Passive Buildings as baseline for the new grid

October 11, 2019

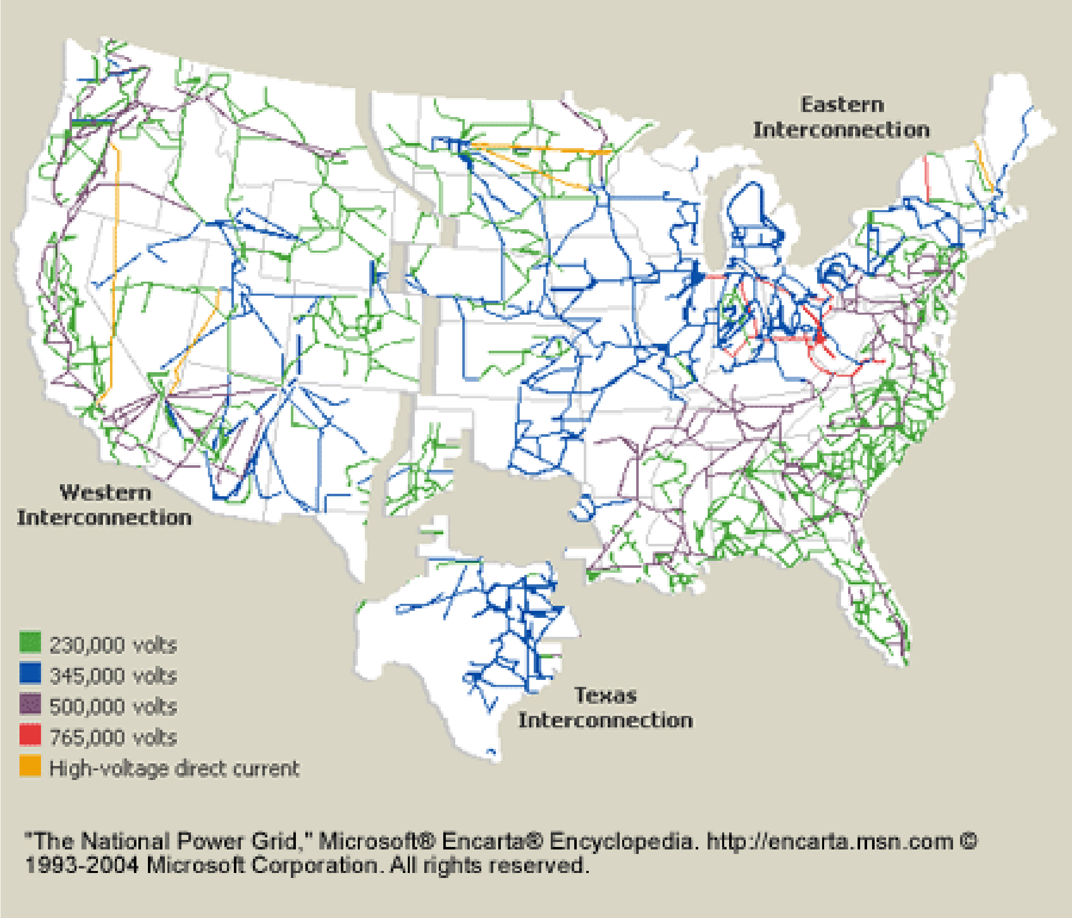
Lisa White, Associate Director
Passive House Institute US

If PV was free (or very cheap), why would I invest in conservation at all?

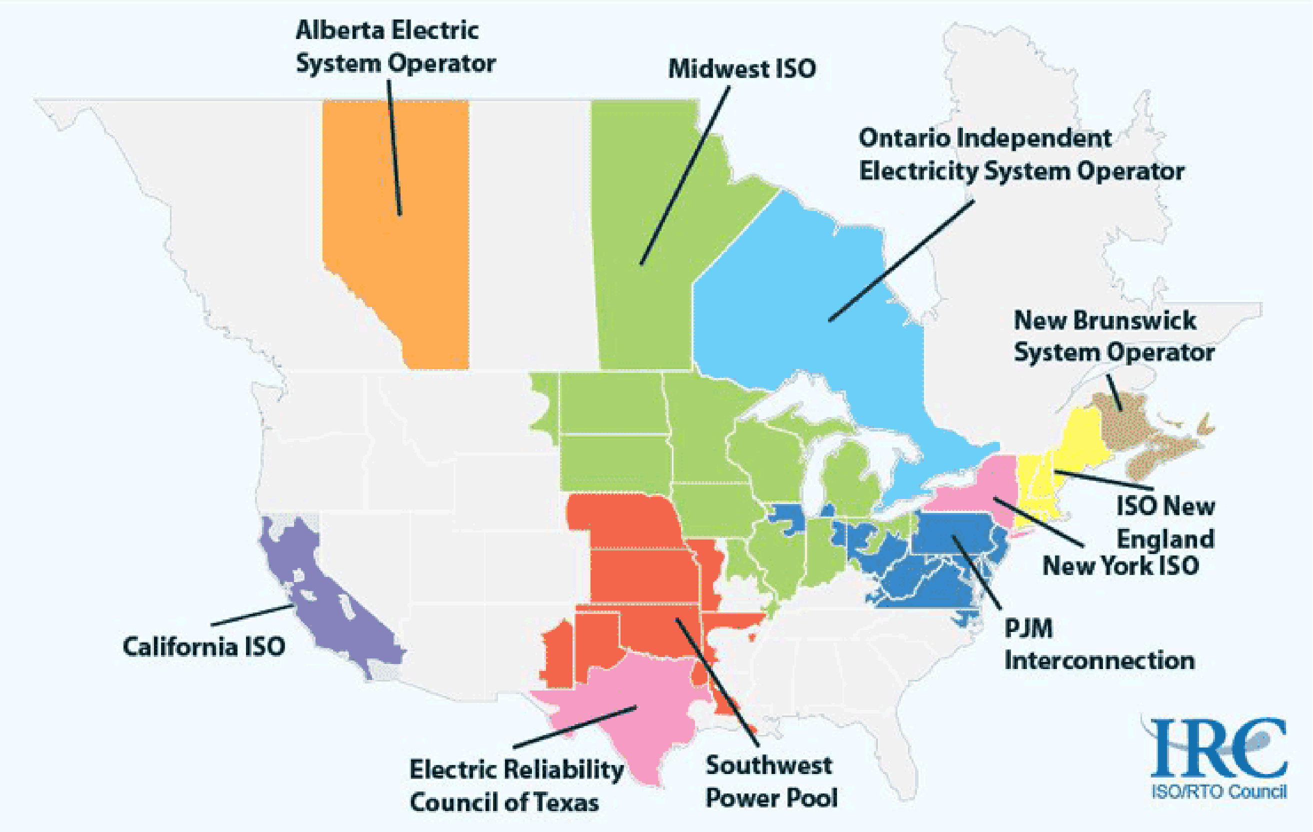
AGENDA

1. Overview of how the electric grid operates
2. Overview of recent changes to the grid structure
3. Challenges of PV integration
4. Intro to building+grid integration strategies
    1. Passive vs Code Case Study
    2. Other strategies
5. Grid independence / Passive Survivability

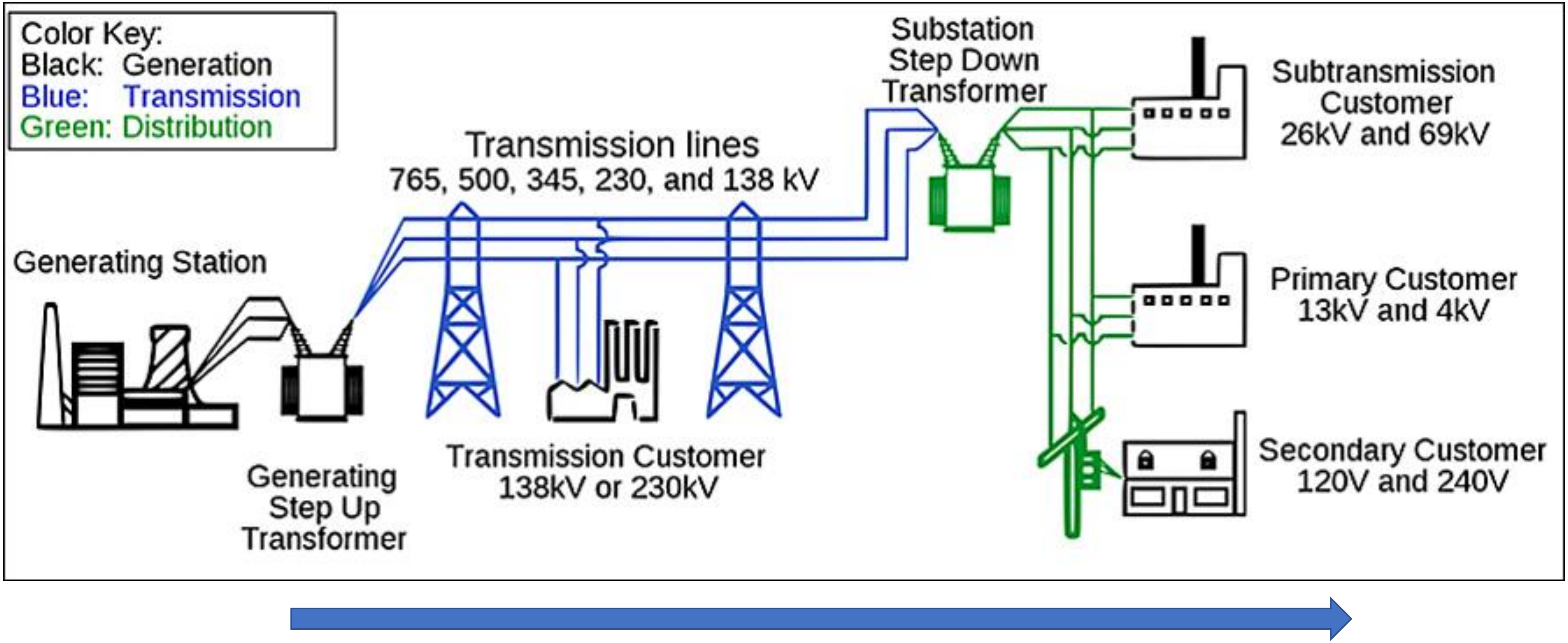
"The biggest machine on earth"



3 Interconnections

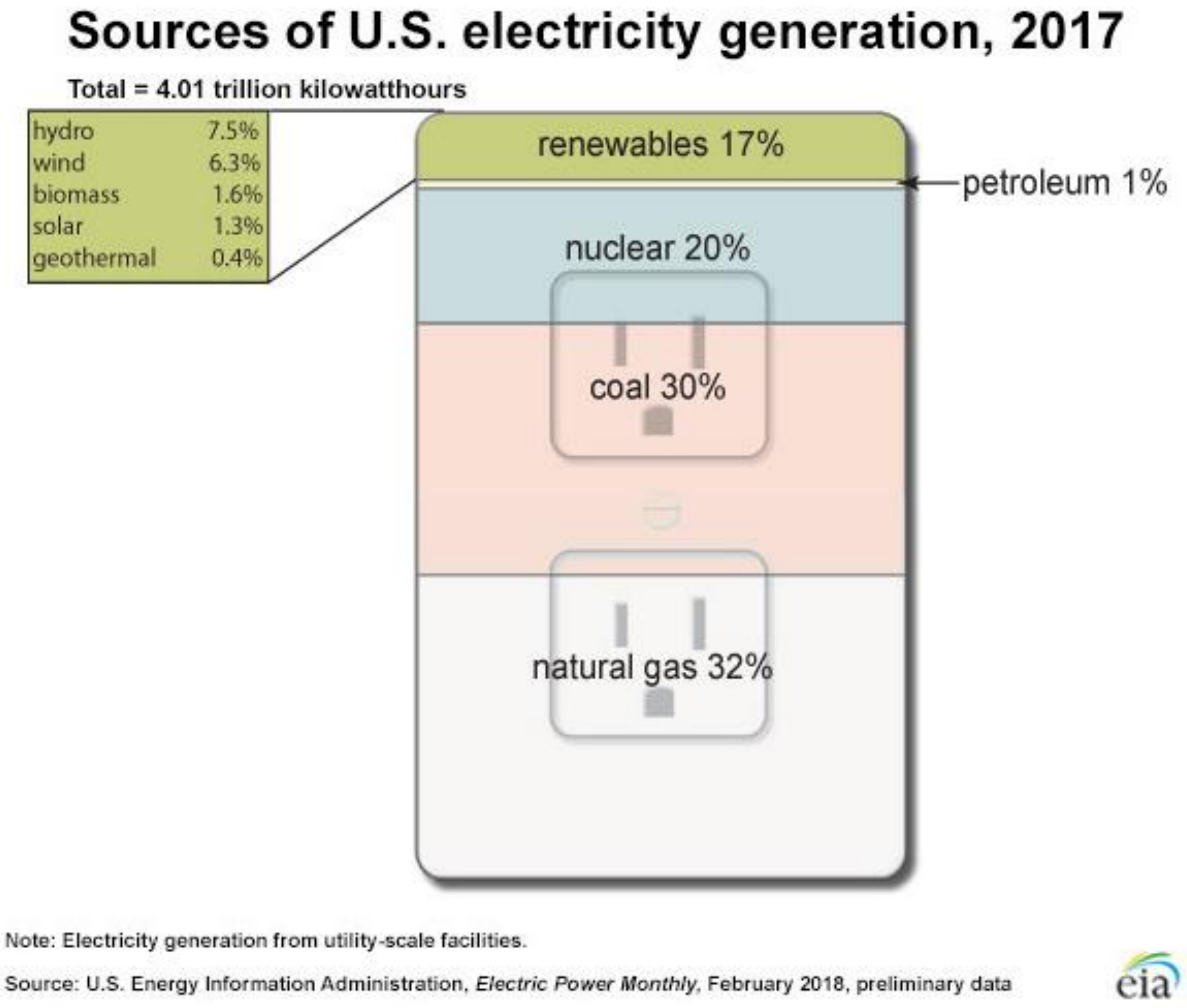


ISO's (Independent Service Operators)



CURRENT INFRASTRUCTURE

GENERATION RESOURCES

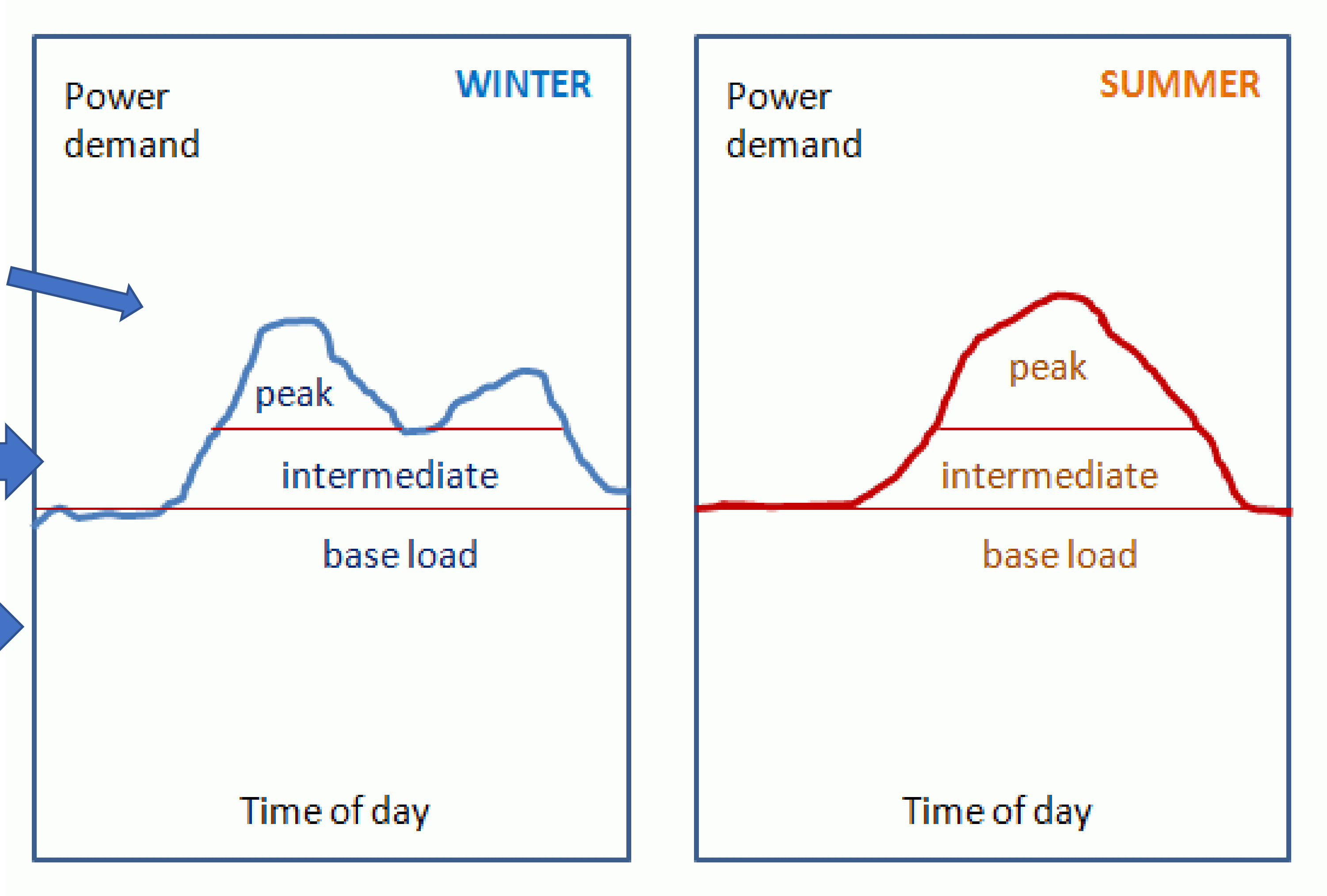


LOAD PROFILES

Natural gas "peaker plants"
Hydro

Natural gas CC
Some renewables

Coal
Nuclear
Some renewables



Electricity Generation Sector – Load Duration Curve

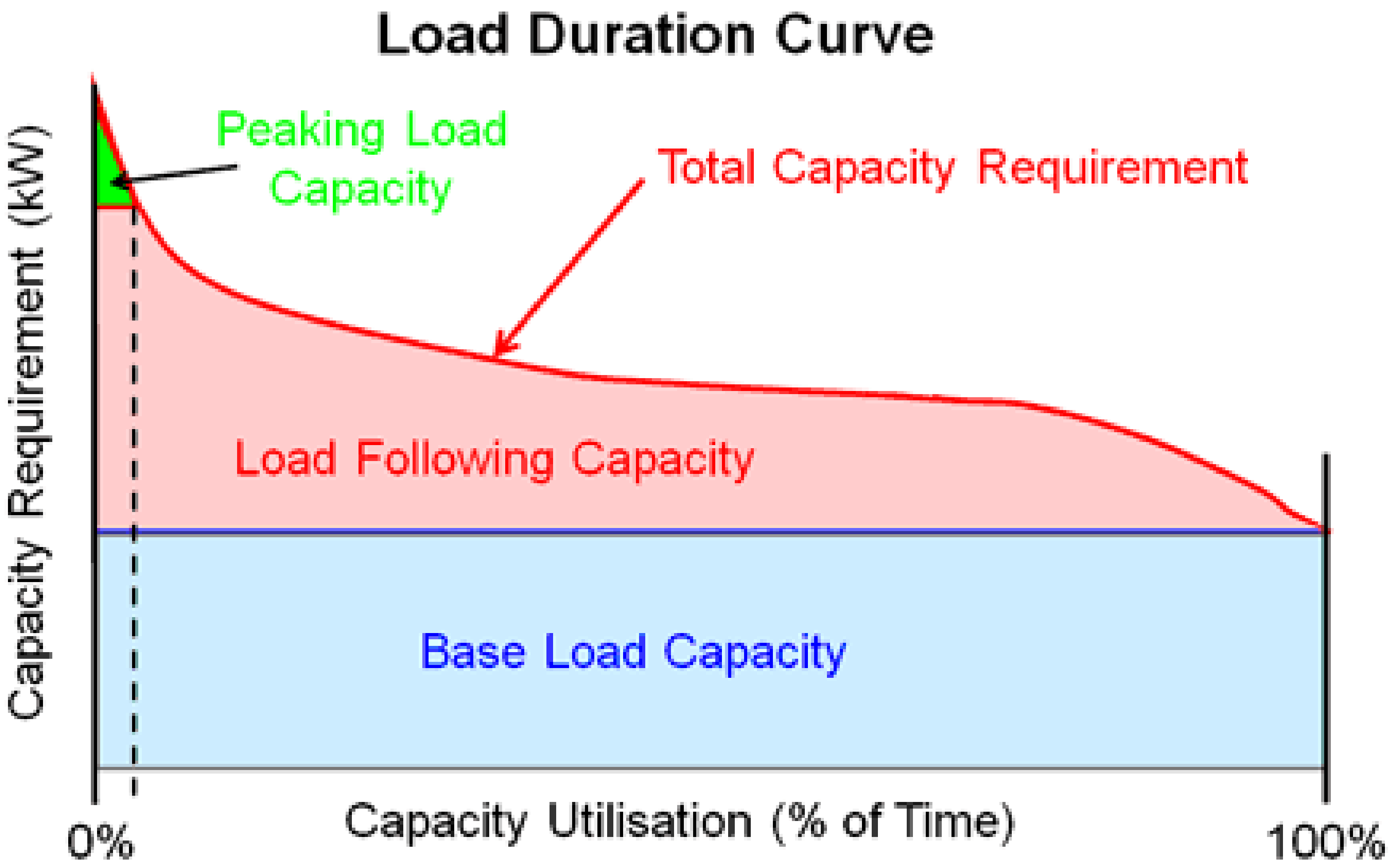
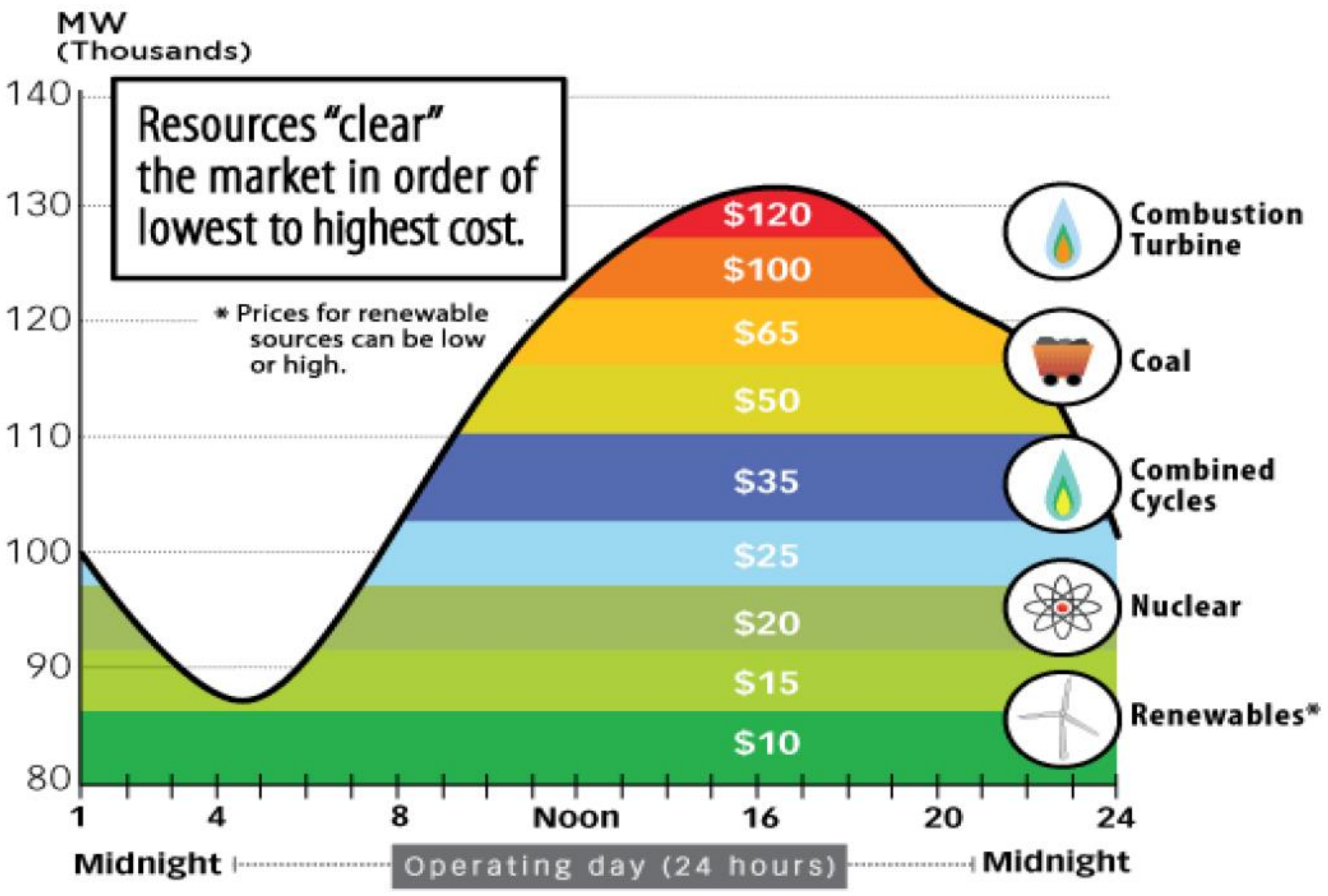


Image Source: Mark Pruitt

MEETING THE ELECTRIC LOAD

- Currently has about 1.17 TW of generating capacity -- 2.5x higher than what's used annually

