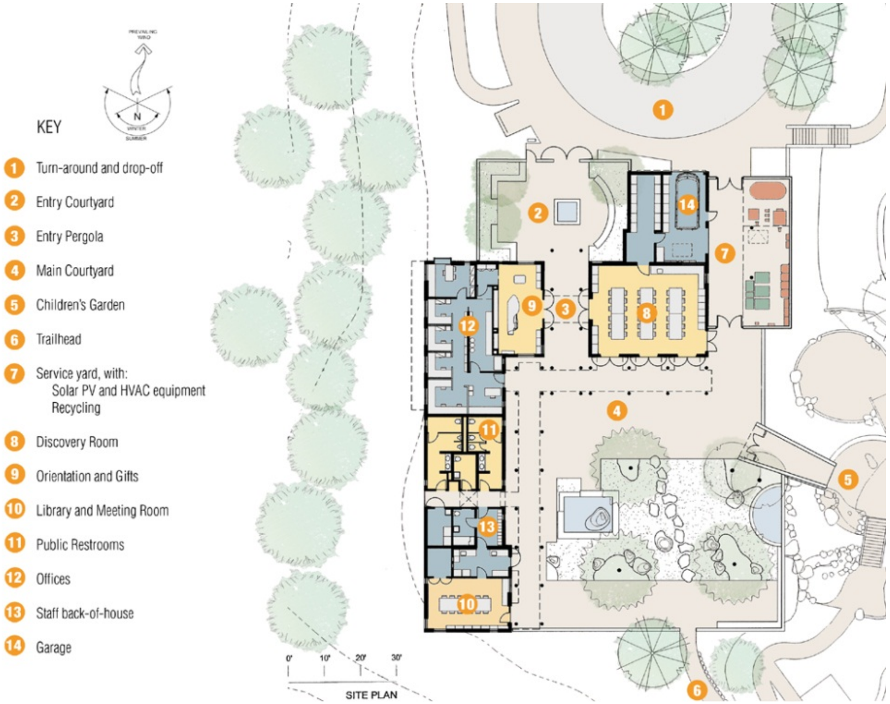

Building
Permit
Issued
Certificate of
Occupancy
Issued
Plan
Design
Construction
Commission
Operate, Maintain, Rennovate
Decommis-
sion, Dispose
1–2 yr
1–3 yr
30–50 yr
1–2 yr
Design and Construction
Team Involvement
Primary Opportunities to
Save Plug-Load Energy


Files
E-mail
Database
Applications
Printers
Virtual Servers

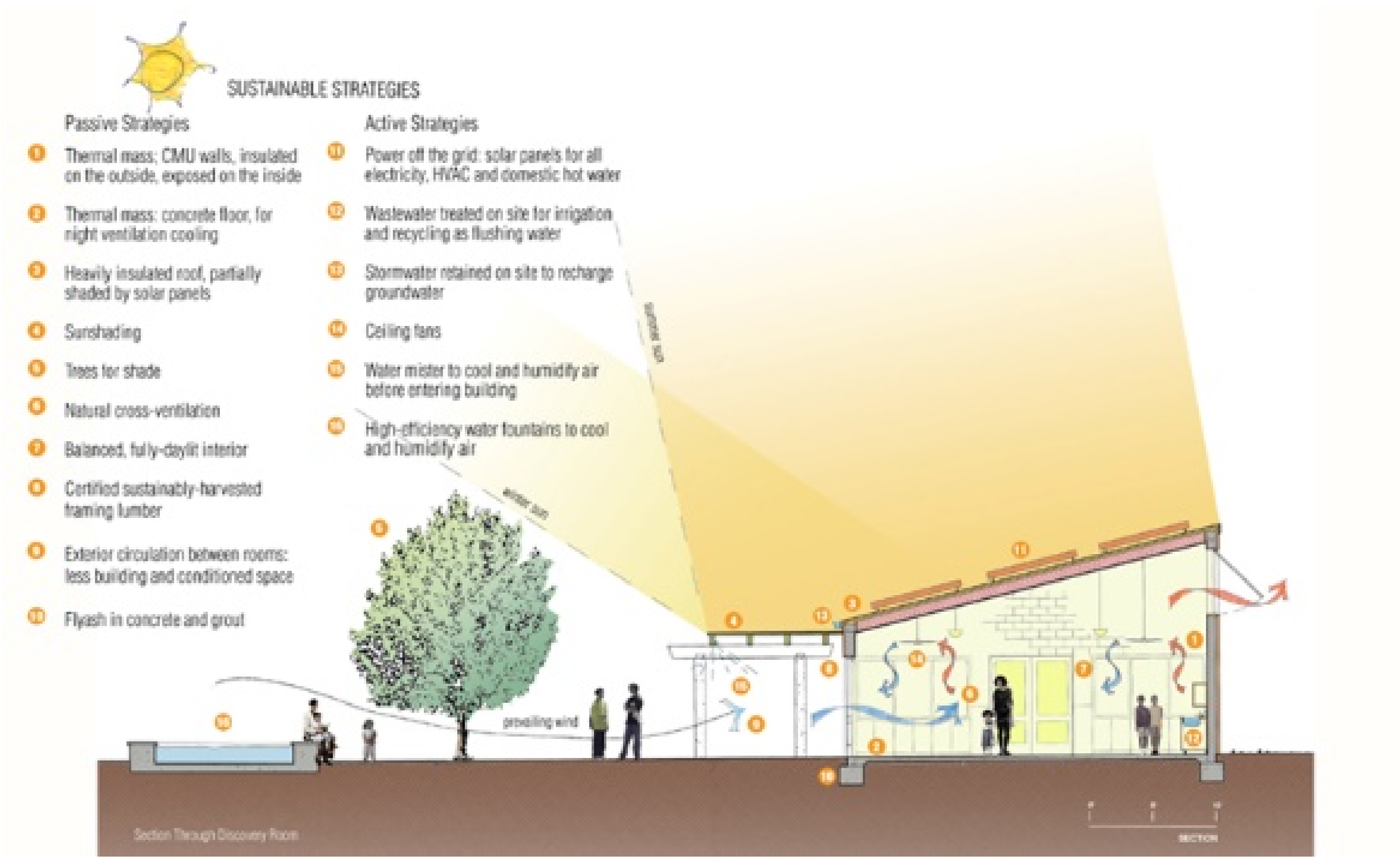

Smart Building Solutions
Annual Reports
KPI Reports
Energy Centre Reports
Building Performance Reports
Profile Reports
Comparison Reports
Multiple Meter Reports
Carbon Emissions Reports

