Architecture 2030 ZERO Code

Charles Eley, FAIA, PE
Architecture 2030 Senior Fellow


National and
International
ZERO Code
Released April 2018

ZERO CODE™

Commercial • Institutional • Mid-Rise/High-Rise Residential Buildings

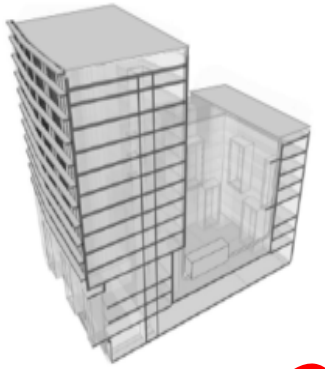
1 Design an energy efficient building

Efficiency Standard: ASHRAE 90.1-2016 minimum; ASHRAE 189.1-2017; others

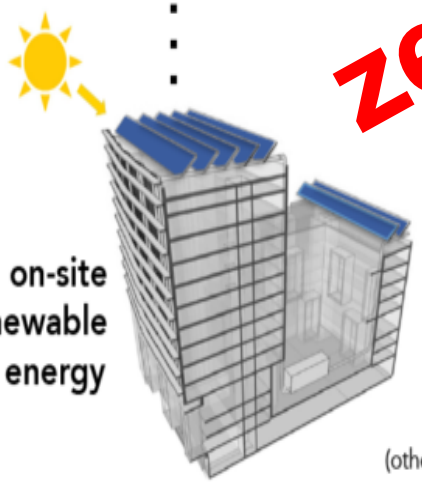
Efficient building envelope / daylighting

Passive heating / cooling / ventilation

Efficient systems / equipment / controls



2 Address the remaining building's energy needs with:



on-site renewable energy

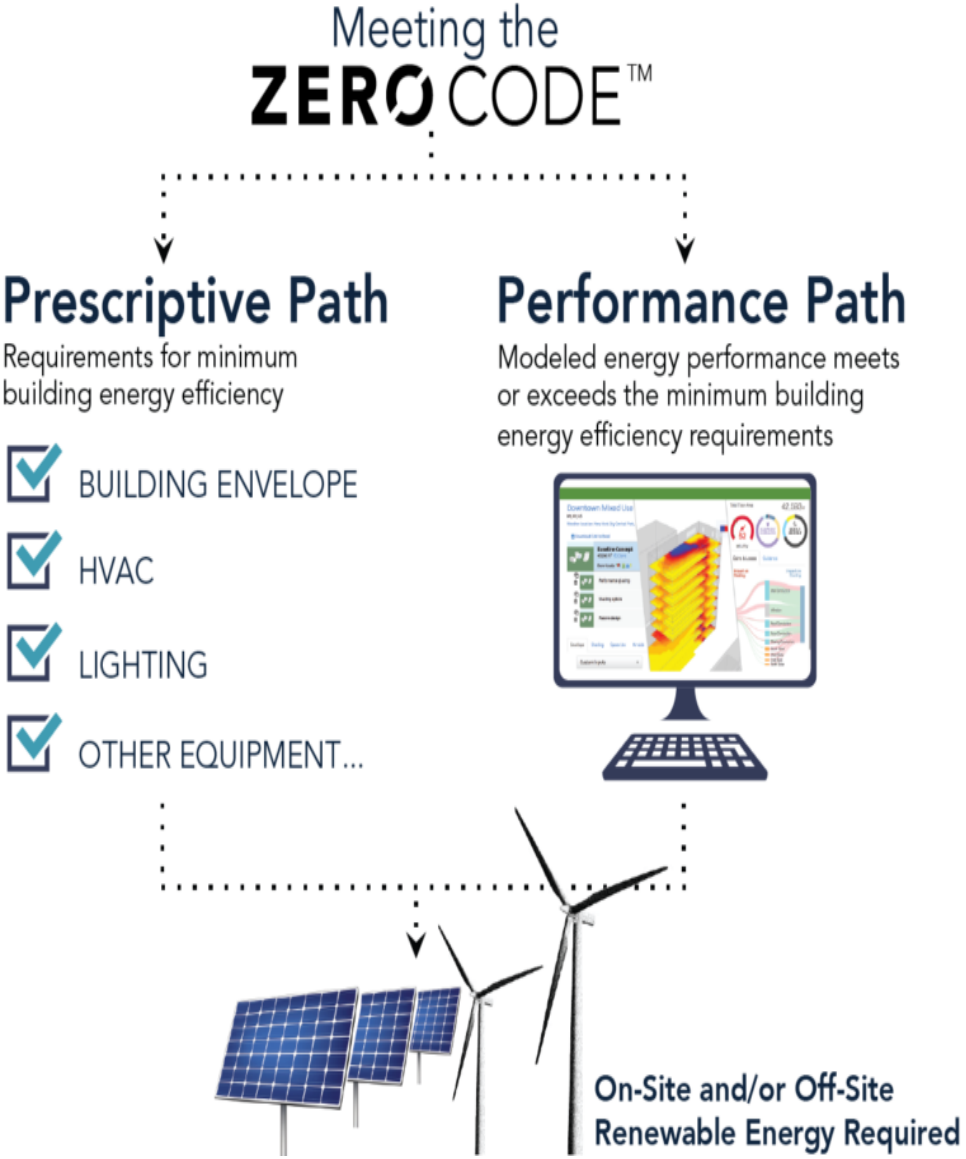
and/or off-site renewable energy

wind • solar • hydro
(other non-CO_2 emitting sources)

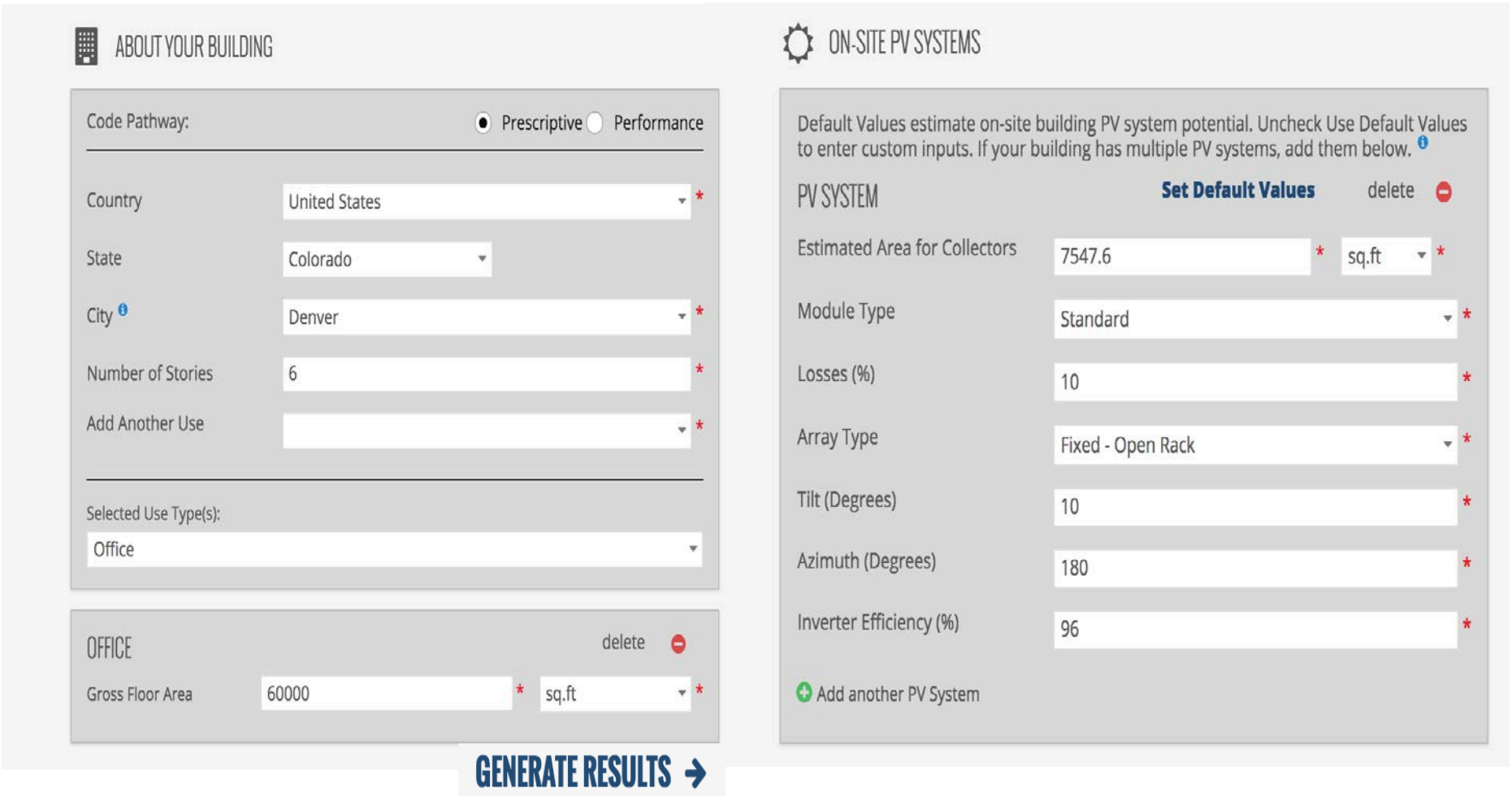
Source: Architecture 2030
Graphic adaptations: Sefaira; DOE

zero-code.org

National and International ZERO Code



https://zero-code.org/energy-calculator/



National and International ZERO Code

ZERO CODE™

HOME ABOUT ZERO CODE ENERGY CALCULATOR CONTACT

RESULTS

metric imperial

RENEWABLE ENERGY REQUIREMENTS

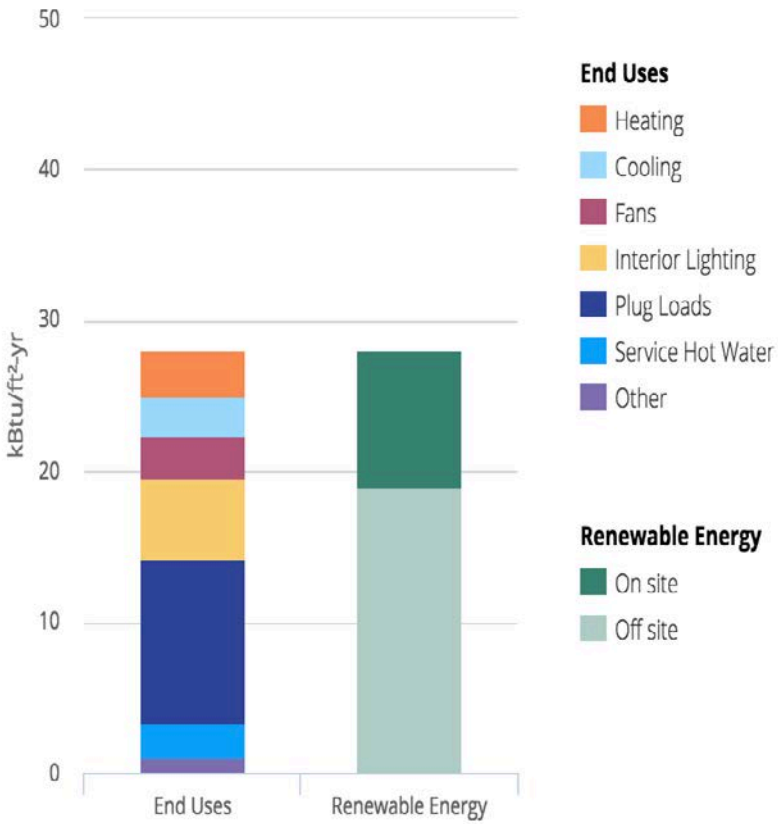
Energy Consumption & Generation

	kBtu/ft²-yr	MBtu/yr
Estimated Building Energy Consumption	**28.0**	**1,681.3**
Total Renewable Energy Required	**28.0**	**1,681.3**
On-Site PV Generation Potential	9.0	540.4
Remaining Off-Site Procured Renewable Energy	19.0	1,140.9

On-Site PV System

Rated Capacity (kW)	105
Estimated Area for Collectors (ft²)	7,548

ESTIMATED BUILDING ENERGY CONSUMPTION

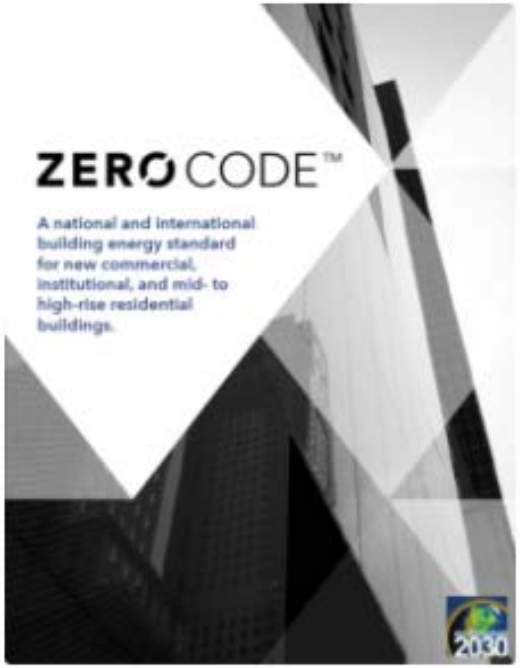


Building Energy Consumption and End Uses are based on a **code compliant prototype building** modeled by Pacific Northwest National Laboratory. Actual building energy consumption will vary from modeled results.

National and International ZERO Code

ZERO CODE™ HOME ABOU ZERO CODE ENERGY CALCULATOR CONTACT

ZERO Code & Technical Support Document downloads:

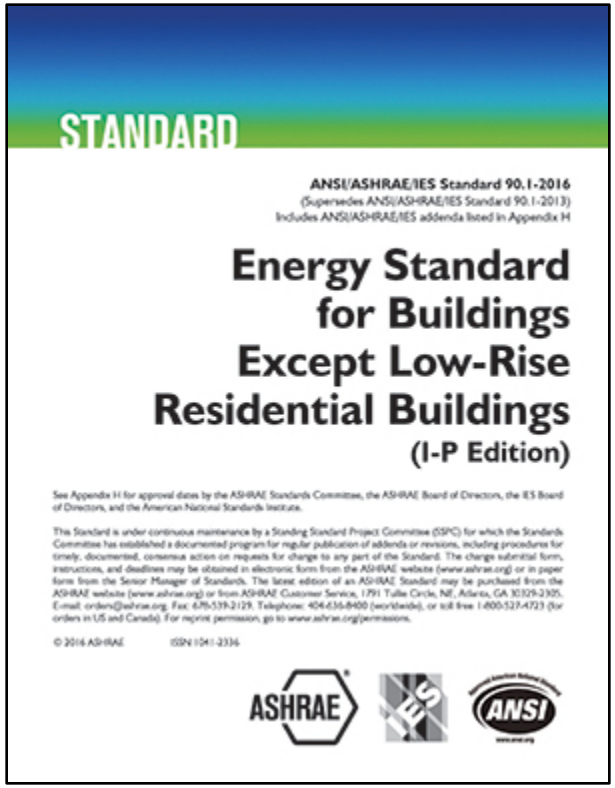


Download the ZERO Code

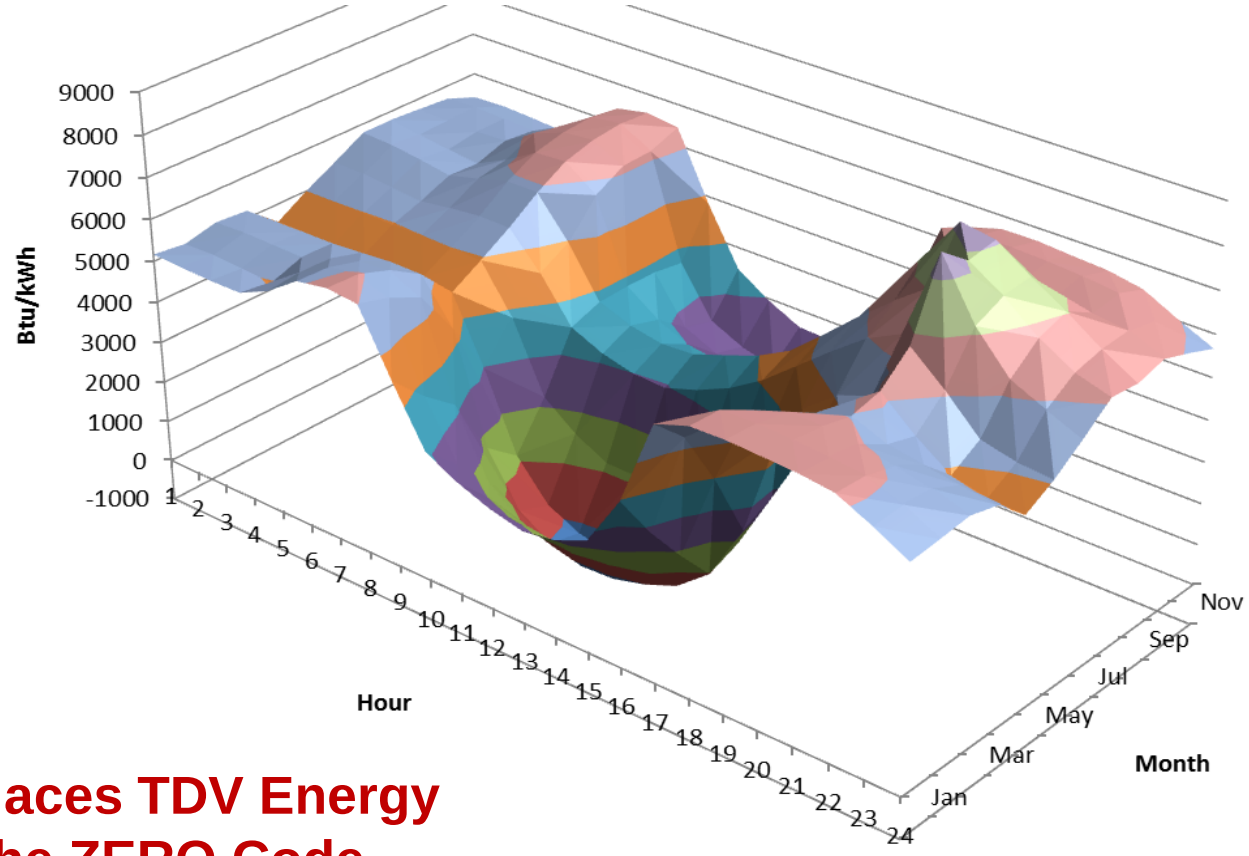
Download the Technical Support Document


The ZERO
Code for
California

Minimum Energy Efficiency



Time-Dependent Source Energy



Replaces TDV Energy for the ZERO Code

Off-Site Renewable Energy Procurement

Class One

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

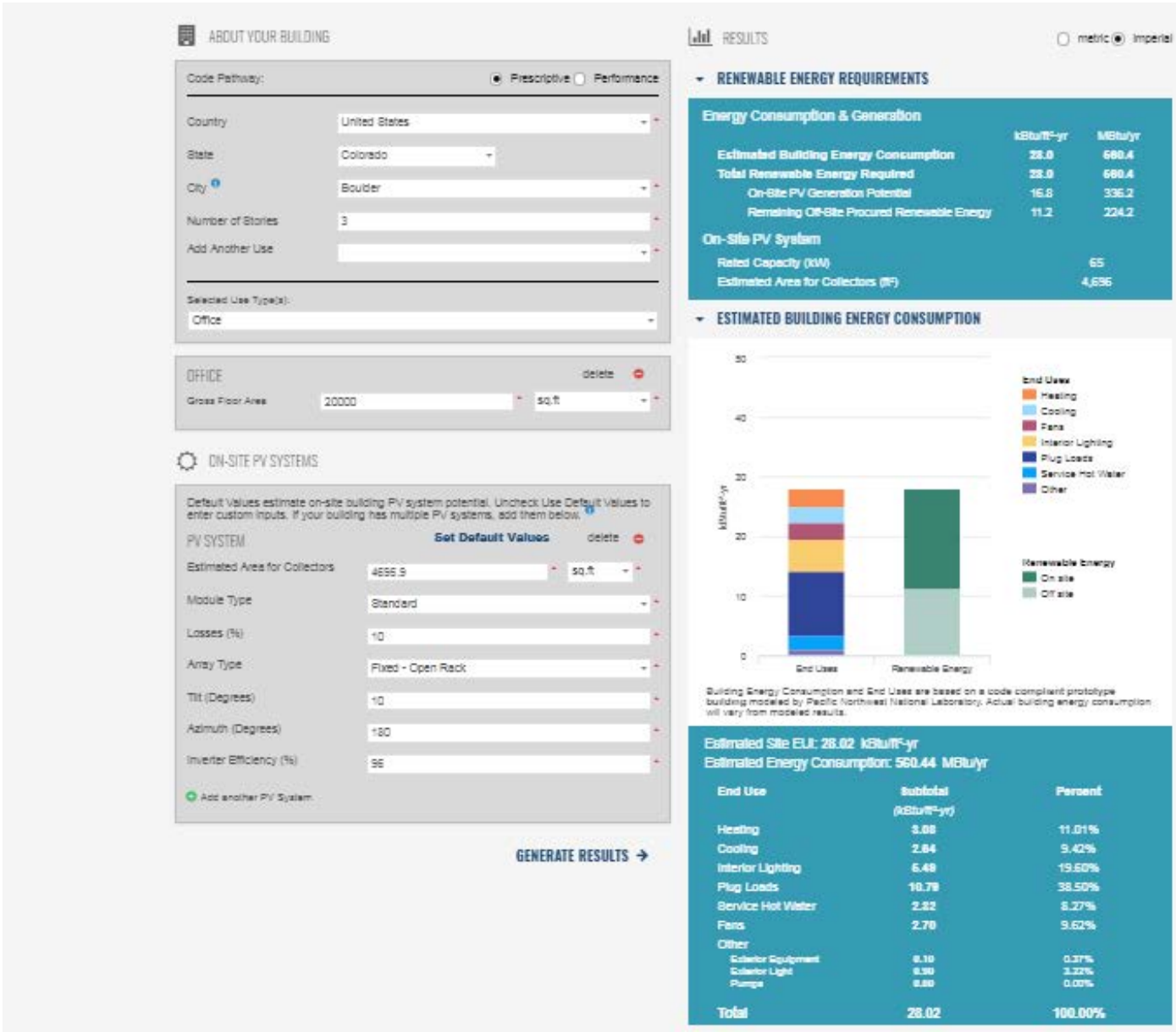
Class Two

- Direct Access to Wholesale Market
- Green Tariffs

Class Three

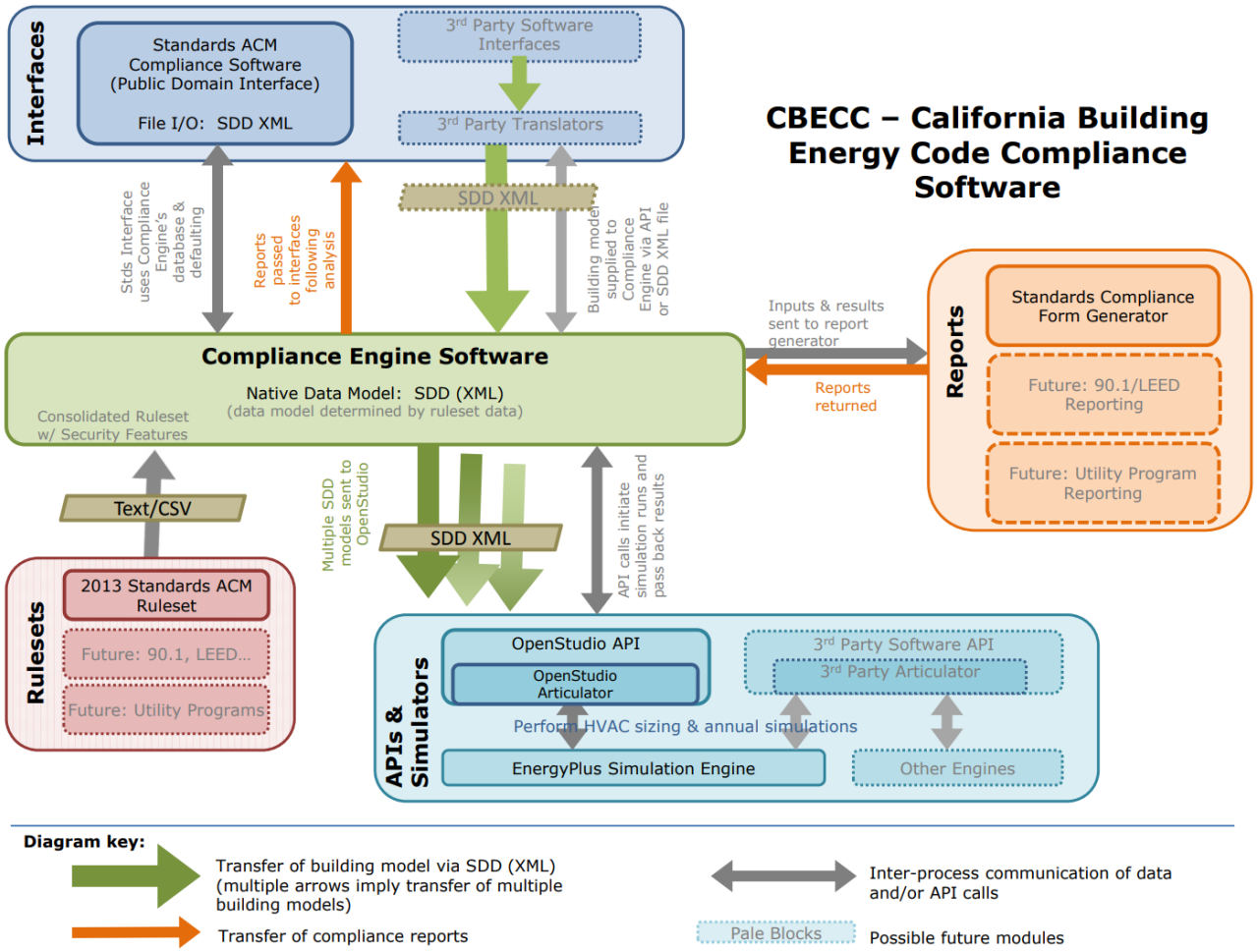
- Unbundled RECs

ZERO-Code.org Website



CBECC-Com Supports the ZERO Code

- PV Modeling Capabilities
- Battery Model
- Multiple Metrics including TDS
- ZERO Code Output Report (CSV)




The California Grid and Source Energy

Site Energy

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

Source Energy

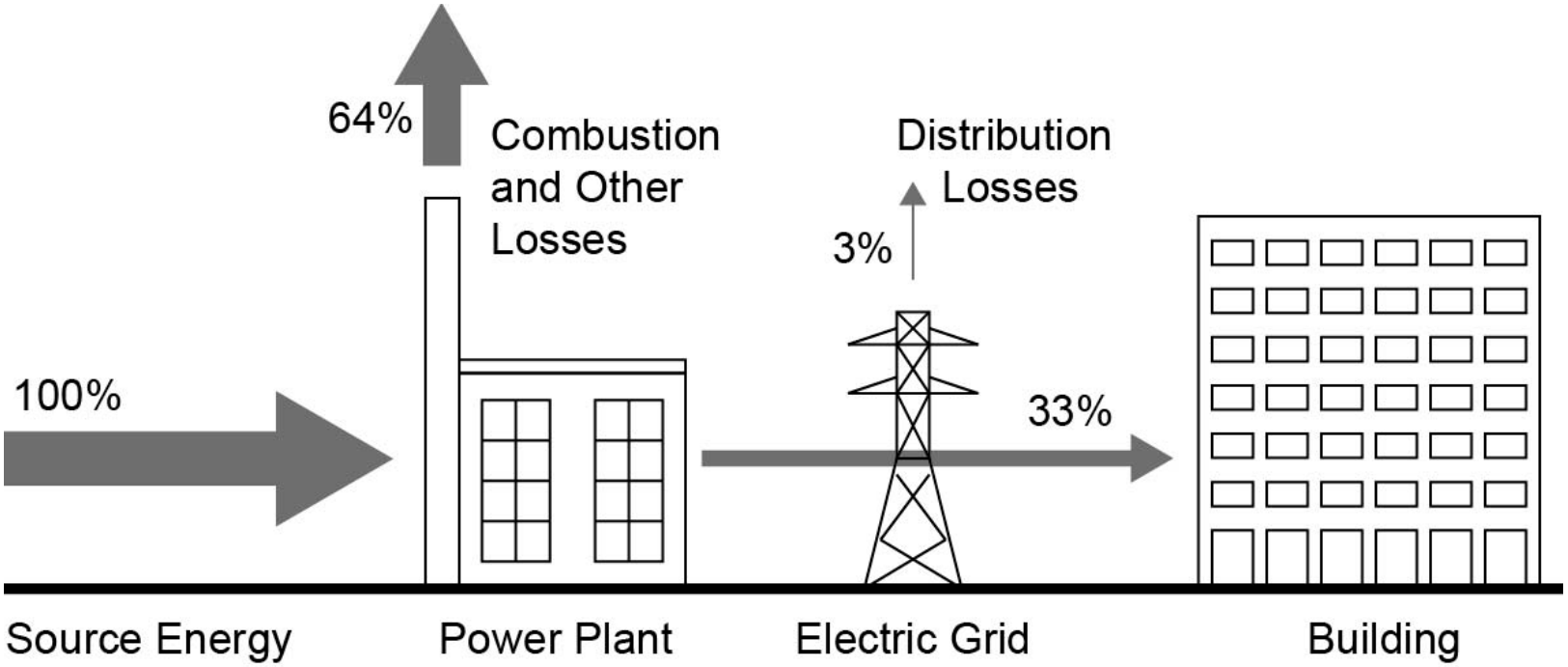
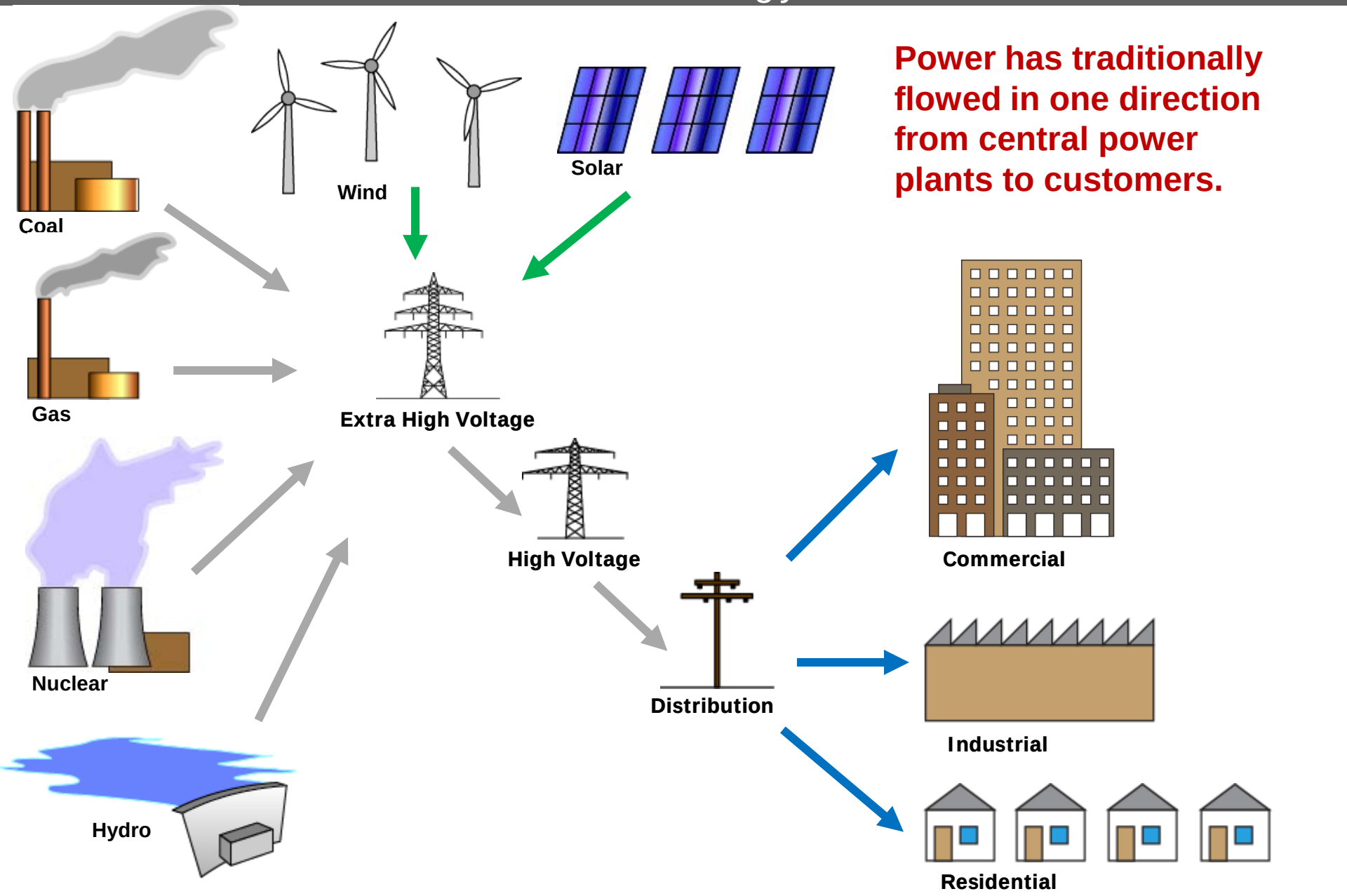