- Vehicles + building heating conversion to electricity may double consumption



Electricity Generation Sector - Scheduling

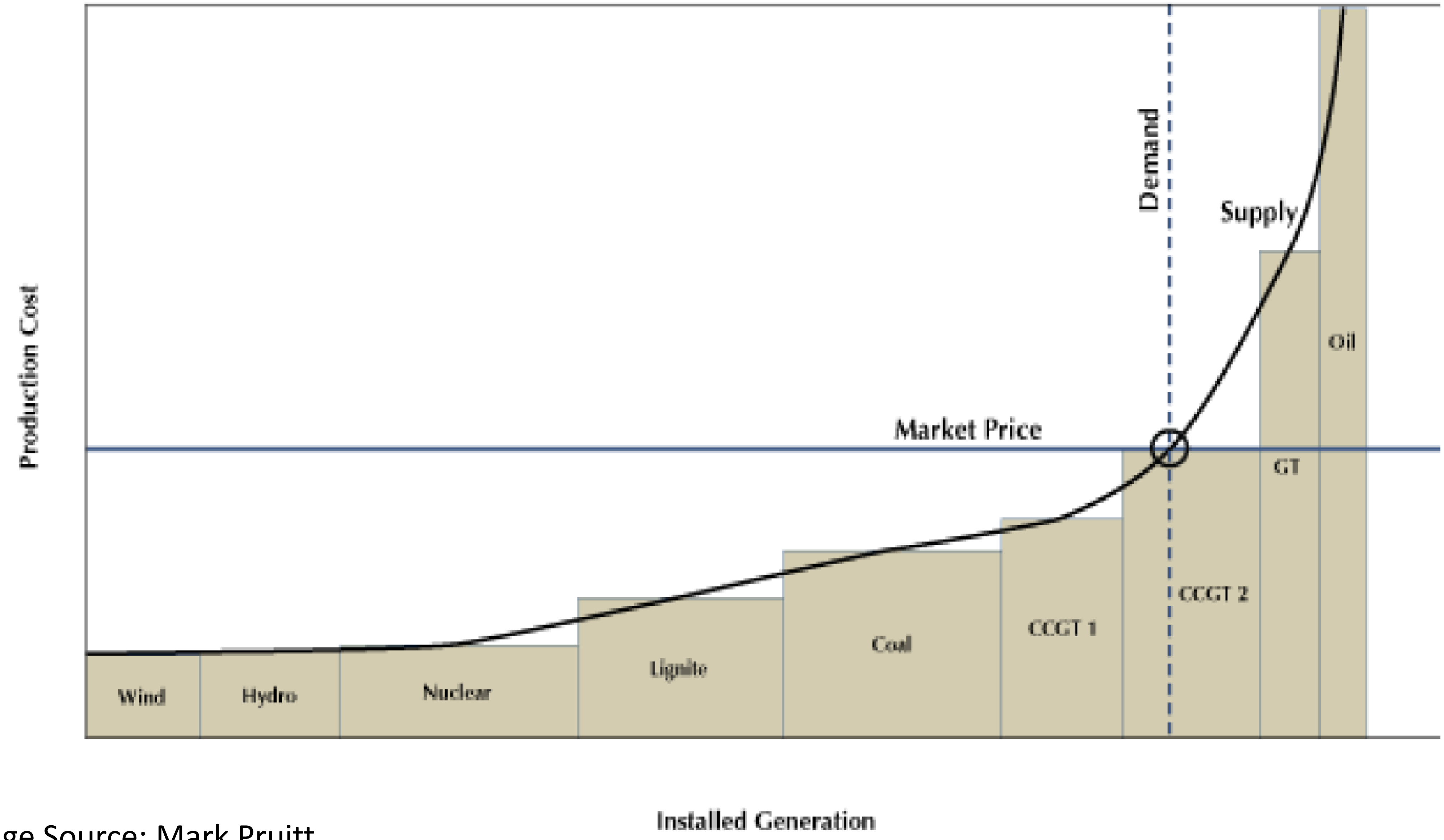
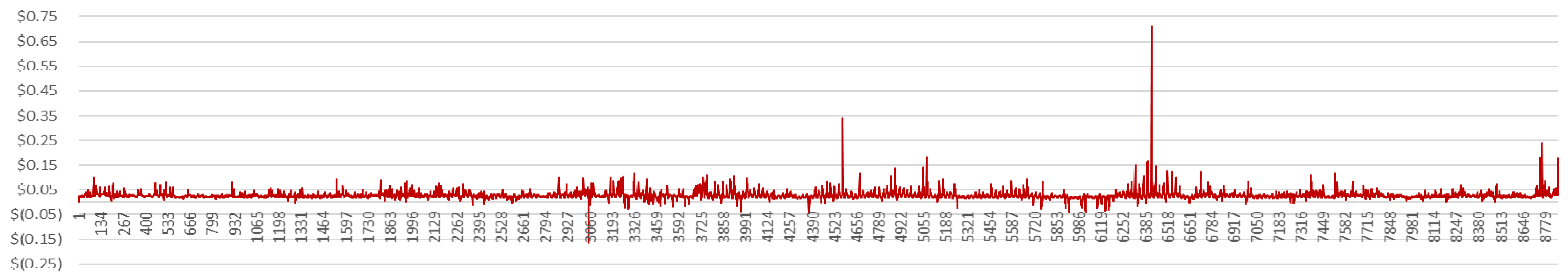


Image Source: Mark Pruitt

REAL TIME PRICING (RTP) – Chicago, IL



Datetime Beginning EPT	Pricing Node ID	Pricing Node Name	Voltage Level	Equipment Description	Pricing Node Type	Transmission Zone Location	System Energy Price ($/MW)	Total LMP ($/MW)	Congestion Component for LMP ($/MW)	Loss Component for LMP ($/MW)	Latest Version	Version Number	Real Time Price ($/kWh)
1/1/2017 0:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	25.43	24.59	-0.21	-0.63	TRUE	1	0.02459
1/1/2017 1:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	25.76	24.77	-0.4	-0.59	TRUE	1	0.02477
1/1/2017 2:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	24.29	23.53	-0.22	-0.54	TRUE	1	0.02353
1/1/2017 3:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	23.74	22.88	-0.45	-0.41	TRUE	1	0.02288
1/1/2017 4:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	23.33	22.49	-0.4	-0.44	TRUE	1	0.02249
1/1/2017 5:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	23.72	22.94	-0.28	-0.5	TRUE	1	0.02294
1/1/2017 6:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	23.29	22.35	-0.41	-0.53	TRUE	1	0.02235
1/1/2017 7:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	24.39	23.55	-0.22	-0.62	TRUE	1	0.02355
1/1/2017 8:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	24.94	24.38	0.06	-0.62	TRUE	1	0.02438
1/1/2017 9:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	24.9	24.48	0.21	-0.63	TRUE	1	0.02448
1/1/2017 10:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	24.16	23.95	0.31	-0.52	TRUE	1	0.02395
1/1/2017 11:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	23.2	23.39	0.55	-0.36	TRUE	1	0.02339
1/1/2017 12:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	23.3	23.3	0.4	-0.4	TRUE	1	0.0233
1/1/2017 13:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	23	23.03	0.4	-0.37	TRUE	1	0.02303
1/1/2017 14:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	22.66	22.69	0.41	-0.38	TRUE	1	0.02269
1/1/2017 15:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	22.76	22.43	0.03	-0.36	TRUE	1	0.02243
1/1/2017 16:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	23.62	23.17	-0.03	-0.42	TRUE	1	0.02317
1/1/2017 17:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	30.31	29.33	0	-0.98	TRUE	1	0.02933
1/1/2017 18:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	29.17	28.36	0	-0.81	TRUE	1	0.02836
1/1/2017 19:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	26.72	25.78	0	-0.94	TRUE	1	0.02578
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1/1/2017 22:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	24.68	23.53	-0.1	-1.05	TRUE	1	0.02353
1/1/2017 23:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	22.91	21.8	-0.14	-0.97	TRUE	1	0.0218

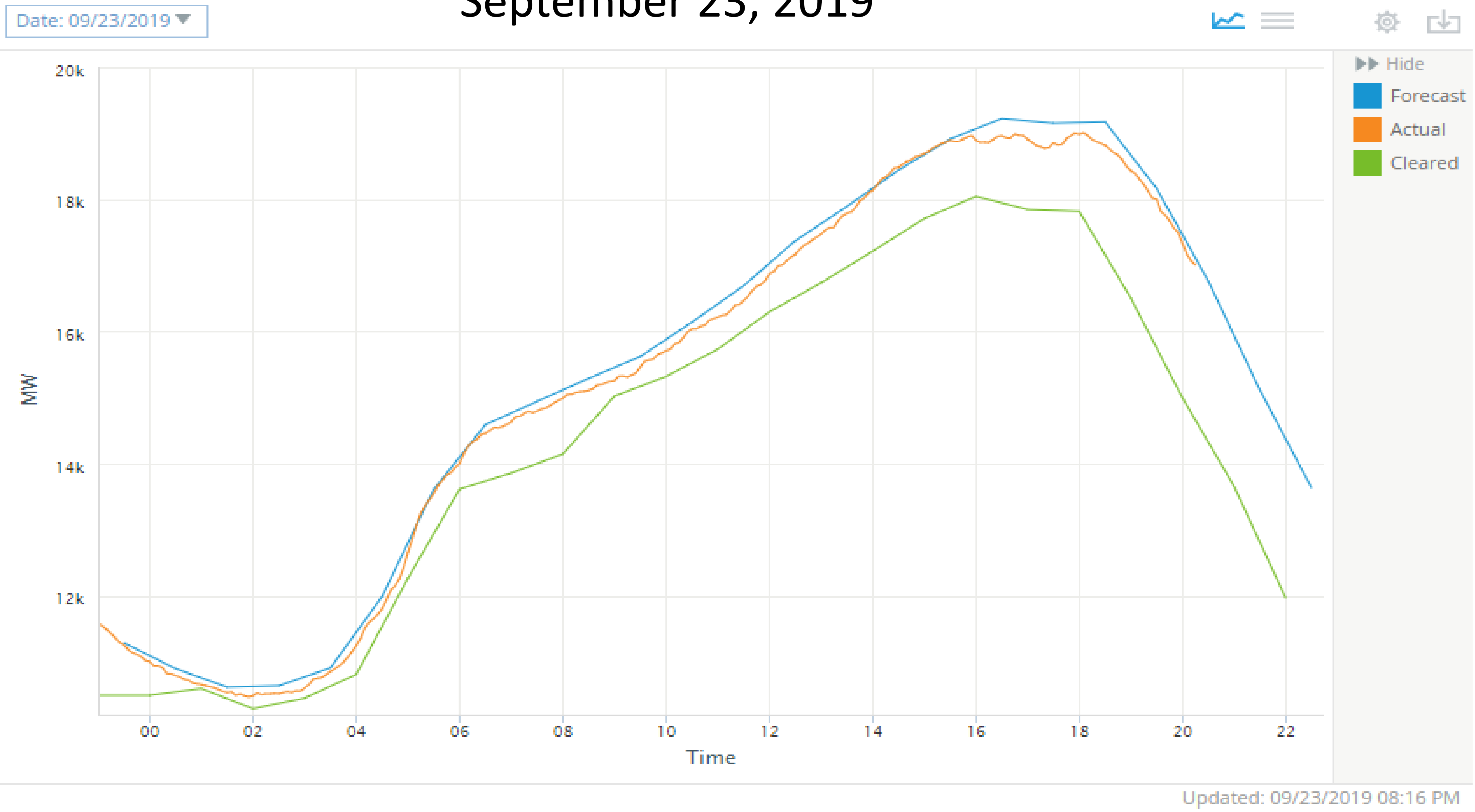
PJM Archive pricing, 2017

65_Ohio node in Chicago – 60622

Data Miner 2. PJM. Real-Time Hourly LMP's. 25 Mar 2018. dataminer2.pjm.com/feed/rt_hrl_lmps/definition

NEW ENGLAND ISO

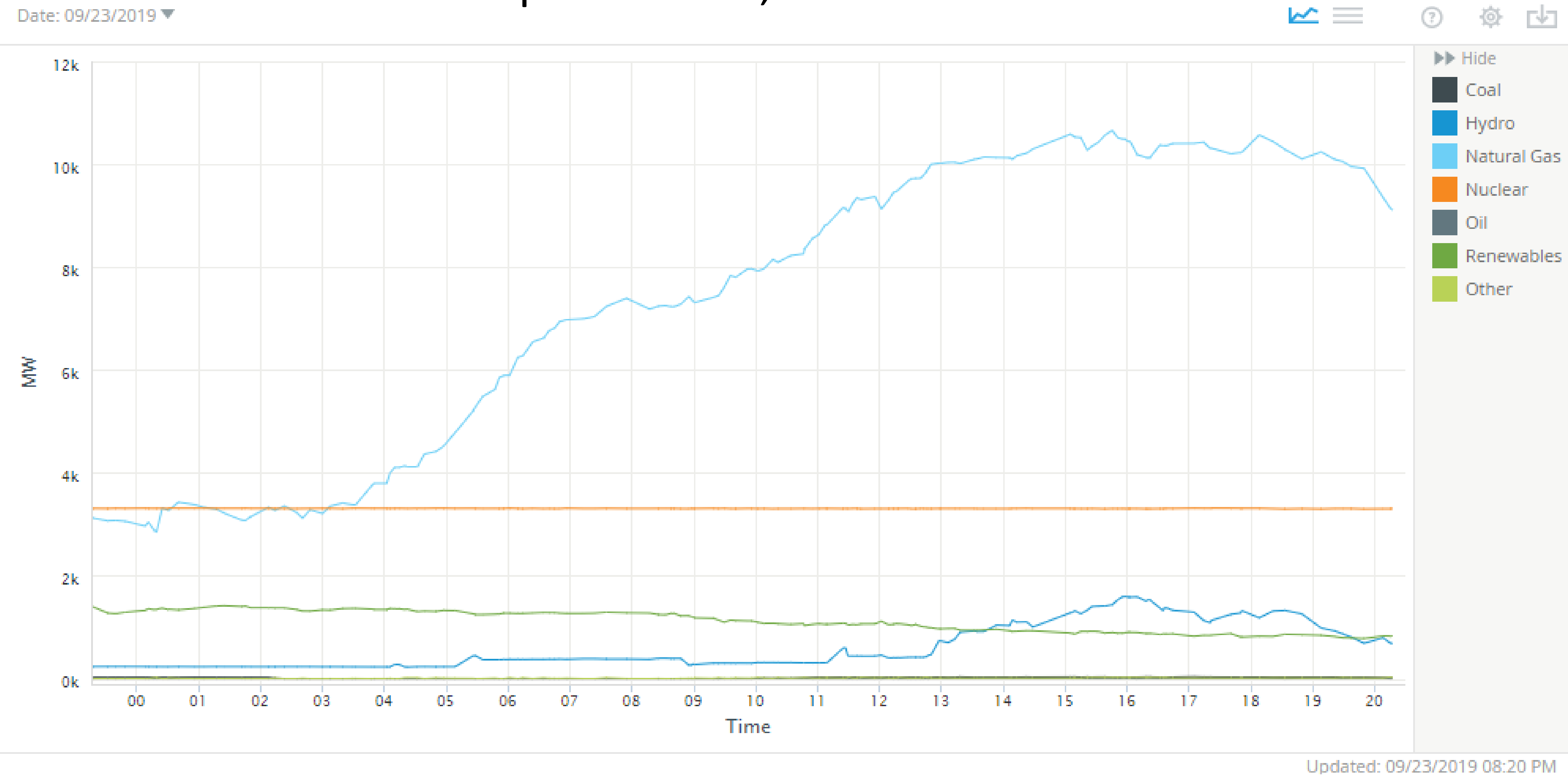
September 23, 2019



Source: https://www.iso-ne.com/isoexpress/

NEW ENGLAND ISO

September 23,2019



Source: https://www.iso-ne.com/isoexpress/

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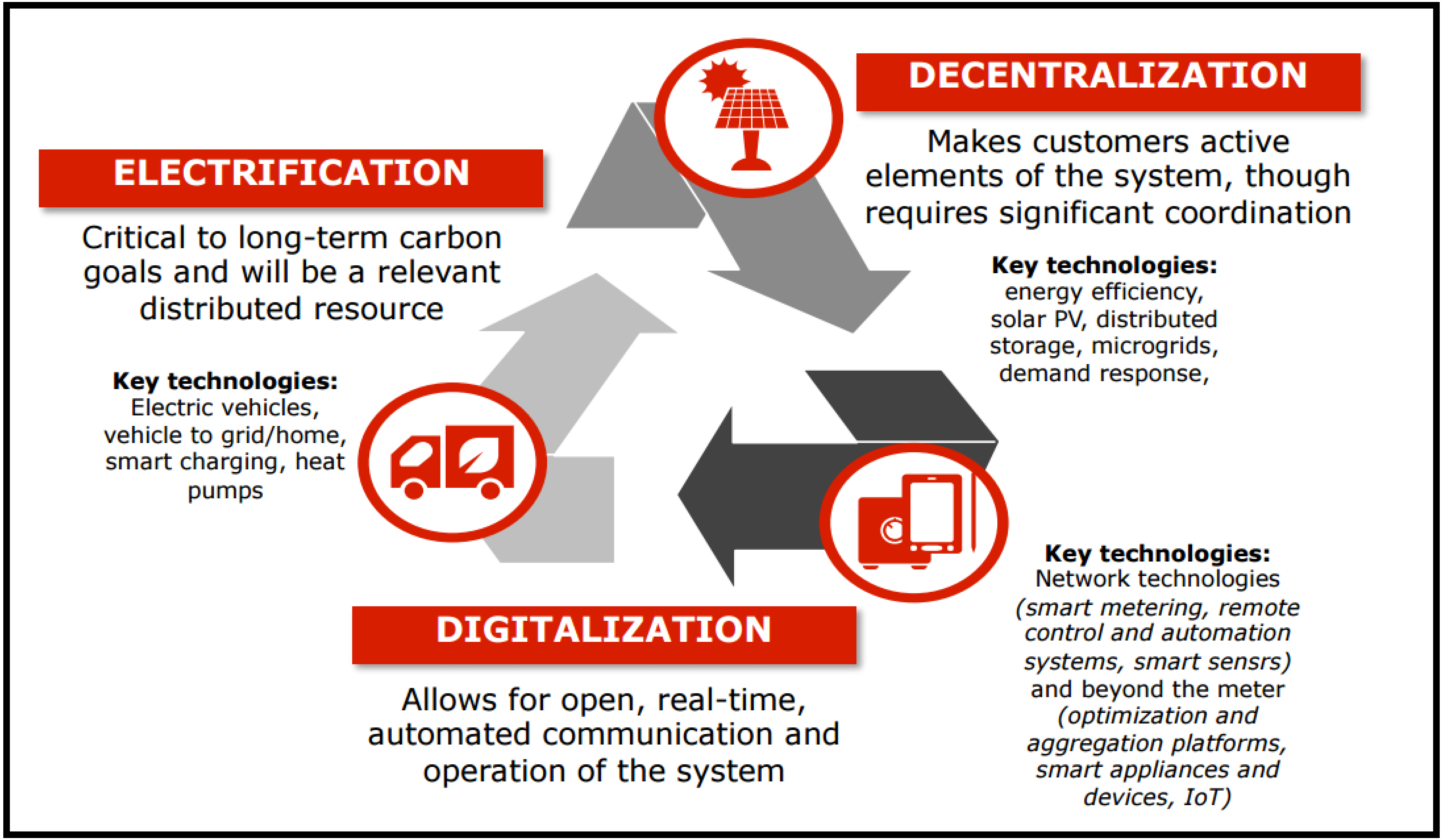
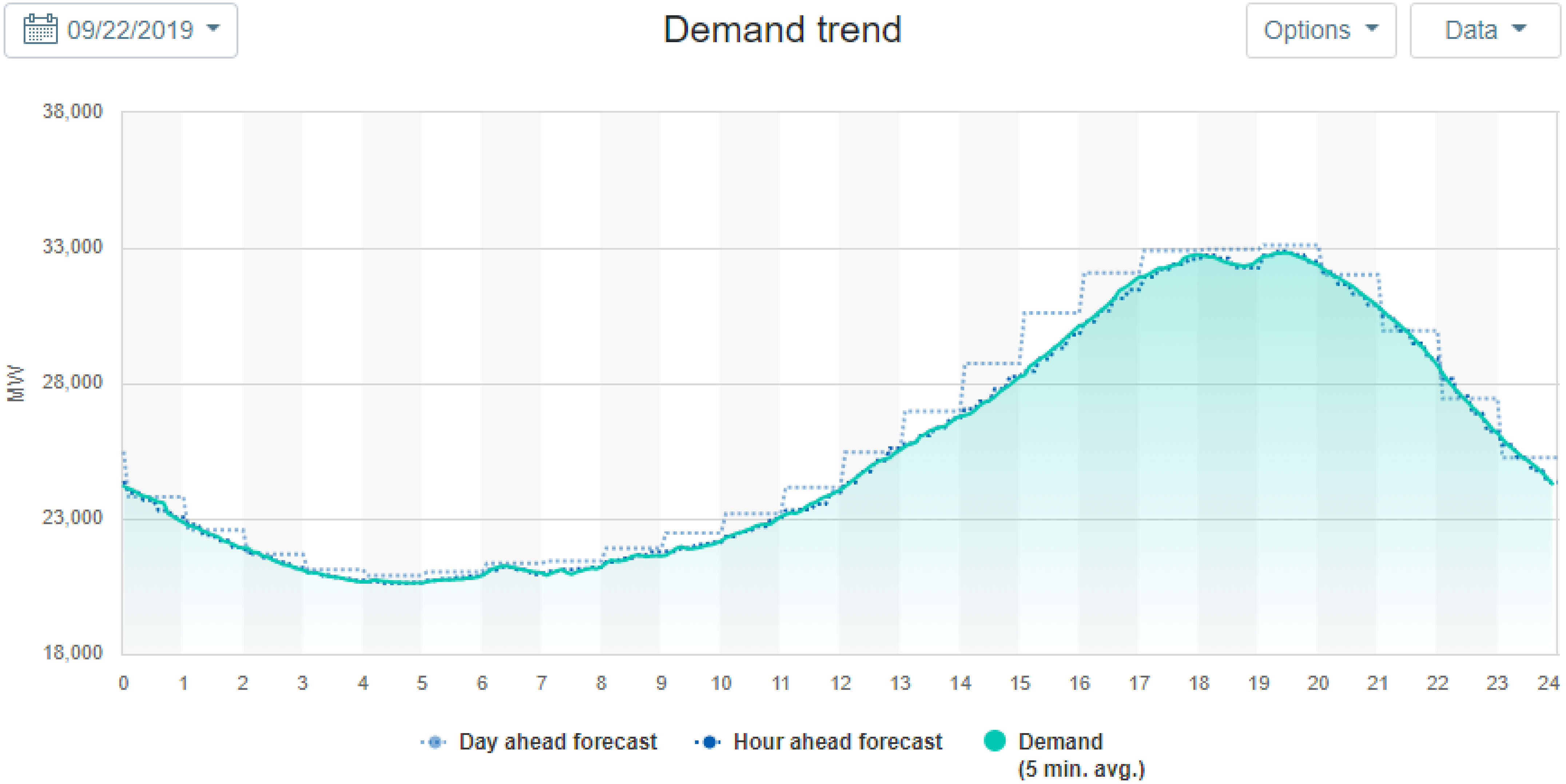
3. Challenges of PV integration
4. Intro to building+grid integration strategies
    1. Passive vs Code Case Study
    2. Other strategies


ELECTRIFICATION
Critical to long-term carbon goals and will be a relevant distributed resource
Key technologies:
Electric vehicles, vehicle to grid/home, smart charging, heat pumps
DECENTRALIZATION
Makes customers active elements of the system, though requires significant coordination
Key technologies:
energy efficiency, solar PV, distributed storage, microgrids, demand response,
DIGITALIZATION
Allows for open, real-time, automated communication and operation of the system
Key technologies:
Network technologies (smart metering, remote control and automation systems, smart sensrs) and beyond the meter (optimization and aggregation platforms, smart appliances and devices, IoT)

