

*Passive Buildings as
baseline for the
new grid*

Lisa White, Certification Manager
Passive House Institute US

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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

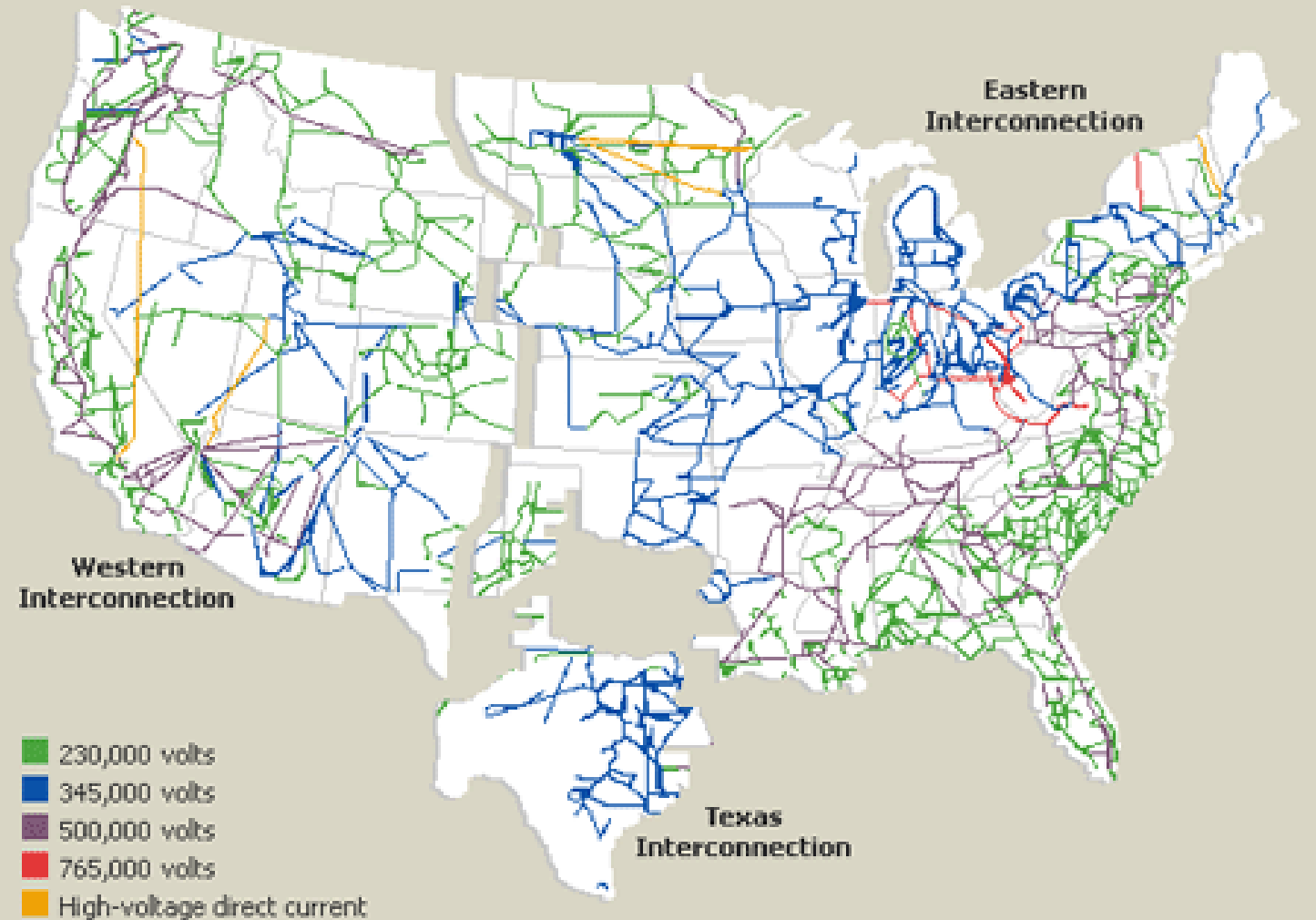
BACKGROUND *on the electric grid*

Need to understand the issues at hand in order to discuss potential solutions!