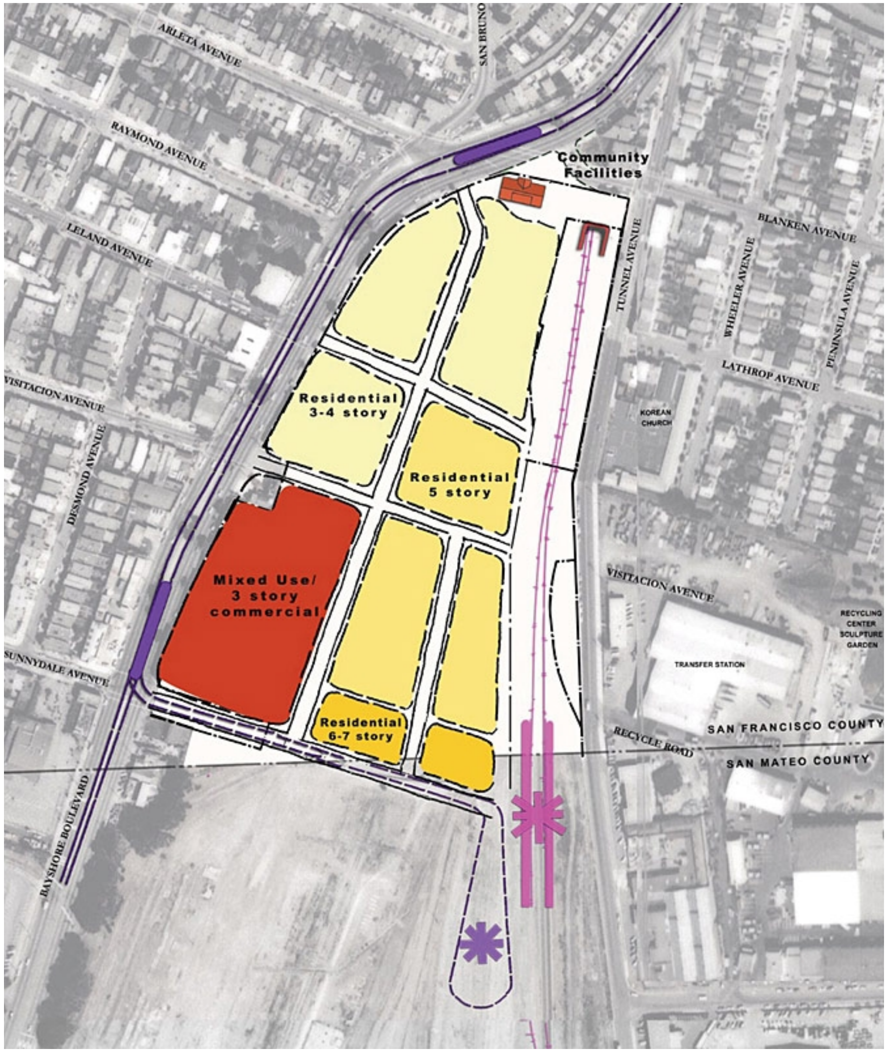
Practical Examples

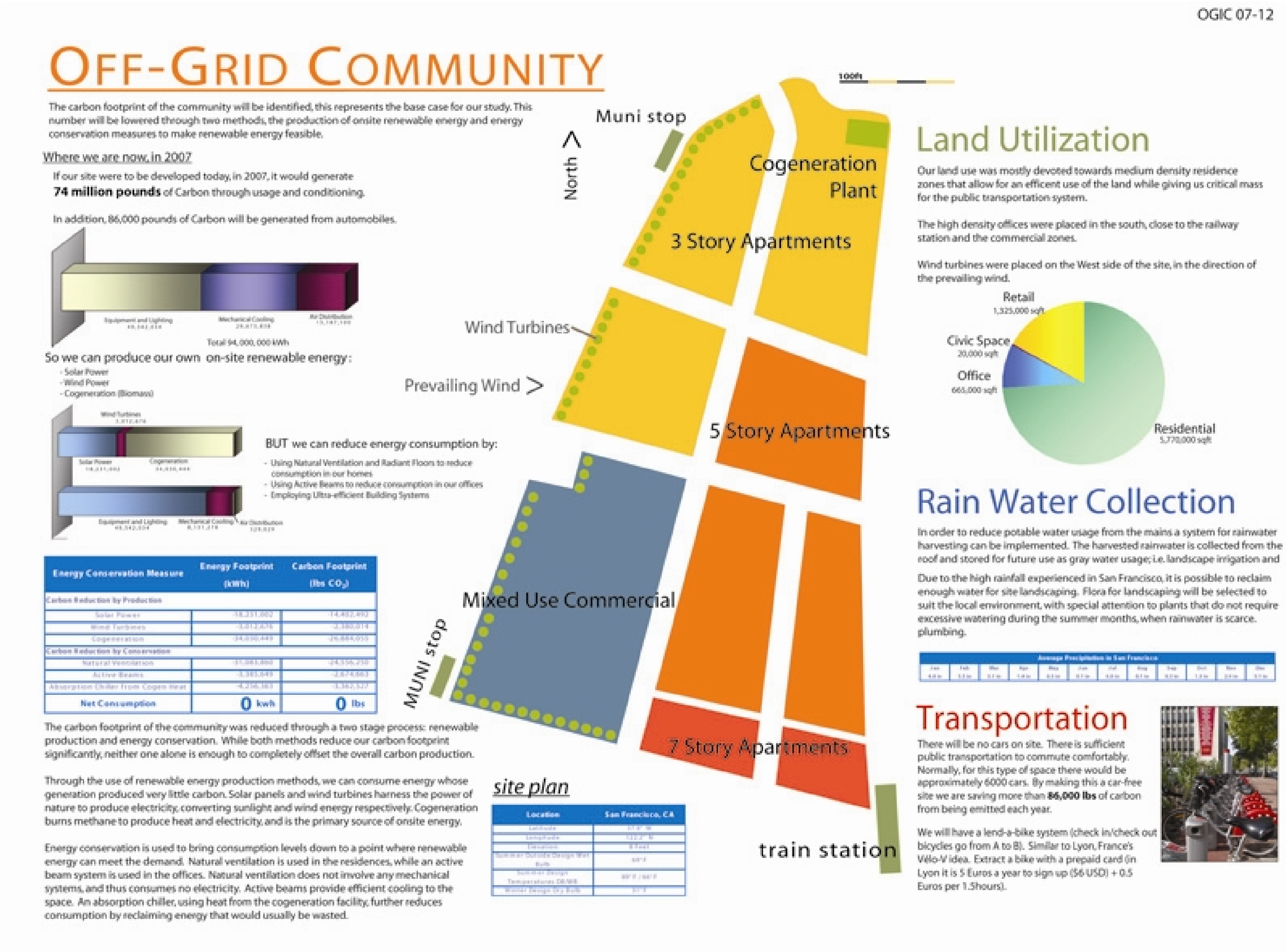

9.02.03


KEY
1 Turn-around and drop-off
2 Entry Courtyard
3 Entry Pergola
4 Main Courtyard
5 Children's Garden
6 Trailhead
7 Service yard, with:
Solar PV and HVAC equipment
Recycling
8 Discovery Room
9 Orientation and Gifts
10 Library and Meeting Room
11 Public Restrooms
12 Offices
13 Staff back-of-house
14 Garage
N
0' 10' 20' 30'
SITE PLAN