CALIFORNIA ISO

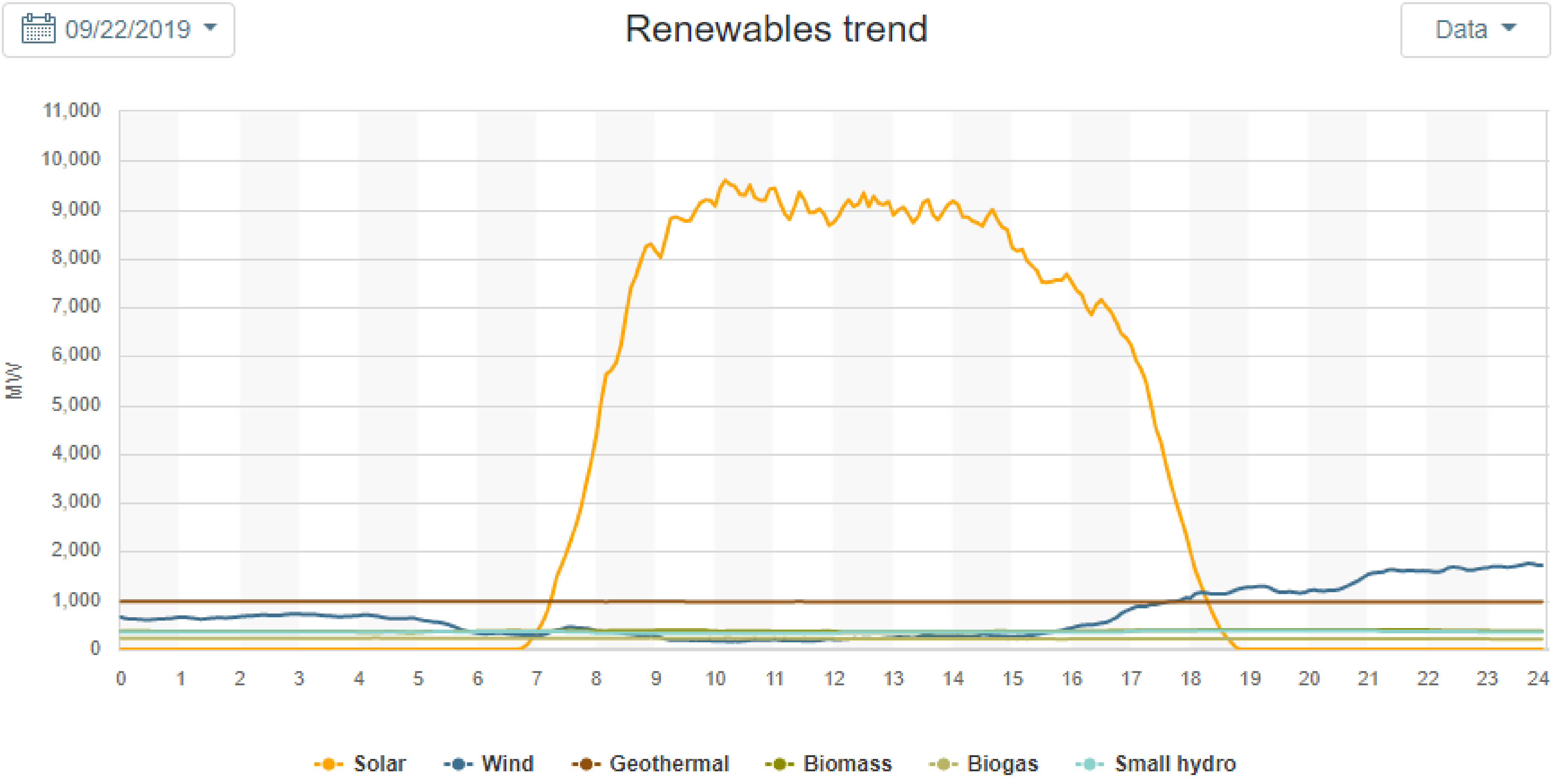
California ISO – September 22, 2019



http://www.caiso.com

CALIFORNIA ISO

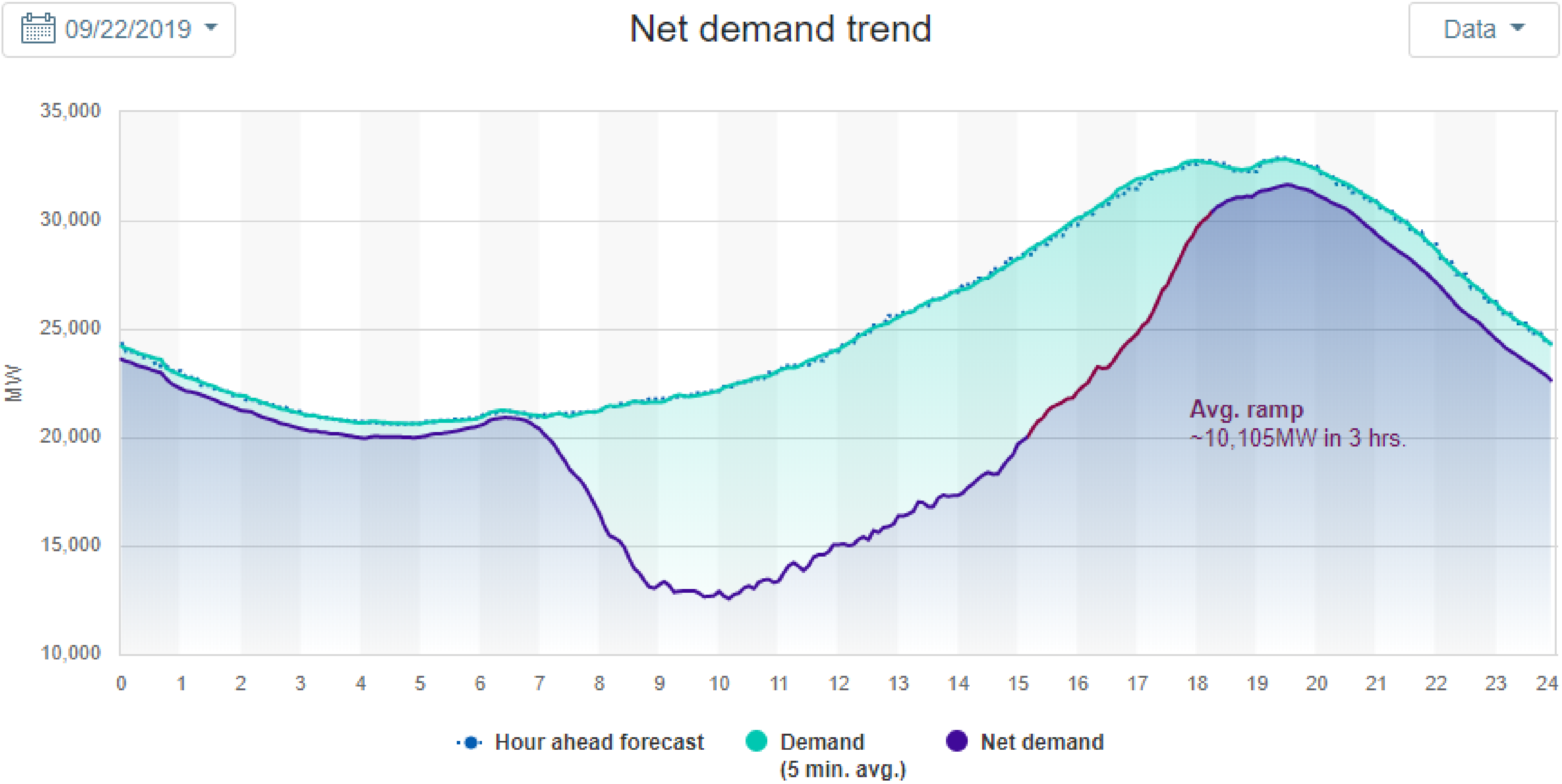
California ISO –September 22, 2019



http://www.caiso.com

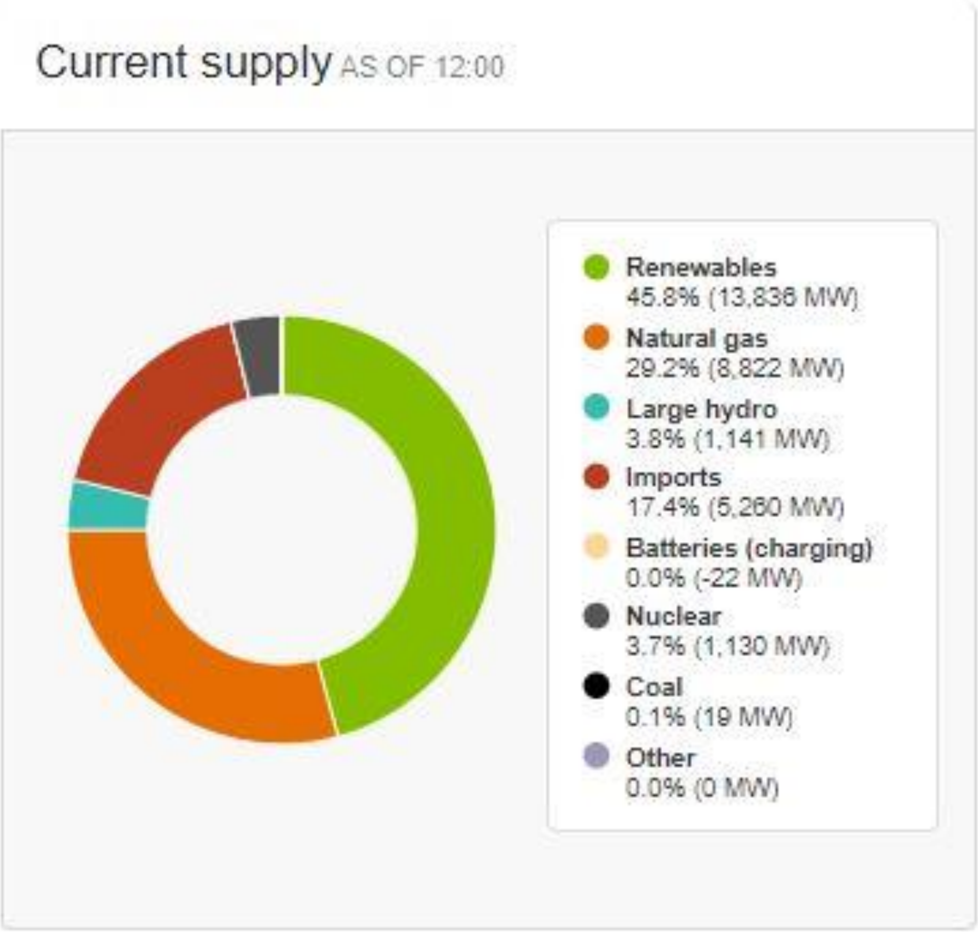
CALIFORNIA ISO

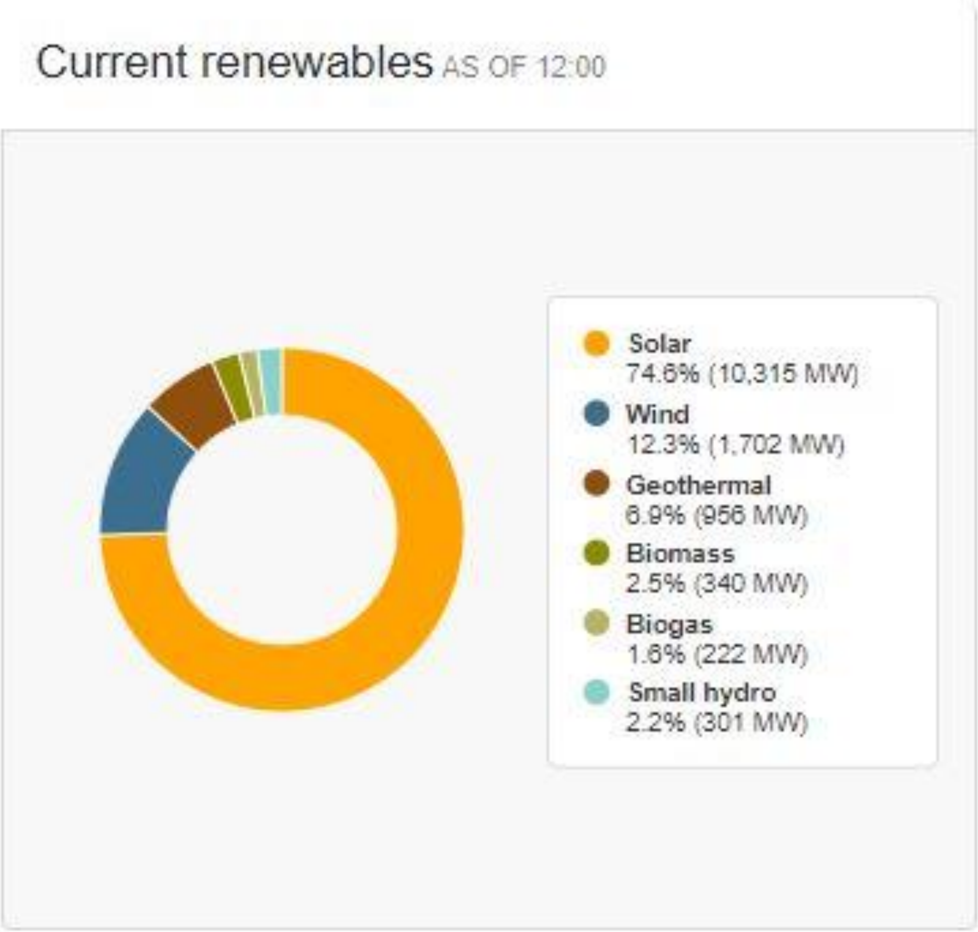
California ISO – September 22, 2019



http://www.caiso.com

California ISO – September 24, 2019 12:00 PM



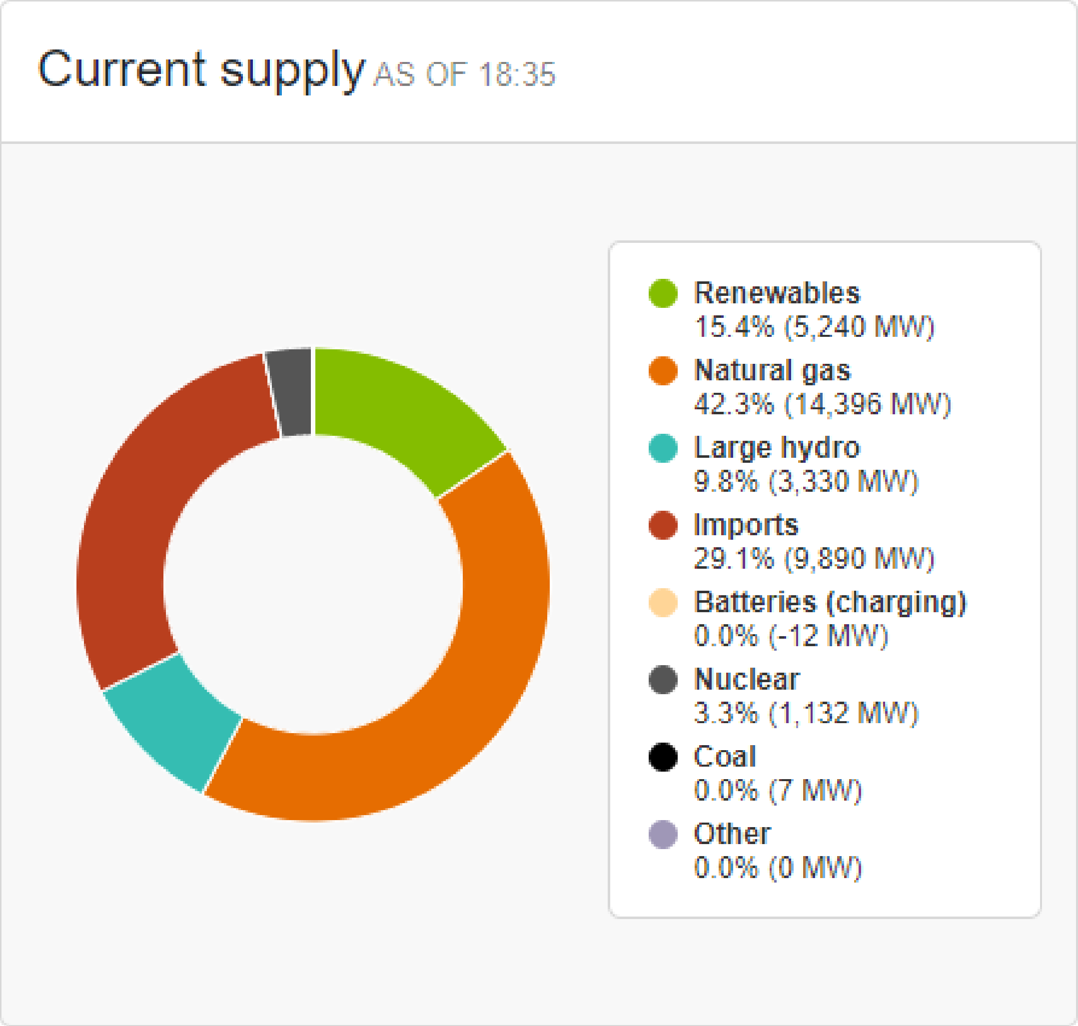


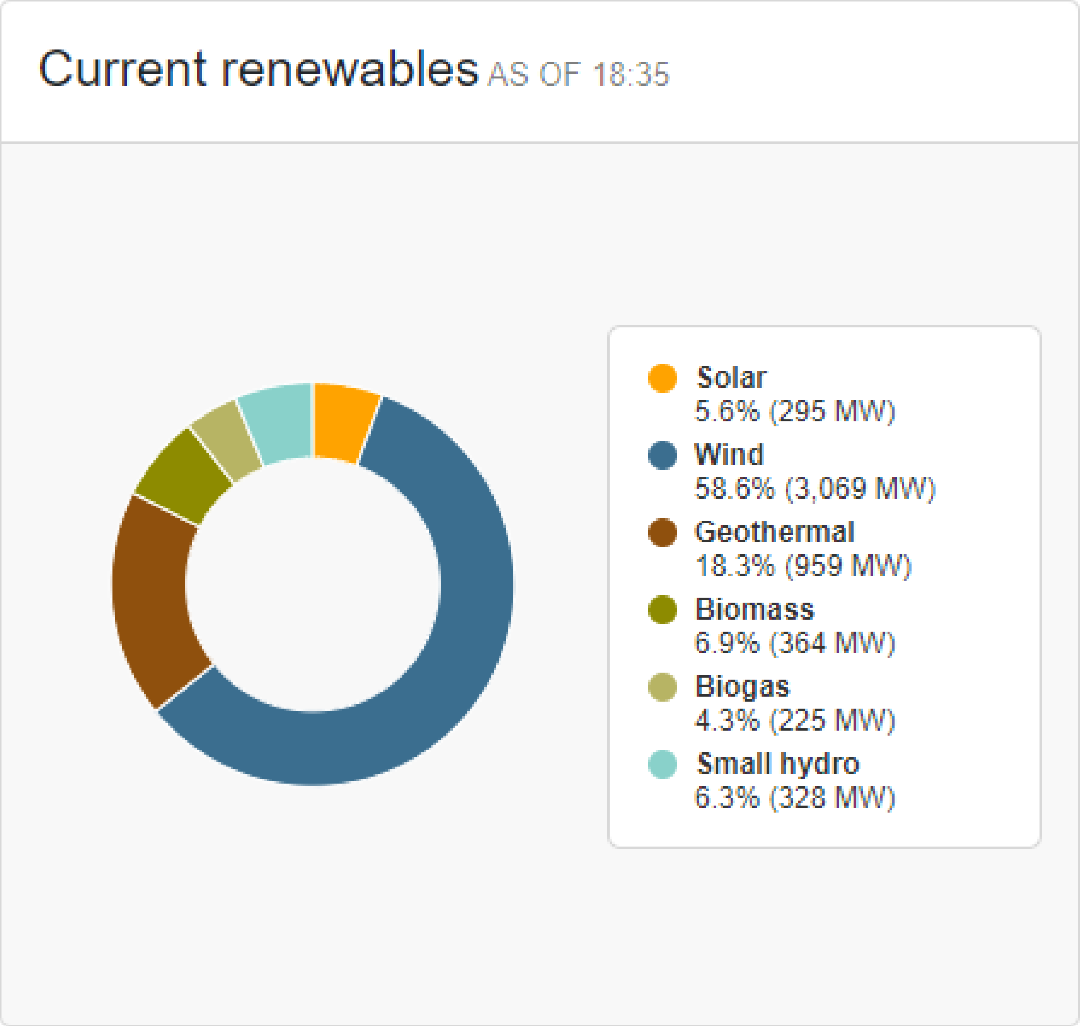
http://www.caiso.com/TodaysOutlook/Pages/supply.aspx

California ISO – September 24, 2019 12:00 PM

http://www.caiso.com/TodaysOutlook/Pages/supply.aspx

California ISO – September 23, 2019 6:35 PM





http://www.caiso.com/TodaysOutlook/Pages/supply.aspx

California ISO – September 23, 2019 6:35 PM

Today's Outlook | Demand | Supply | Emissions | Prices

AS OF **18:35 09/23/2019**

Grid status | ● Normal | Learn more about active alerts, warnings and emergencies

Supply and renewables

View official data in OASIS

33,937 MW	**5,240 MW**	**295 MW**	**3,069 MW**
Current demand	Current renewables	Current solar	Current wind

http://www.caiso.com/TodaysOutlook/Pages/supply.aspx

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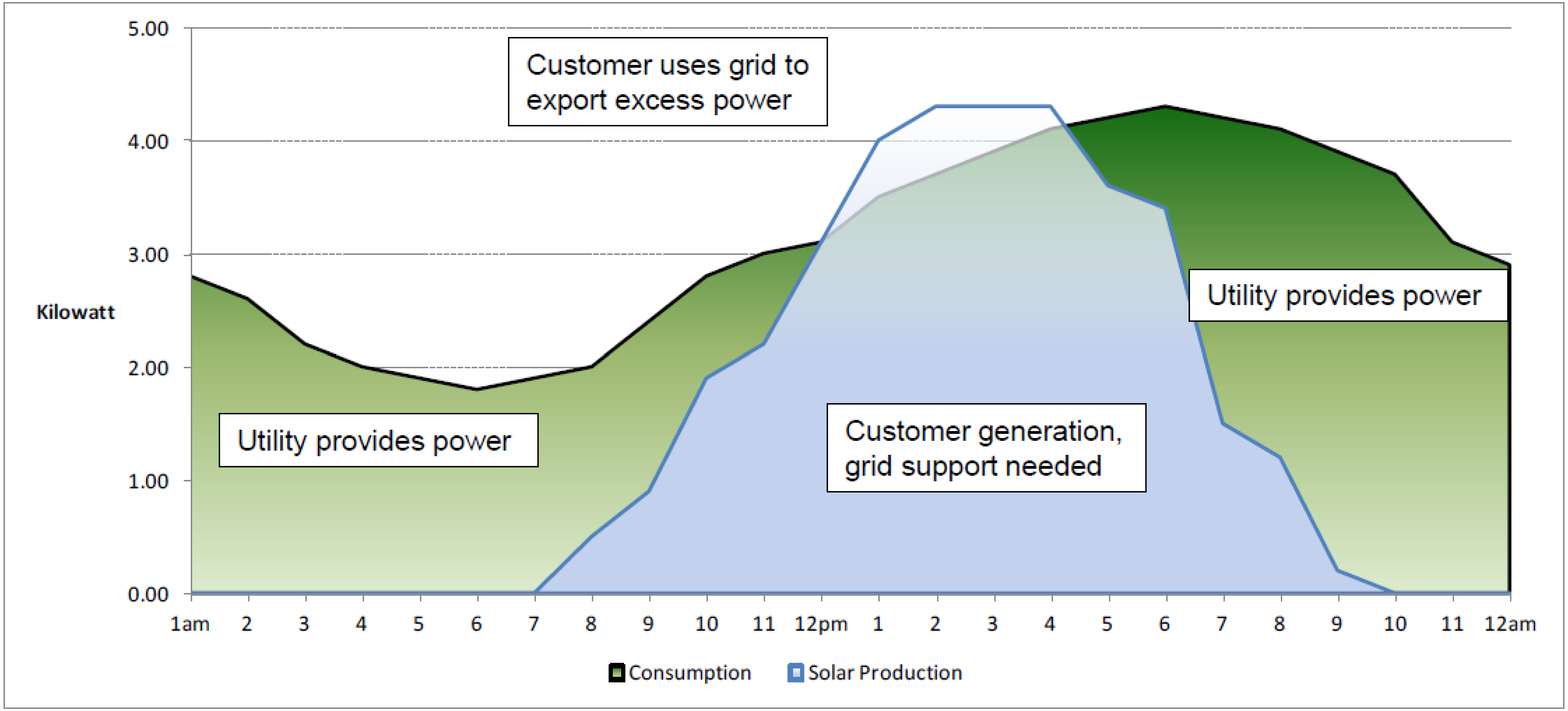
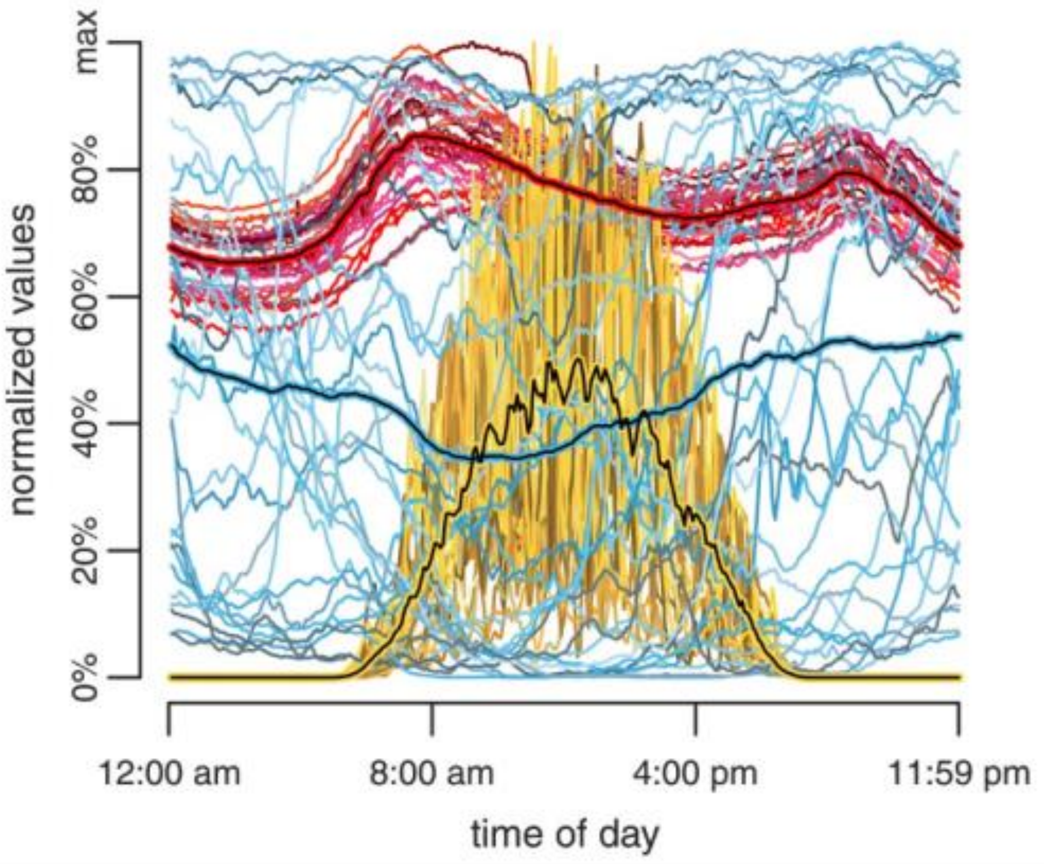
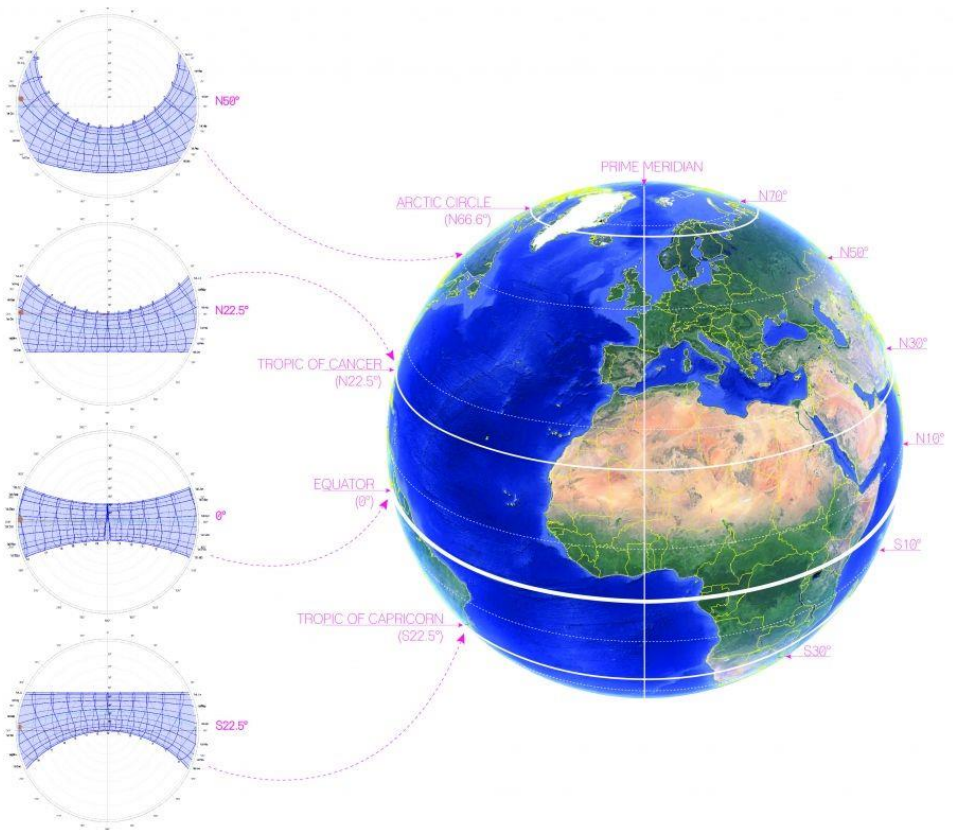
MISMATCH CHALLENGES



INTERMITTENCY

Intermittent, but not unpredictable.