Image: Design Professionals Guide to Zero Net Energy Buildings, Charles Eley, Island Press, 2016

California BEES 1975-2005

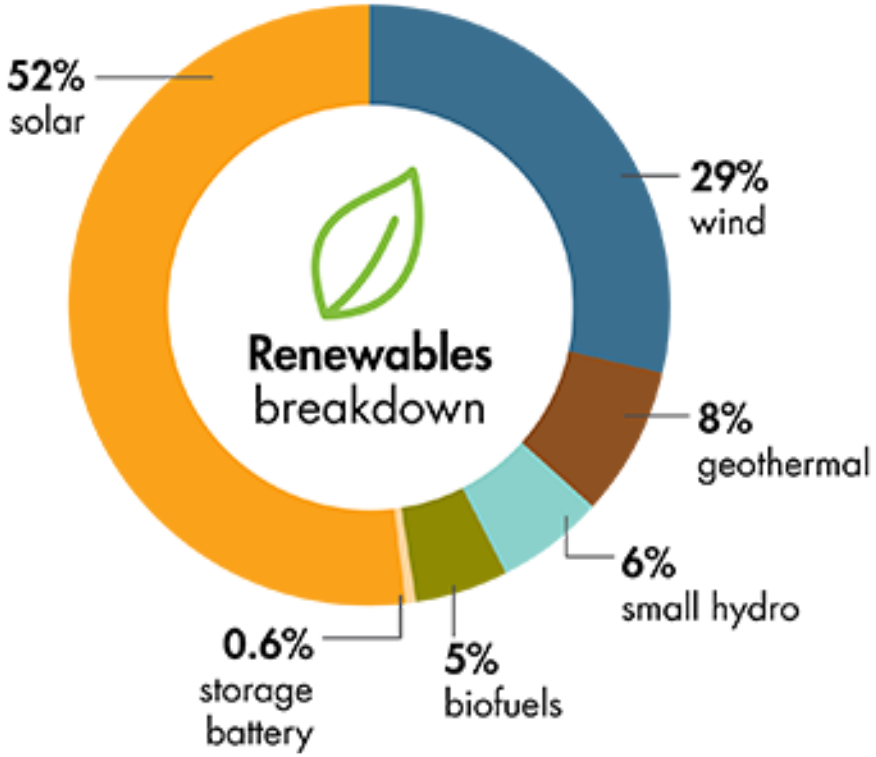
- For three decades, California used a flat source energy multipliers:
  - 3.0 for electricity
    (1 kWh = 10,236 Btu)
  - 1.0 for gas
    (1 therm = 100,000 Btu)
- Replaced by time-dependent valued (TDV) energy in 2005

The California Grid and Source Energy



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

Installed Renewable Resources (as of 05/01/2018)



	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

2017 Total System Electric Generation

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%

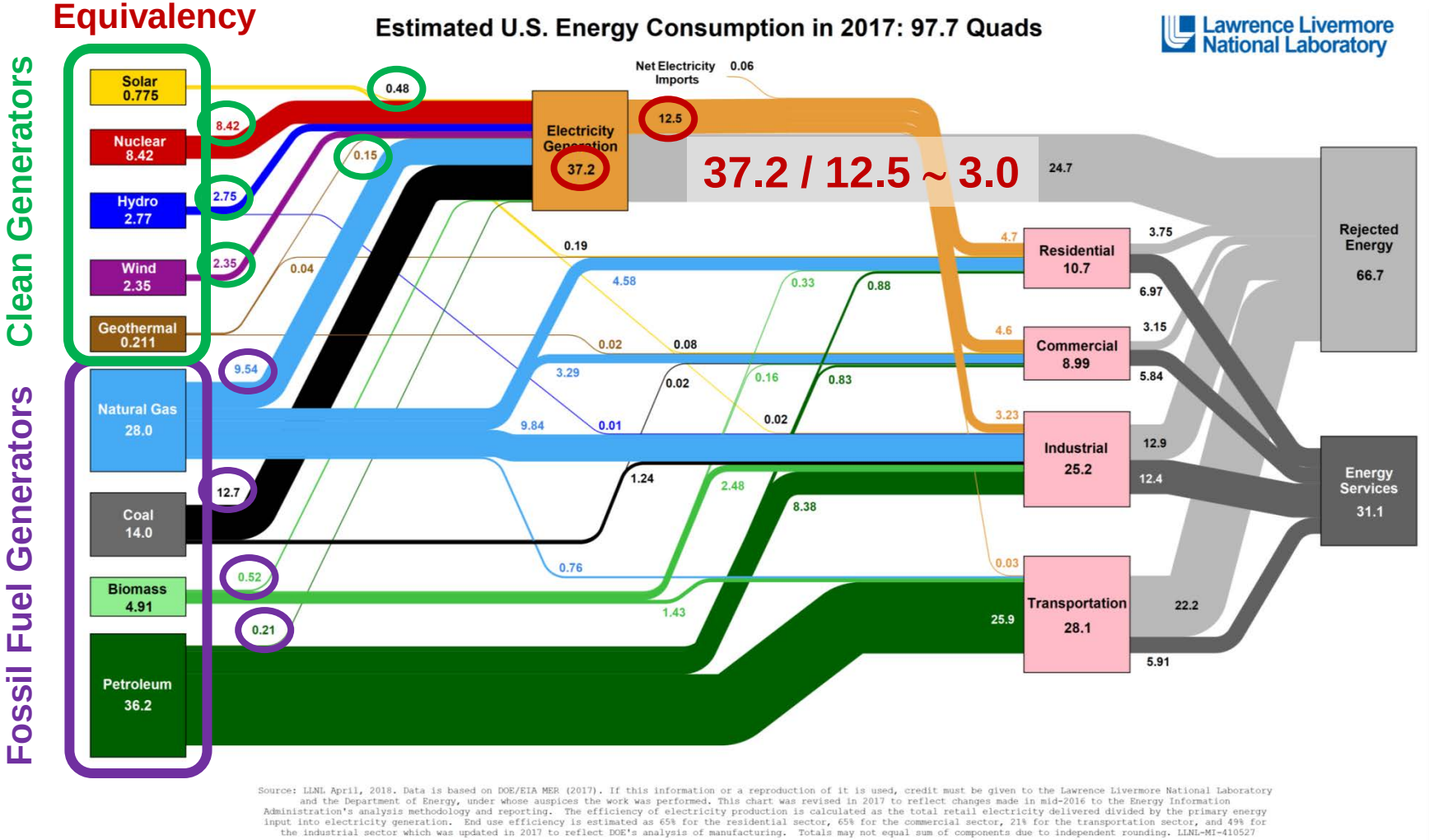
Source: http://www.energy.ca.gov/almanac/electricity_data/total_system_power.html

Senate Bill 100
(recently signed by Governor Brown)

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

The California Grid and Source Energy

Fossil Fuel Equivalency



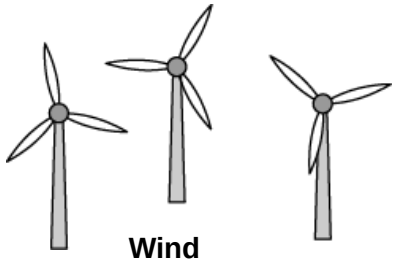
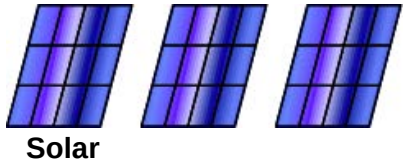
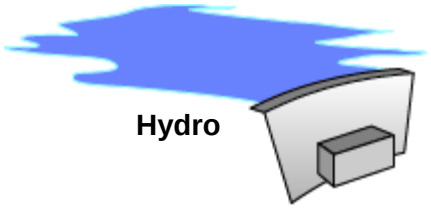
Source: LLNL April, 2018. Data is based on DOE/EIA MER (2017). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes 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

Site Source Multipliers

Energy Type	Source Multiplier	Common Units	Site Btu / unit	Source Btu / unit
Imported Electricity	3.15	kWh	3,412	10,751
Exported Renewable Electricity	3.15	kWh	3,412	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	1,000	1,450
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.				

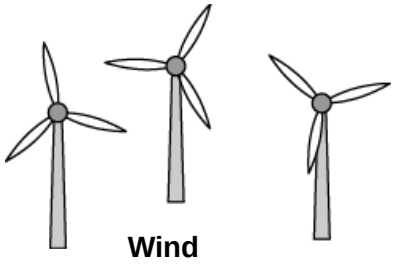
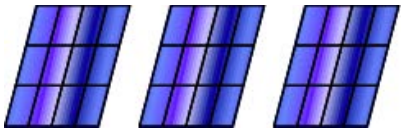
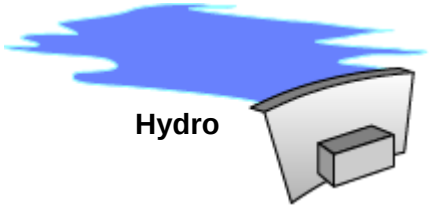
Source: DOE Common Definition, ASHRAE Standard 105, ASHRAE Standard 189.1-2017 Addendum

Fossil Fuel Equivalency Approach

Primary Energy		Electricity Production
~ 10,000 Btu	 Wind	1 kWh
~ 10,000 Btu	 Solar	1 kWh
~ 10,000 Btu	 Hydro	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.

Captured Energy Approach

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.

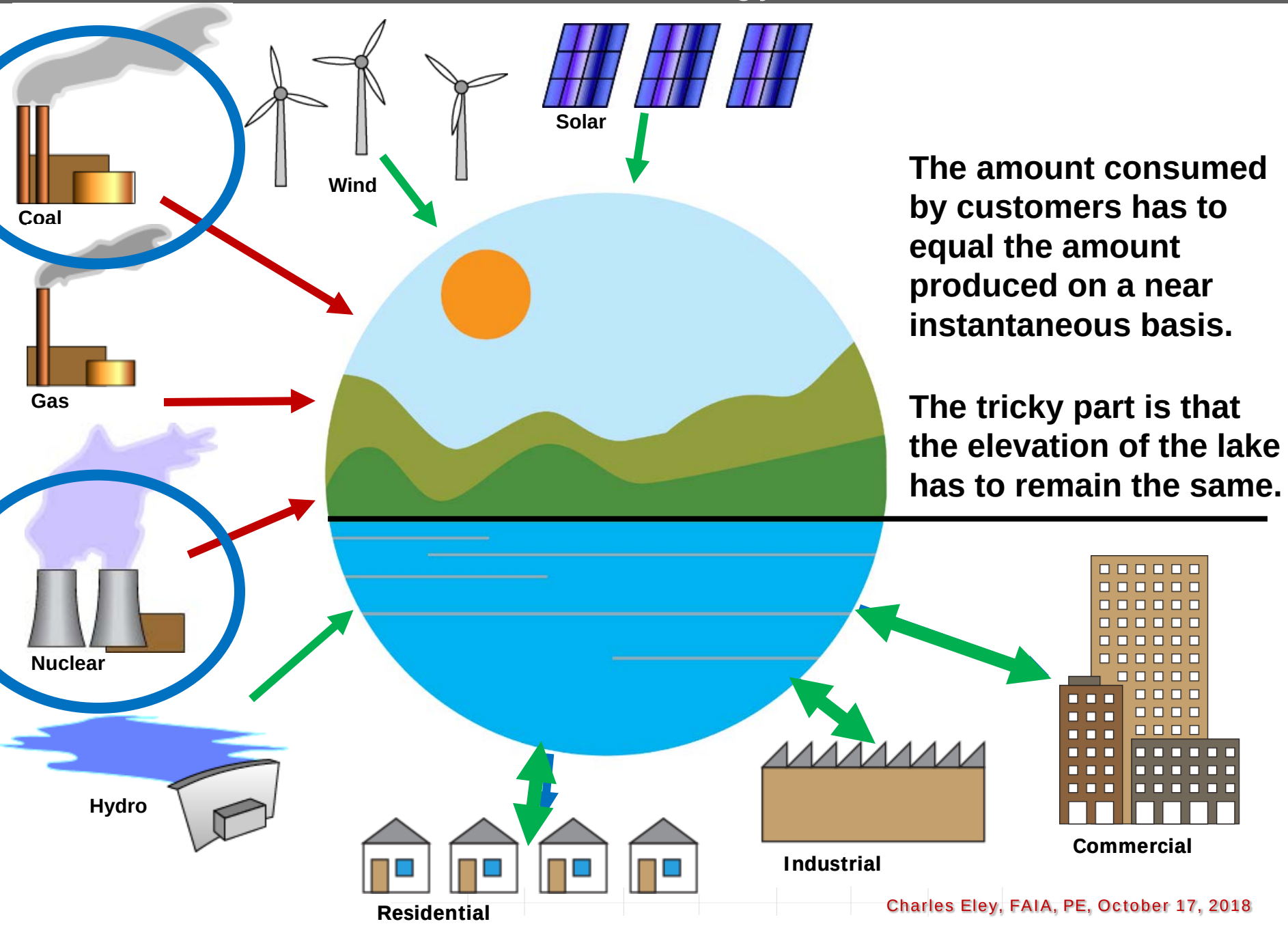
"Zero Heat Content" Approach

Primary Energy			Electricity Production
ZERO Btu	→	Wind	→ 1 kWh
ZERO Btu	→	Solar	→ 1 kWh
ZERO Btu	→	Hydro	→ 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.

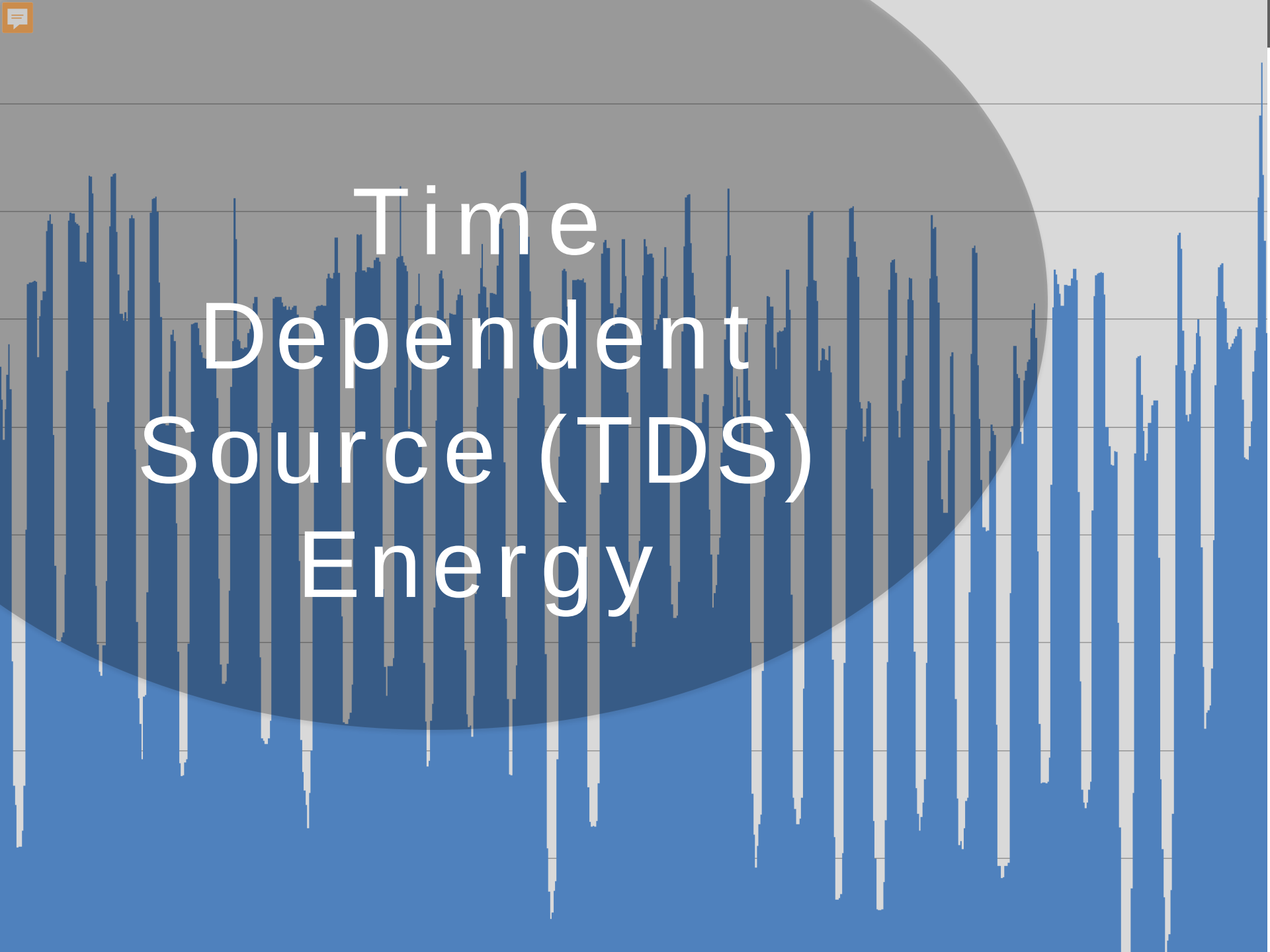
is Constantly Changing

The California Grid and Source Energy



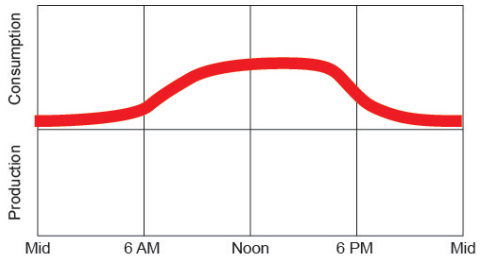
The amount consumed by customers has to equal the amount produced on a near instantaneous basis.