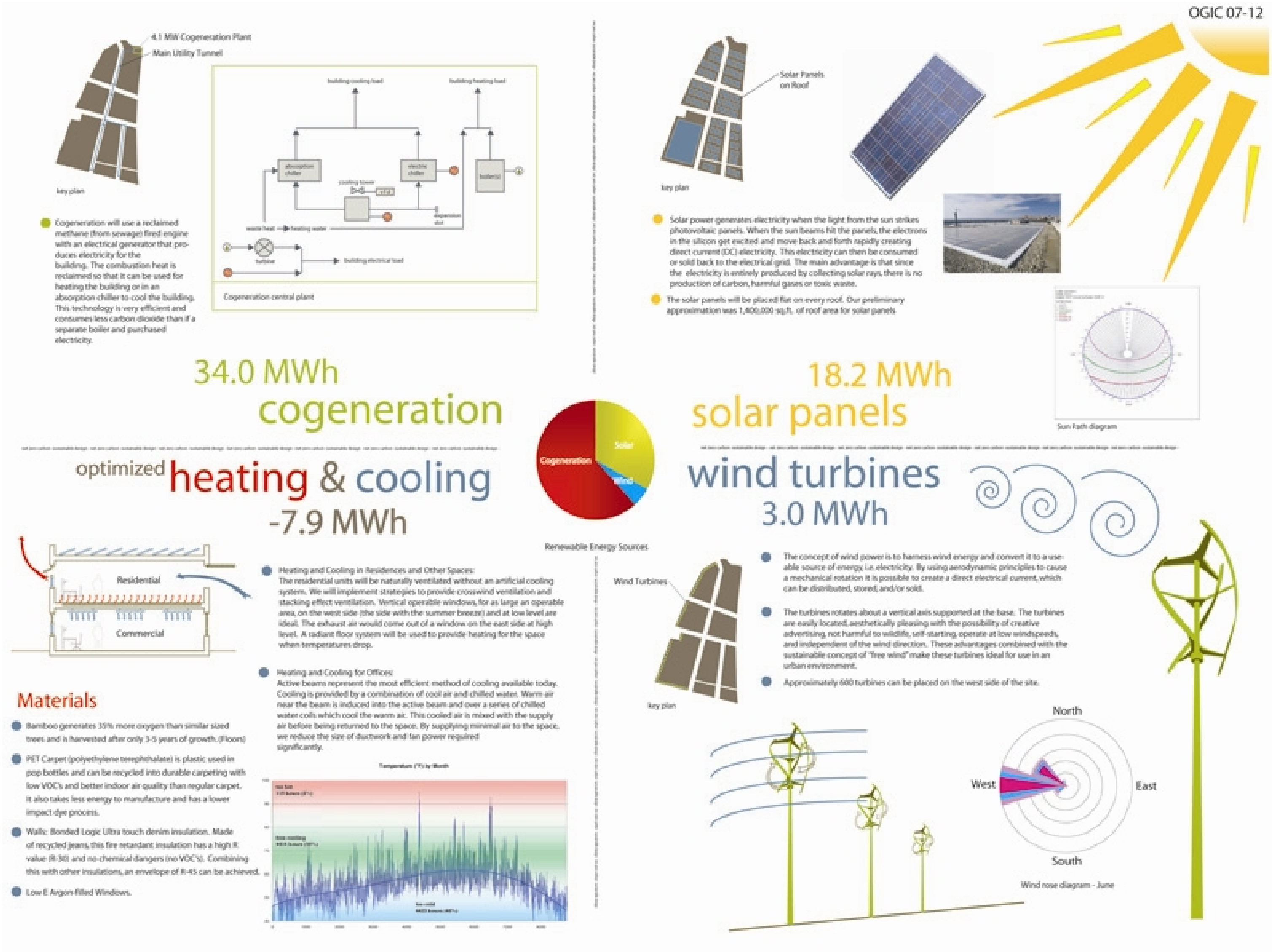
Practical Examples

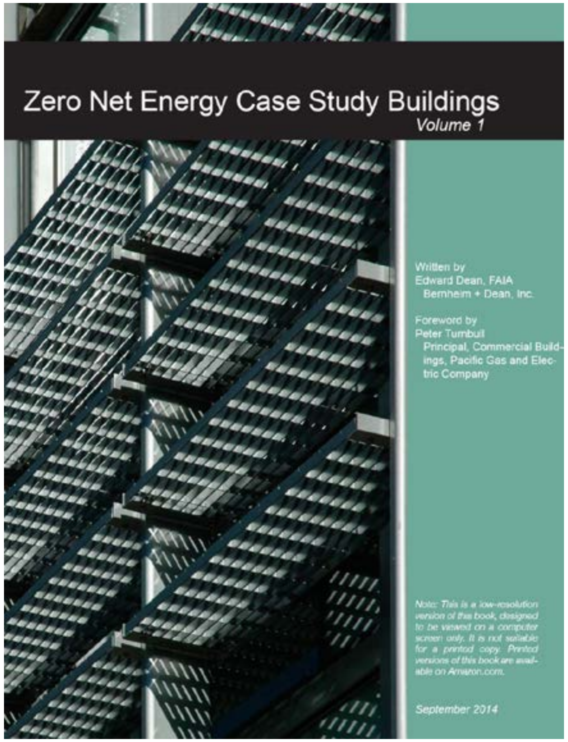


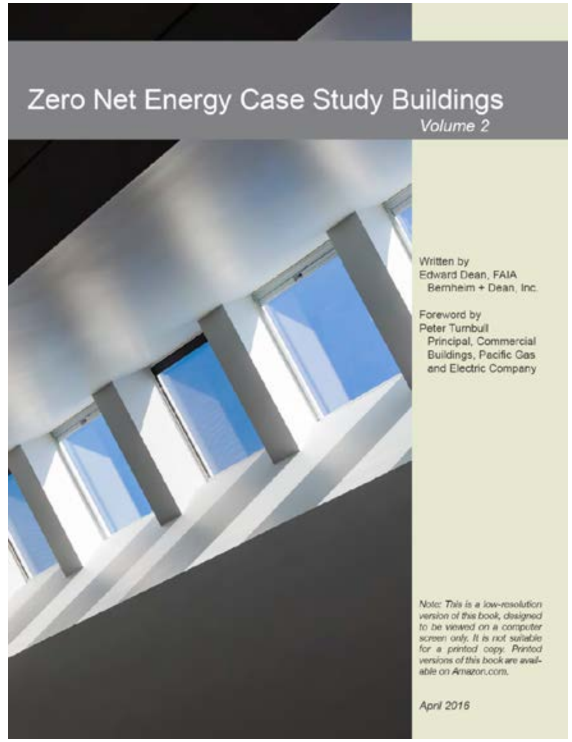

Community Facilities
Residential 3-4 story
Residential 5 story
Mixed Use/ 3 story commercial
Residential 6-7 story
ARLETA AVENUE
RAYMOND AVENUE
LELAND AVENUE
VISITACION AVENUE
DESMOND AVENUE
SUNNYDALE AVENUE
BAYSHORE BOULEVARD
SAN BRUNO
TUNNEL AVENUE
BLANKEN AVENUE
WHEELER AVENUE
PENINSULA AVENUE
LATHROP AVENUE
KOREAN CHURCH
VISITACION AVENUE
RECYCLING CENTER SCULPTURE GARDEN
TRANSFER STATION
RECYCLE ROAD
SAN FRANCISCO COUNTY
SAN MATEO COUNTY