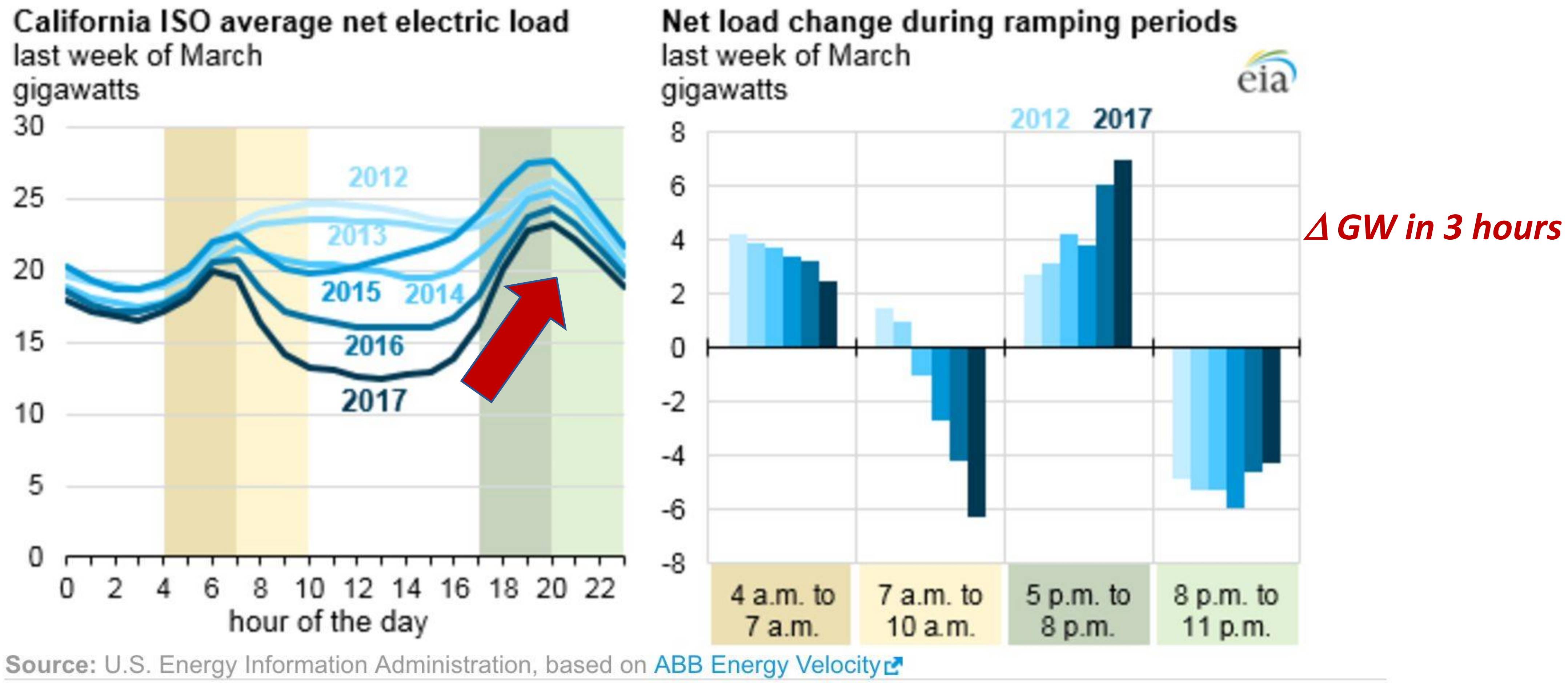




RED: POWER DEMAND
BLUE: WIND ENERGY GENERATION
YELLOW: SOLAR INSOLATION DATA

Source: Bonneville Power Administration, April 2010

NET LOAD/RAMPING CHALLENGES



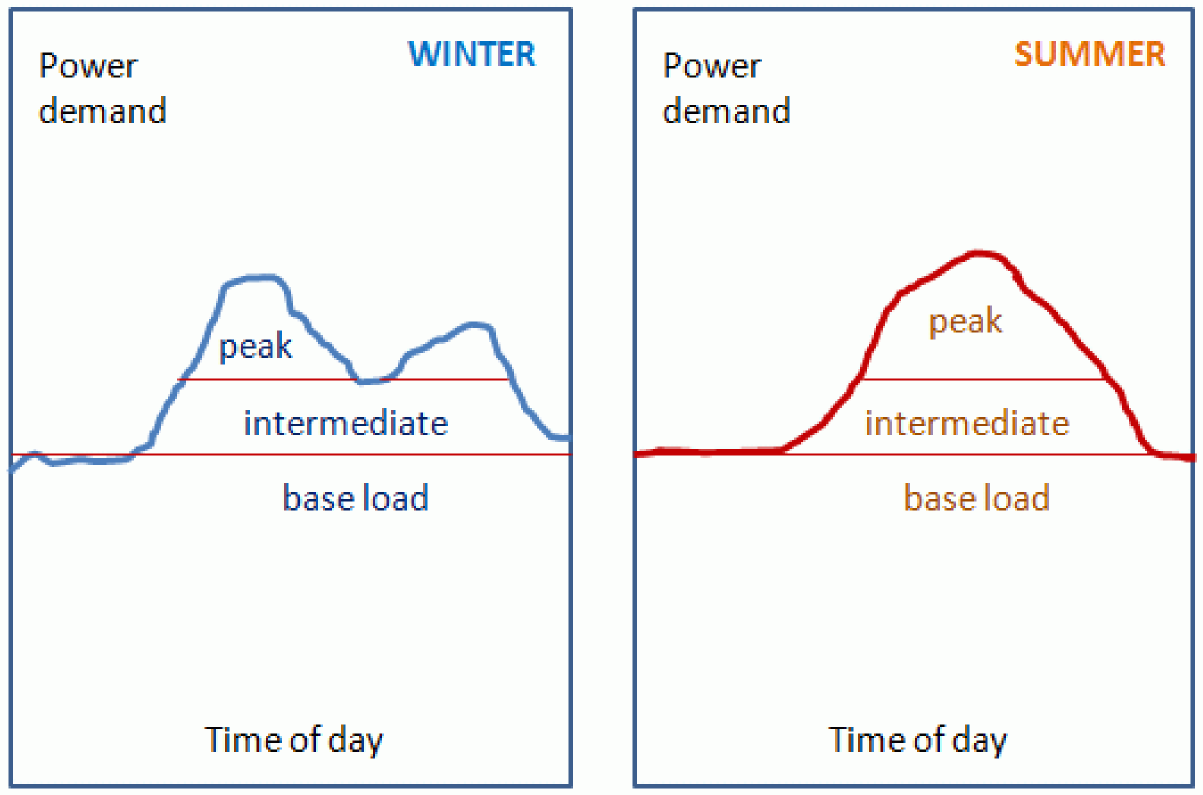
- Net Load on grid ramps dramatically as PV generation declines (sunset)
- Most generation resources cannot adjust/increase output that quickly (Natural Gas can)

BASELOAD CHALLENGES

Similarly to difficulty in quickly increasing load, some baseload resources cannot 'turn down'.

Nuclear: 80% max load minimum

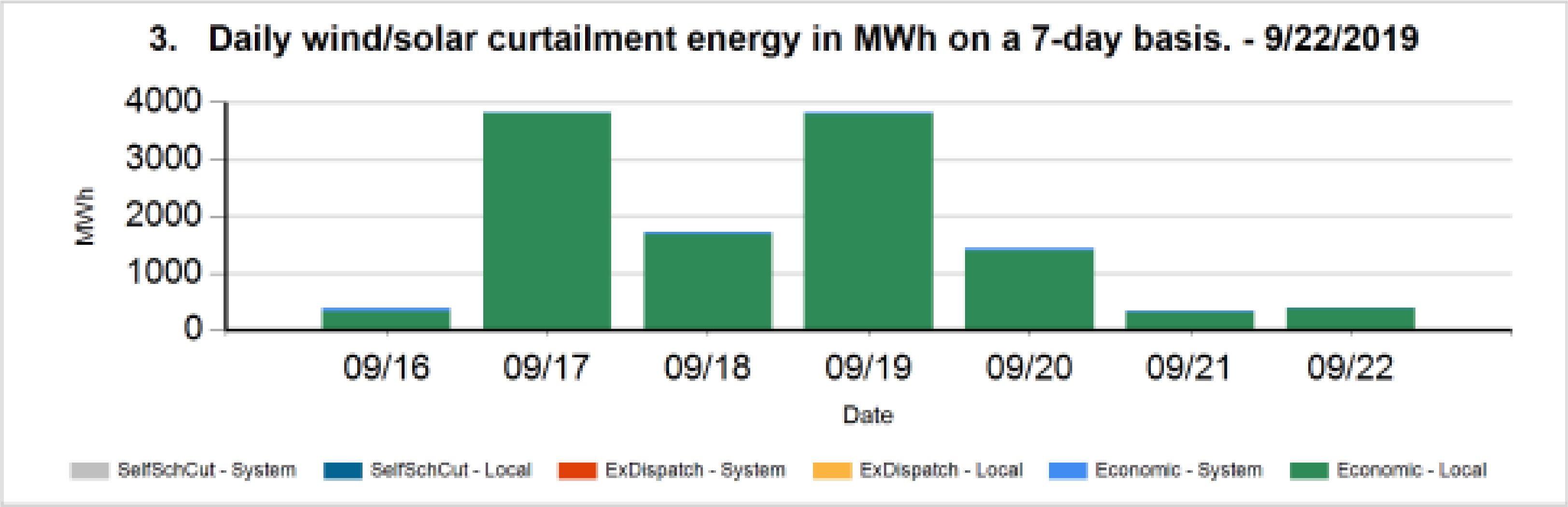
Coal: Varies, but takes hours to lower output, and days to re-start if brought down to 0.

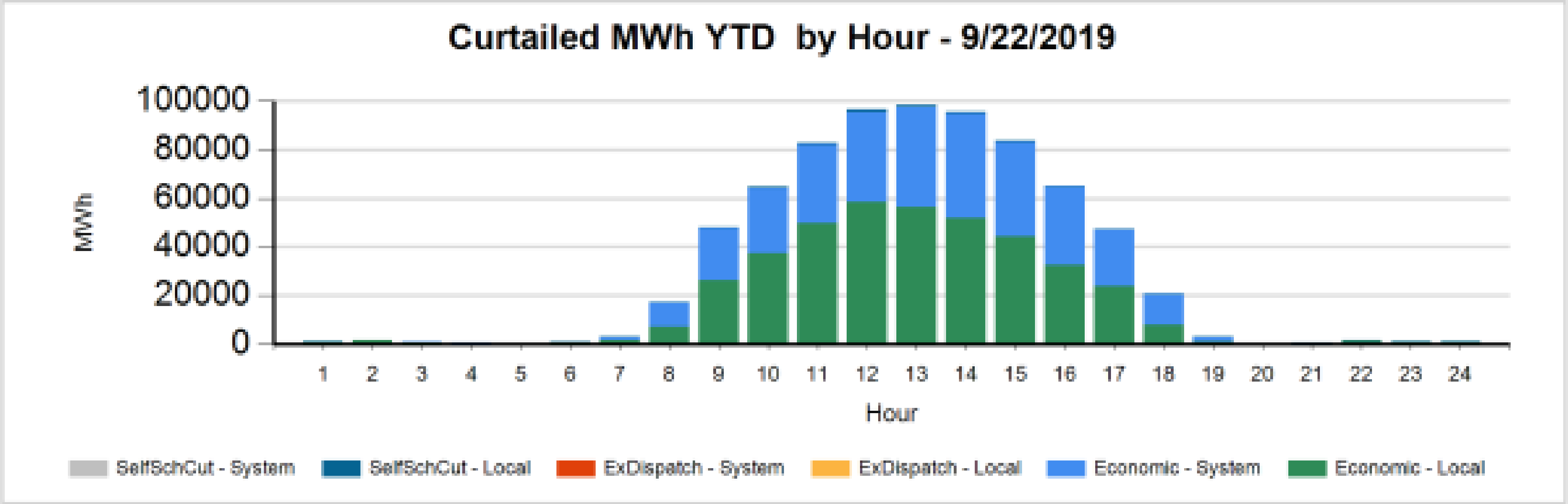


CURTAILMENT

California ISO (CAISO) Curtailment – Daily Report

What if the net load on the grid is lower than or equal to the fossil-fueled baseload?
Or, if the transmission system does not have capacity to handle the output?





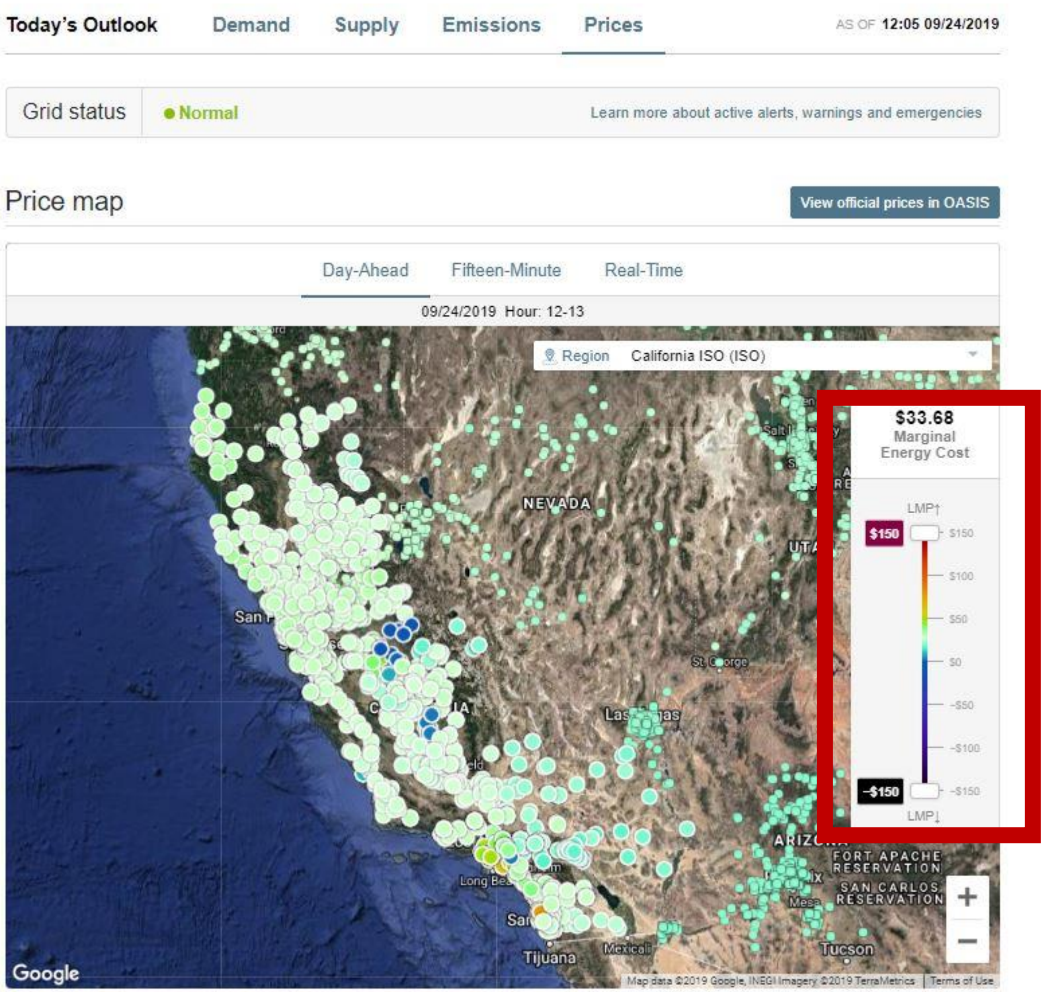
<u>Economic – Local</u>: *Market dispatch over generators with economic bids to mitigate local congestion**

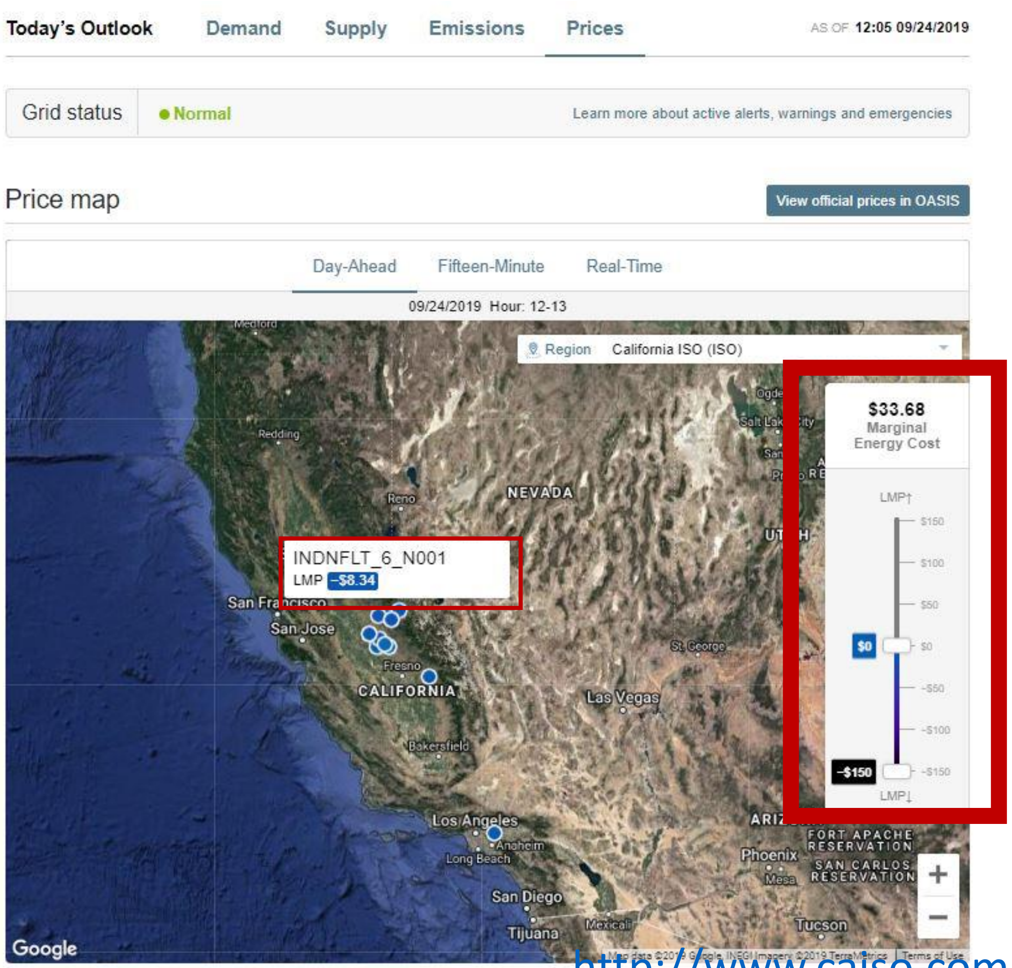
**Congestion occurs when available, least cost energy cannot be delivered to some loads because transmission facilities do not have sufficient capacity to deliver the energy.*

<u>Economic – System</u>*: Market dispatch of generators with economic bids to mitigate system-wide oversupply*

CURTAILMENT

*Negative values for LMP (Locational Marginal Pricing) – **September 24, 2019 – 12:00pm Local Time***





http://www.caiso.com

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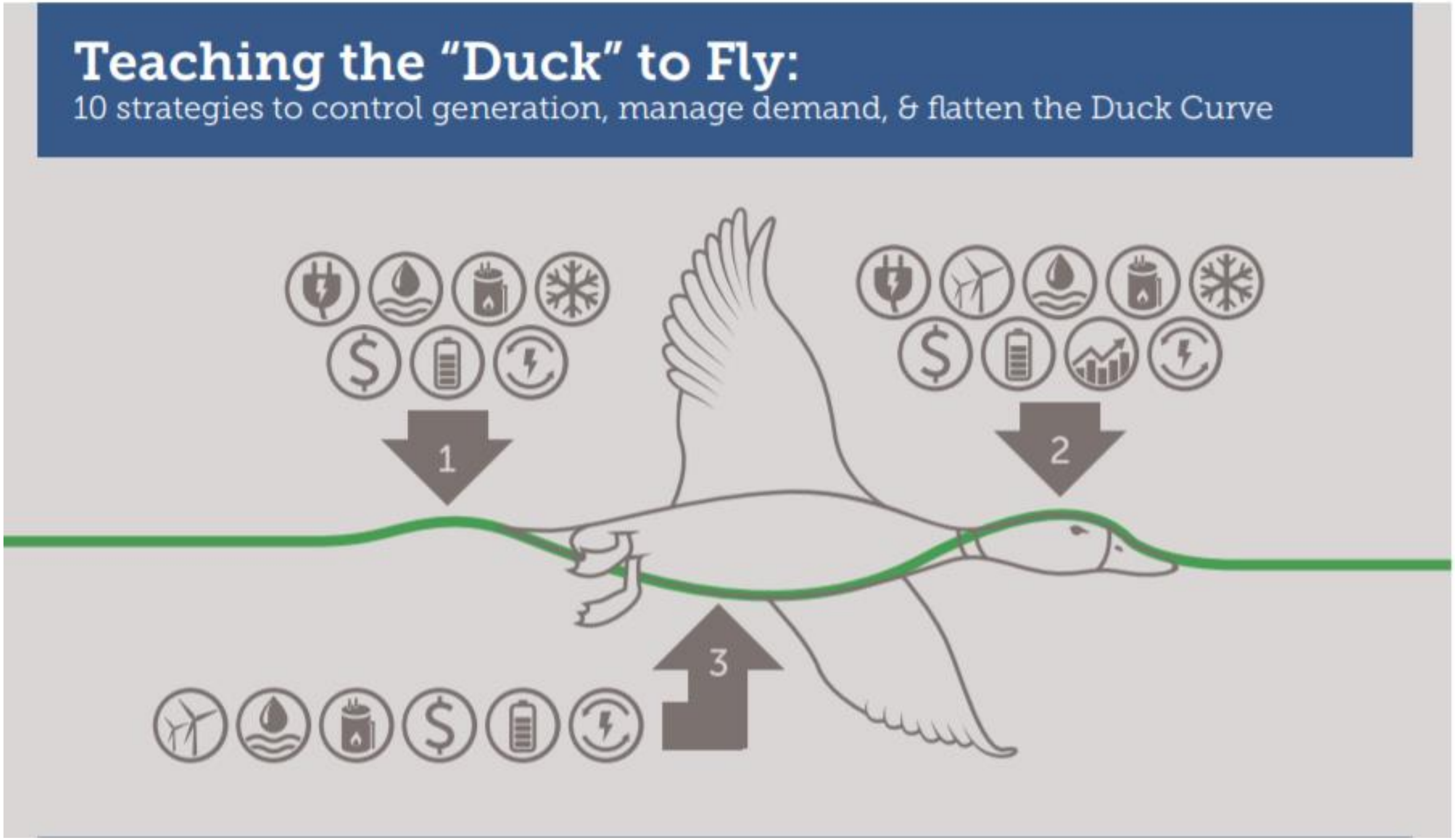
GRID INTEGRATION STRATEGIES

Passive at core

1. Reduce overall electrical load
   Build passive
2. Flatten daily electrical load curve
   Build passive
3. Reduce mismatch between on-site PV generation and energy use
   Build passive
4. Deploy demand response systems
   Better suited to passive buidlings than conventional
5. Control electric water heaters
   Electric water heaters common in passive buildings
6. Control other major appliances

TEACHING THE DUCK TO FLY

Image Source: Jim Lazar (RAP)



TEACHING THE DUCK TO FLY

Image Source: Jim Lazar (RAP)

Targeted Efficiency
Focus energy efficiency measures to provide savings in key hours of system stress. 1 2

Rate Design
Focus pricing on crucial hours. Replace flat rates & demand charge rate forms with time-of-use rates. Avoid high fixed charges. 1 2 3

Peak-Oriented Renewables
Add renewables with favorable hourly production. Modify the dispatch protocol for existing hydro with multi-hour "pondage." 2 3

Targeted Electric Storage
Deploy storage to reduce need for transmission & distribution, & to enable intermittent renewables. 1 2 3

Manage Water Pumping
Run pumps during periods of low load or high solar output, curtailing during ramping hours. 1 2 3

Demand Response
Deploy demand response programs that shave load during critical hours on severe stress days. 2

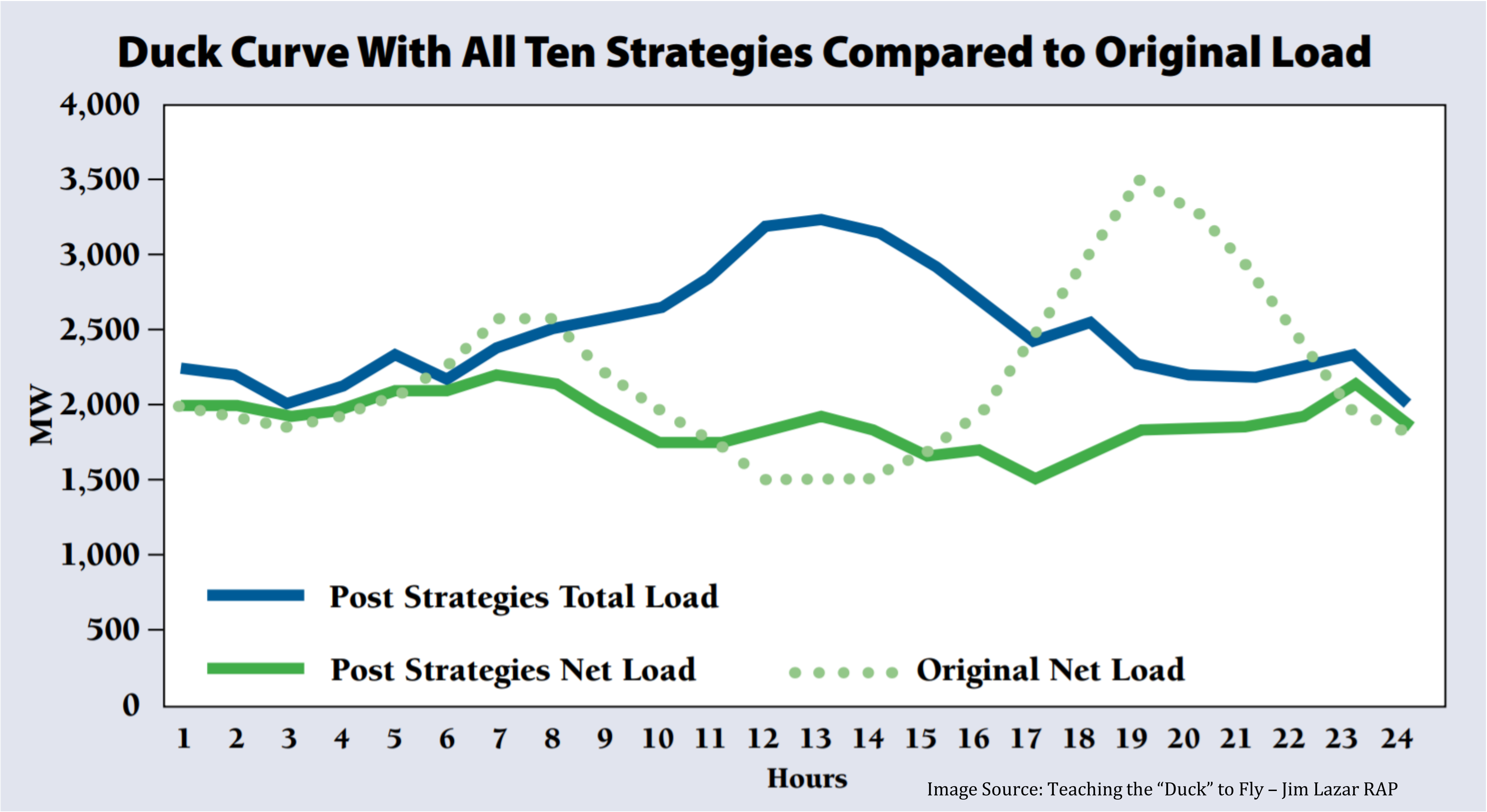
Control Electric Water Heaters
Increase usage during night & mid-day hours, & decrease during peak demand periods. 1 2 3

Inter-Regional Power Exchange
Import power from & export power to other regions with different peaking periods. 1 2 3

Ice Storage for Commercial AC
Convert commercial AC to ice or chilled-water storage operated during non-ramping hours. 1 2

Retire Inflexible Generating Plants
Replace older fossil & nuclear plants with a mix of renewables, flexible resources, & storage.