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


Time
Dependent
Source (TDS)
Energy

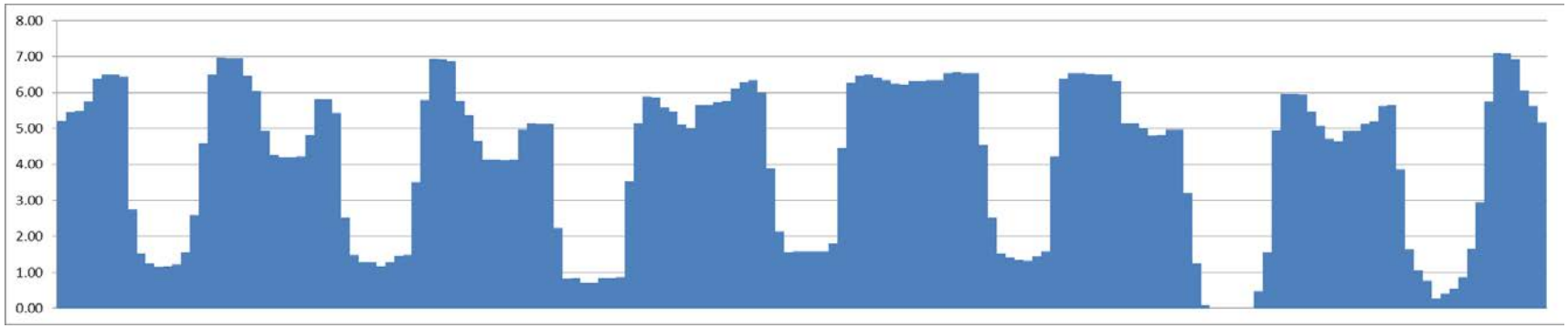
Application to Building Design

Building Electricity Load



Week Beginning March 23 (on the official weather files)

Time-Dependent Source Energy (kBtu/kWh)



Headline:

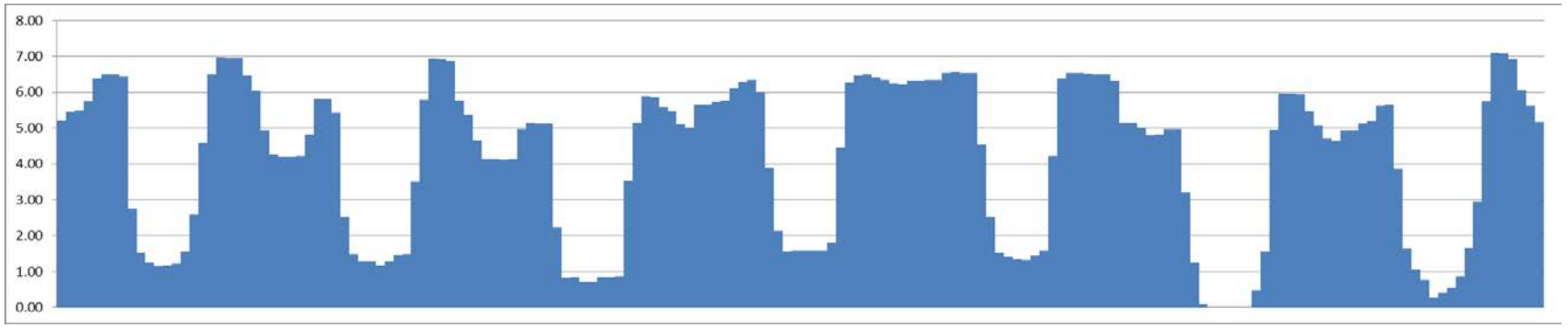
SUNSHINE STATE

California is getting so much power from solar that wholesale electricity prices are turning negative

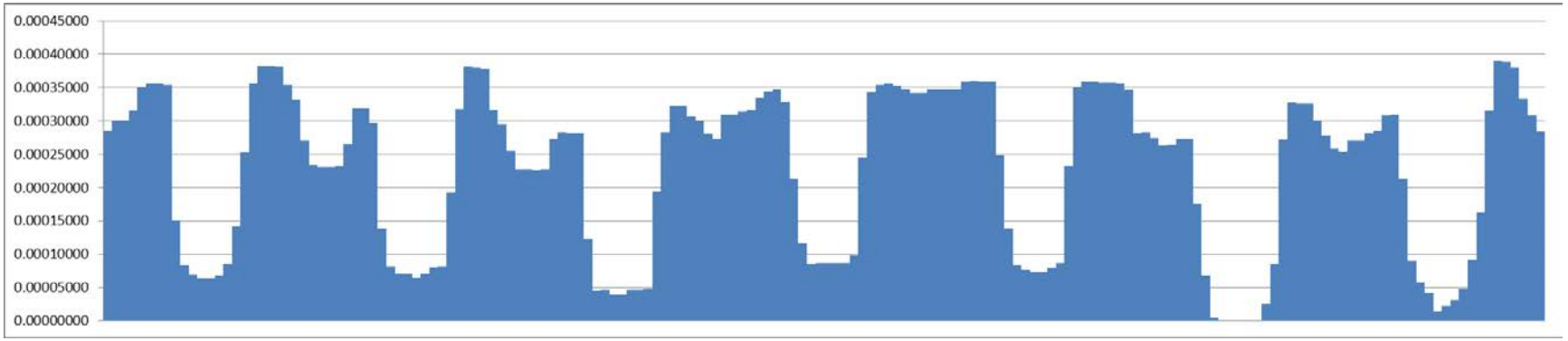
architecture 2030 ZEROCODE™

Patterns of TDS and Carbon Emissions are Identical

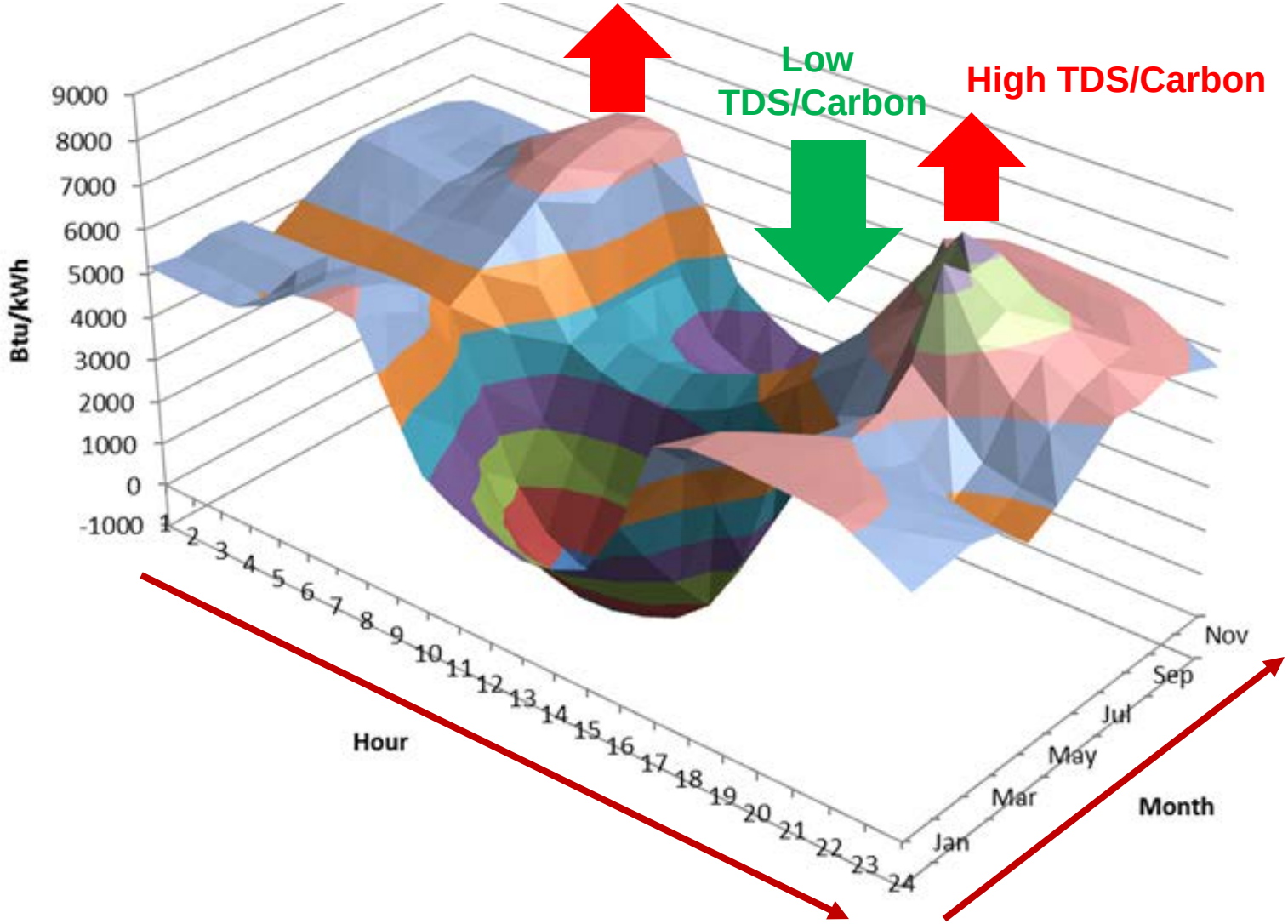
Time-Dependent Source Energy (kBtu/kWh)



Hourly Carbon Emissions (tons/kWh)

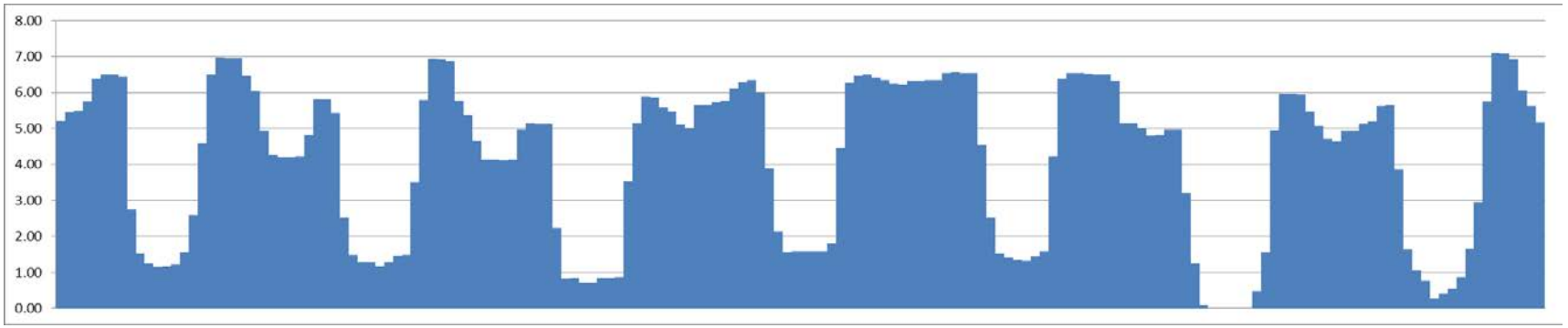


Simplified Visualization of the 8760 Time-Series

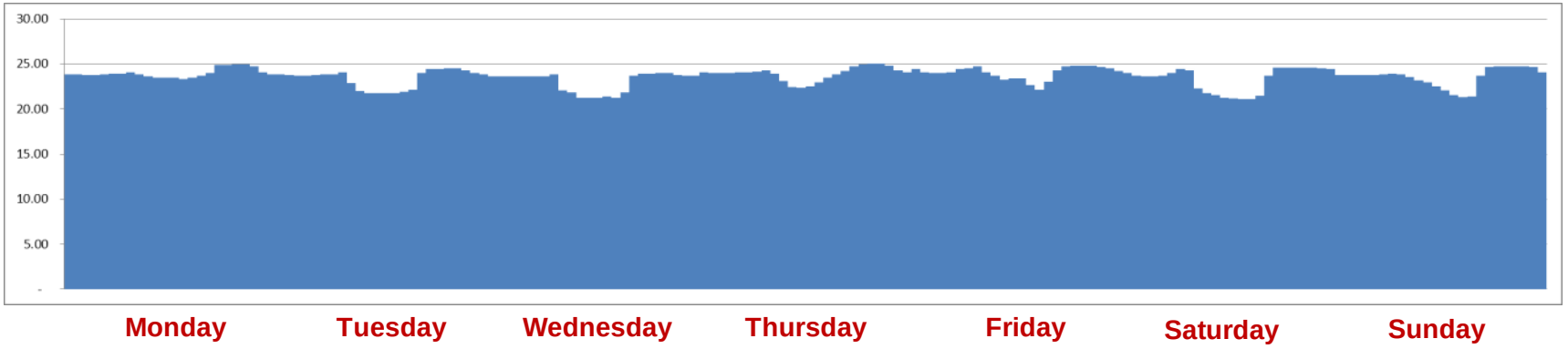


TDS vs. TDV – Week of March 23

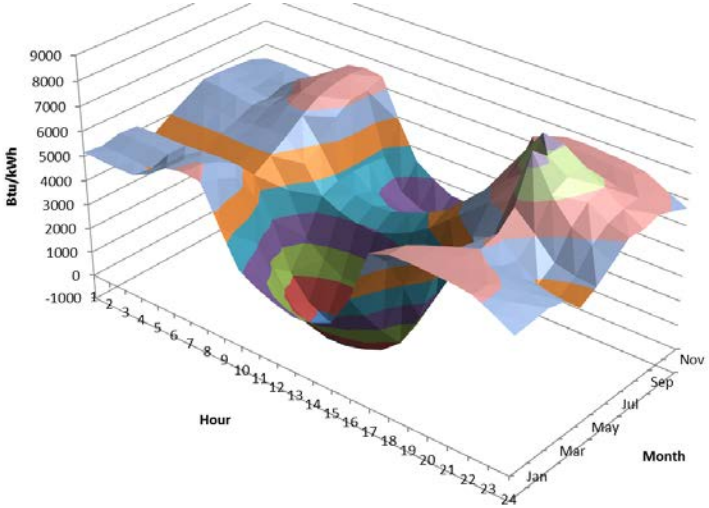
TDS Energy (kBtu/kWh)



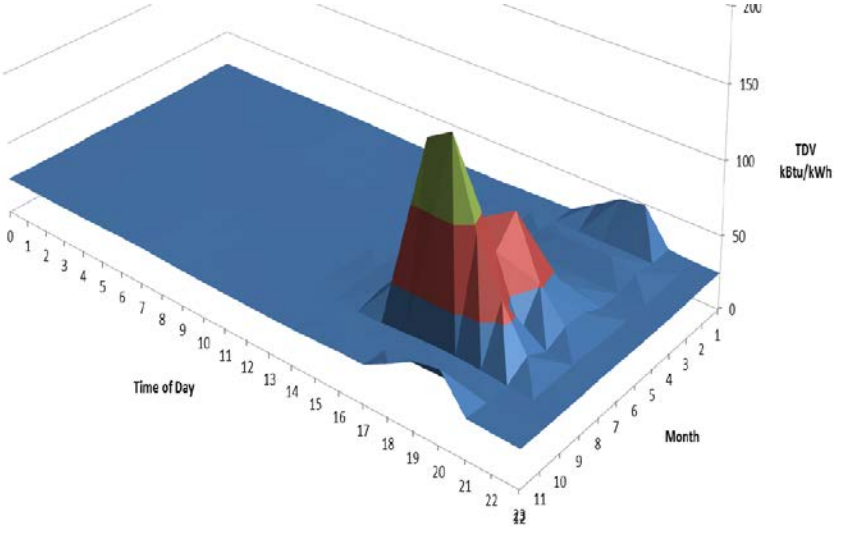
TDV Energy (kBtu/kWh)