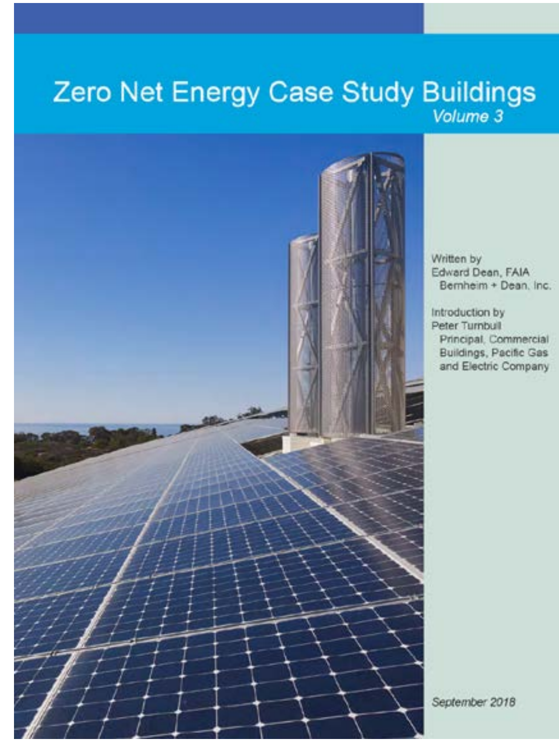

OGIC 07-12
OFF-GRID COMMUNITY
The carbon footprint of the community will be identified, this represents the base case for our study. This number will be lowered through two methods, the production of onsite renewable energy and energy conservation measures to make renewable energy feasible.
Where we are now, in 2007
If our site were to be developed today, in 2007, it would generate 74 million pounds of Carbon through usage and conditioning.
In addition, 86,000 pounds of Carbon will be generated from automobiles.
Total 94,000,000 kWh
So we can produce our own on-site renewable energy:
- Solar Power
- Wind Power
- Cogeneration (Biomass)
BUT we can reduce energy consumption by:
- Using Natural Ventilation and Radiant Floors to reduce consumption in our homes
- Using Active Beams to reduce consumption in our offices
- Employing Ultra-efficient Building Systems
Energy Conservation Measure
Energy Footprint (kWh)
Carbon Footprint (lbs CO2)
Carbon Reduction by Production
Solar Power
Wind Turbines
Cogeneration
Carbon Reduction by Conservation
Natural Ventilation
Active Beams
Absorption Chiller from Cogen Heat
Net Consumption
0 kwh
0 lbs
The carbon footprint of the community was reduced through a two stage process: renewable production and energy conservation. While both methods reduce our carbon footprint significantly, neither one alone is enough to completely offset the overall carbon production.
Through the use of renewable energy production methods, we can consume energy whose generation produced very little carbon. Solar panels and wind turbines harness the power of nature to produce electricity, converting sunlight and wind energy respectively. Cogeneration burns methane to produce heat and electricity, and is the primary source of onsite energy.
Energy conservation is used to bring consumption levels down to a point where renewable energy can meet the demand. Natural ventilation is used in the residences, while an active beam system is used in the offices. Natural ventilation does not involve any mechanical systems, and thus consumes no electricity. Active beams provide efficient cooling to the space. An absorption chiller, using heat from the cogeneration facility, further reduces consumption by reclaiming energy that would usually be wasted.
Muni stop
North
Cogeneration Plant
3 Story Apartments
Wind Turbines
Prevailing Wind
5 Story Apartments
Mixed Use Commercial
MUNI stop
7 Story Apartments
train station
site plan
Location
San Francisco, CA
Land Utilization
Our land use was mostly devoted towards medium density residence zones that allow for an efficent use of the land while giving us critical mass for the public transportation system.
The high density offices were placed in the south, close to the railway station and the commercial zones.
Wind turbines were placed on the West side of the site, in the direction of the prevailing wind.
Retail
Civic Space
Office
Residential
Rain Water Collection
In order to reduce potable water usage from the mains a system for rainwater harvesting can be implemented. The harvested rainwater is collected from the roof and stored for future use as gray water usage; i.e. landscape irrigation and
Due to the high rainfall experienced in San Francisco, it is possible to reclaim enough water for site landscaping. Flora for landscaping will be selected to suit the local environment, with special attention to plants that do not require excessive watering during the summer months, when rainwater is scarce. plumbing.
Transportation
There will be no cars on site. There is sufficient public transportation to commute comfortably. Normally, for this type of space there would be approximately 6000 cars. By making this a car-free site we are saving more than 86,000 lbs of carbon from being emitted each year.
We will have a lend-a-bike system (check in/check out bicycles go from A to B). Similar to Lyon, France's Vélo-V idea. Extract a bike with a prepaid card (in Lyon it is 5 Euros a year to sign up ($6 USD) + 0.5 Euros per 1.5hours).

Off-Grid Competition







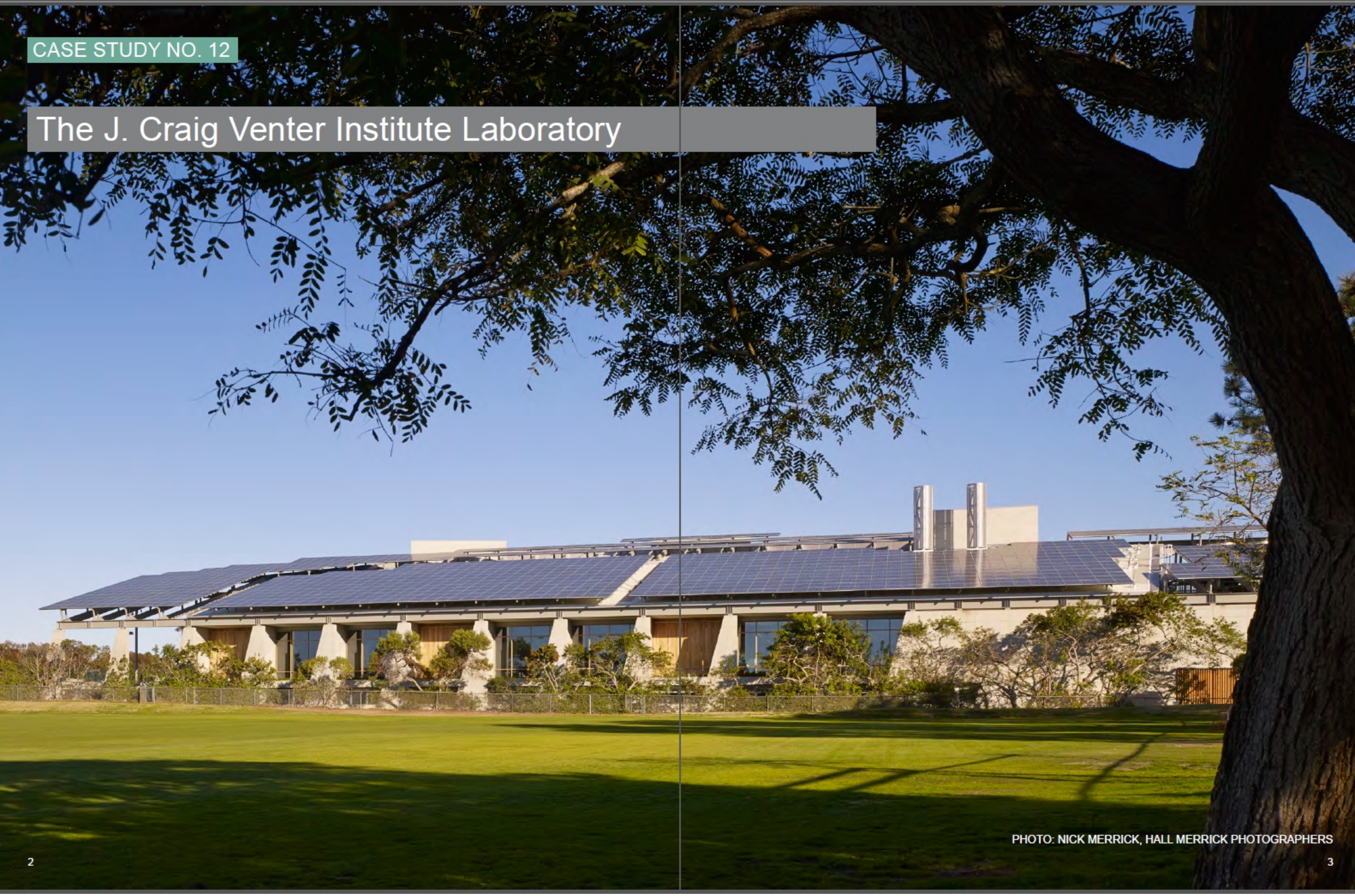


Packard Foundation
Stevens Library
IDeAS Office
Watsonville Water Resources
U.C. Merced

DPR Office (SF)
IBEW-NECA JATC Training
435 Indio Way
West Berkeley Library
SF Exploratorium

J. Craig Venter Institute Lab
La Escuelita Education Center
California DMV Field Office
Butte College
LACCD Harbor College Science
Stanford University

https://www.pge.com/pge_global/common/pdfs/save-energy-money/savings-programs/zero-net-energy-program/ZNE-Case-Study-Buildings-Vol1.pdf
https://www.pge.com/pge_global/common/pdfs/save-energy-money/savings-programs/zero-net-energy-program/ZNE-Case-Study-Buildings-Vol2.pdf
https://www.pge.com/pge_global/common/pdfs/save-energy-money/savings-programs/zero-net-energy-program/ZNE-Case-Study-Buildings-Vol3.pdf


CASE STUDY NO. 12
The J. Craig Venter Institute Laboratory
PHOTO: NICK MERRICK, HALL MERRICK PHOTOGRAPHERS
2
3