Image Source: Teaching the "Duck" to Fly – Jim Lazar RAP

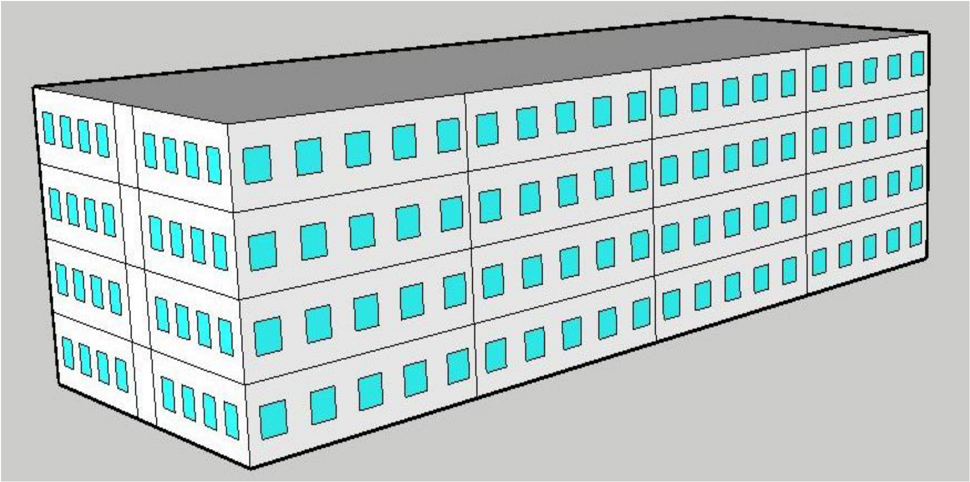


Load Factor: 63.6% → 86.5%

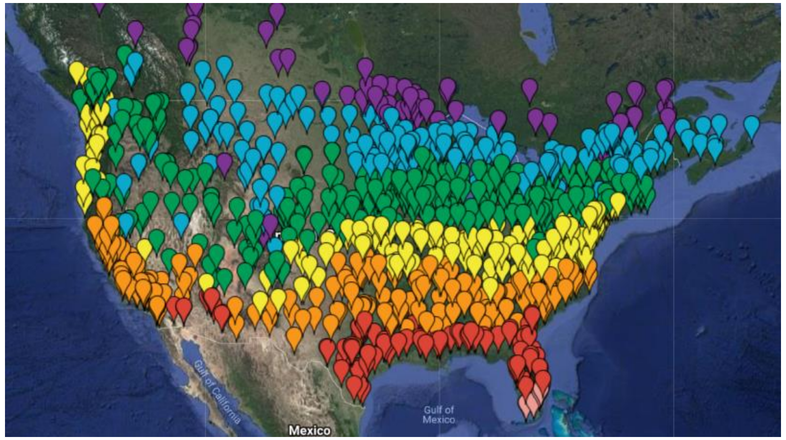
Max Hourly Ramp: 350 MW → 198 MW

Total Difference Between Highest and Lowest Hour: 2000 MW → 600 MW

‘**NET ZERO**’ CASE STUDY



Multifamily Building – DOE Prototype
Location: Chicago, IL
32 units, 96 occupants, ~35,000 sf iCFA
All Electric
Energy Model: BeOpt (Energy Plus engine)



Two ‘Net Zero’ buildings studied:

1. Baseline “Renewable Oriented” (code compliant):
290 kW PV Array
All south facing, 10 degree tilt

2. Passive building (PHIUS+ 2015 compliant):
159 kW PV Array
All south facing, 10 degree tilt

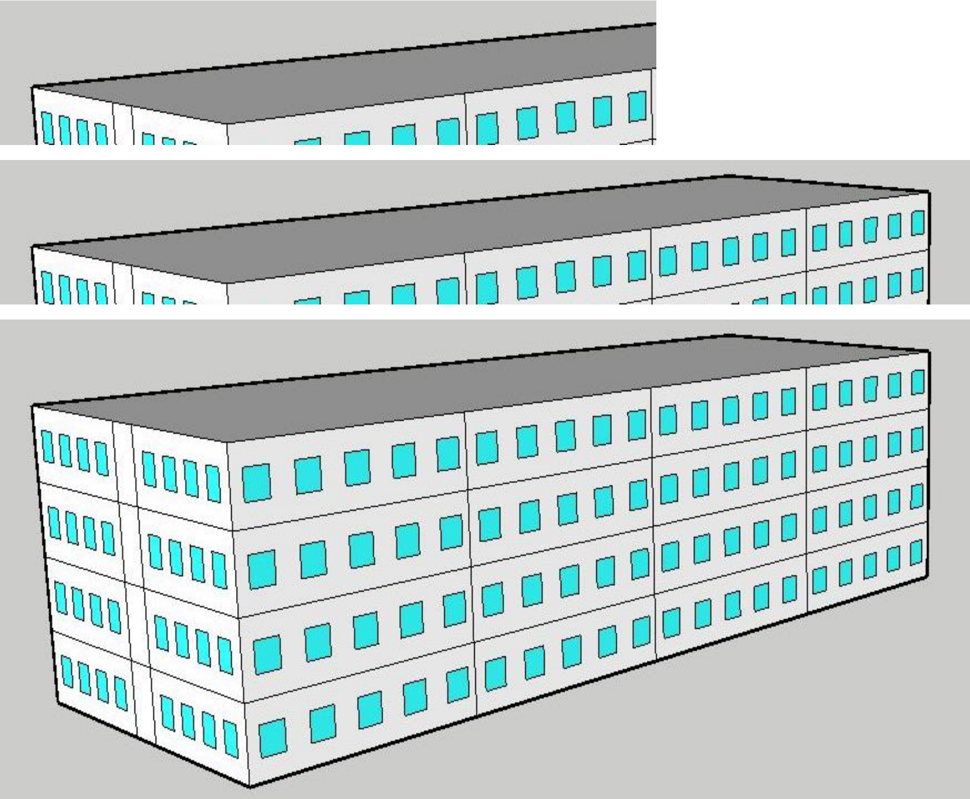
‘NET ZERO’ CASE STUDIES

Baseline “Renewable Oriented”
290 kW PV Array
All south facing, 10 degree tilt
Site EUI: **33.4** kBTU/ft^2.yr

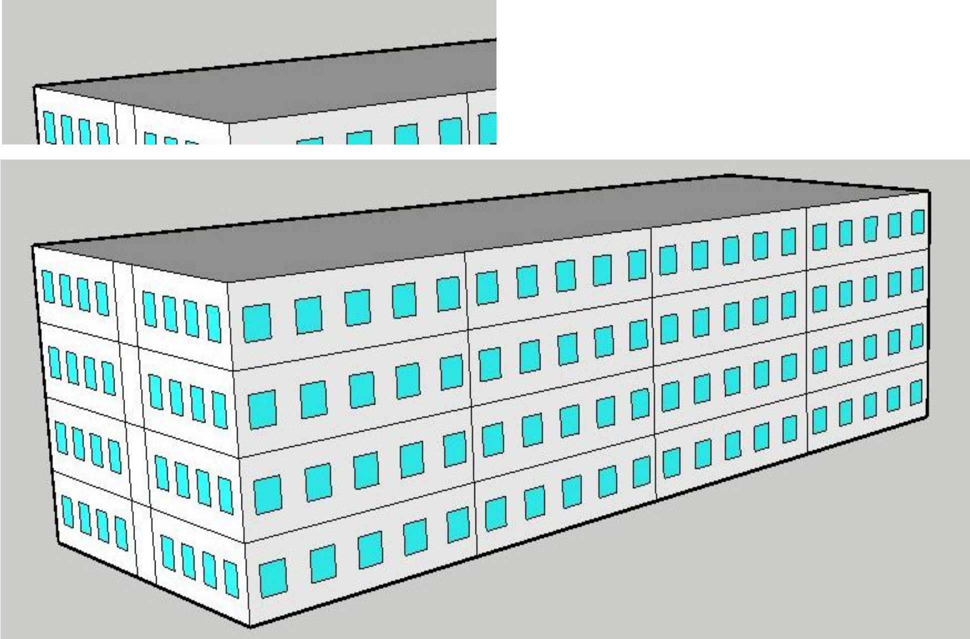
Passive building (PHIUS+ 2015 compliant):
159 kW PV Array
All south facing, 10 degree tilt
Site EUI: **18.7** kBTU/ft^2.yr

Roof Area = 9,000 ft^2
Estimate 80% usable = 7,200 ft^2
Estimate 1 ft^2 = ~15 W

Need 19,333 ft2, or 2.7x roof area!



Need 10,600 ft2, or 1.5x roof area!



‘NET ZERO’ BUILDINGS - Commitments

Oregon: 2023 target for all new home construction to meet Zero Energy (ZE)
Austin, TX: All new homes Zero Energy-Ready as of 2015
Cambridge, MA: Developing multi-year plan to move towards net zero energy community. All new residential homes to be ZE by 2022.
....

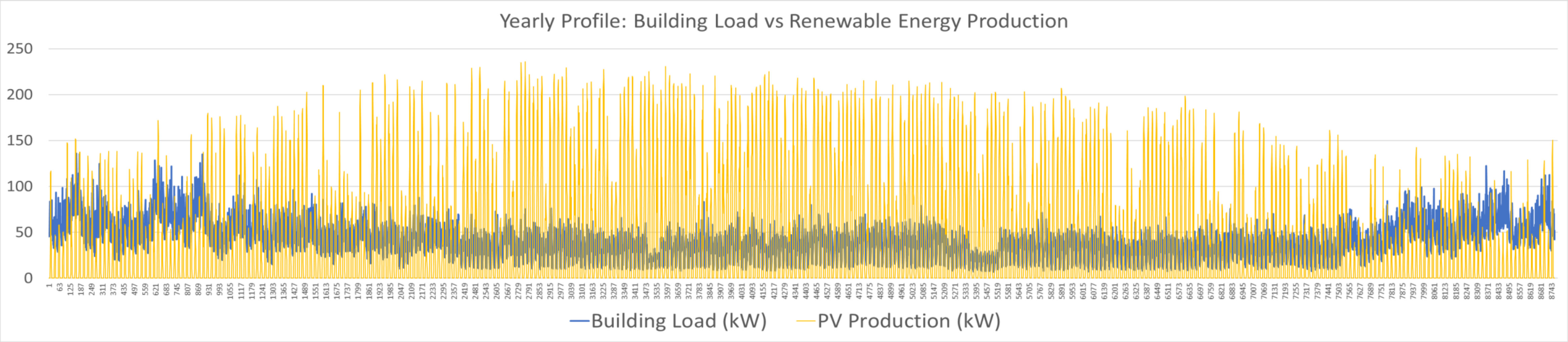
Net Zero Carbon Buildings Commitment: All buildings net zero in operation by 2050
New York City, Seattle, San Francisco, Portland, Washington D.C., Los Angeles, San Jose, Santa Monica, Toronto, Vancouver....

The list goes on...

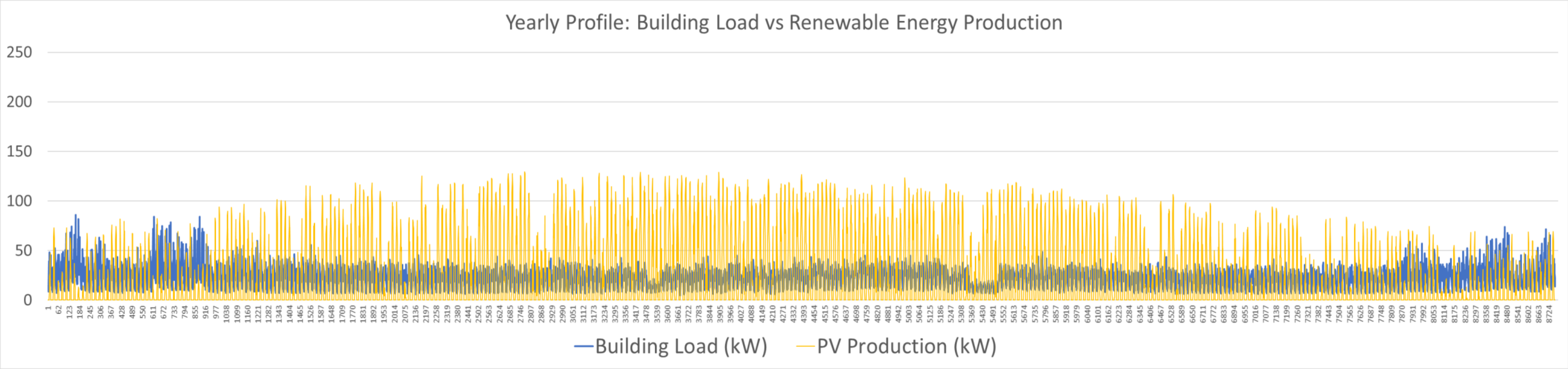
https://www.worldgbc.org/thecommitment

CASE STUDY

Baseline building



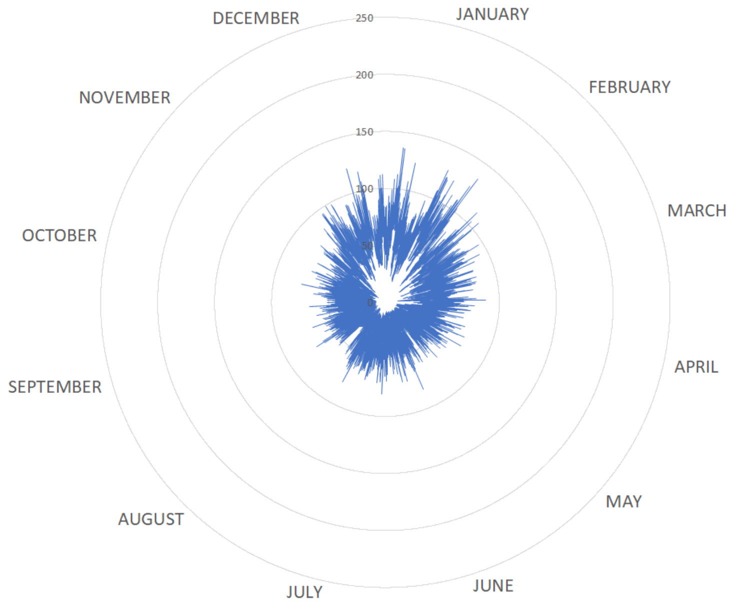
Passive (PHIUS+) building

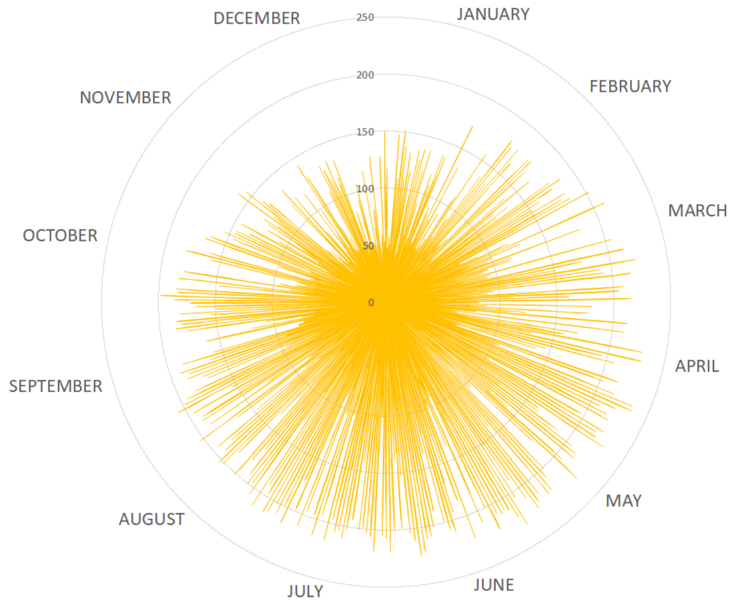


CASE STUDY

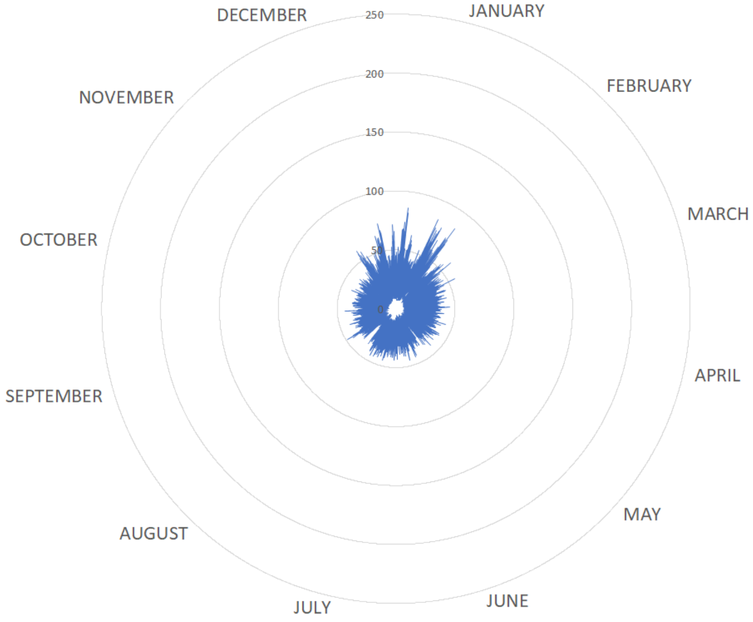
Hourly Building Load (kW) | Hourly PV Production (kW)

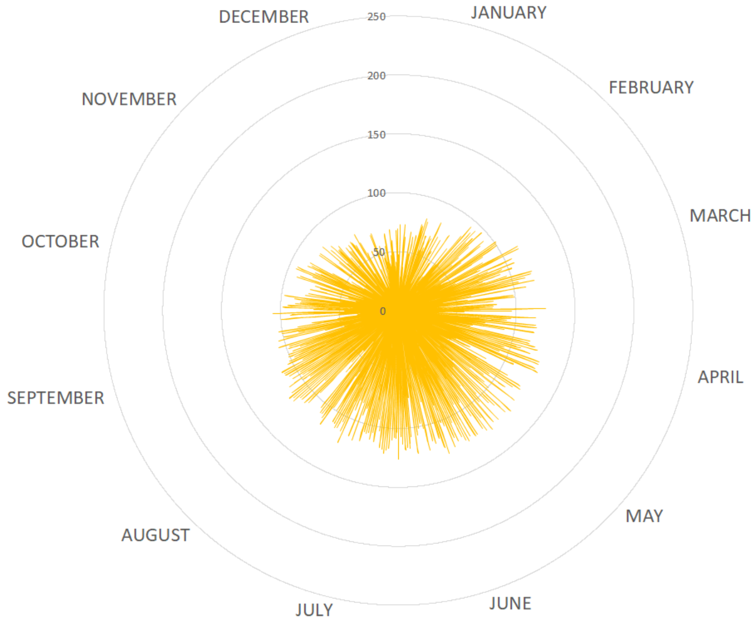
Baseline building





Passive building

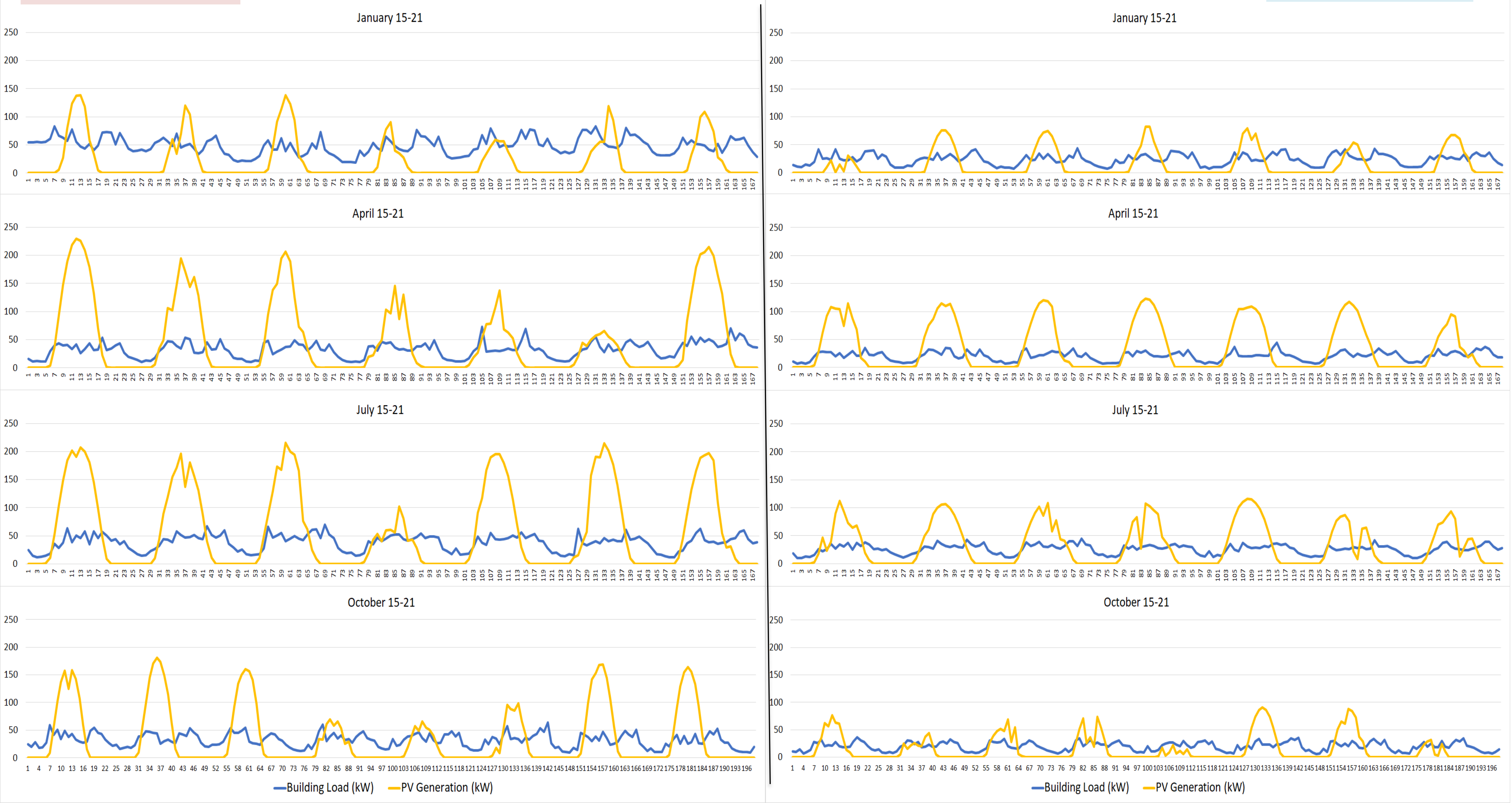




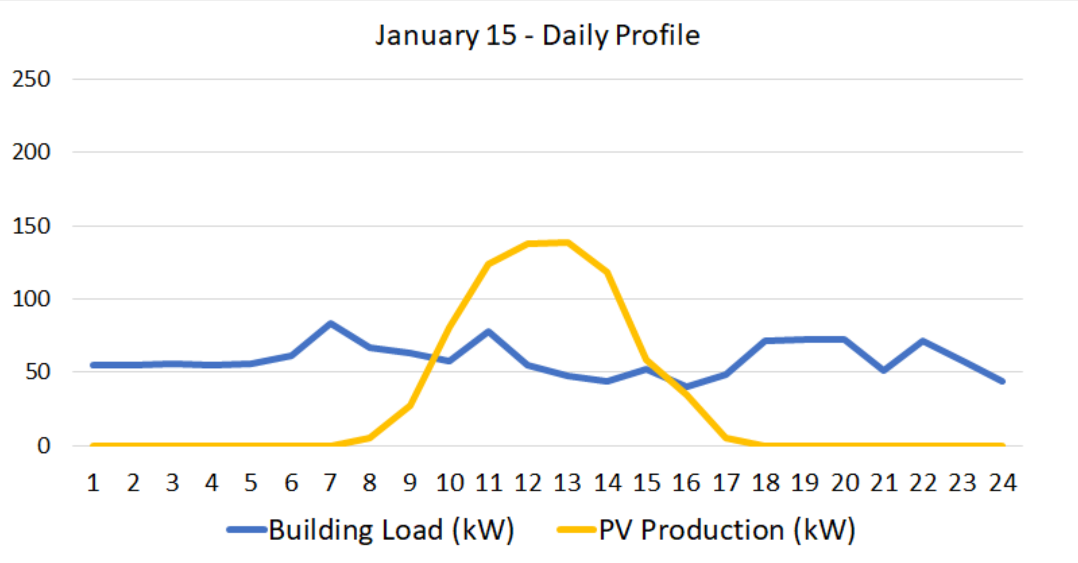
Baseline building

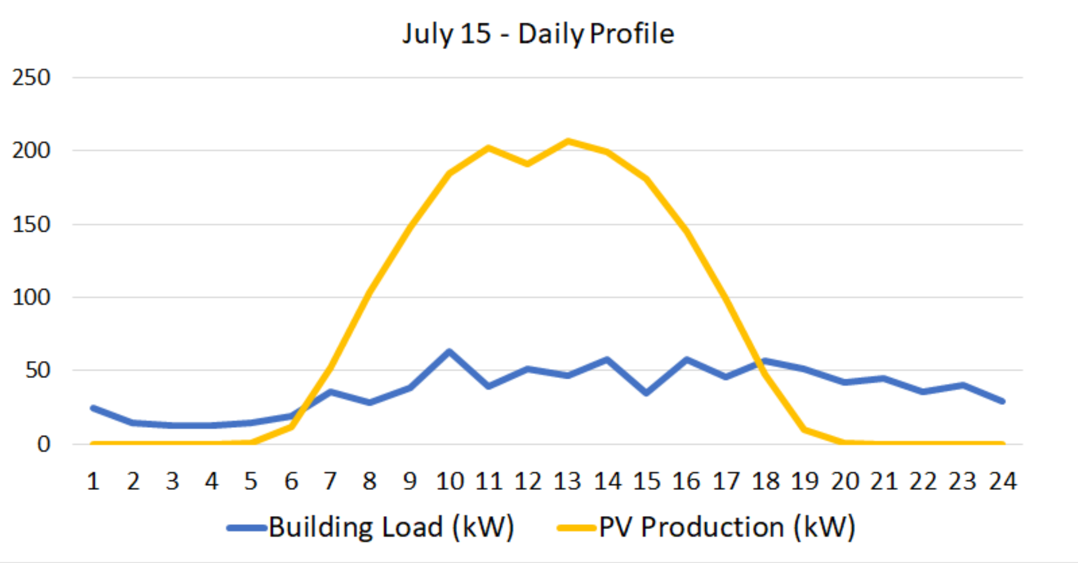
WEEKLY MISMATCH – ON SITE PRODUCTION vs USE