TDS vs. TDV – Climate Zone 3

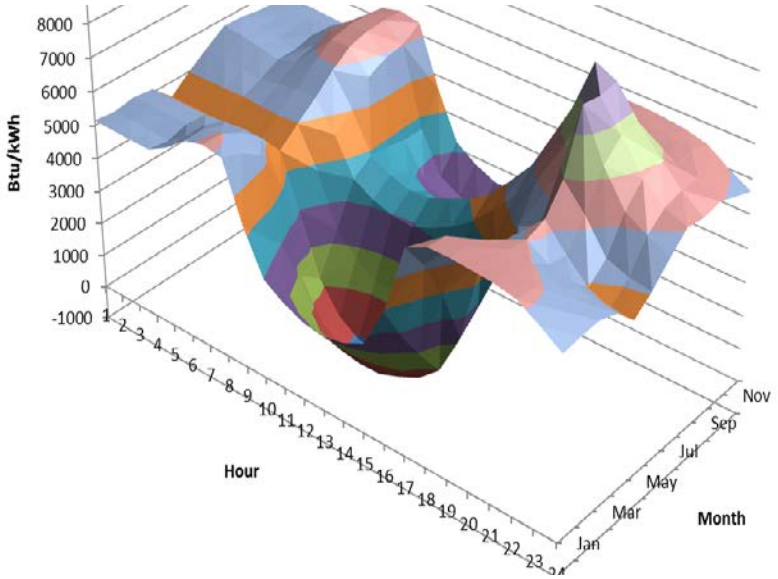


TDS

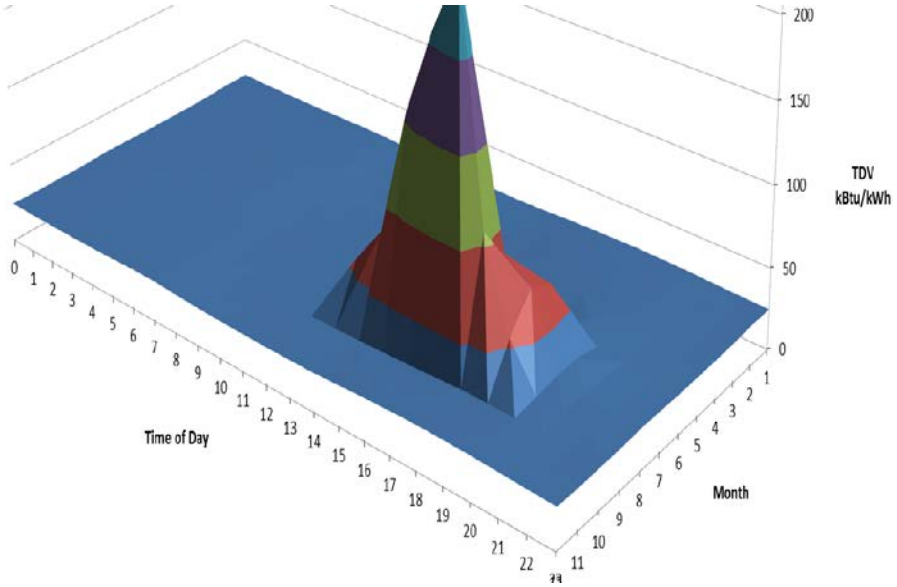


TDV

TDS vs. TDV – Climate Zone 10

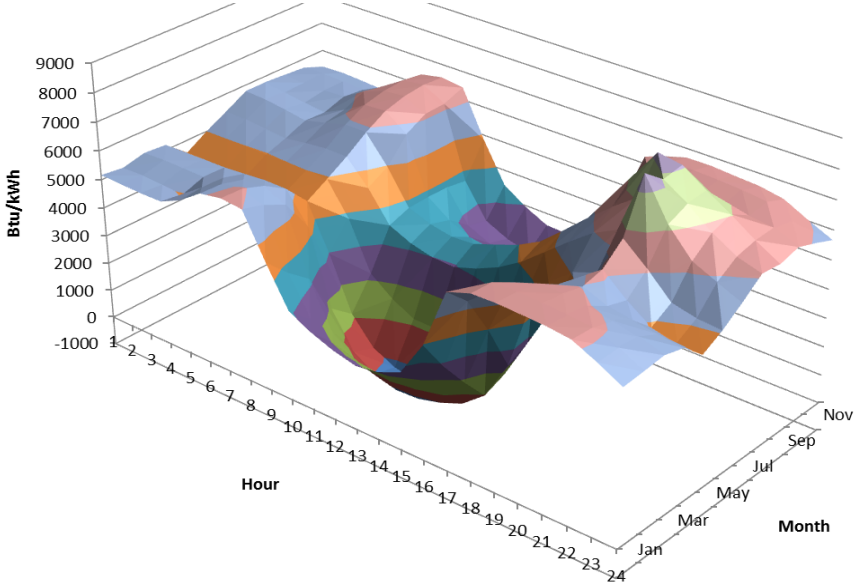


TDS

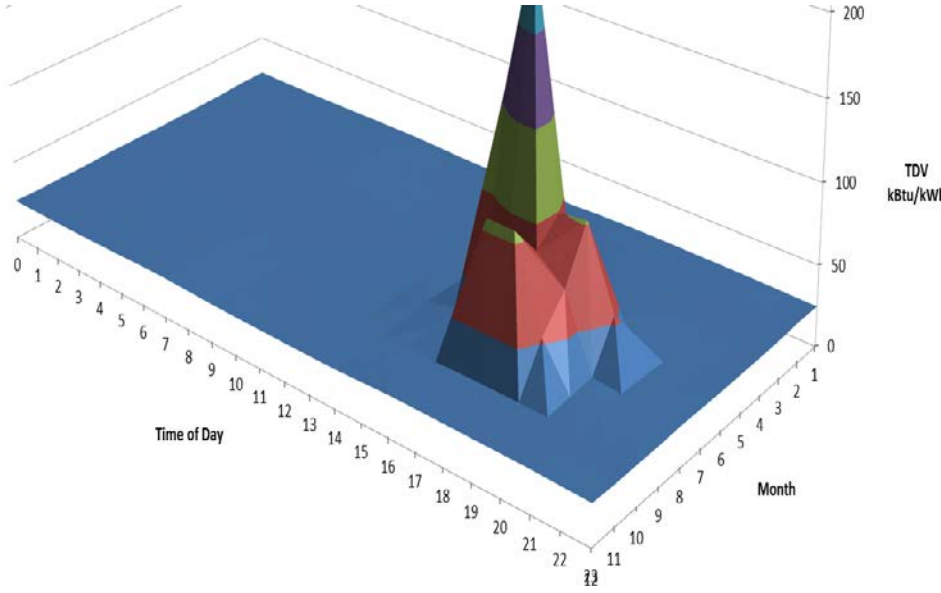


TDV

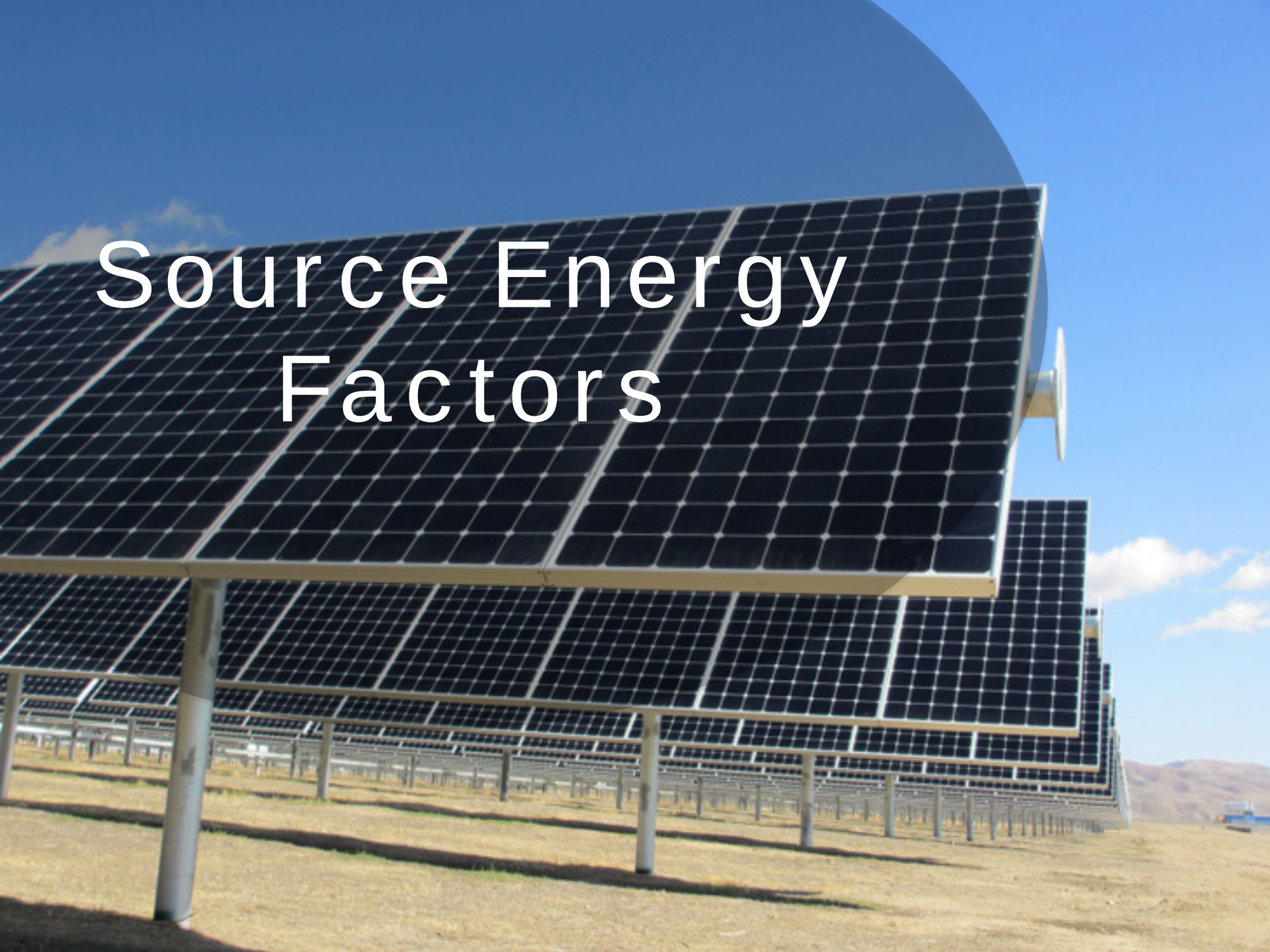
TDS vs. TDV – Climate Zone 12



TDS

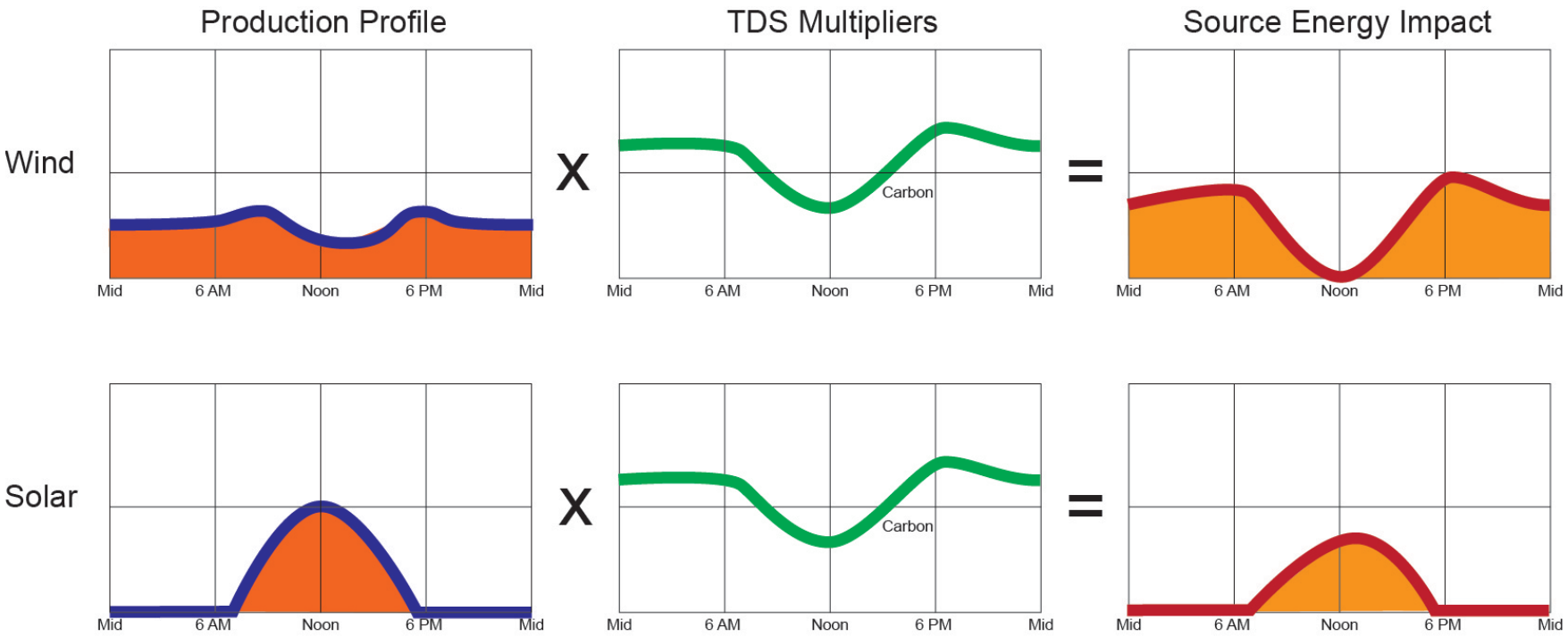


TDV

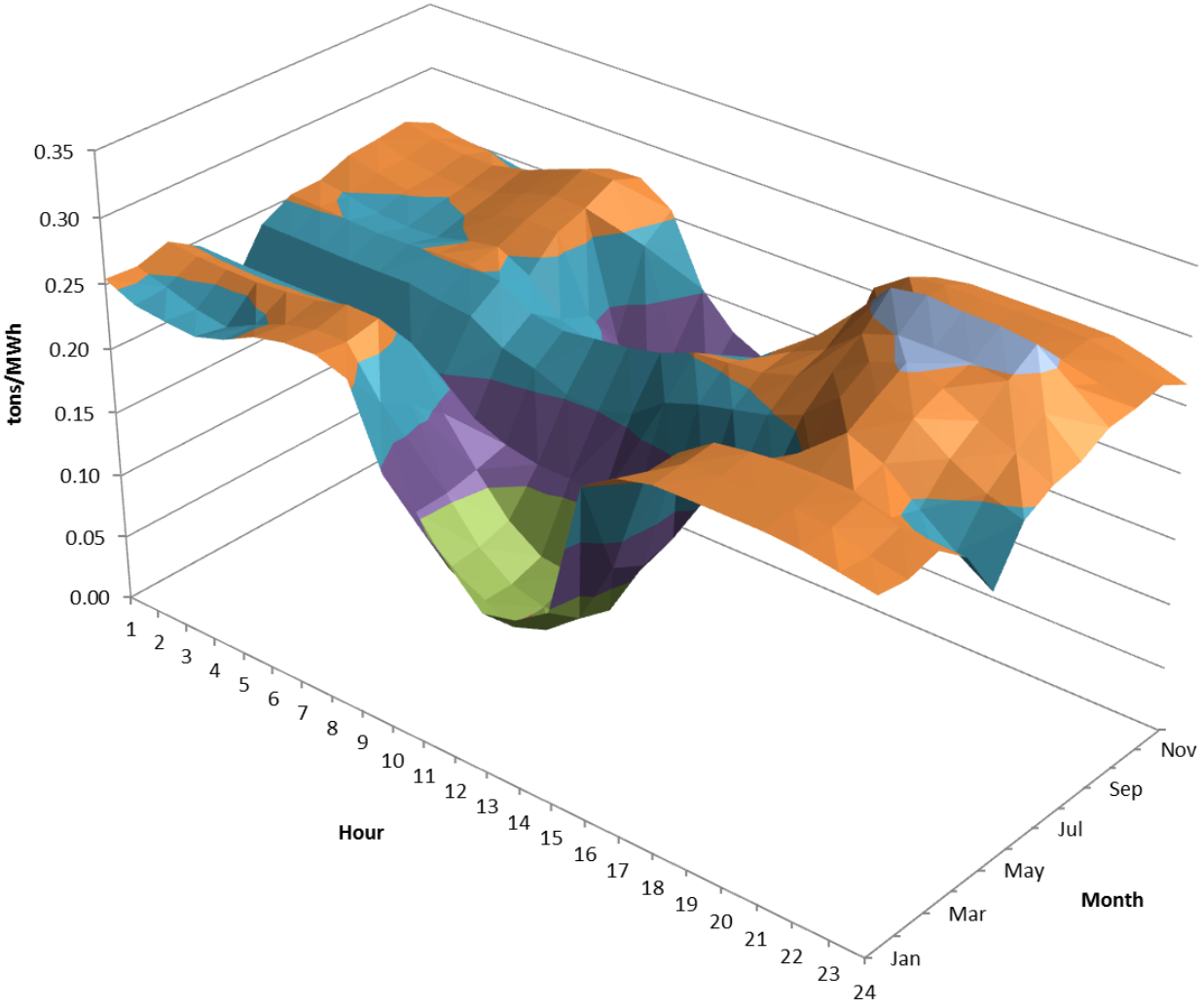

Source Energy
Factors

Sources of Off-Site Renewable Energy

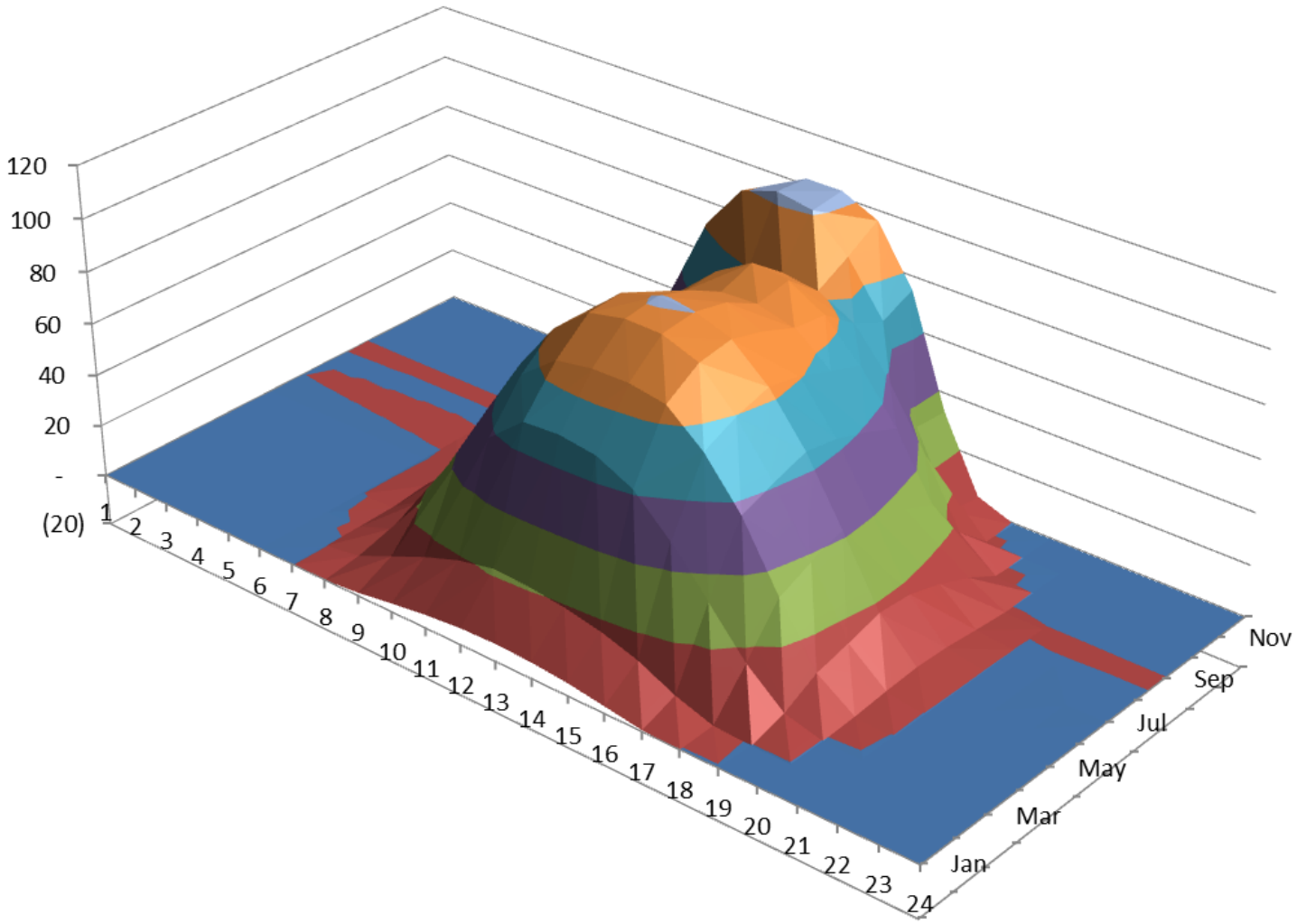
Source Energy Factors



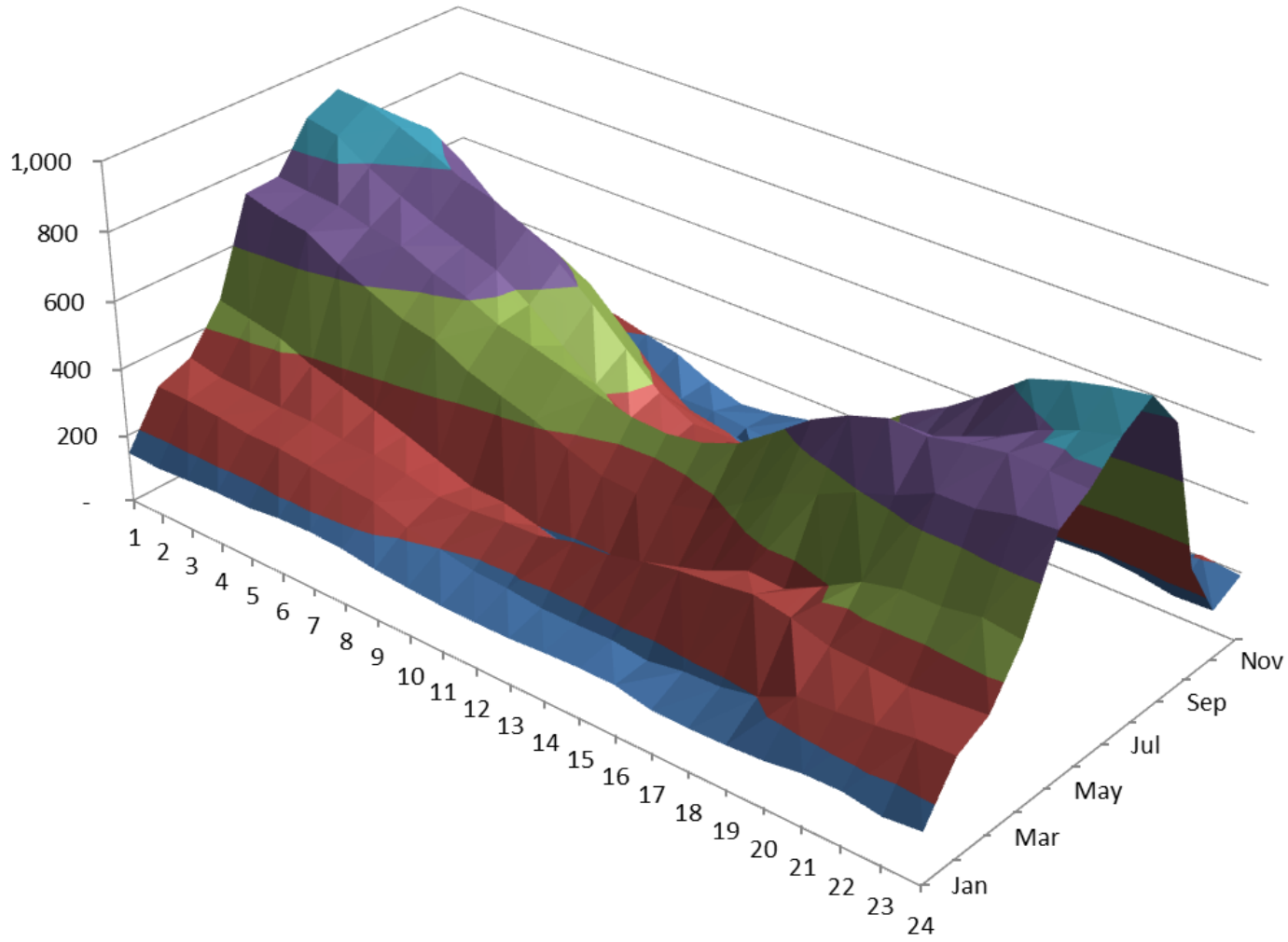
Hourly Time Dependent Carbon – NonRes – 15 years



2012 Solar Production – NP15 Trading Hub



2012 Wind Production – NP15 Trading Hub



Source Energy Factors for On-Site PV

Climate Zone	Source Energy Factor	Climate Zone	Source Energy Factor