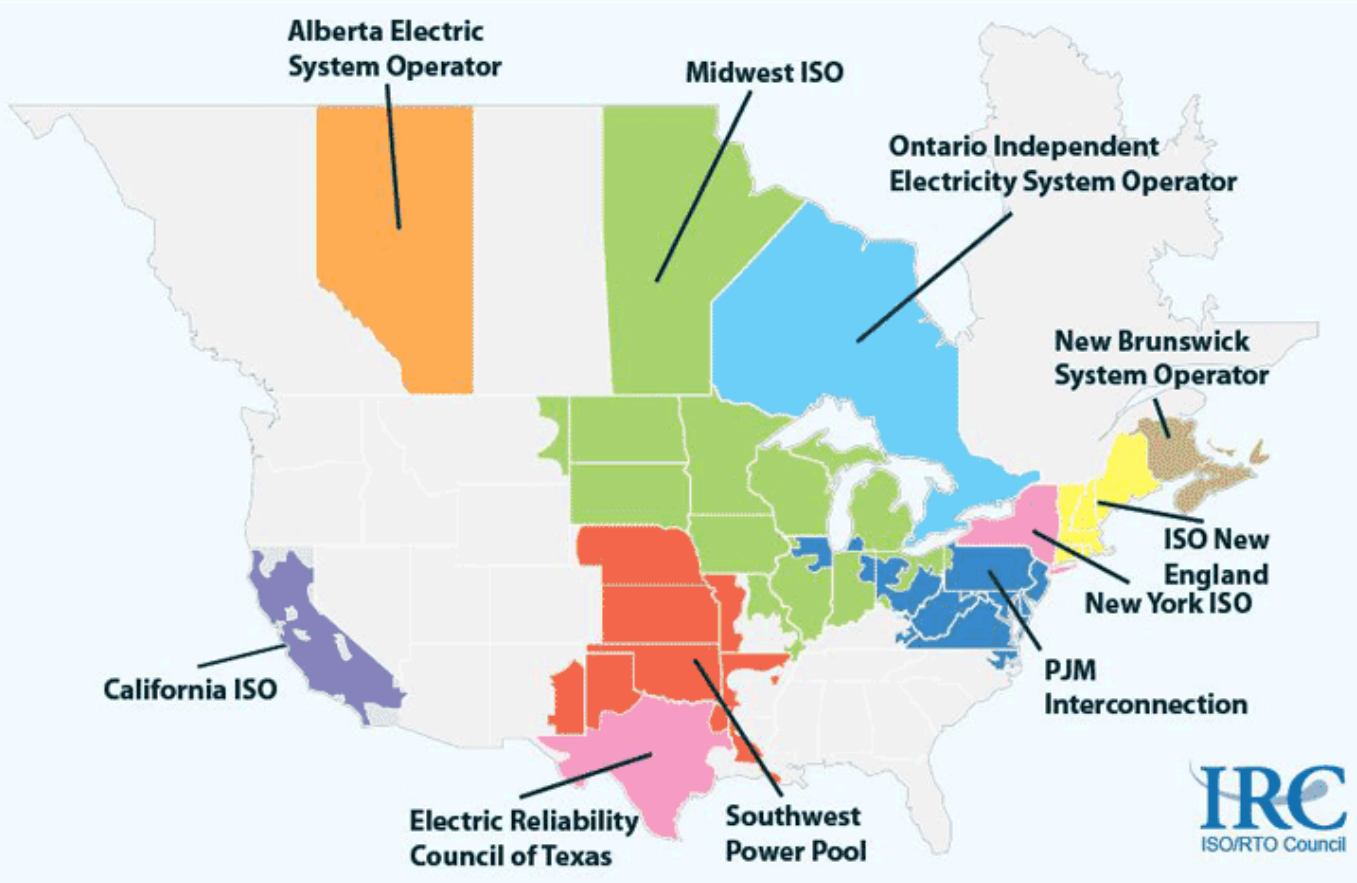
1. What it's made out of
2. Load profiles
3. Generation resources
4. Meeting the electric load

THE ELECTRIC GRID

“The biggest machine on earth”