Practical Examples

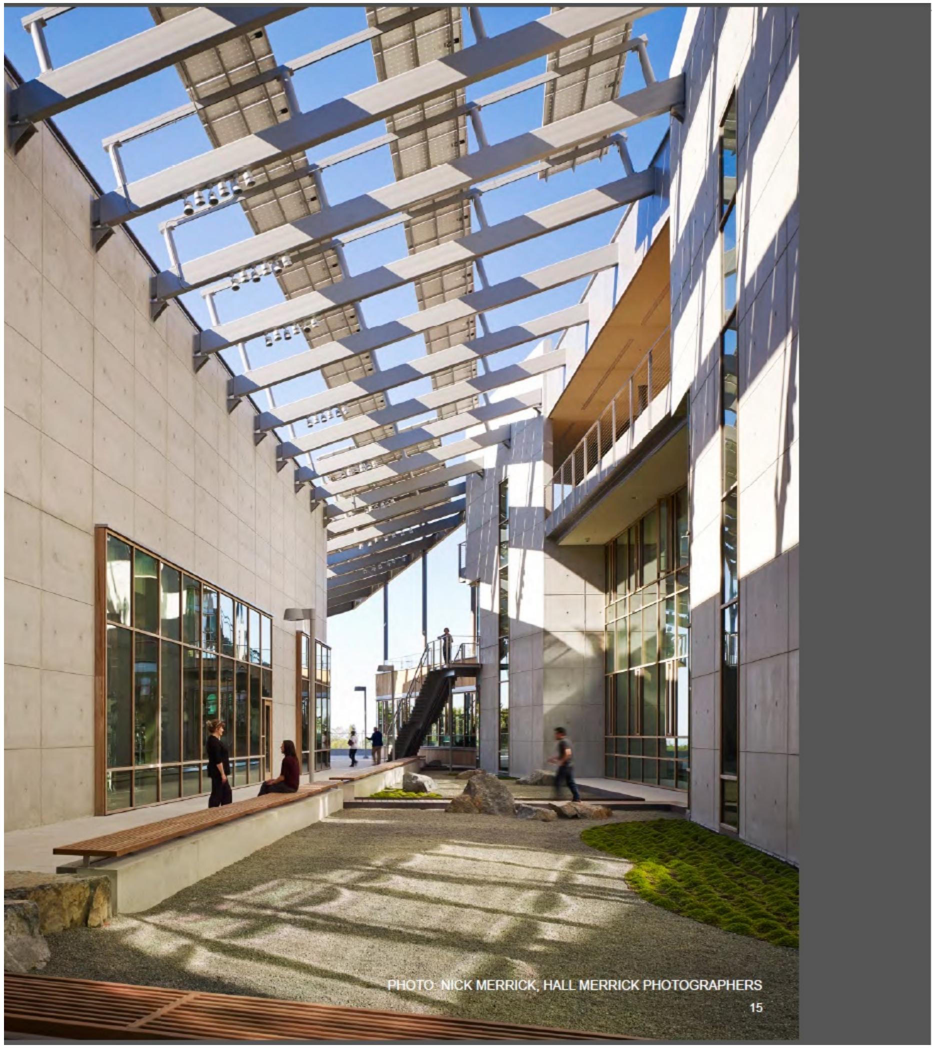
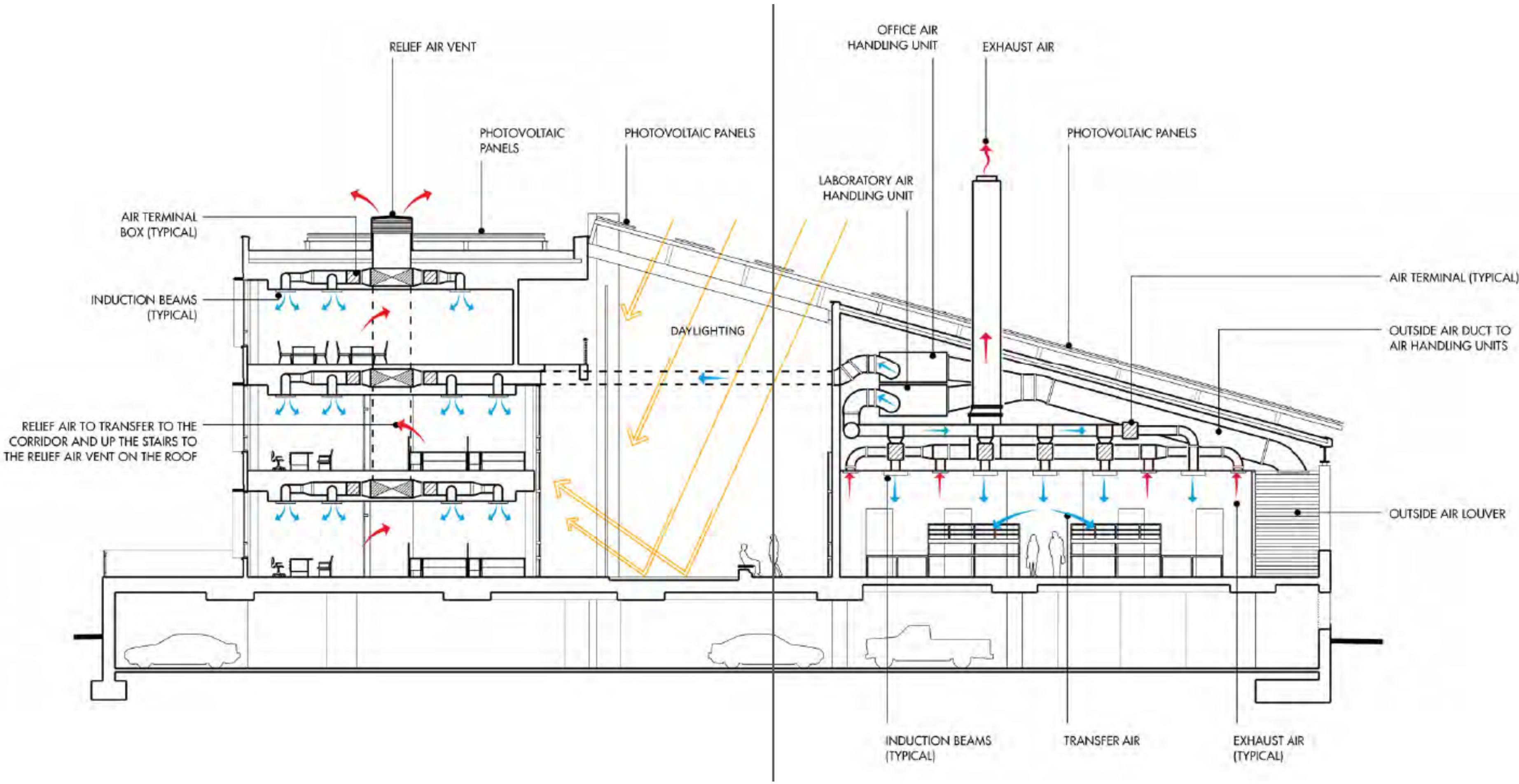