1	3,296	9	3,319
2	3,330	10	3,295
3	3,322	11	3,322
4	3,322	12	3,287
5	3,293	13	3,274
6	3,260	14	3,292
7	3,277	15	3,304
8	3,307	16	3,344

Source Energy Factors for Off-Site Procurement

	Avoided Source Energy (Btu/kWh)	Avoided Emissions (lb/MWh)	Avoided TDV Energy (kBtu/kWh)
Wind	5,374	650	28.06
Solar	3,542	429	27.77
Geothermal	5,190	628	27.57
Hydro	5,190	628	27.57

The values for wind and solar are based on the average of power procured through the NP-15 and SP-15 trading hubs for 2012. Annual average values are used for geothermal and hydro.

Source: Table 5, TSD for the ZERO Code for California

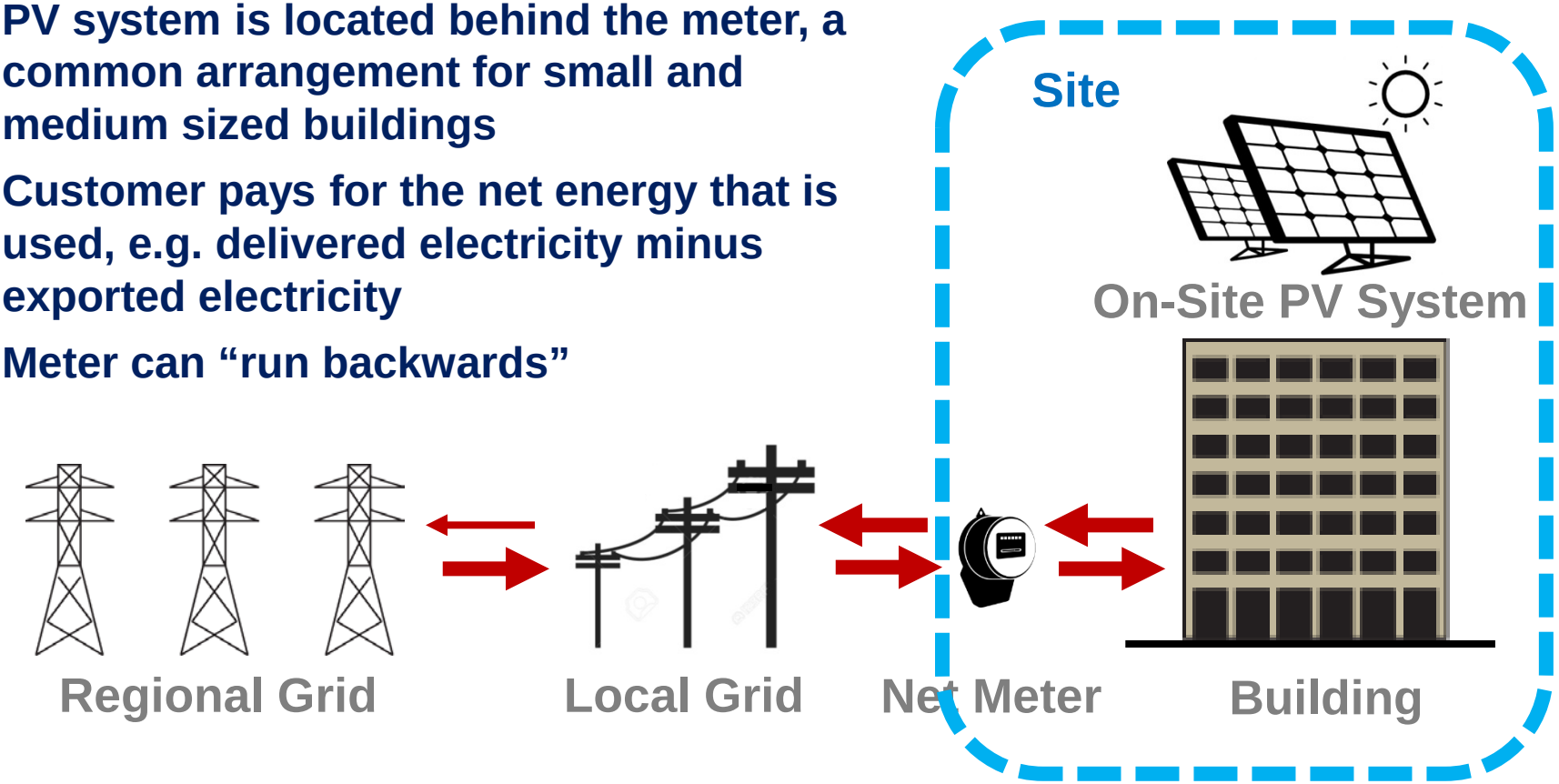

Off-Site
Renewable
Energy
Procurement

Net Metering

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

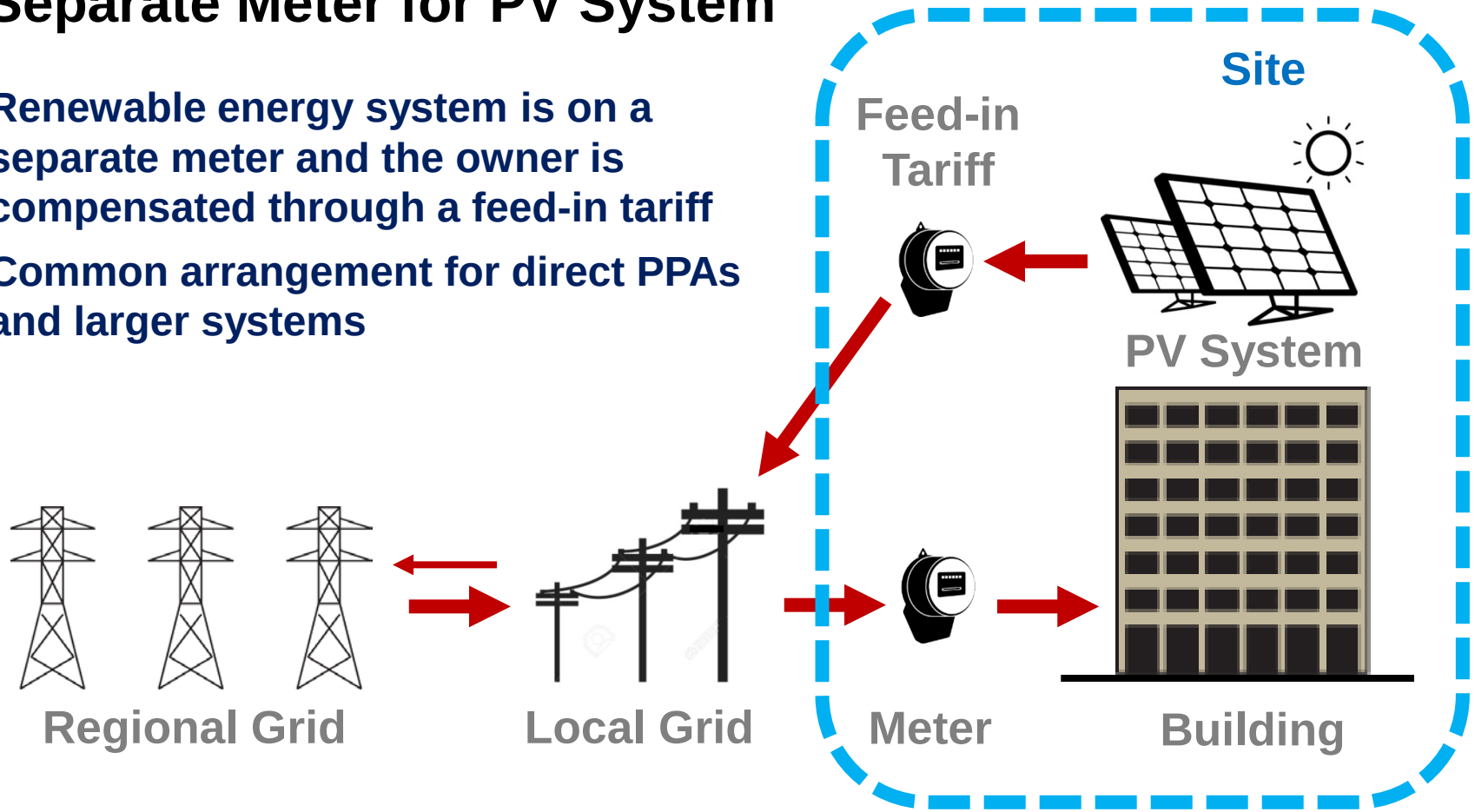
Meter can “run backwards”