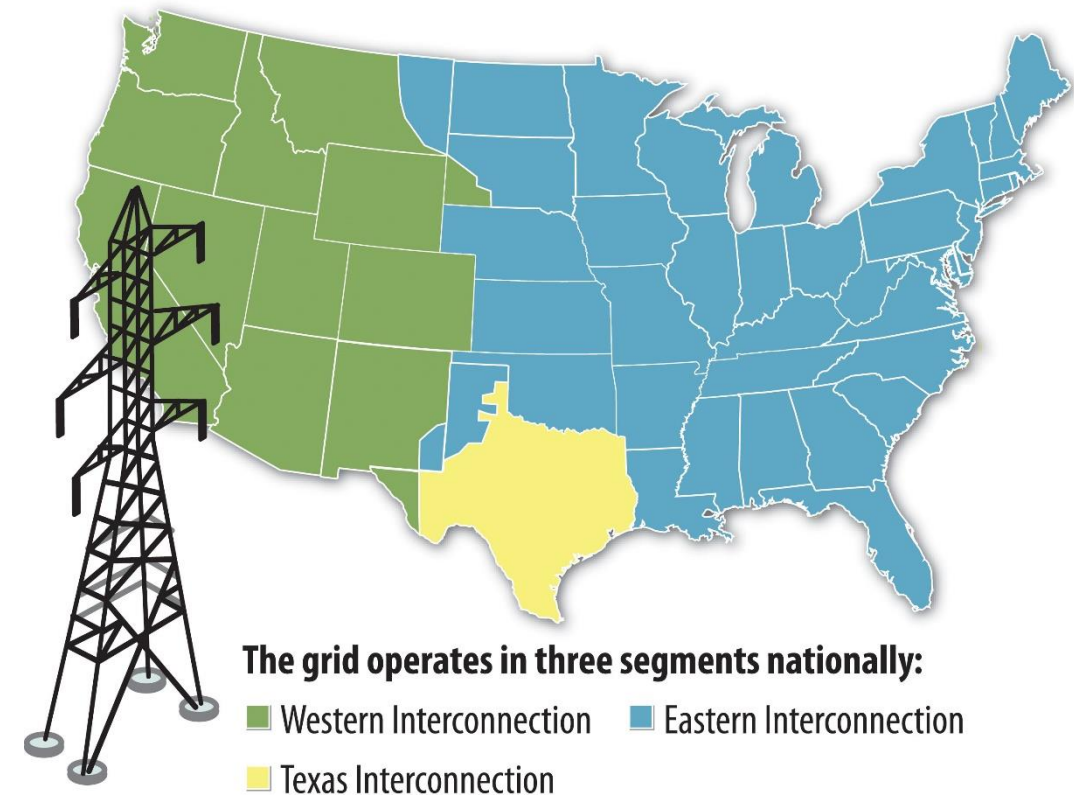


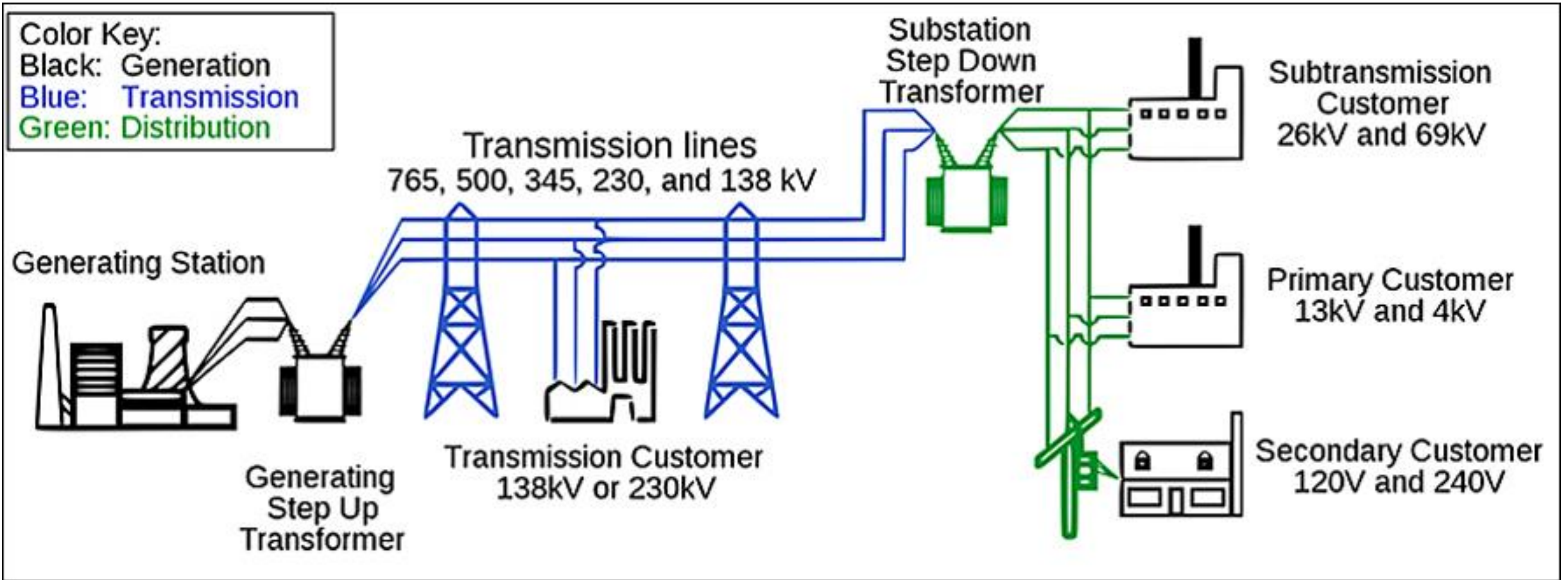
“The National Power Grid,” Microsoft® Encarta® Encyclopedia. <http://encarta.msn.com> © 1993-2004 Microsoft Corporation. All rights reserved.