PHOTO: NICK MERRICK, HALL MERRICK PHOTOGRAPHERS
15

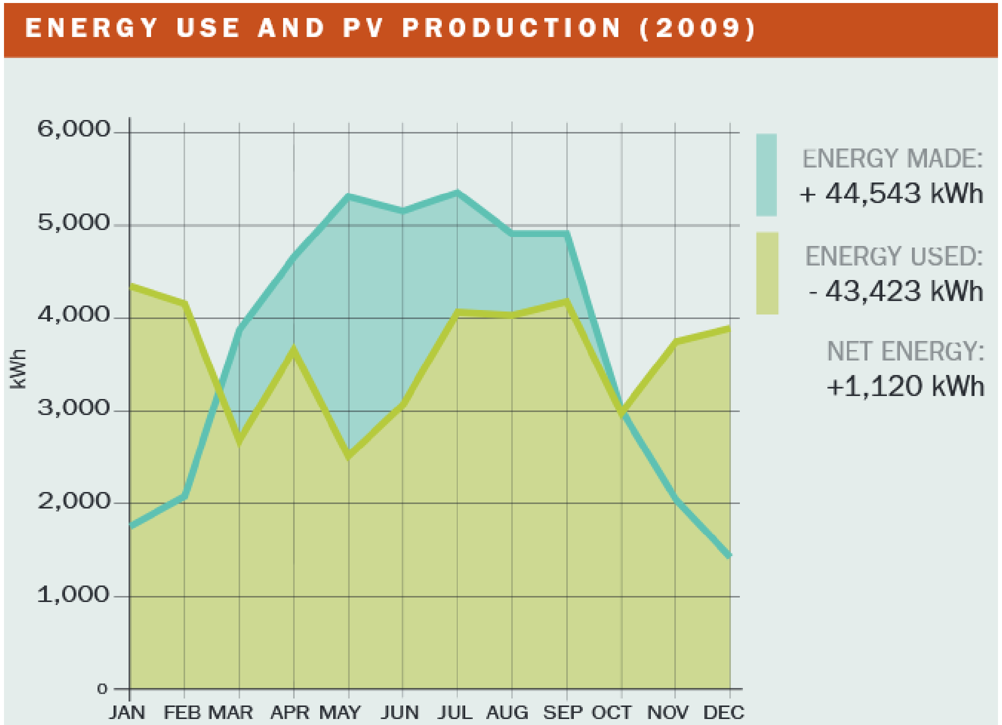

PHOTO: NICK MERRICK, HALL MERRICK PHOTOGRAPHERS

Practical Examples

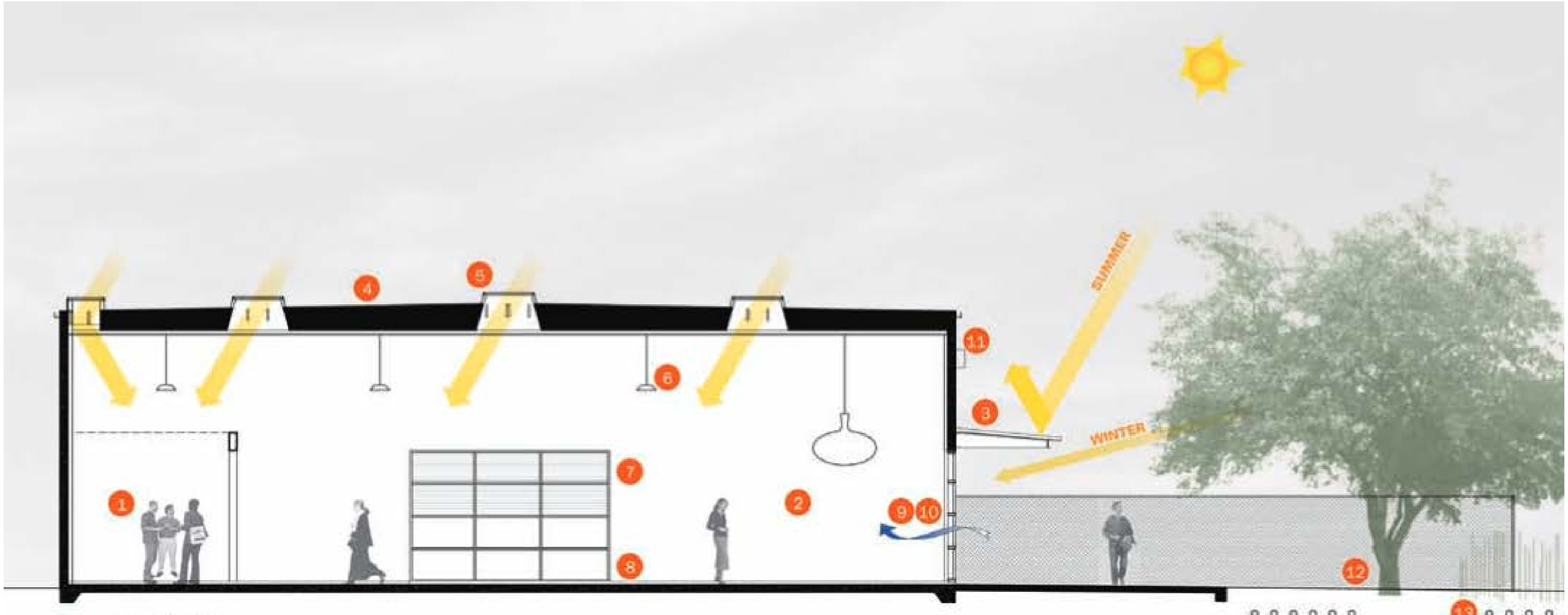


Images Courtesy Integral Group.

Images Courtesy Integral Group.



Source: Kaneda, D., P. Rumsey, and S. Shell. 2010. Less than Zero. *High Performing Building.* http://www.hpbmagazine.org/attachments/article/12143/10F-IDeAs-Z2-Design-Facility-San-Jose-CA.pdf. Photographs © David Wakely. Graphic © EHDD Architecture.



1 Private office
2 Open office
3 Sunshade with building-integrated photovoltaics
4 Roof with building-integrated photovoltaics
5 Skylight
6 Energy-efficient and occupancy sensor controlled light fixtures
7 Electrochromic glass
8 Radiant heat floor
9 Natural ventilation
10 High performance glass
11 Reduction of outdoor light pollution
12 Water-efficient landscaping
13 Ground-source heat pump

Zero gas usage

CO_2 Zero CO_2 emissions

Section view of IDeAs building. Integrated Design Associates (IDeAs) transformed a 1960s-era concrete windowless bank building by adding windows, skylights and energy-efficient lighting and HVAC. By maximizing efficiency before sizing the photovoltaic system to cover the remaining loads, costs were kept to a minimum. In 2009, the building used less energy than it produced, achieving the goal of net zero energy and carbon emissions.

Source: Kaneda, D., P. Rumsey, and S. Shell. 2010. Less than Zero. *High Performing Building*. http://www.hpbmagazine.org/attachments/article/12143/10F-IDeAs-Z2-Design-Facility-San-Jose-CA.pdf. Photographs © David Wakely. Graphic © EHDD Architecture.