Separate Meter for PV System

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

Common arrangement for direct PPAs and larger systems



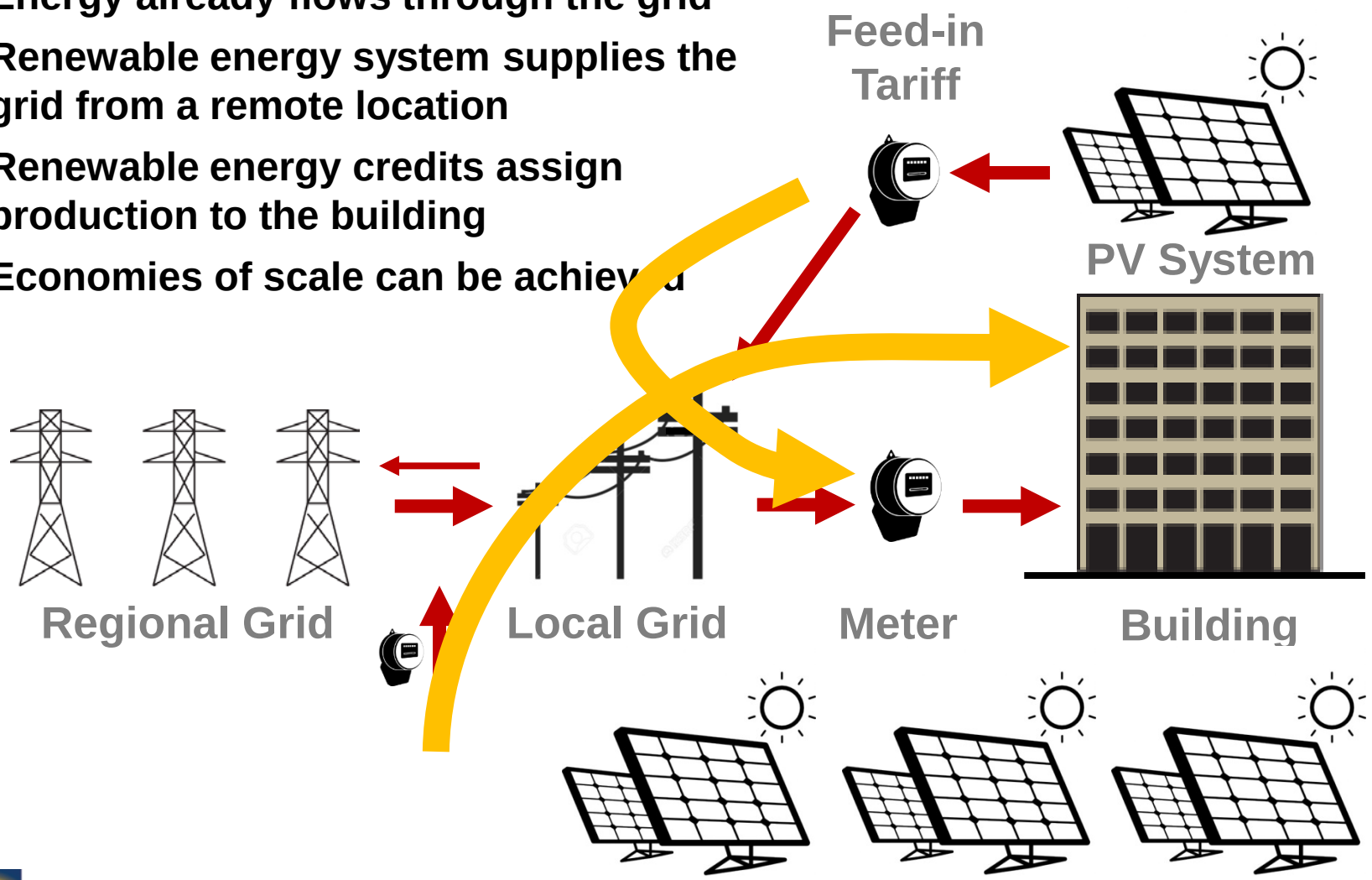
Off-Site Renewable Energy

Energy already flows through the grid

Renewable energy system supplies the grid from a remote location

Renewable energy credits assign production to the building

Economies of scale can be achieved



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 TSD at zero-code.org for more details

Evaluation Criteria for Off-Site Systems

- Additionality
- Long-Term Commitment
- Renewable Energy Generation Source
- Assignment to ZNC Building
- Grid Management Capability
- Environmental Impact
- Inspirational/Educational Value
- Incremental Acquisition
- Permanent Financing

Most Important

Least Important

Renewable Energy Procurement Factors

		Class 1				Class 2		Class 3
Considerations	Weights	On-Site	Self-Owned Off-Site	Community Renewables	Virtual PPA	RECs	Direct Access	Green Retail Tariffs	Unbundled RECs
Inspirational/Educational Value	6%	High	Medium	Medium	Low	Zero	Low	Low	Low
Probability of Additionality	30%	High	Medium	Medium	Medium	Zero	Low	Low	Zero
Long-Term Commitment	24%	Yes	Possible	Possible	Difficult	No	Possible	Difficult	Difficult
Permanent Financing	3%	Yes	Possible	Possible	Unlikely	No	No	No	No
Environmental Impact	6%	Low	Depends	Depends	High	Depends	Depends	Depends	Depends
Incremental Acquisition	6%	Yes	Yes	Possible	Difficult	No	No	Yes	Yes
Assignment to ZNC Building	12%	Yes	Possible	Possible	Difficult	No	Difficult	Yes	No
Grid Management Capability	12%	Possible	Possible	Possible	Difficult	No	Yes	Yes	No
Renewable Generation Source	24%	Qualifying	Qualifying	Mixed	Some RECs	All RECs	Some RECs	Some RECs	All RECs
	100%		3	2	1	0			
			Good			Bad			
Calculation of Coefficients									
Inspirational/Educational Value	3		2	2	1	1	1	1	1
Probability of Additionality	3		2	2	2	2	1	1	0
Long-Term Commitment	3		2	2	3	3	2	1	1
Permanent Financing	3		2	1	2	2	0	0	0
Environmental Impact	3		2	2	2	2	2	2	2
Incremental Acquisition	3		3	3	2	3	0	3	3
Assignment to ZNC Building	3		2	3	2	2	1	3	0
Grid Management Capability	2		2	3	2	2	3	3	0
Renewable Generation Source	3		3	3	3	3	1	1	0
Sumproduct	3.61		2.79	3.00	2.91	2.97	1.70	1.88	0.61
Calculated Coefficient	**1.00**		**0.77**	**0.83**	**0.81**	**0.82**	**0.47**	**0.52**	**0.17**
Average for Class				**0.81**			**0.50**		**0.17**
Recommended for Class				**0.80**			**0.50**		**0.20**

Minimum Requirements

- **Legally binding contract to procure qualifying off-site renewable energy.**
- **Contract shall have duration of not less than 15 years**
- **RECs and other environmental attributes associated with the procured off-site renewable energy shall be assigned to the building project**
- **The renewable energy generating source shall be photovoltaic systems, solar thermal power plants, geothermal power plants, wind turbines or eligible hydro.**
- **The generation source shall be located where the energy can be delivered to the building site (probably within CaISO)**
- **The off-site renewable energy producer shall maintain transparent accounting that clearly assigns production to the ZNC building**

Procurement Factors

Class	Procurement Factor (PF)	Procurement Method	Additional Requirements
1	0.75	Community Solar	
		REIFs	Entity must be managed to prevent fraud or misuse of funds.
		Virtual PPA	
		Self-Owned Off-Site	Provisions shall prevent the generation asset from being sold separately from the building.
2	0.55	Green Retail Tariffs	The offering shall not include the purchase of unbundled RECs.
		Direct Access	The offering shall not include the purchase of unbundled RECs.
3	0.20	Unbundled RECs	The vintage of the RECs shall align with building energy use.

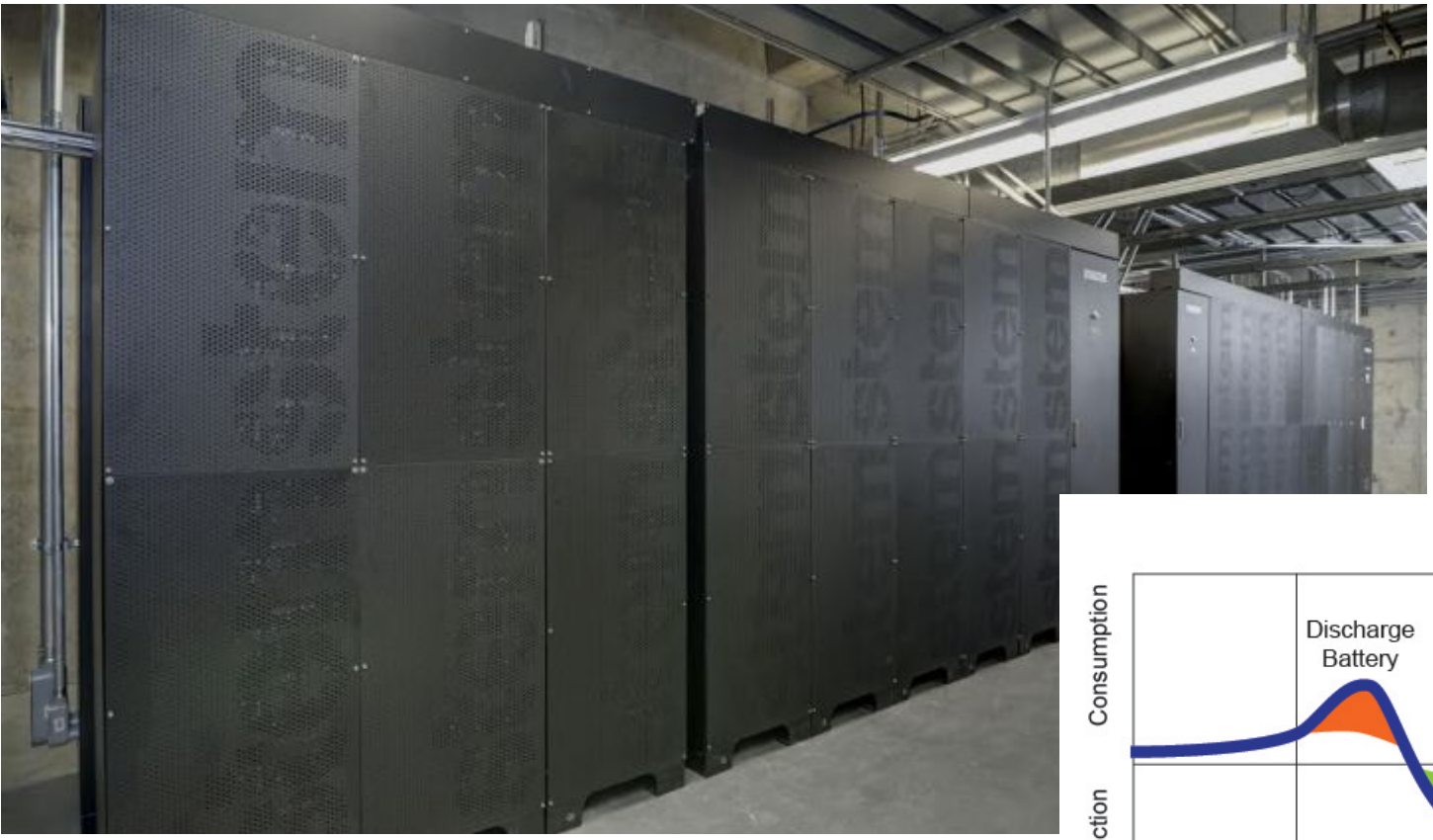
Avoided Source Energy from Off-Site Procurement

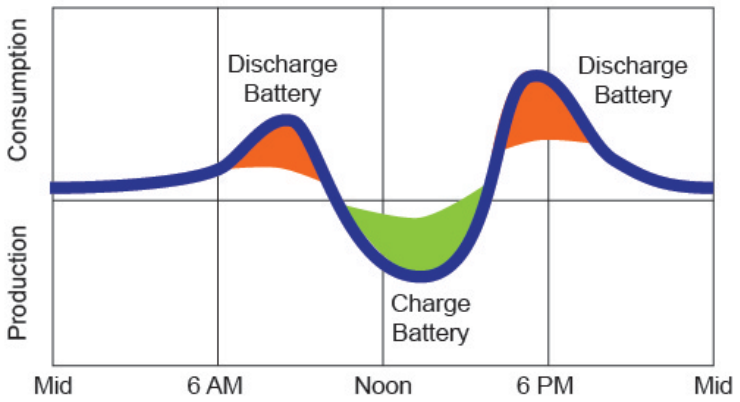
Avoided Source Energy	=	Procured Off-Site Renewable Energy	X	Source Energy Factor	X	Procurement Factor
		Amount purchased through vPPA or other means		Depends on generation source		Depends on procurement method
		(kWh)		(Btu/kWh)		(unitless)

Batteries and Storage

Mira Loma Battery Storage Facility

Batteries Behind the Meter





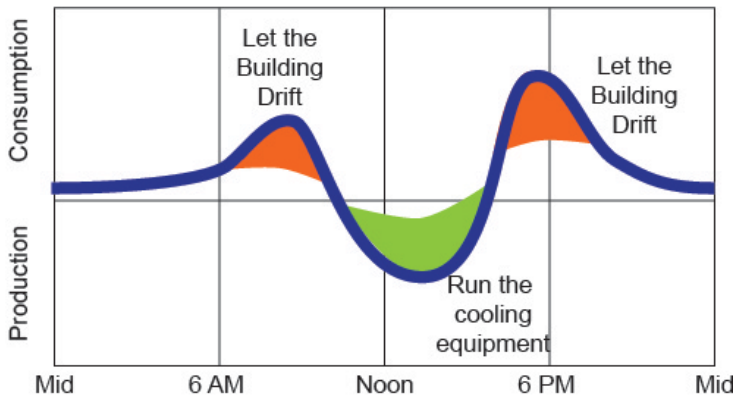
Batteries

Comparison of Metrics with Regard to Batteries

	Site Energy (kBtu/ft²/y)	Time-Dependent Source (TDS) Energy (kBtu/ft²-y)	Carbon Emissions (lb/ft²-y)	Time-Dependent Valued (TDV) Energy (kBtu/ft²-y)
Building Energy Use				
Electricity	25.90	29.46	3.80	217.28
Gas	5.83	5.83	0.75	12.32
Total	31.72	35.29	4.55	229.60
On-Site PV System				
Production	-25.90	-19.32	-2.49	-184.40
Battery				
Charging	8.02	5.79	0.70	54.82
Discharging	-7.22	-15.35	-1.86	-77.42
Net (battery alone)	0.80	-9.55	-1.16	-22.60
Summary				
Net (without battery)	5.83	15.04	1.87	45.20
Net (with battery)	6.63	5.49	0.71	22.28
Battery Benefit	14%	-64%	-62%	-50%