ISO's (Independent Service Operators)

3 segments



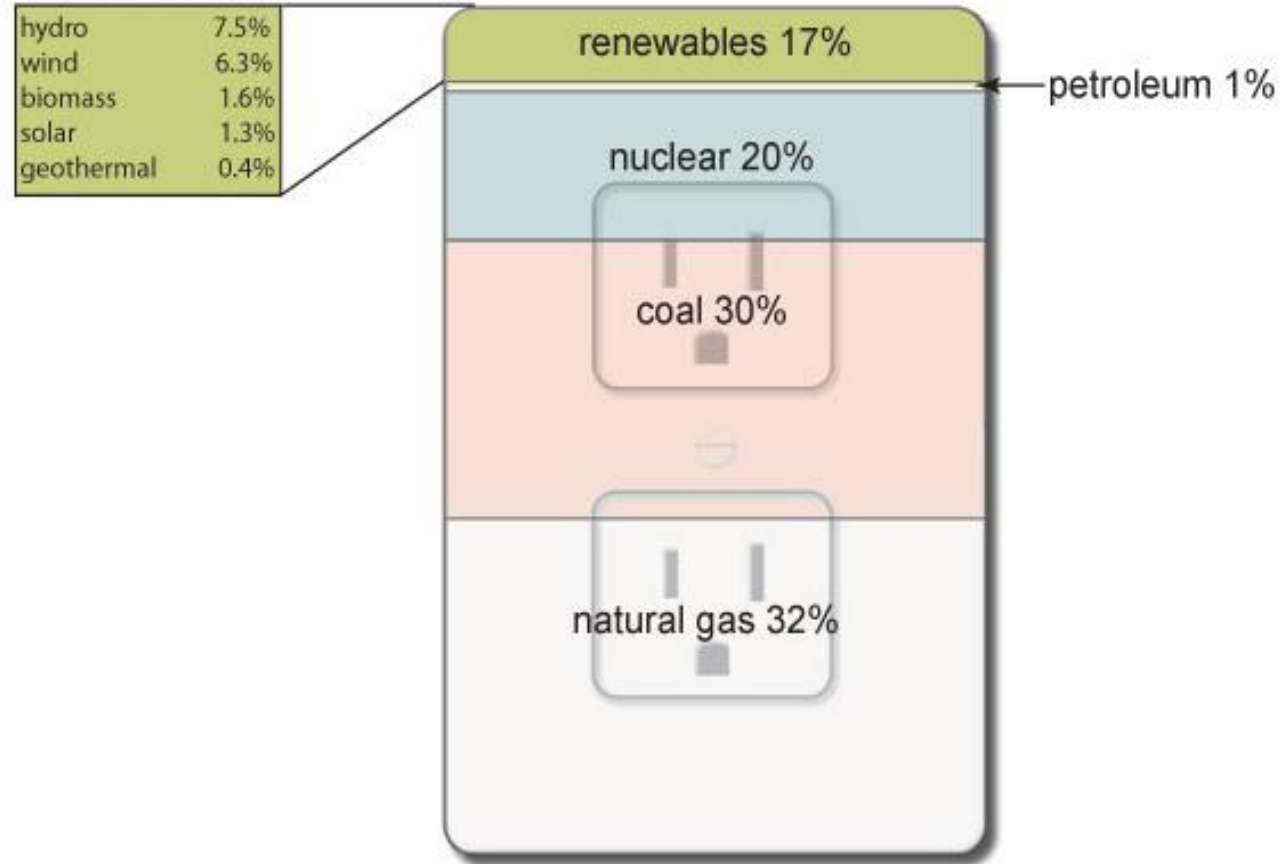


CURRENT INFRASTRUCTURE

GENERATION RESOURCES

Sources of U.S. electricity generation, 2017

Total = 4.01 trillion kilowatthours



Note: Electricity generation from utility-scale facilities.