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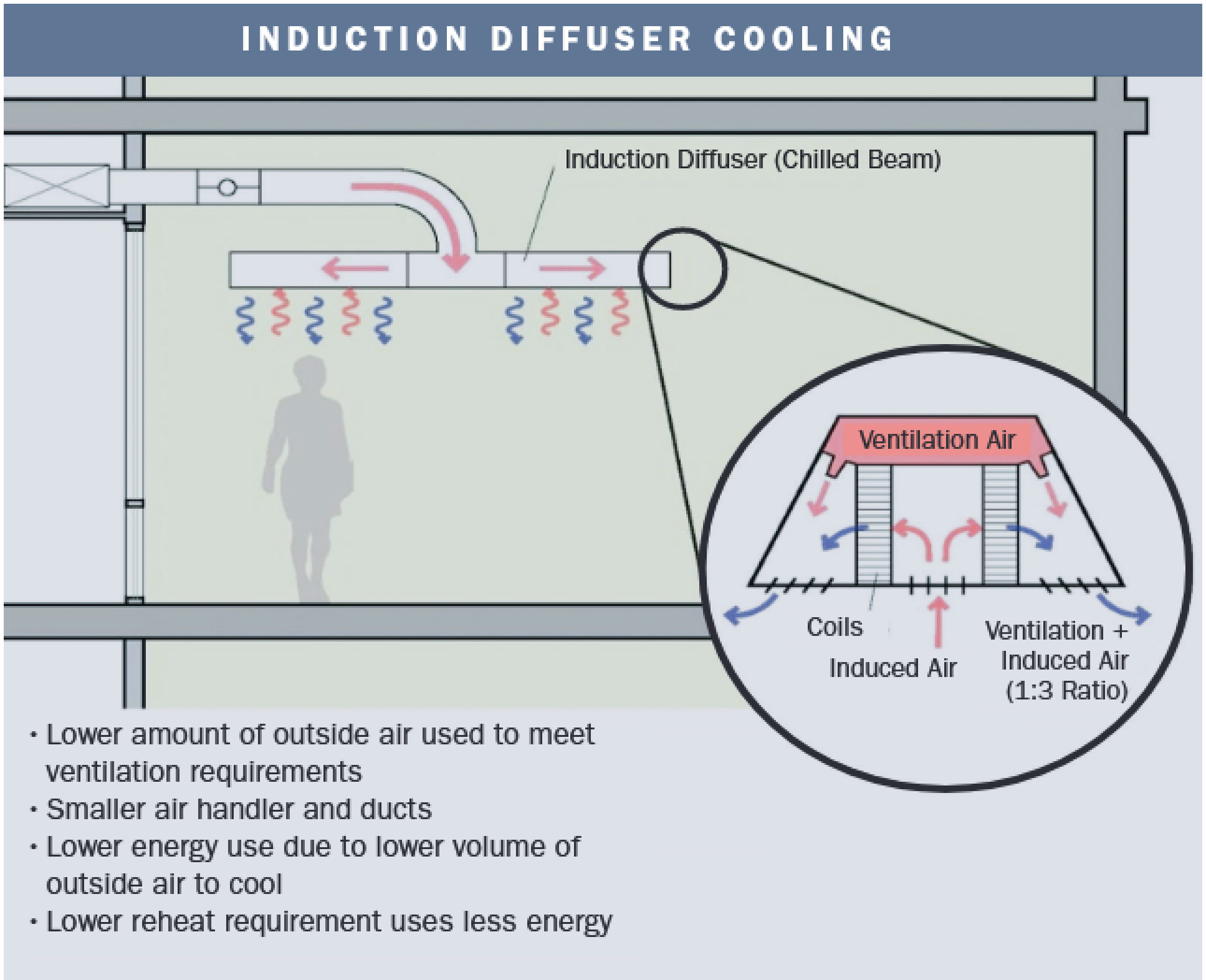
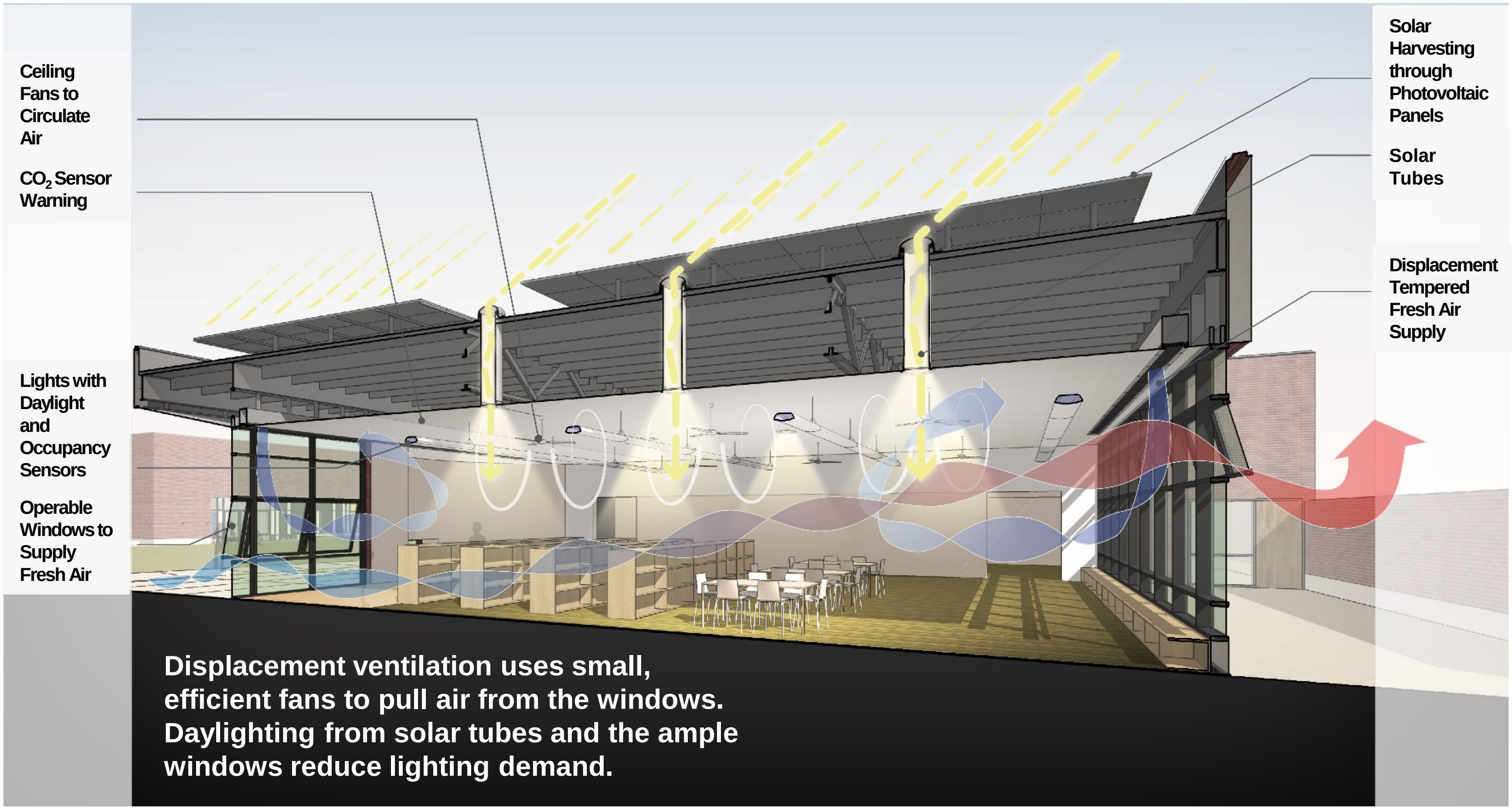
Source: P. Rumsey, E. Soladay, and A. Murphree. 2015. Graceful Inspiration. *High Performing Building.* http://www.hpbmagazine.org/attachments/article/12152/15W-David-&-Lucile-Packard-Foundation-Headquarters-Los%20Altos-California.pdf. Photographs © Jeremy Bitterman.



Source: P. Rumsey, E. Soladay, and A. Murphree. 2015. Graceful Inspiration. *High Performing Building.* http://www.hpbmagazine.org/attachments/article/12152/15W-David-&-Lucile-Packard-Foundation-Headquarters-Los%20Altos-California.pdf. Photographs © Jeremy Bitterman.

Stevens Library at Sacred Heart Schools, Atherton

http://www.hpbmagazine.org/Web-Exclusive-Stevens-Library-at-Sacred-Heart-Schools-Atherton-Calif/.



Source: P. Souza. 2016. Stevens Library at Sacred Heart Schools: Atherton, Calif. *High Performing Building.* http://www.hpbmagazine.org/Web-Exclusive-Stevens-Library-at-Sacred-Heart-Schools-Atherton-Calif/.