Passive building

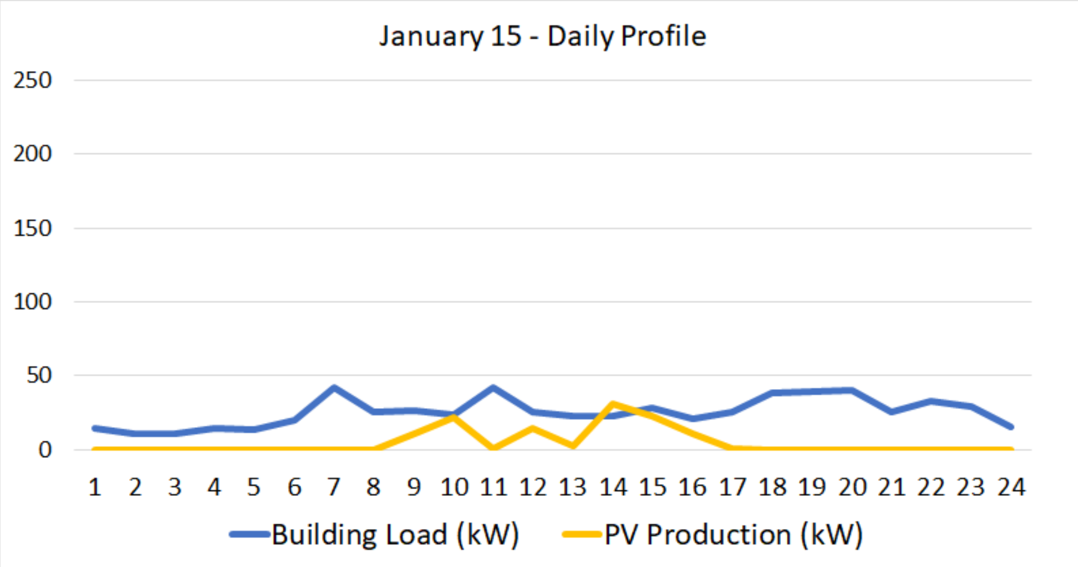


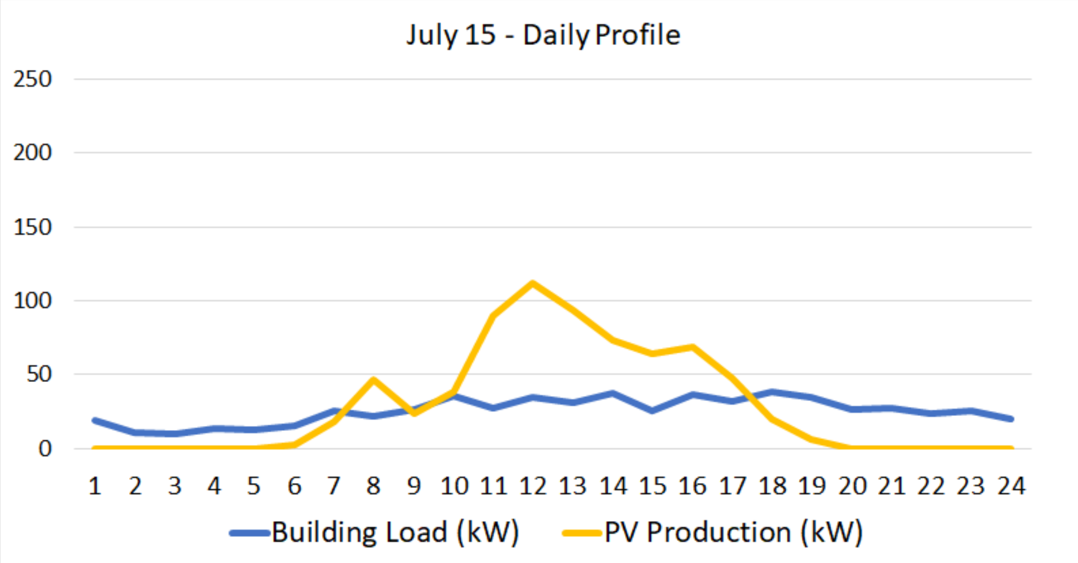
Daily Analysis – January & July





Baseline building

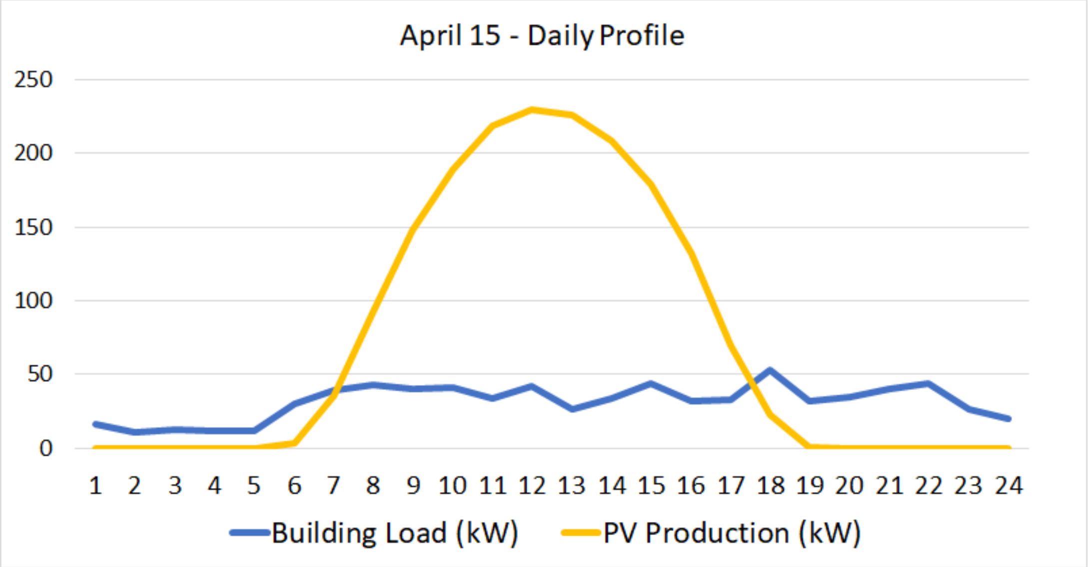


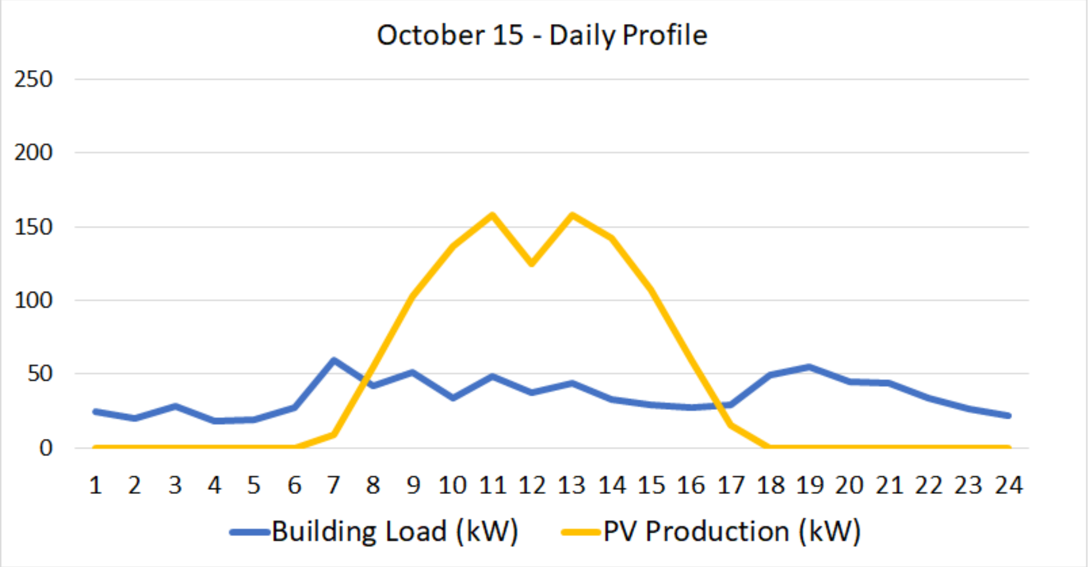


Passive building

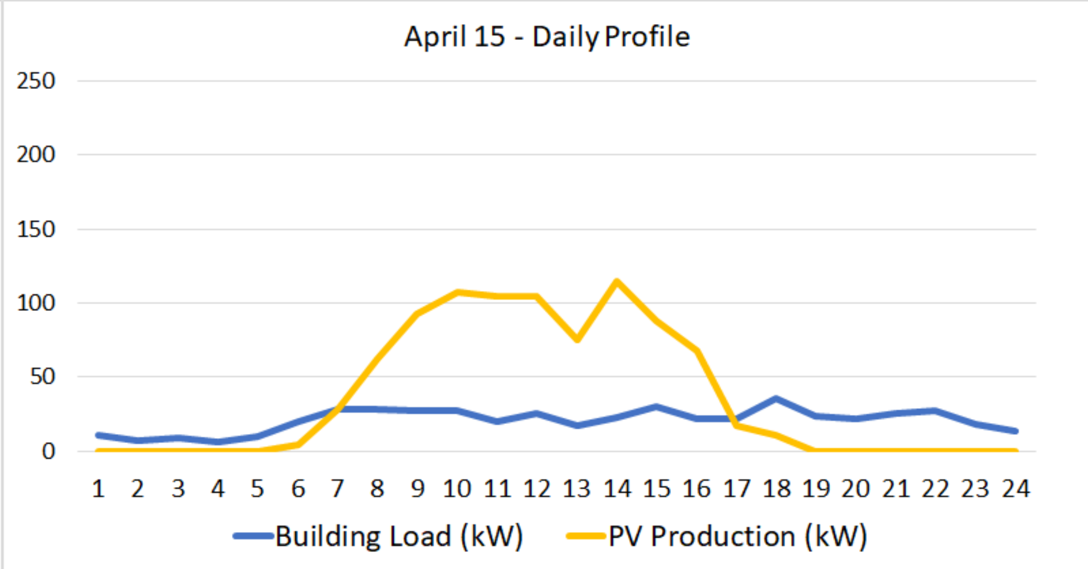
CASE STUDY

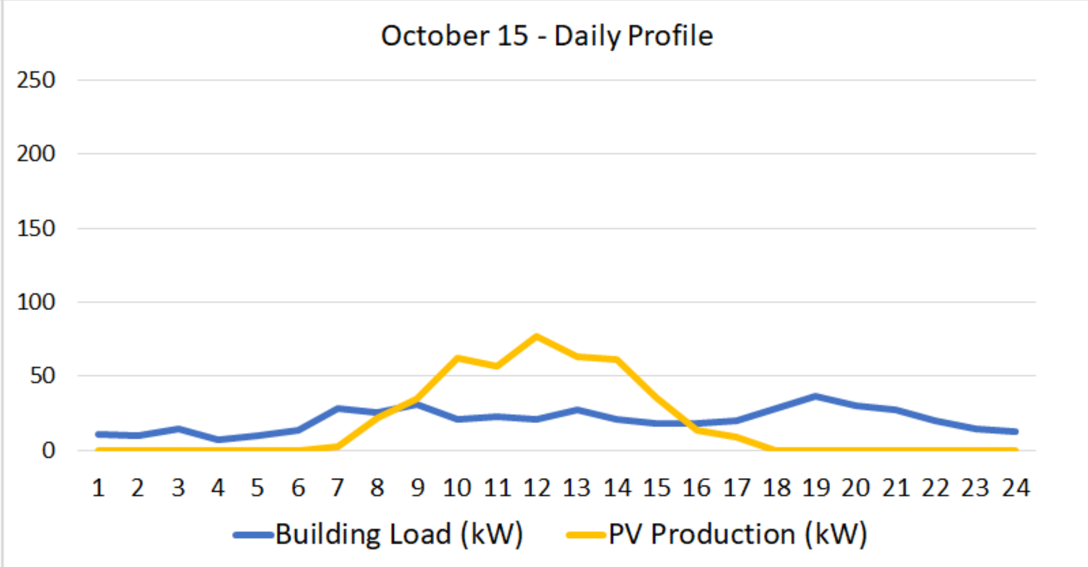
Daily Analysis – April & October





Baseline building



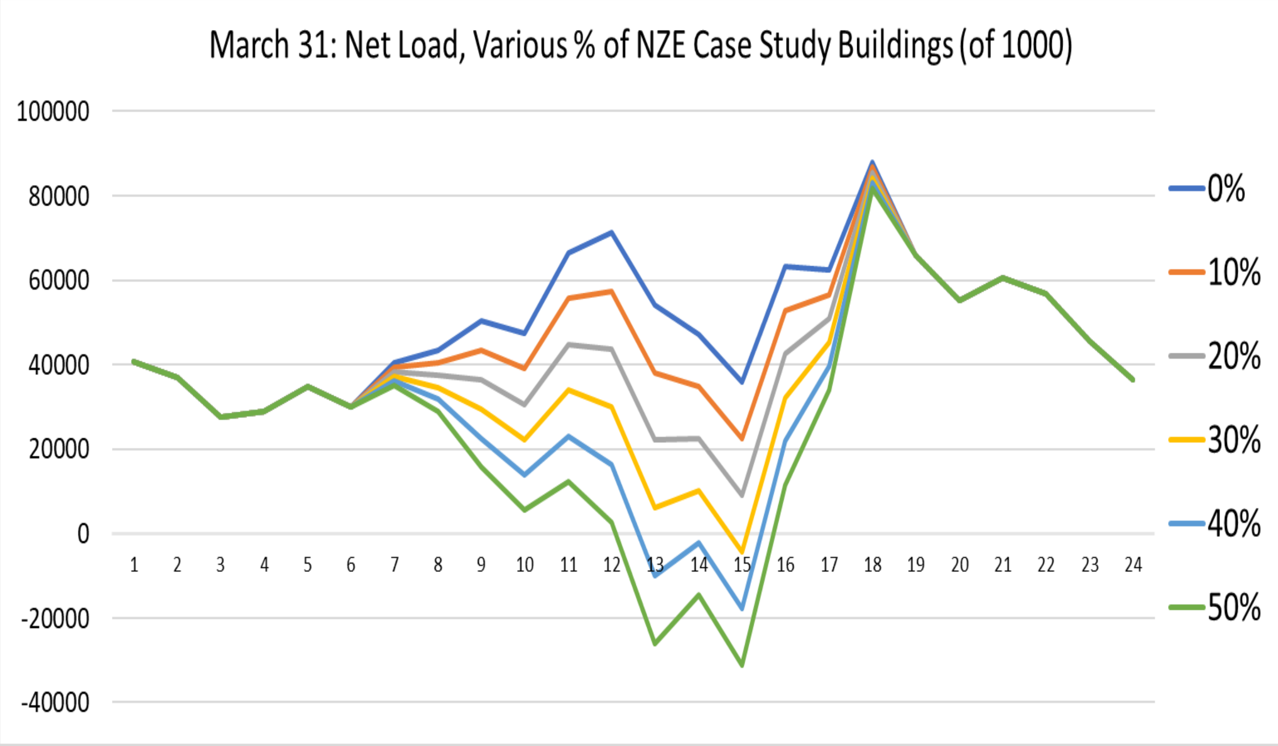


Passive building

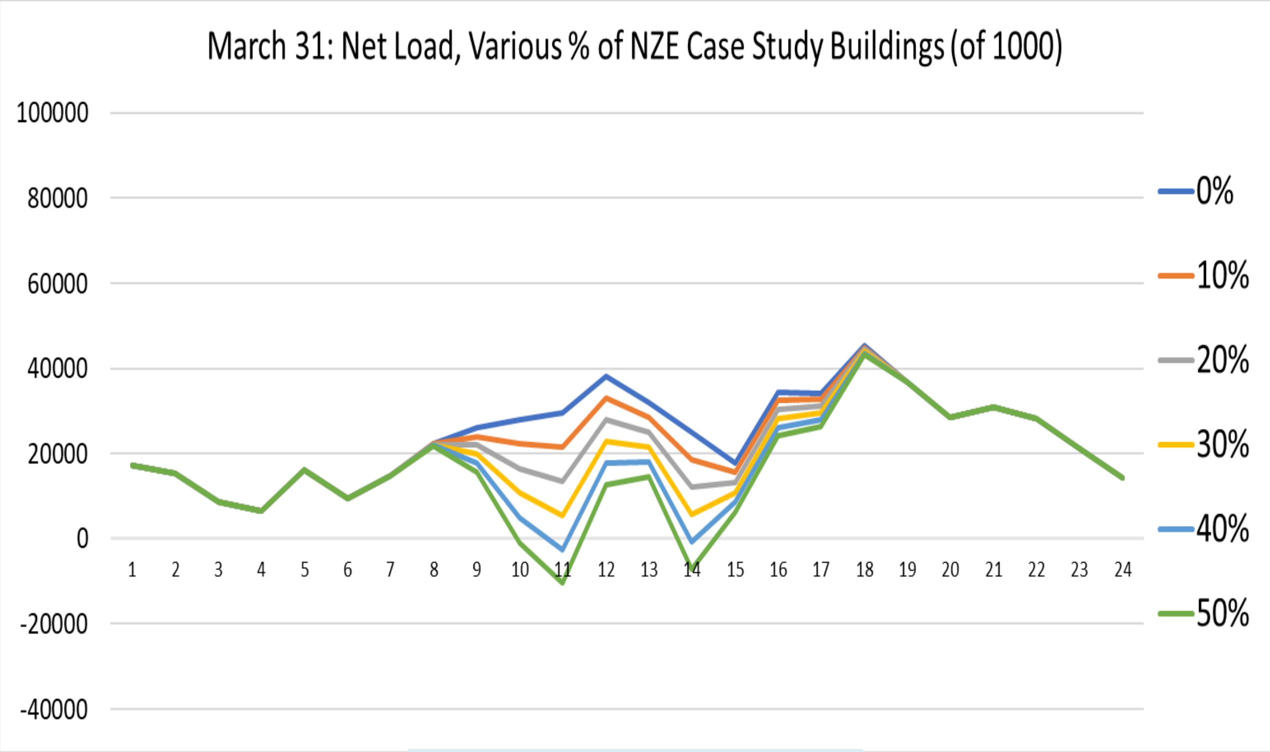
Net Load/ Ramping Analysis

Of 1000 NZE Buildings

- **Example plotting various %'s of NZE buildings on grid**
- Few energy generation types can match this ramp.
- Curtailment occurs when 'net load' hits the flat-line baseload.



Baseline building



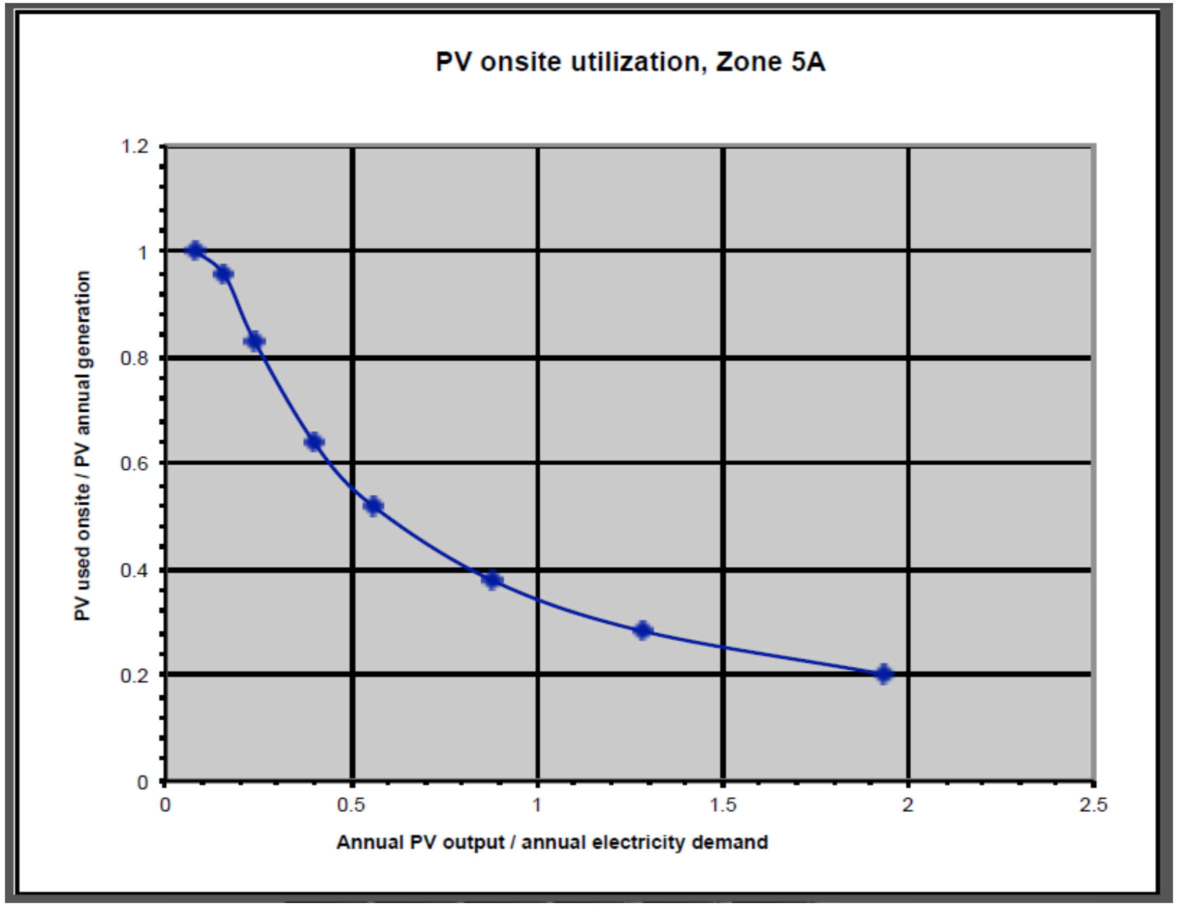
Passive building

Greatest 3-hr ramp ~3x higher than passive building

CASE STUDY

PV UTILIZATION

	Site Energy Use (kWh/yr)	PV Production (kWh/yr)	Utilization Factor (%)	On-site Coverage (kWh/yr)	Covered by Grid (kWh/yr)
CODE/BASELINE	352,162	352,187	36%	126,788	225,374
PHIUS+	197,636	198,234	36%	71,364	126,272

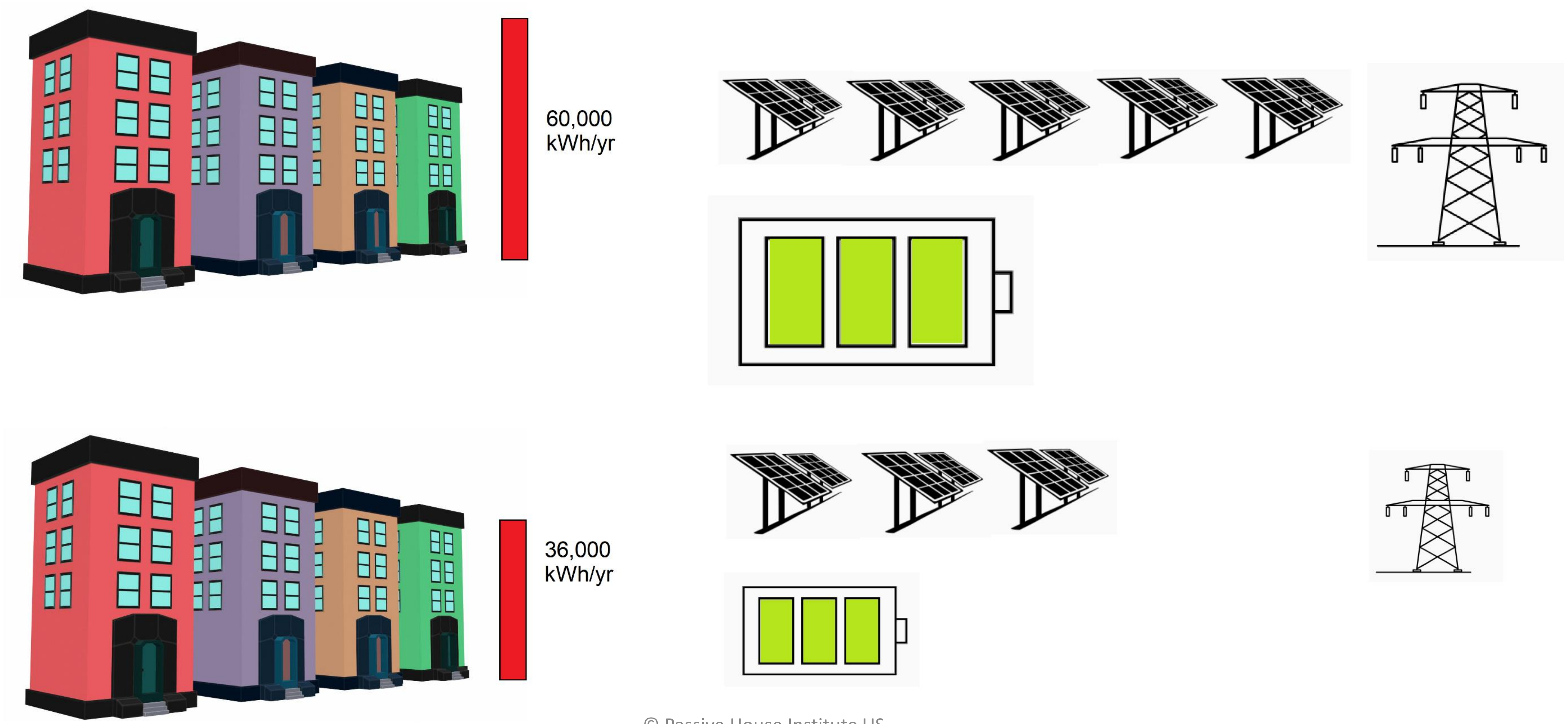


Two ‘NZE’ buildings:
DIFFERENCE in electricity covered by grid =
99,102 kWh/yr!