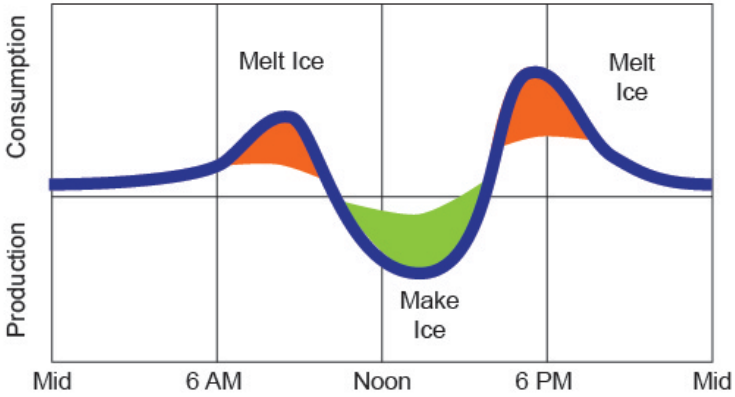


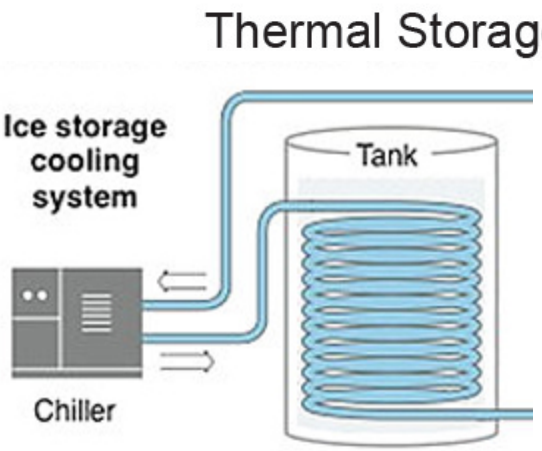

Thermal Mass in Envelope



Building Mass

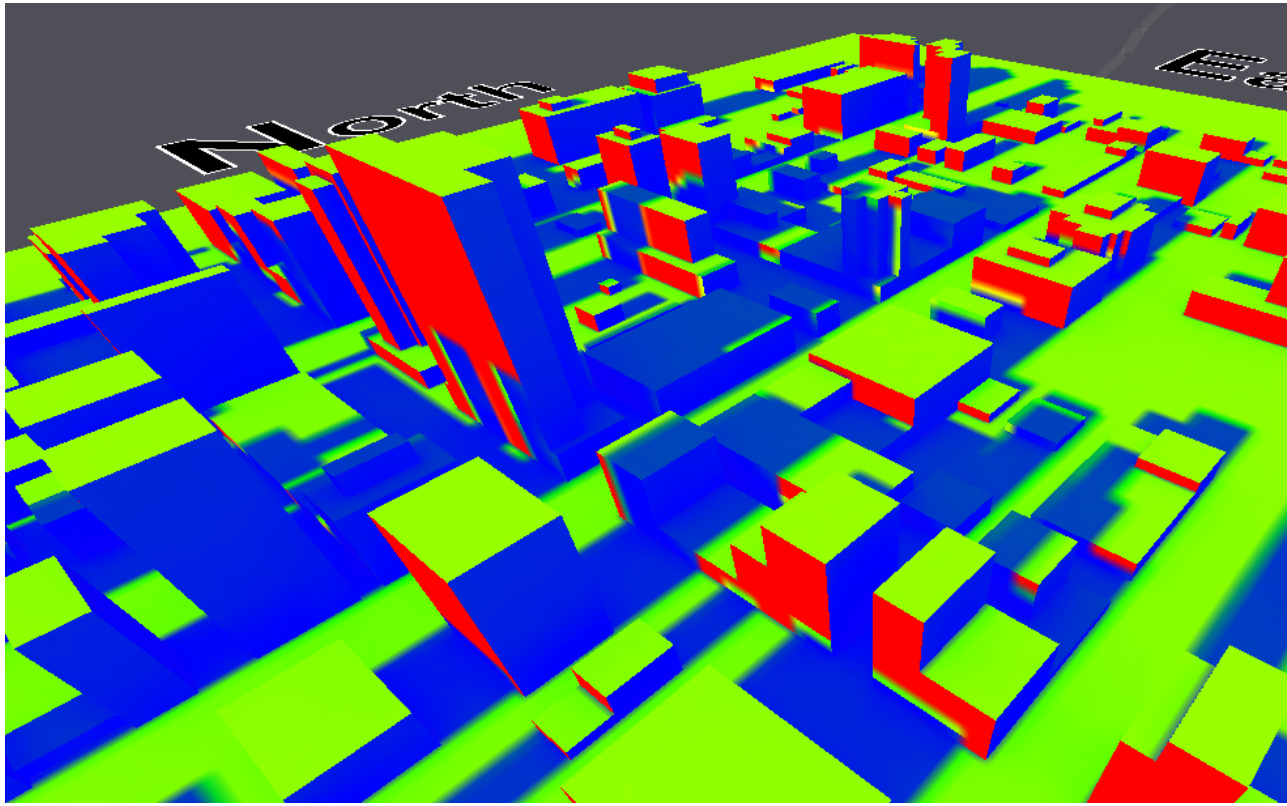
Thermal Storage Revisited



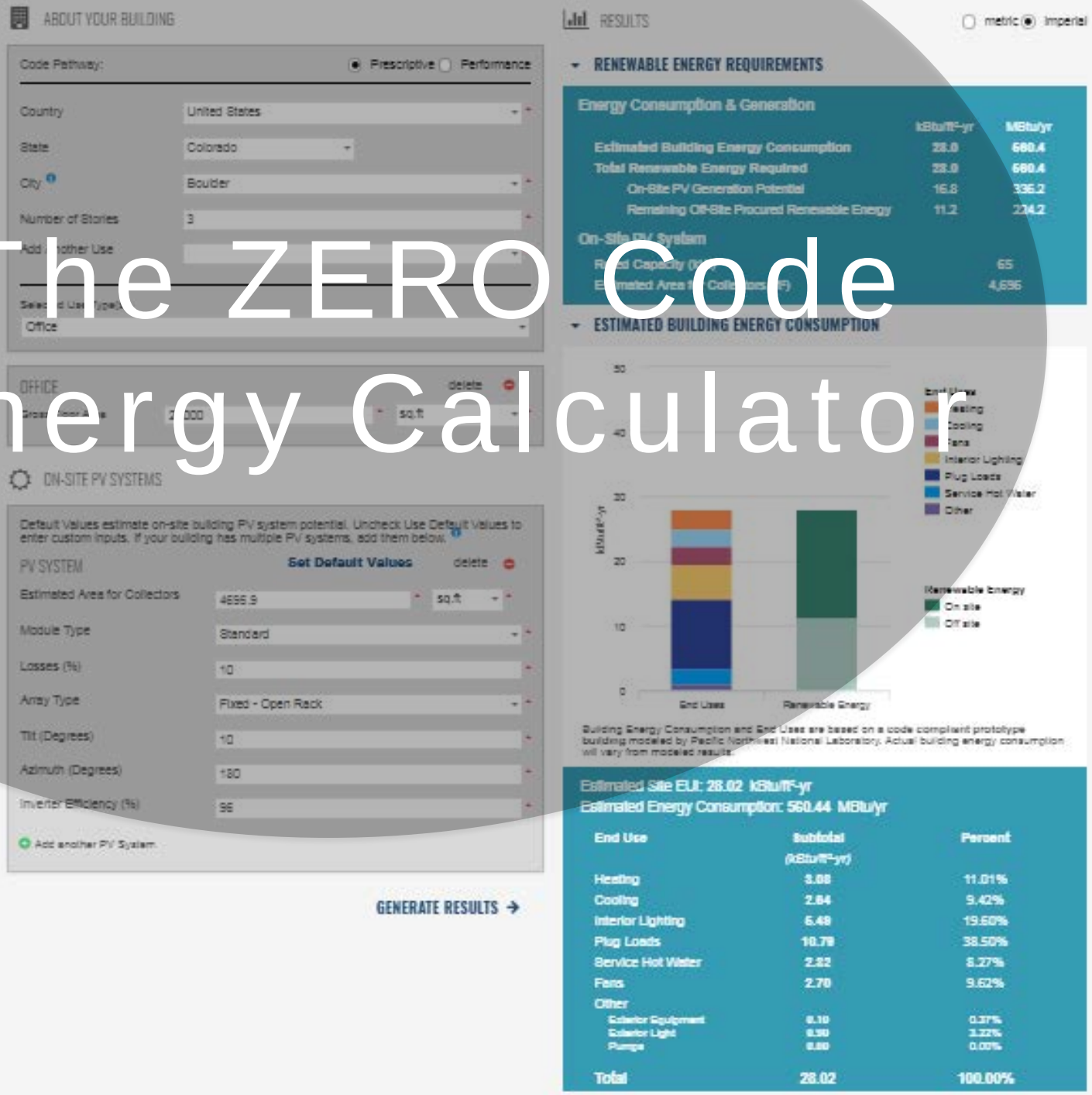


CBECC-Com Battery Control Strategies

- Basic
- Time of Use
- Advanced DR Control (TDV)
- Advanced DR Control (TDS)



The ZERO Code Energy Calculator



The ZERO Code Energy Calculator

ABOUT YOUR BUILDING

Code Pathway: (•) Prescriptive ( ) Performance

Climate Zone: 3 *

Number of Stories: 2 *

Add Another Use: *

Selected Use Type(s):

School

SCHOOL

delete

Gross Floor Area (sq.ft): 50000 *

ON-SITE PV SYSTEMS

Default Values estimate on-site building PV system potential. Uncheck Use Default Values to enter custom inputs. If your building has multiple PV systems, add them below.

PV SYSTEM

Set Default Values delete

Estimated Area for Collectors: 21022.3 * sq.ft *

Module Type: Standard *

Losses (%): 10 *

Array Type: Fixed - Open Rack *

Tilt (Degrees): 10 *

Azimuth (Degrees): 180 *

Inverter Efficiency (%): 96 *

Add another PV System

GENERATE RESULTS →

RESULTS

← ENTER BUILDING AND PV INFORMATION TO THE LEFT TO GENERATE REQUIREMENTS FOR REACHING ZERO NET CARBON

The ZERO Code Energy Calculator

ABOUT YOUR BUILDING

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Climate Zone: 3 *

Number of Stories: 2 *

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Azimuth (Degrees): 180 *

Inverter Efficiency (%): 96 *

Add another PV System

RESULTS

RENEWABLE ENERGY REQUIREMENTS

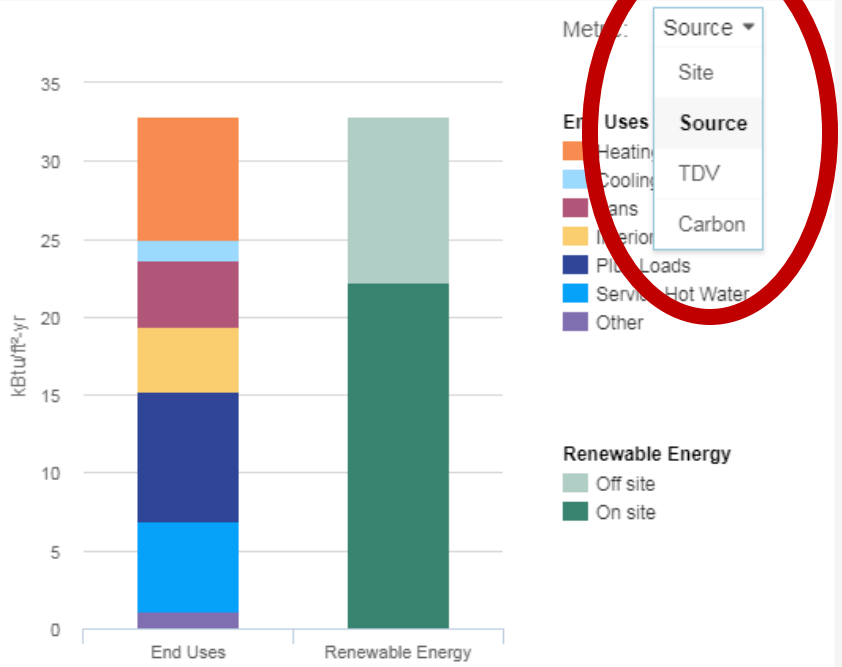
Energy Consumption & Generation

	kBtu/ft²-yr	MBtu/yr
Estimated Building Source Energy Consumption	**32.8**	**1,642.1**
Total Renewable Energy Required	**32.8**	**1,642.1**
On-Site PV Generation Potential	22.2	1,110.6
Remaining Off-Site Procured Renewable Energy	10.6	531.5

On-Site PV System

Rated Capacity (kW)	293
Estimated Area for Collectors (ft²)	21,022

ESTIMATED BUILDING ENERGY IMPACTS



Building Energy Impacts and End Uses are based on **code compliant prototype buildings** modeled by NORESCO in their Impact Analysis. Actual building energy consumption will vary from modeled results.

The ZERO Code Energy Calculator

GENERATE RESULTS →

Estimated Source EUI: **32.84** kBtu/ft²-yr
Estimated Source Energy Consumption: **1,642.09** MBtu/yr

End Use	Subtotal (kBtu/ft²-yr)	Percent
Heating	7.87	23.97%
Cooling	1.35	4.10%
Interior Lighting	4.15	12.65%
Plug Loads	8.25	25.13%
Service Hot Water	5.85	17.80%
Fans	4.29	13.07%
Other		
Exterior Light	0.66	2.00%
Heat Rejection	0.03	0.09%
Pumps	0.39	1.19%
Total	**32.84**	**100.00%**

PVWATTS RESULTS

ANNUAL AC & DC PRODUCTION


Wrapup

The ZERO Code for California:

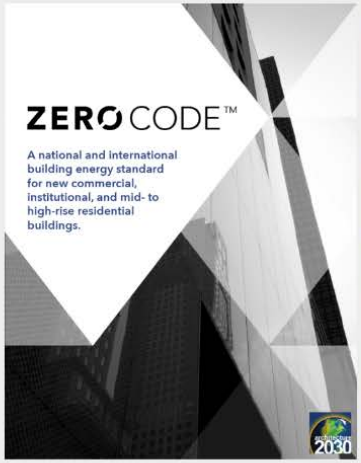
- Builds on the adopted 2019 California Building Energy Efficiency Standards, the global energy efficiency benchmark for commercial, institutional and mid- to high-rise residential buildings
- Supplements the energy efficiency requirements of the California BEES by requiring that on-site renewable energy systems be installed or off-site renewable energy be procured such that ZERO Code compliant buildings result in zero net carbon emissions on an annual basis
- Represents a paradigm shift in building codes to directly address climate change by using hourly source energy / carbon emissions as the metric for building performance
- Sets a framework for addressing tall and energy intensive buildings
- Is flexible, impactful, performance-based, and harmonious with the renewables-rich California electric grid
- Easily adoptable by local governments as a reach standard
- Encourages:
  - Even greater energy efficiency than required by the California BEES
  - Storage technologies to shift load to periods when grid carbon emissions are low
  - On-site renewable energy systems when feasible

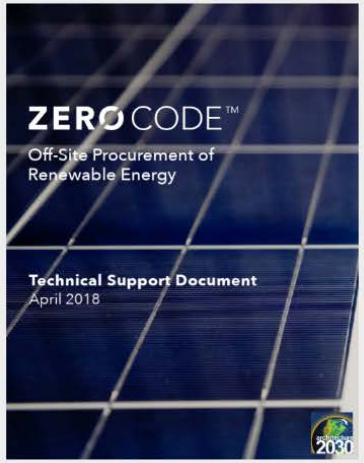
More Reading

ZERO CODE™ HOME ABOUT ZERO CODE ENERGY CALCULATORS CONTACT

ZERO Code & Technical Support Document:

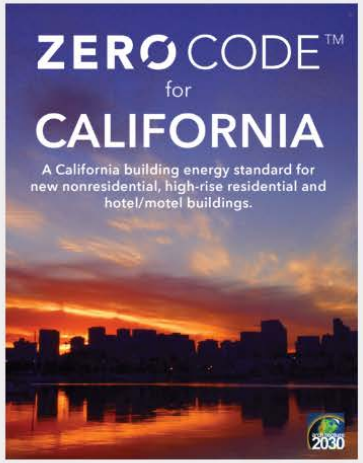
Access ASHRAE 90.1-2016

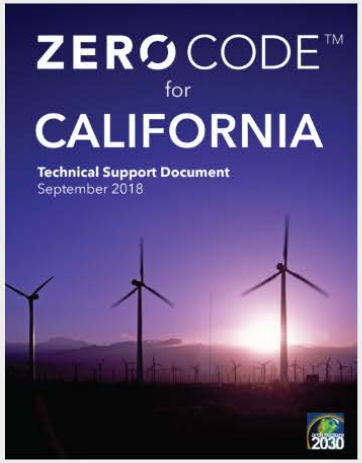




ZERO Code for California & Technical Support Document for California:

Access 2019 California BEES





ZERO Code Energy Calculators

The ZERO Code is supported by **Energy Calculators** that eases the implementation process and reduces errors when applying the prescriptive compliance path of ASHRAE 90.1-2016 or 2019 California Building Energy Efficiency Standards (BEES). An Application Program Interface (API) for the national and international ZERO Code Energy Calculator has been developed so that users can interact in a programmatic way with the software, enabling its implementation as a website or application for smart phones and tablets. Ultimately this approach will save years and valuable resources that would otherwise be spent on developing new compliance tools and mechanisms.

The ZERO Code Energy Calculator API is free and open source. For access to the ZERO Code Energy Calculator API documentation, or for information about incorporating the International Green Construction Code (IgCC), ASHRAE Standard 189.1-2017 or other building energy standard, please contact Architecture 2030 at info@architecture2030.org.

architecture 2030 ZERO CODE™

https://zero-code.org/zero-code/