Closing Comments

Growth in ZNE Buildings

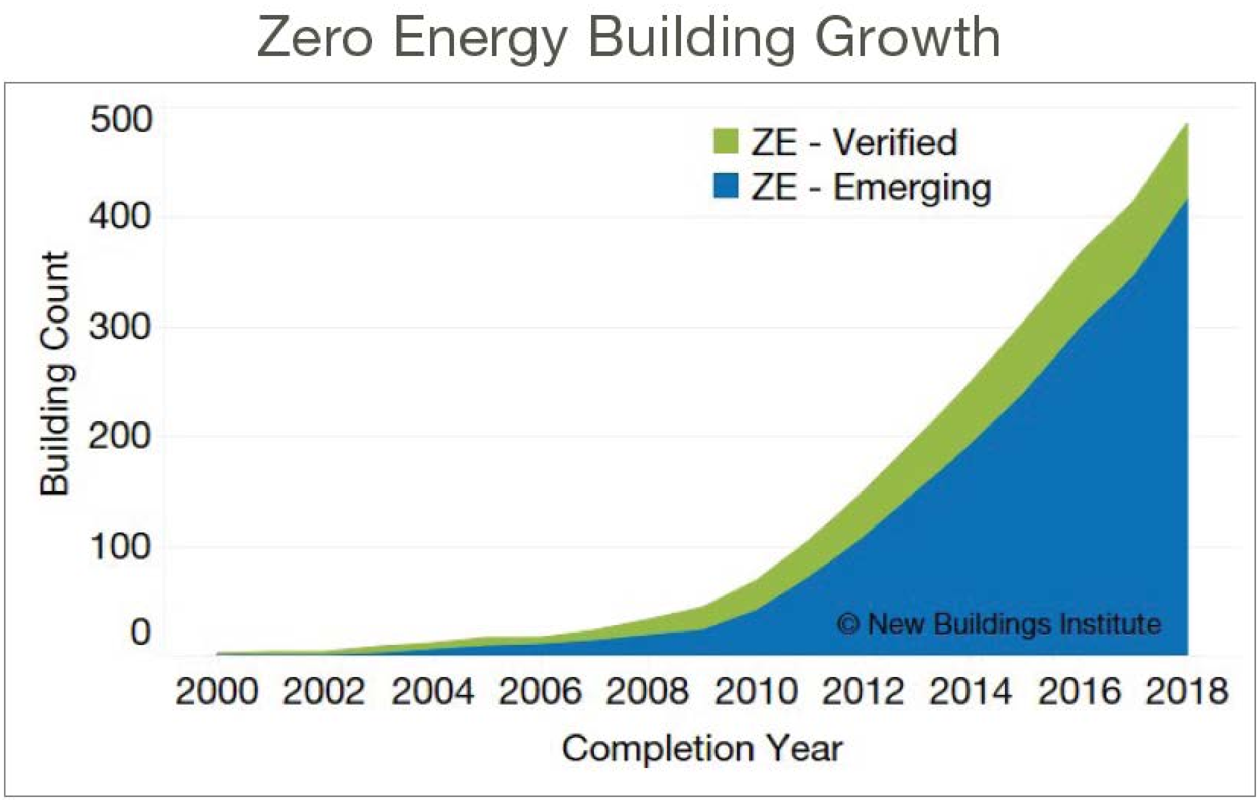
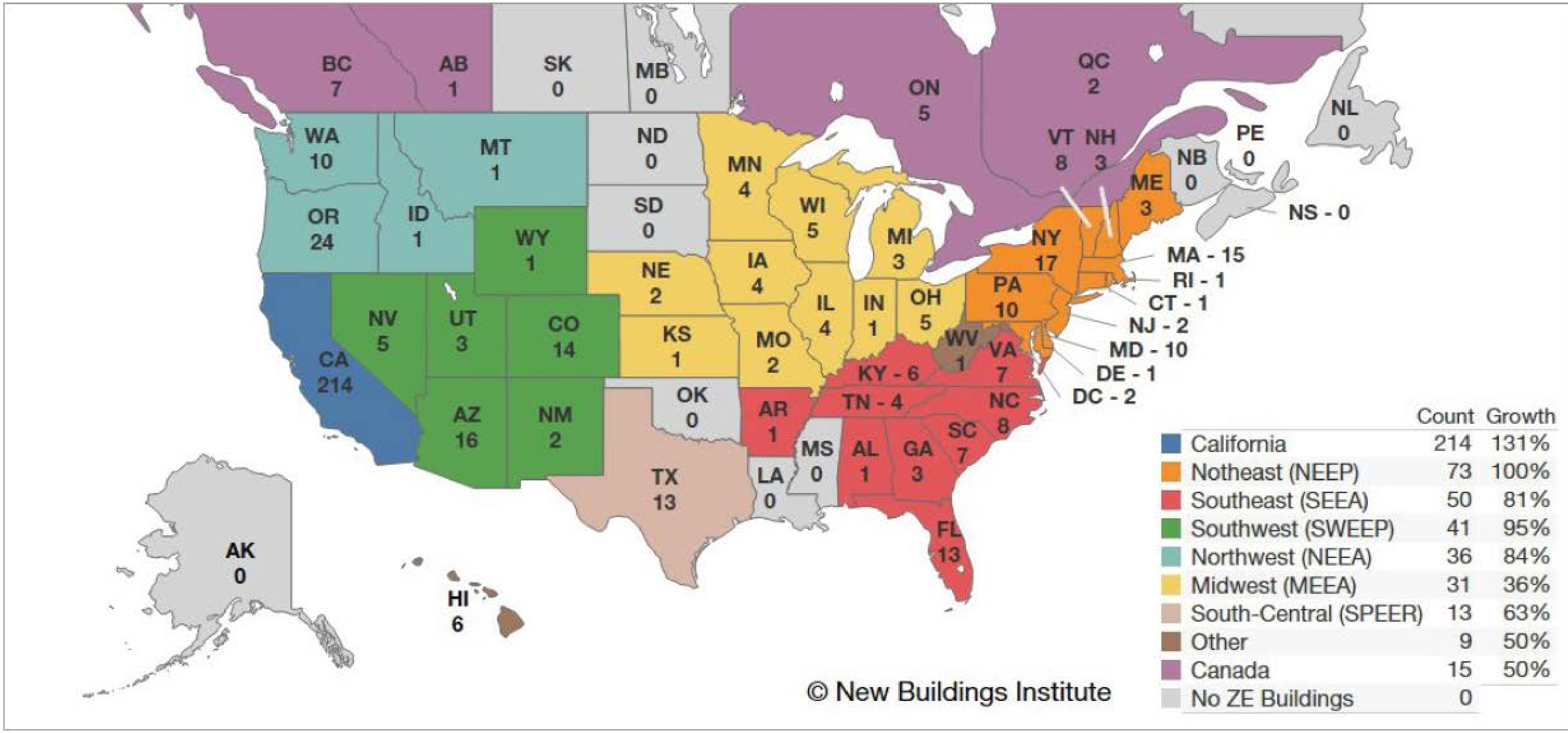


Fig 1. The Buildings List includes nearly 500 projects and is on a steep curve upward, having increased over 700% since 2012.

North American ZNE Locations – 2018

2018 Buildings List Project Locations



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Sustainability—The Big Picture

- Transportation
- Water
- Materials and products

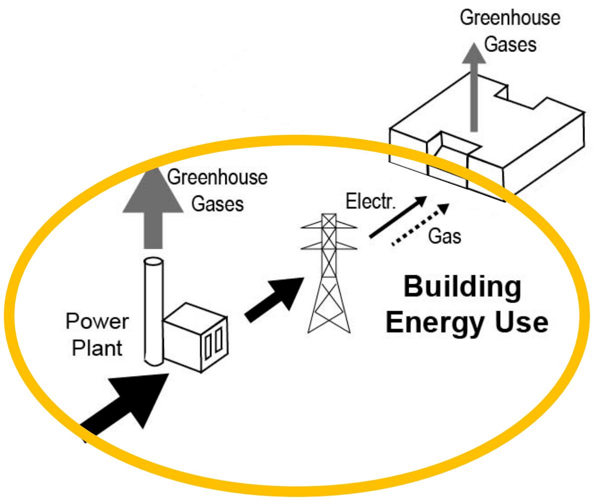
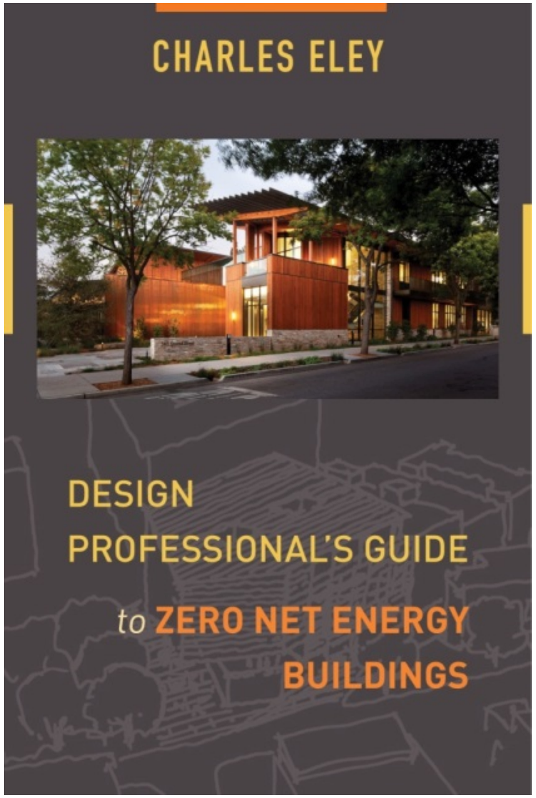


Image from Design Professionals Guide to Zero Net Energy Buildings,

Wrap-Up

Wrap-Up



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