That’s half the annual energy use of the PHIUS+ building.

The Ripple Effect of Conservation

Conservation means less generation, less storage, and less transmission capacity needed

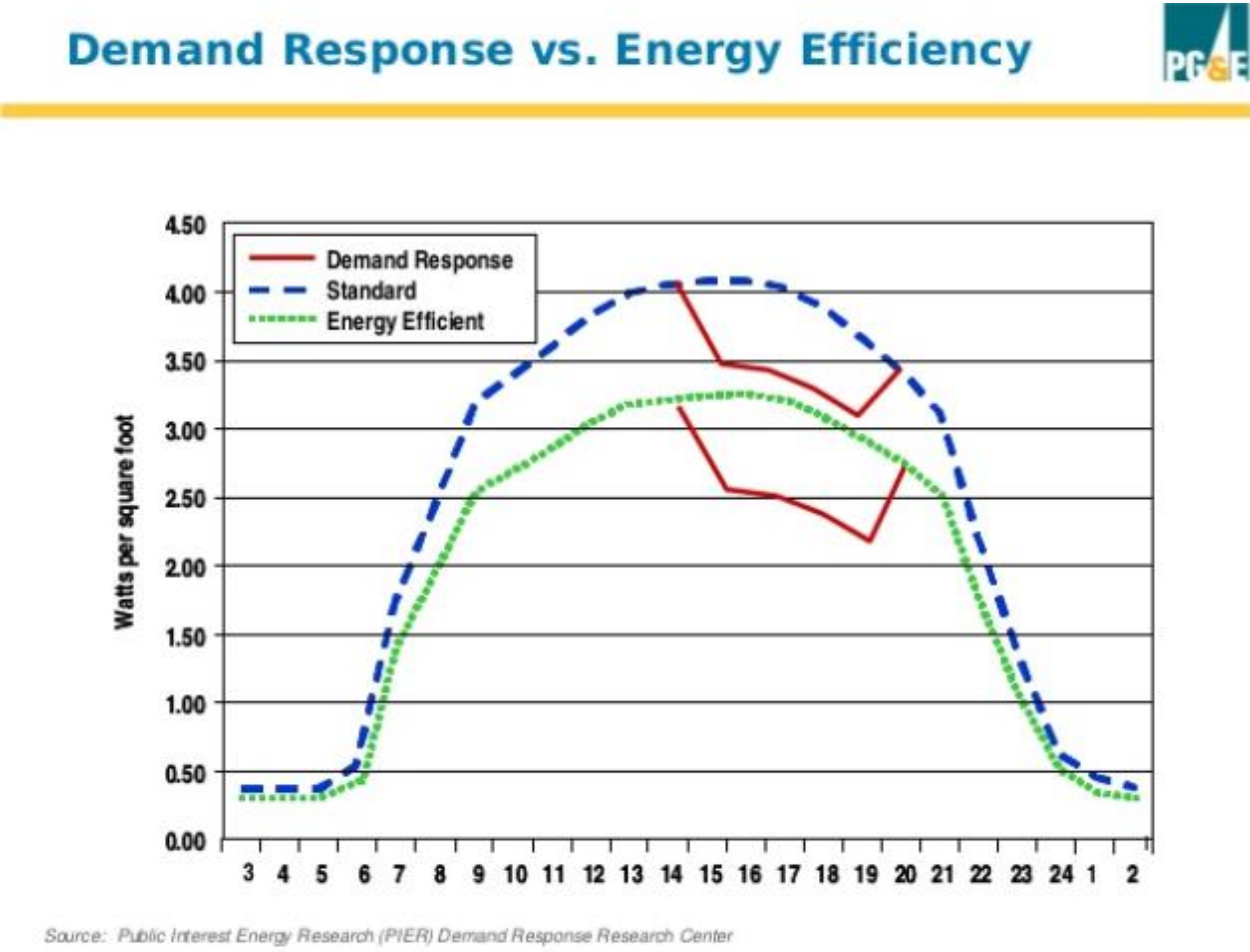


DEMAND RESPONSE

Instead of calling on new generation during peaks, demand response enables the demand side of the equation to optimize resources.

Energy efficiency may lower the peak, but it doesn't necessarily change the shape.

Customers are paid significant $ to sign on to these programs, as it reduces the need for the grid to start up "peaker plants" - $$



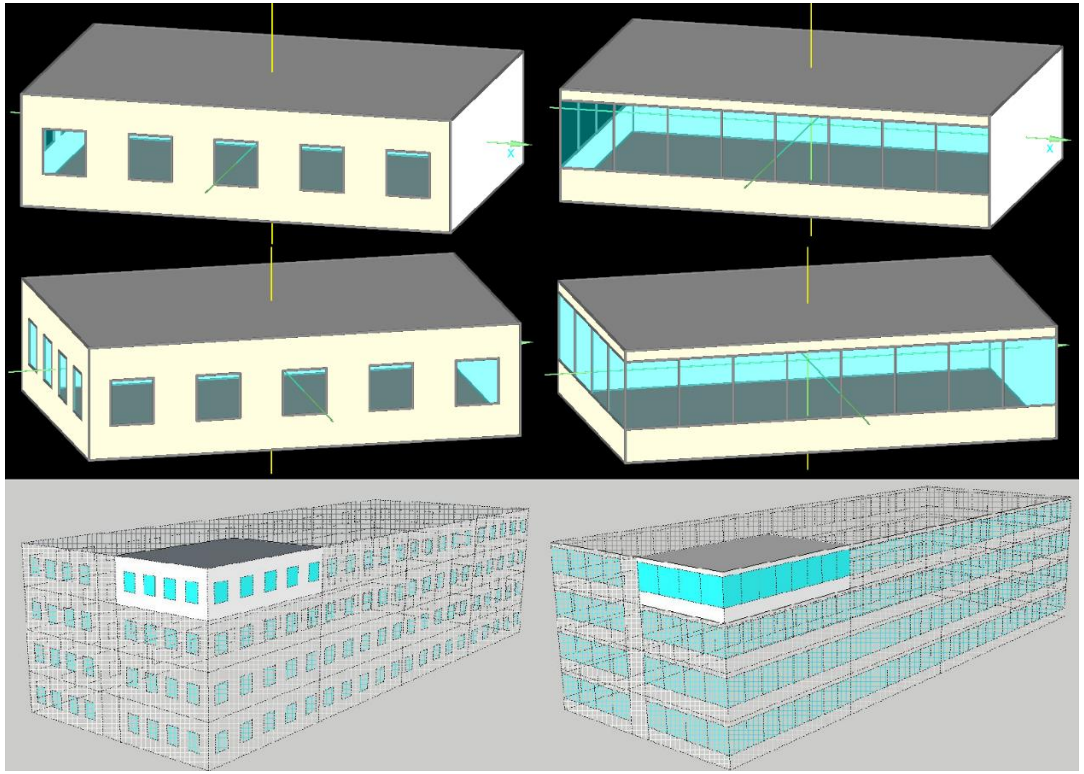
DEMAND RESPONSE

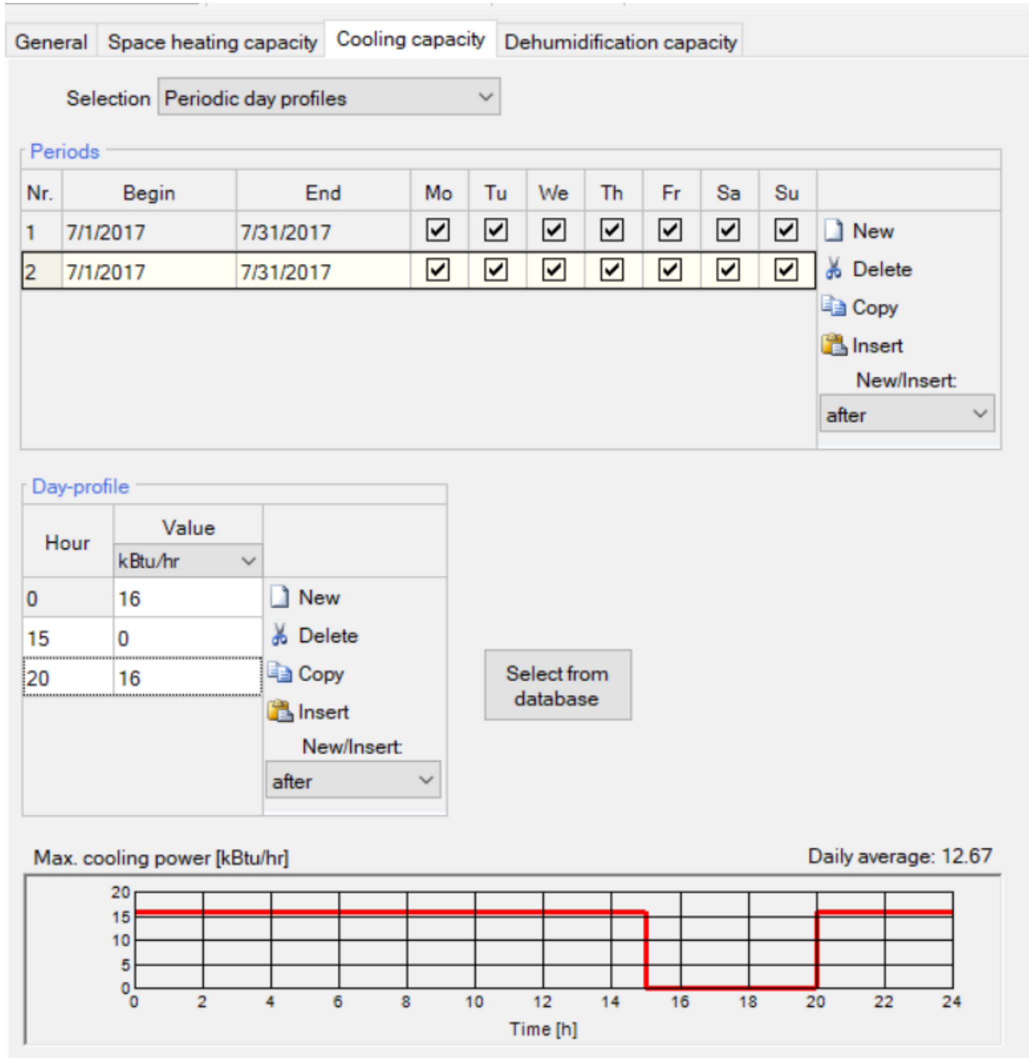
BUT – Passive buildings can potentially shift and change the load shape!

Passive Buildings – Can alllow for adjustments in space conditioning based on grid responses, and float through peak times with little to no impact on comfort.

DEMAND RESPONSE

Ex WUFIplus simulation: **Remove space cooling/dehumidification capacity from 3pm-8pm**
July 1-July 31 – Chicago O'Hare
Single SW corner unit of study building (20% & 60% WWR)
Internal Loads: 'Single Family – Weekday'