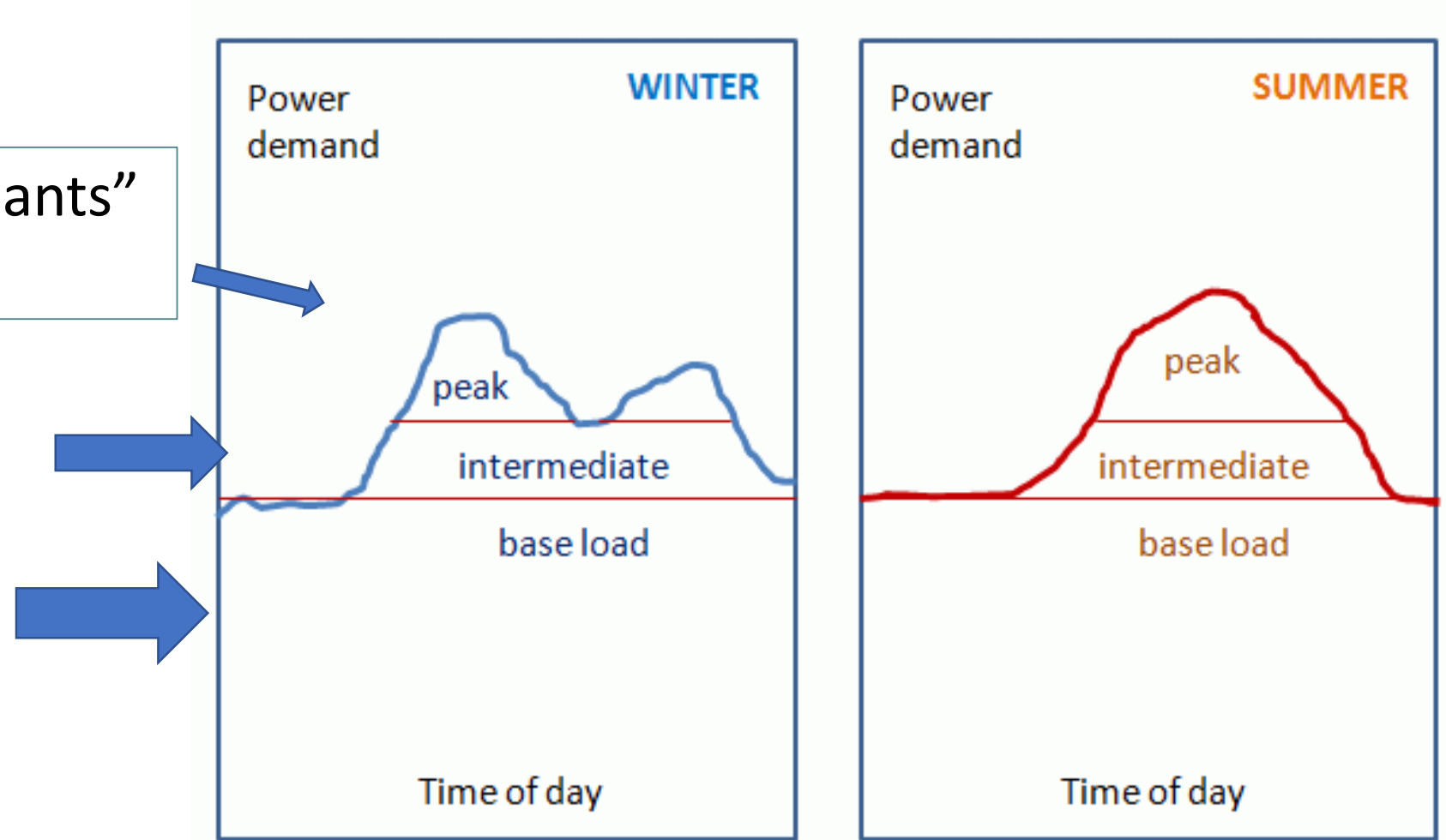
Source: U.S. Energy Information Administration, *Electric Power Monthly*, February 2018, preliminary data