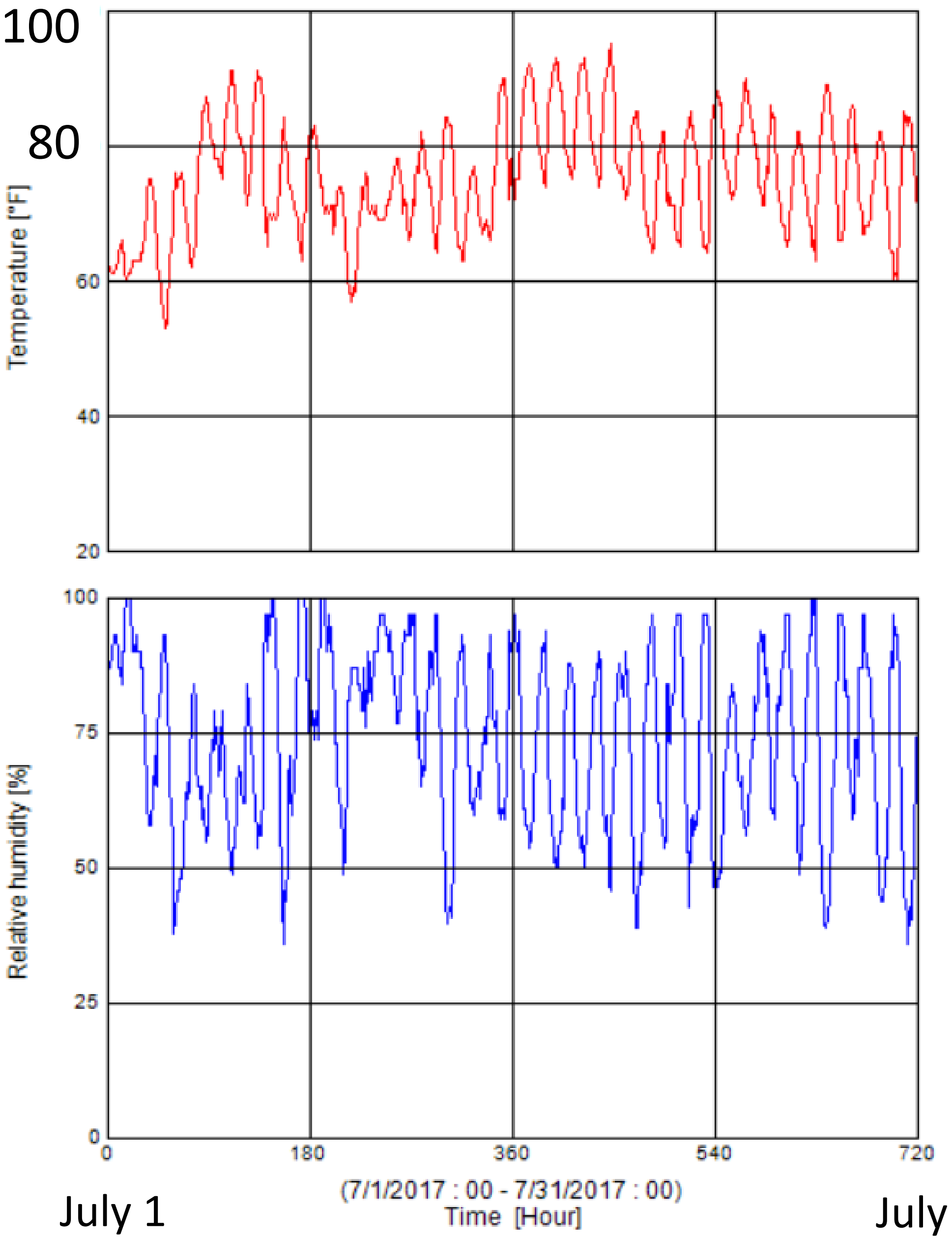




DEMAND RESPONSE

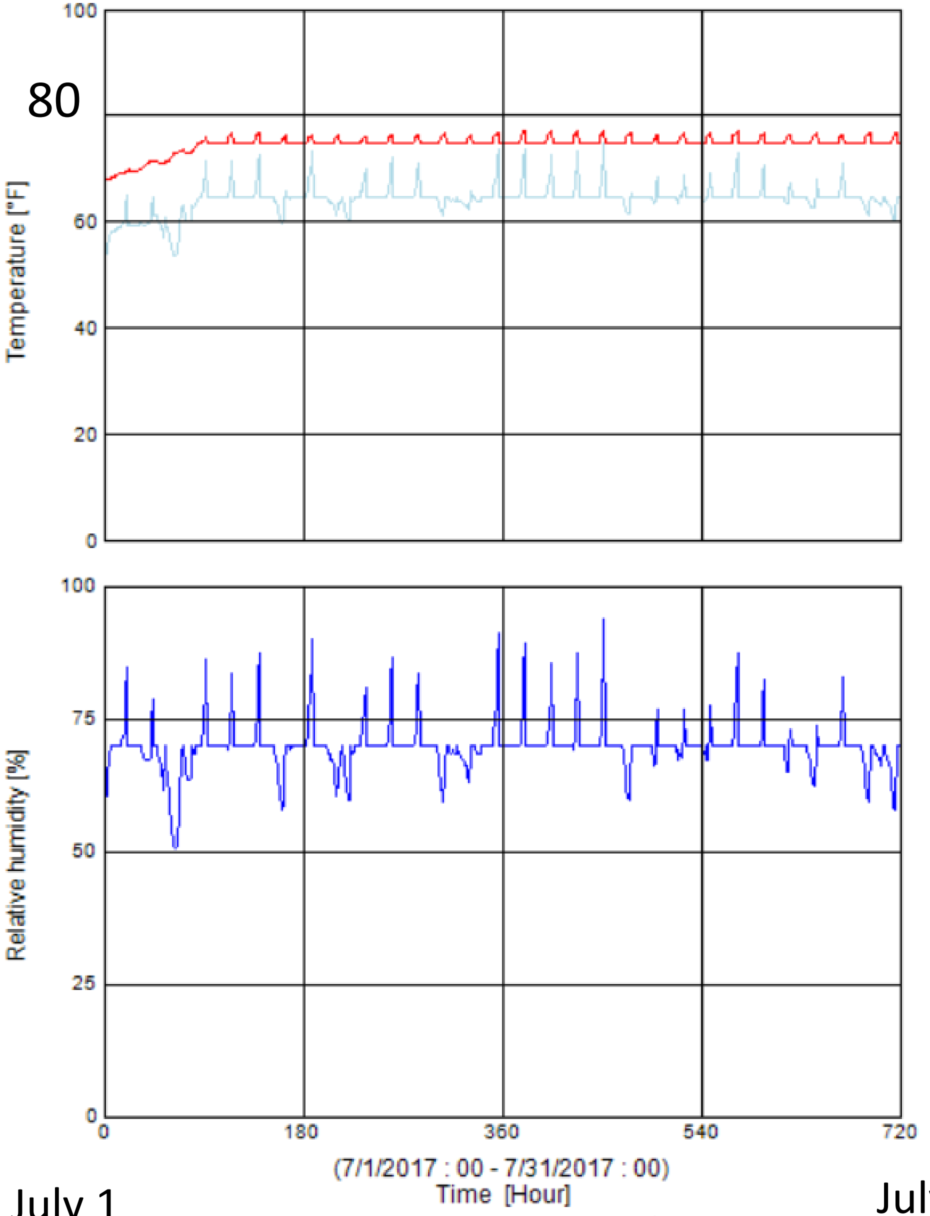
Starting set-point for cooling 75F

Ambient Conditions



July 1 July 31

20% WWR

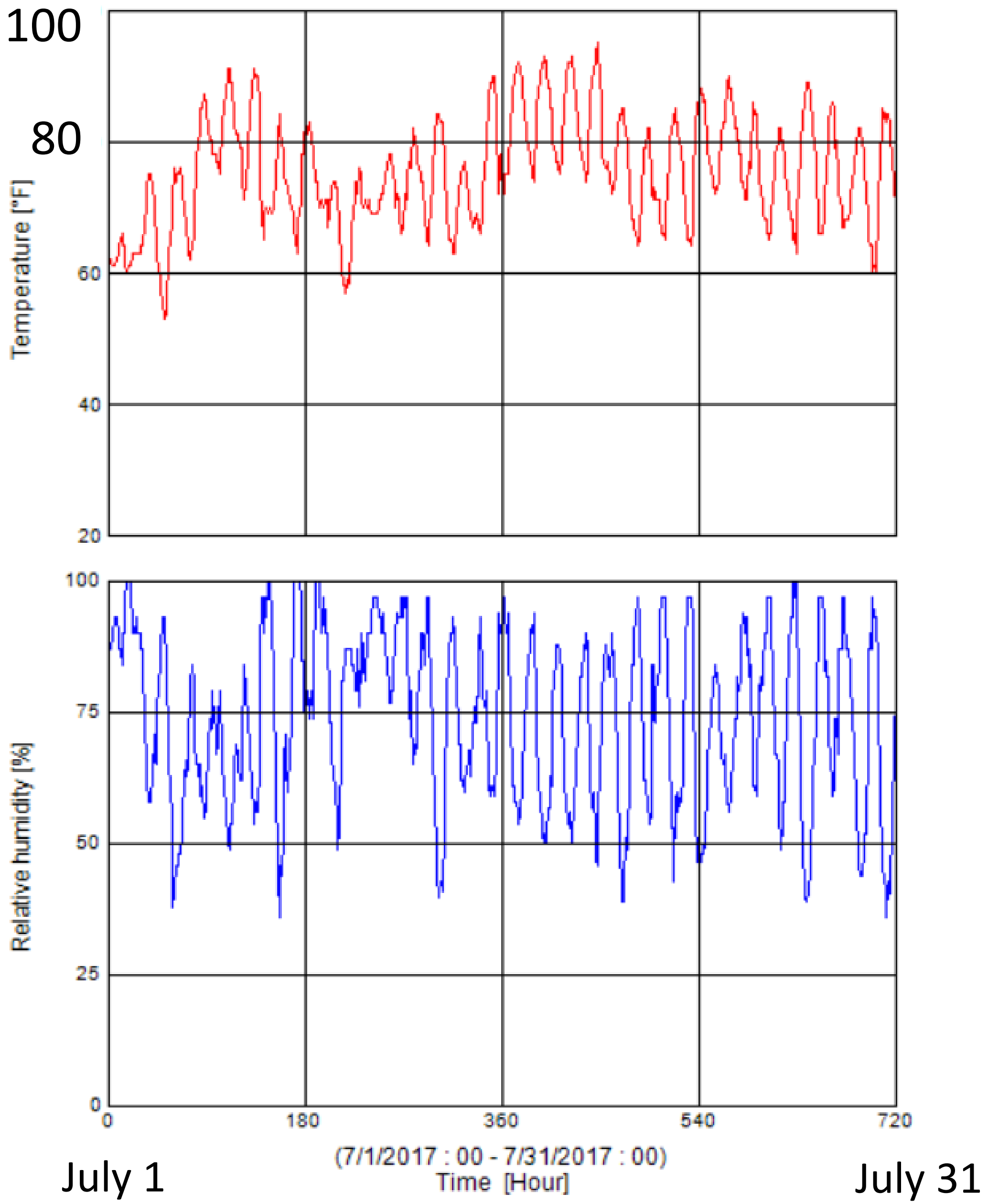


July 1 July 31

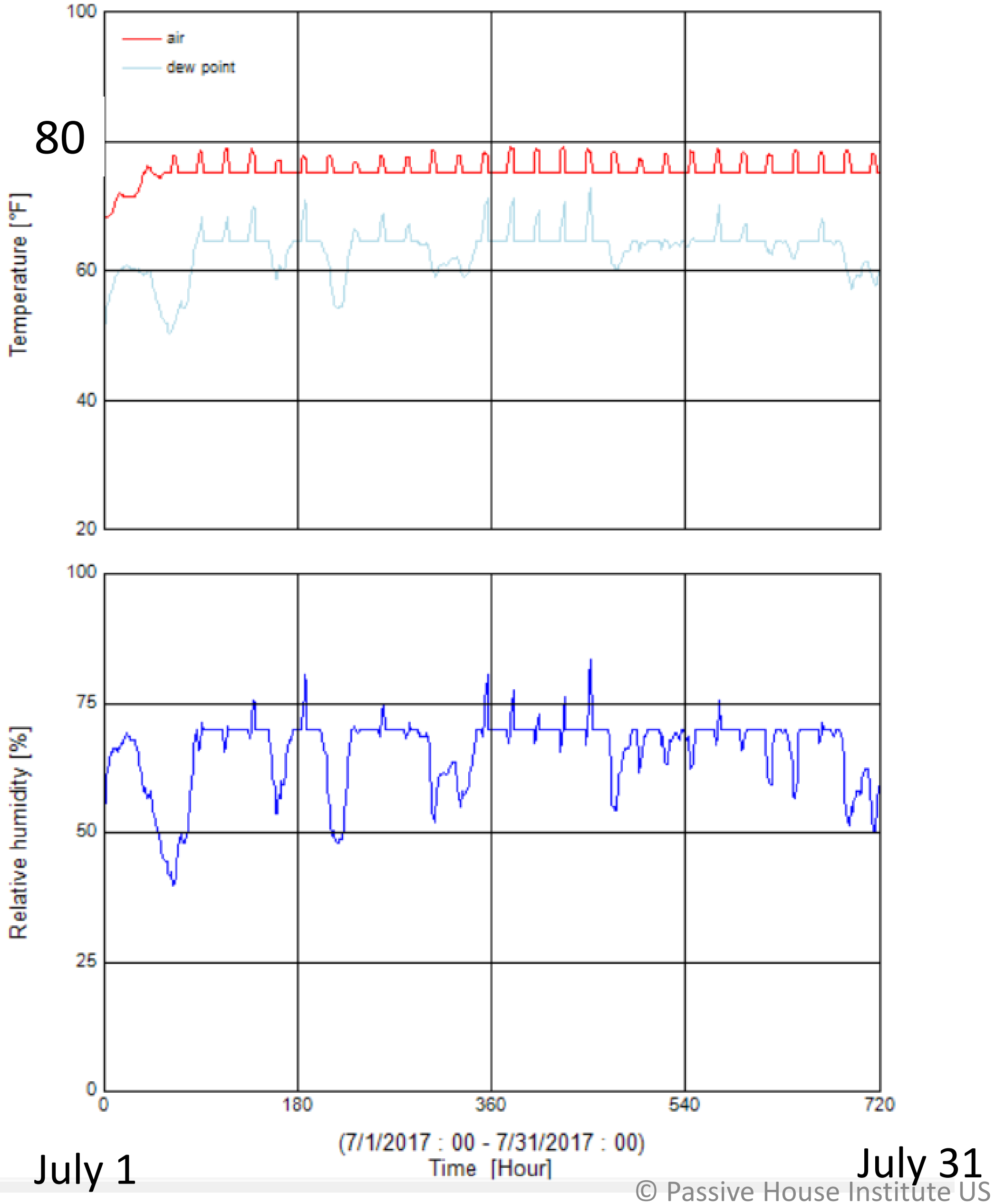
DEMAND RESPONSE

Starting set-point for cooling 75F

Ambient Conditions



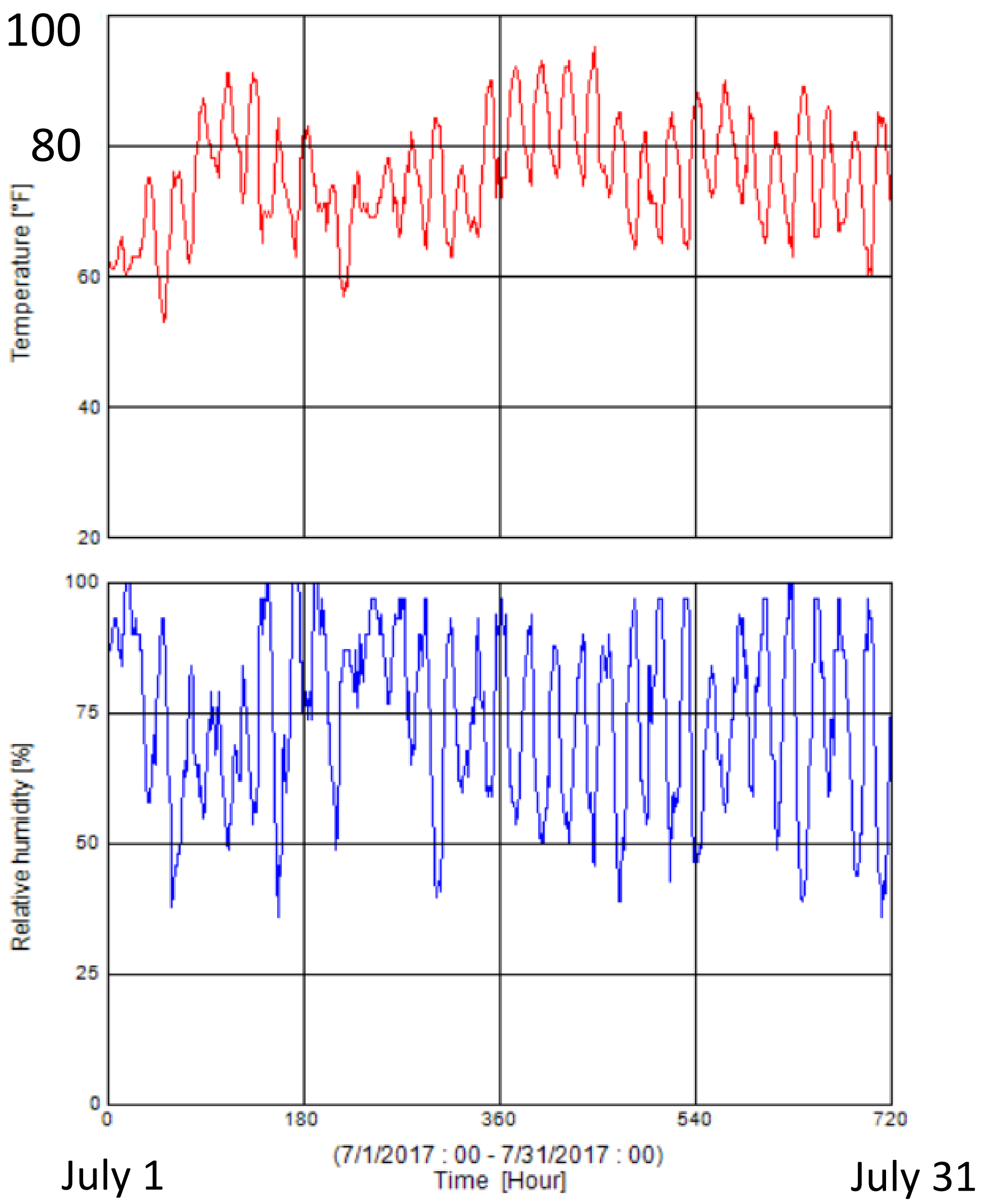
60% WWR



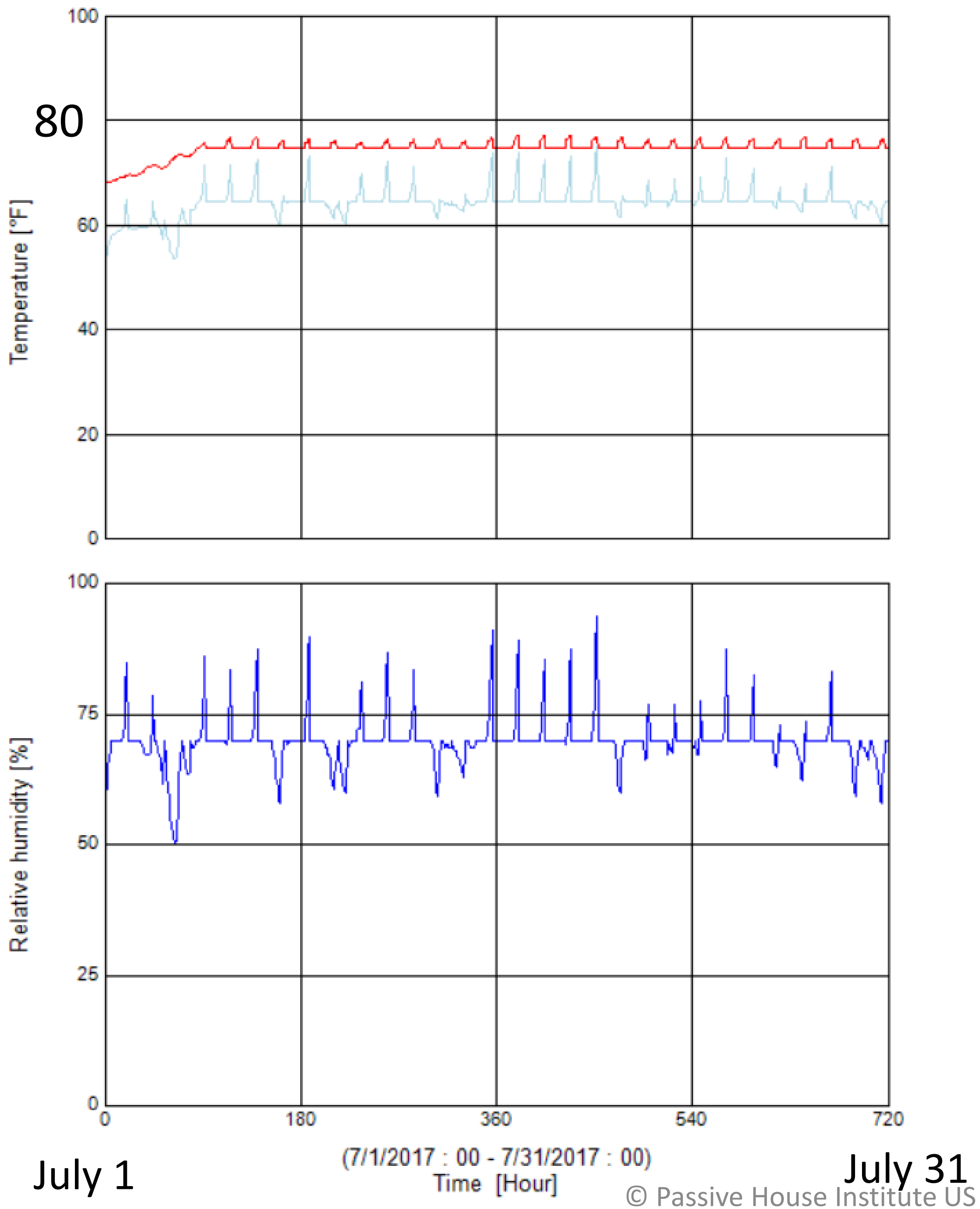
DEMAND RESPONSE

Starting set-point for cooling 70F

Ambient Conditions



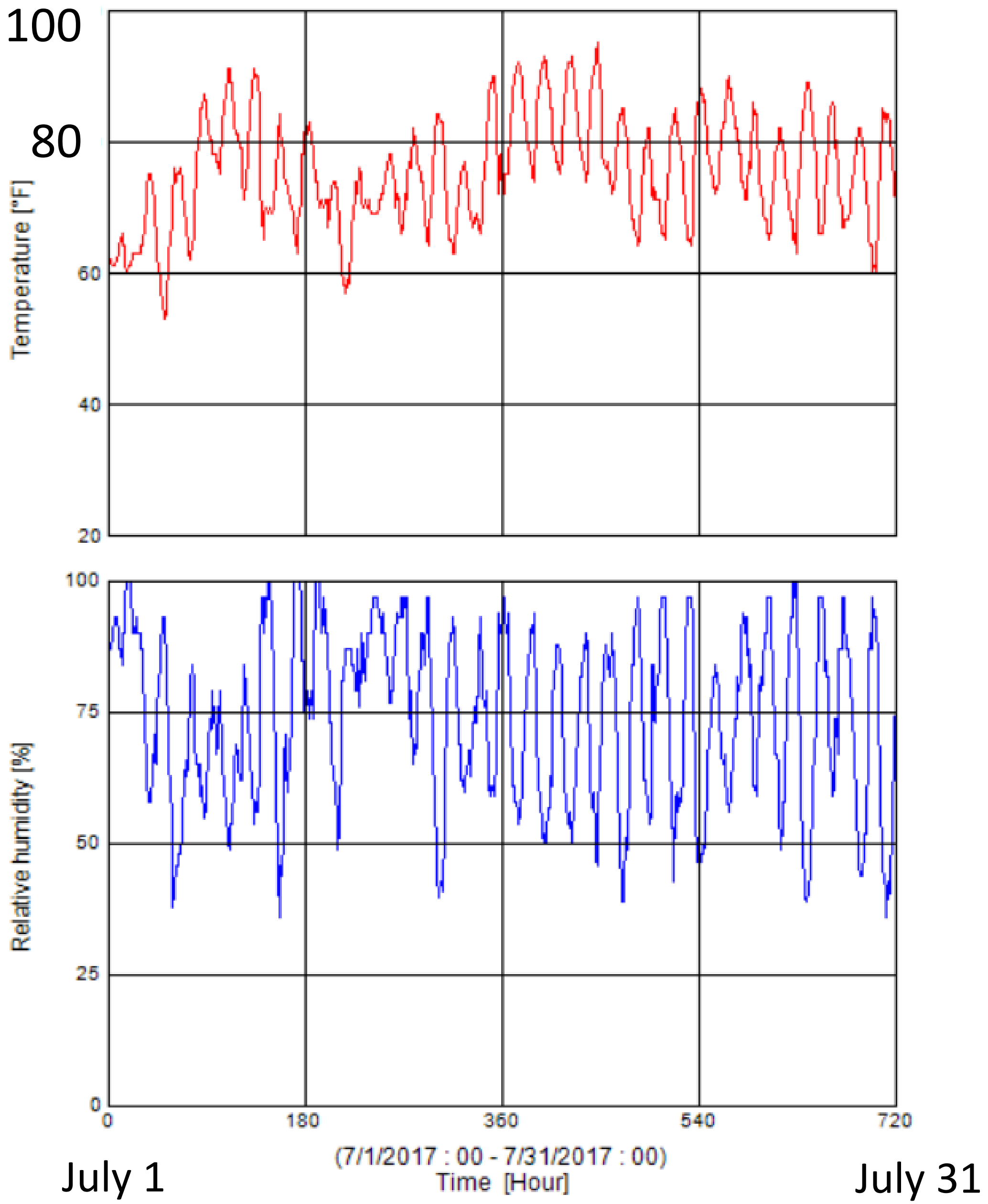
20% WWR



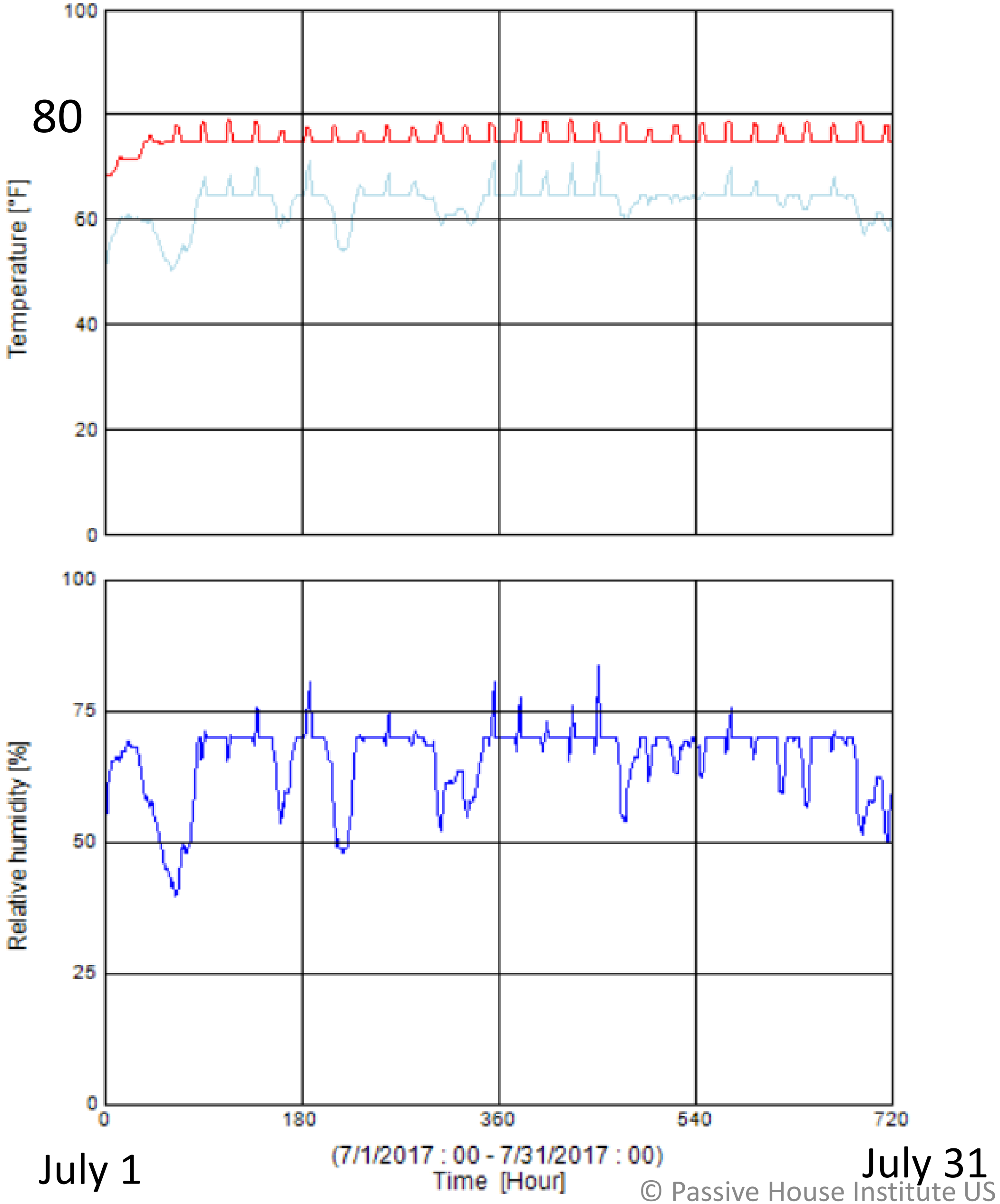
DEMAND RESPONSE

Starting set-point for cooling 70F

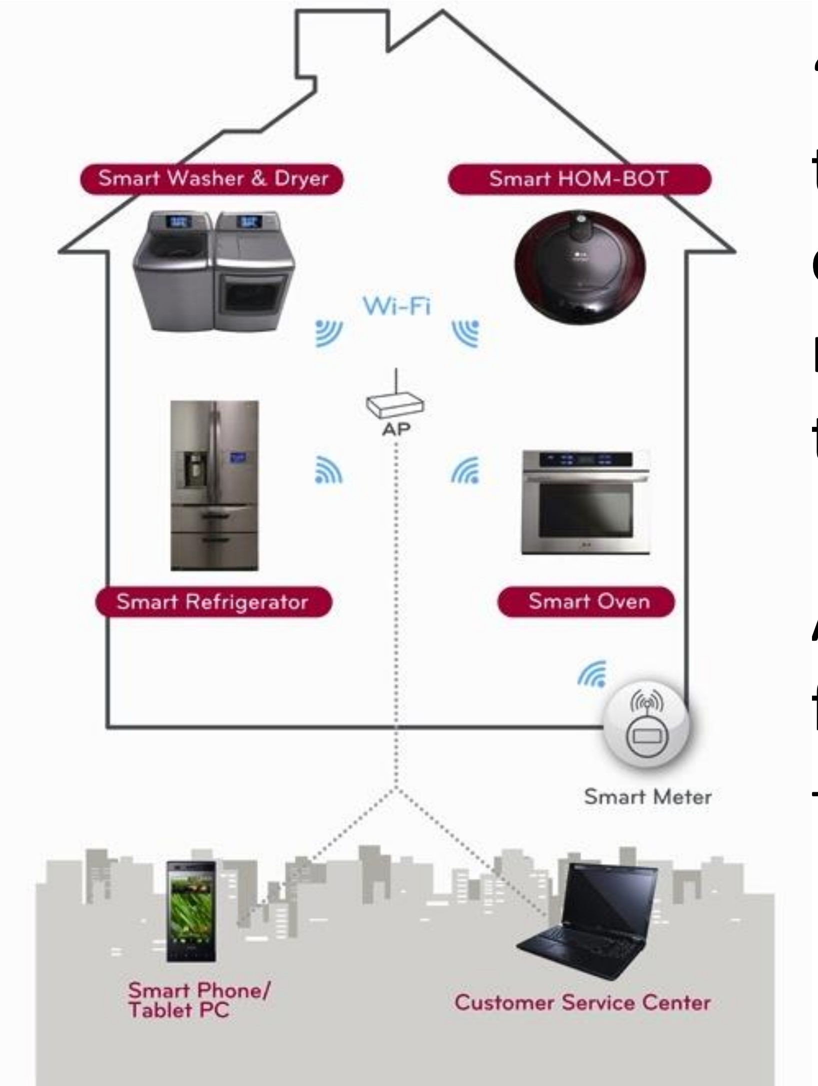
Ambient Conditions



60% WWR



GRID CONNECTED APPLIANCES



‘Smart’ appliances, connected to networks, allow grid operators to re-work and manage the demand side of the equation.

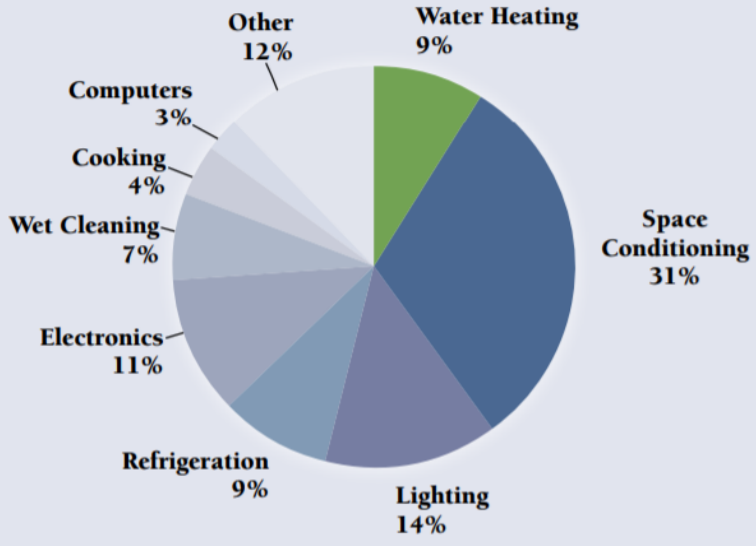
Appliances respond to signals from grid:

- Maybe low price, low load, etc.

Sure, it's smart, but is it a good conversationalist?

CONTROL ELECTRIC WATER HEATERS

Residential Electricity Demand by End-Use



Source: Department of Energy (2012). Buildings Energy Data Book. *Table 2.1.5.*

U.S. Water Heaters by Region (×1,000)

	US	North-east	Mid-west	South	West
Total	115,745	21,085	25,896	42,893	25,871
Electric	48,607	5,149	8,005	28,363	7,090
Market Share	42%	24%	31%	66%	27%

Water heating = 9% of total elec load in residential application

Can be 50% or more in passive buildings!

- Stabilize intermittent renewable energy generation
- Act as storage and provide ancillary services (frequency regulation) for the grid.

<u>Example calc:</u>
Water Heater: 4000 kWh/yr
1 kW Wind: ~2000 kWh/yr
1 grid-controlled WH provides balancing for 2 kW wind power.
(typical turbine is 1.5 MW, or 1500 kW, or 750 grid-controlled WH's)

Image Source: Teaching the "Duck" to Fly – Jim Lazar RAP

GRID INDEPENDENCE

Passive Survivability **=** *A building's ability to maintain livable conditions when sources such as electricity, water, or heating fuel are cut off*

Passive Buildings greatly improve Passive Survivability

Assessing Passive Survivability in Multifamily Buildings:
http://www.phius.org/NAPHC2018/Assessing%20Passive%20Survivability_Lisa%20White.pdf?_ga=2.116998854.1549949209.1555946076-364422003.1462897107

ASSESSMENT OVERVIEW - VARIABLES

1) **Window to wall ratio**

   20%, 60%

2) **Building Performance Standards**

   ASHRAE 90.1, PHIUS+ 2015

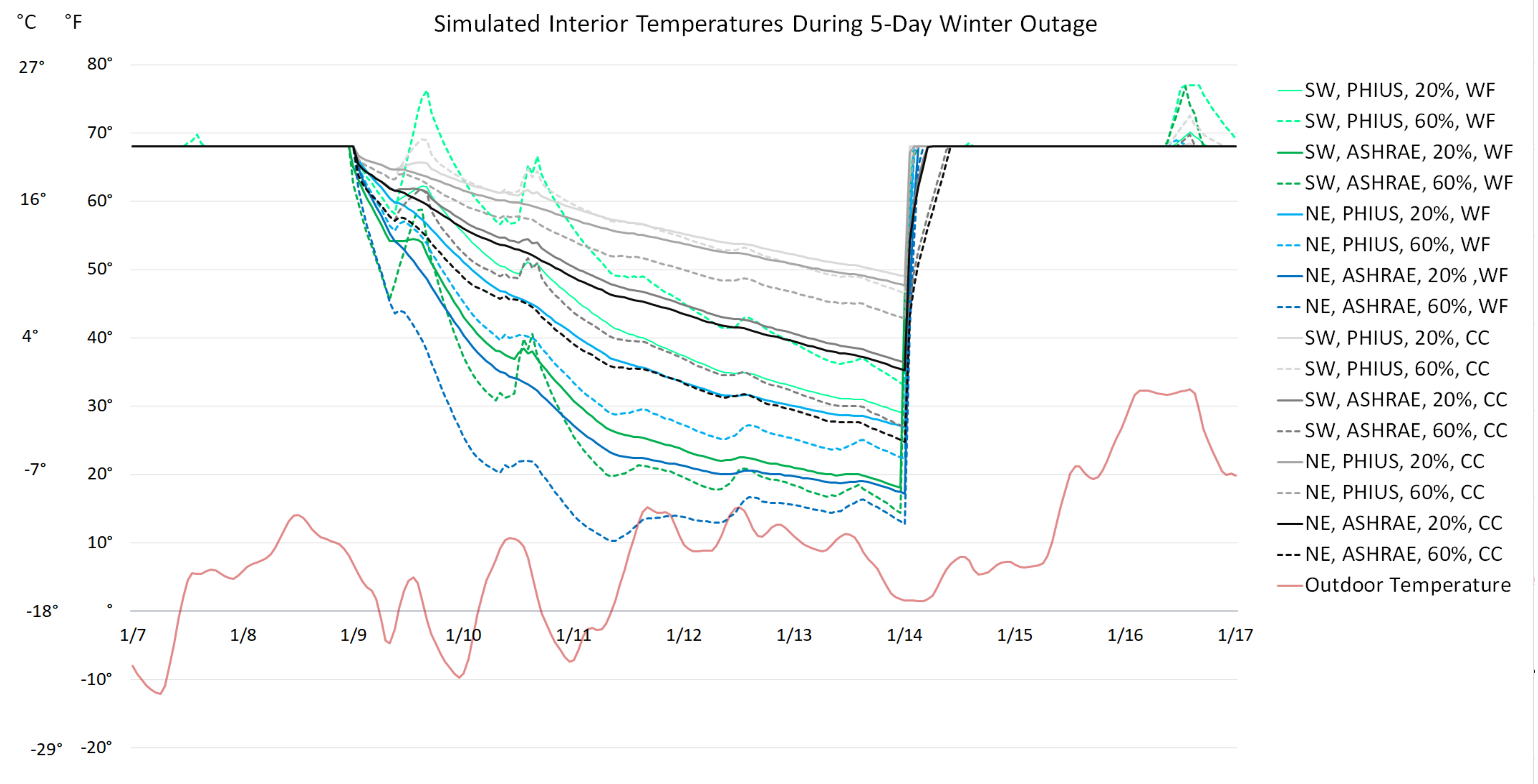
3) **Construction Types / Thermal Mass**

   Wood-framed, concrete/insulated concrete forms

4) **Orientation of units**

   Southwest, Northeast

WINTER RESILIENCE RESULTS



WINTER RESILIENCE RESULTS

Case #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Season	Winter															
Construction Type	Wood framed								Concrete/ICF							
Orientation	SW				NE				SW				NE			
Standard	PHIUS		ASHRAE		PHIUS		ASHRAE		PHIUS		ASHRAE		PHIUS		ASHRAE	
WWR (%)	20	60	20	60	20	60	20	60	20	60	20	60	20	60	20	60
°F dropped in 1 hour	1.8	2.3	1.7	2.7	1.8	2.8	3.1	6.0	1.3	1.8	2.5	4.2	1.3	1.8	2.5	4.2
°F dropped in 4 hours	4.4	5.3	5.7	9.1	4.4	6.8	7.5	13.9	2.3	3.2	4.2	7.1	2.3	3.2	4.2	7.1
°F dropped in 12 hours	6.9	1.0	10.5	7.6	9.1	11.3	15.9	25.0	2.7	1.1	6.2	7.7	3.6	4.2	7.1	10.9
Temp (°F) at 1 AM Day 1	66.2	65.8	63.2	59.8	66.2	65.2	64.9	62.0	66.7	66.2	65.5	63.8	66.7	66.2	65.5	63.8
Temp (°F) at 4 AM Day 1	63.6	62.7	59.2	53.4	63.6	61.2	60.5	54.1	65.8	64.8	63.8	60.9	65.8	64.8	63.8	60.9
Temp (°F) at Noon Day 1	61.1	67.0	54.4	54.9	58.9	56.7	52.1	43.0	65.3	66.9	61.8	60.3	64.4	63.8	60.9	57.1

Decrease in interior temperature after 1 hour, 4 hours, and 12 hours

Picture Courtesy of Lisa White

KEY TAKEAWAYS

- Current operation of the grid is complicated, and consumers acting as generator adds more complexity

- Allowing for quick communication and building response to grid signals is critical

- ‘Conservation-oriented’ Net-Zero buildings should be favored by utilities (over ‘renewable-oriented’) because they:
    - Decrease the mis-match between daily on-site energy generation and use
    - Depend less on the grid overall
    - Have the ability to shed space conditioning loads when called upon (demand response) and minimally impact comfort in the space.

- Conservation has ripple effect throughout the electric grid – lowering the renewable generation capacity needed, storage needed, and transmission capacity needed to handle future electric loads.

- Communication between the grid and building for large appliances and water heaters has a lot of potential.

THANK YOU

QUESTIONS?

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