LOAD PROFILES

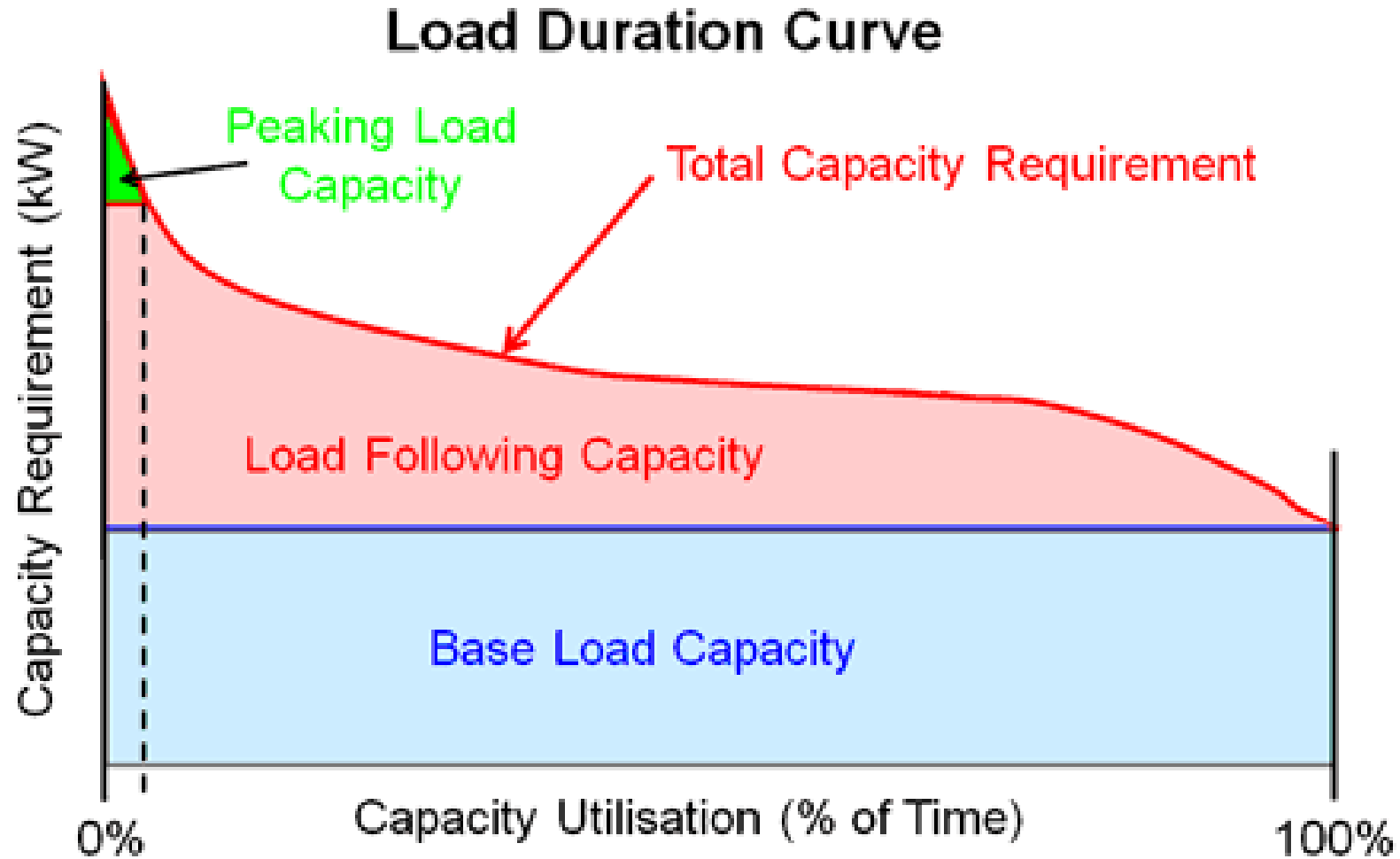
Natural gas “peaker plants”
Hydro

Natural gas CC
Some renewables

Coal
Nuclear
Some renewables

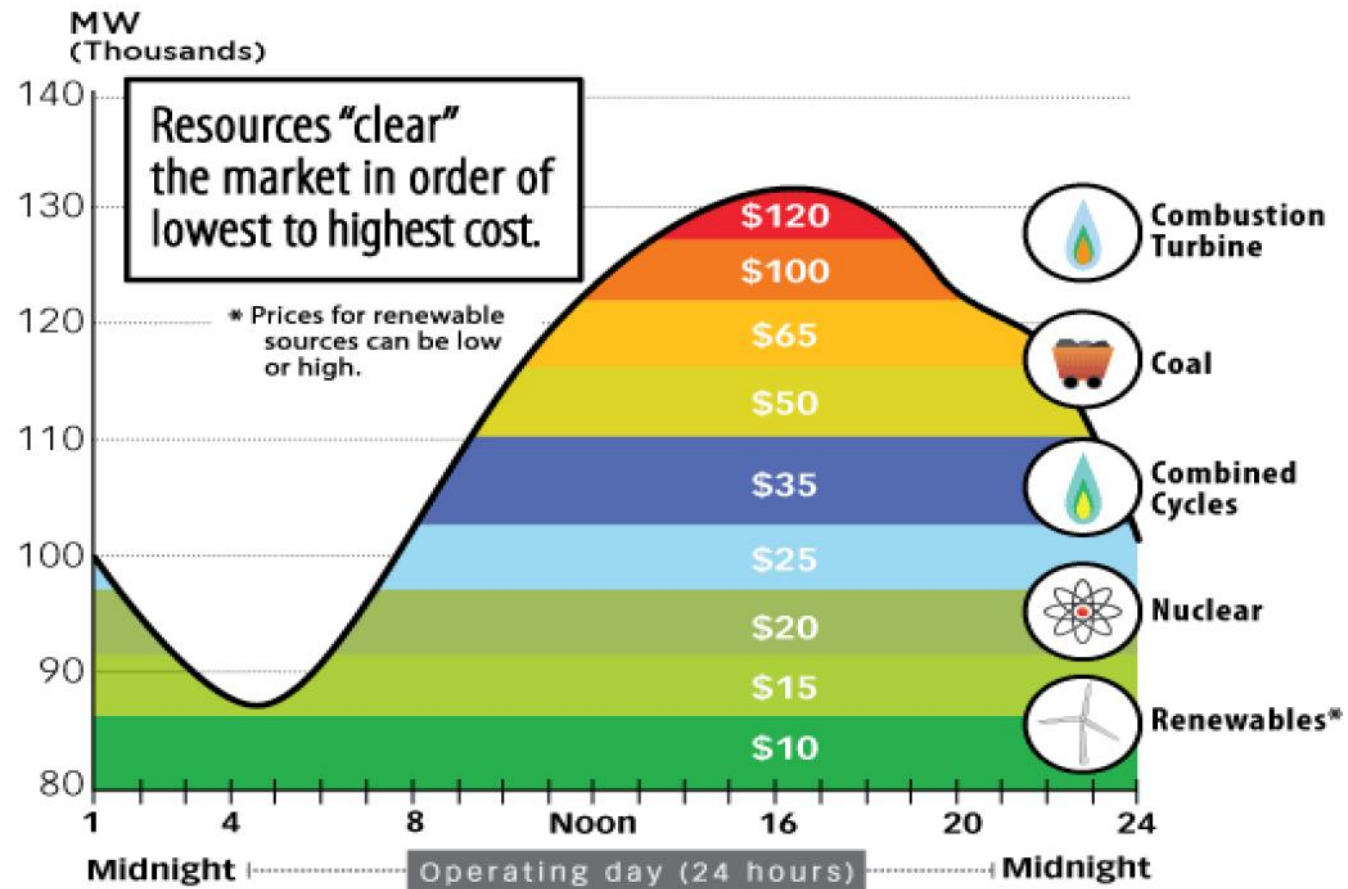


Electricity Generation Sector - Scheduling



MEETING THE ELECTRIC LOAD

- Currently has about 1.17 TW of generating capacity
- United States uses about 4,000 TWh/yr of energy (4 trillion kWh)
- Current electric generating capacity is about 2.5 times higher than what is used on an annual basis
- If vehicles + building heating were converted to electricity by 2050, the electricity consumption would almost double



Electricity Generation Sector - Scheduling

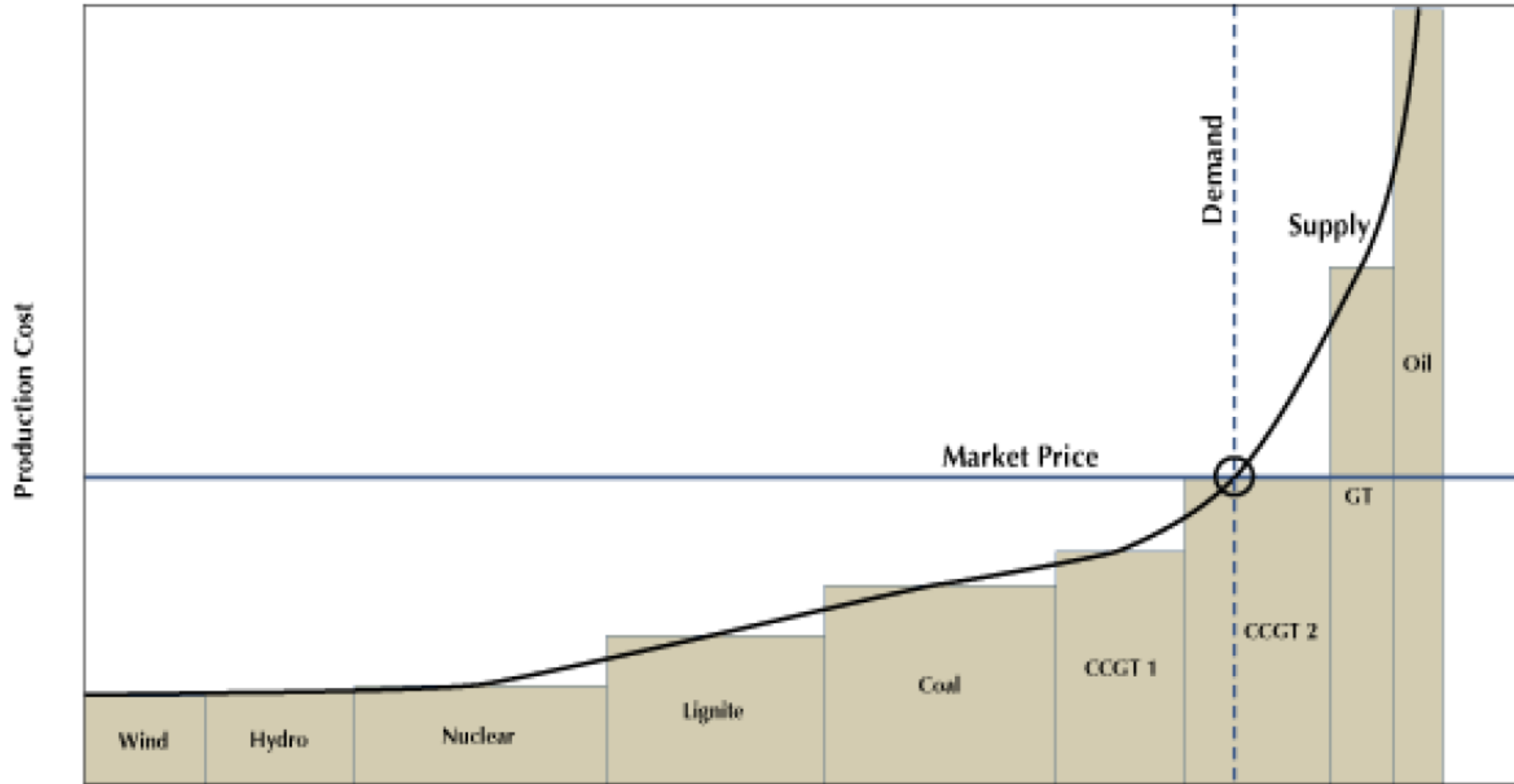
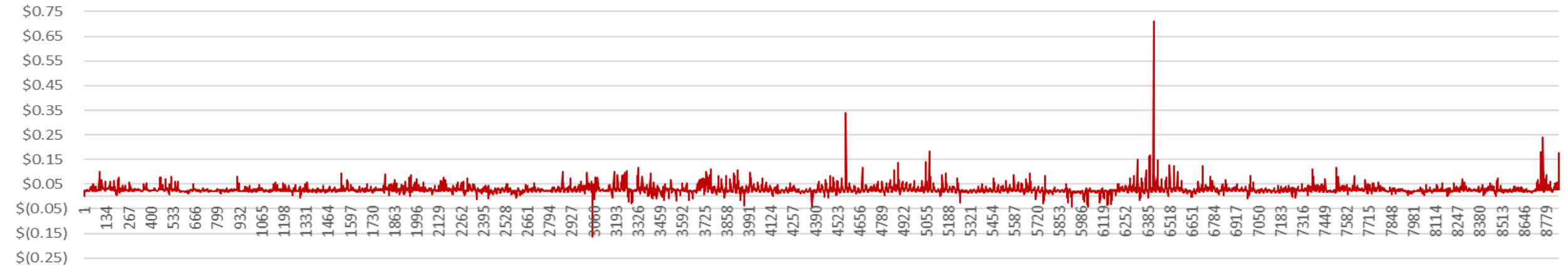


Image Source: Mark Pruitt

Installed Generation
© Passive House Institute US

REAL TIME PRICING (RTP) – Chicago, IL



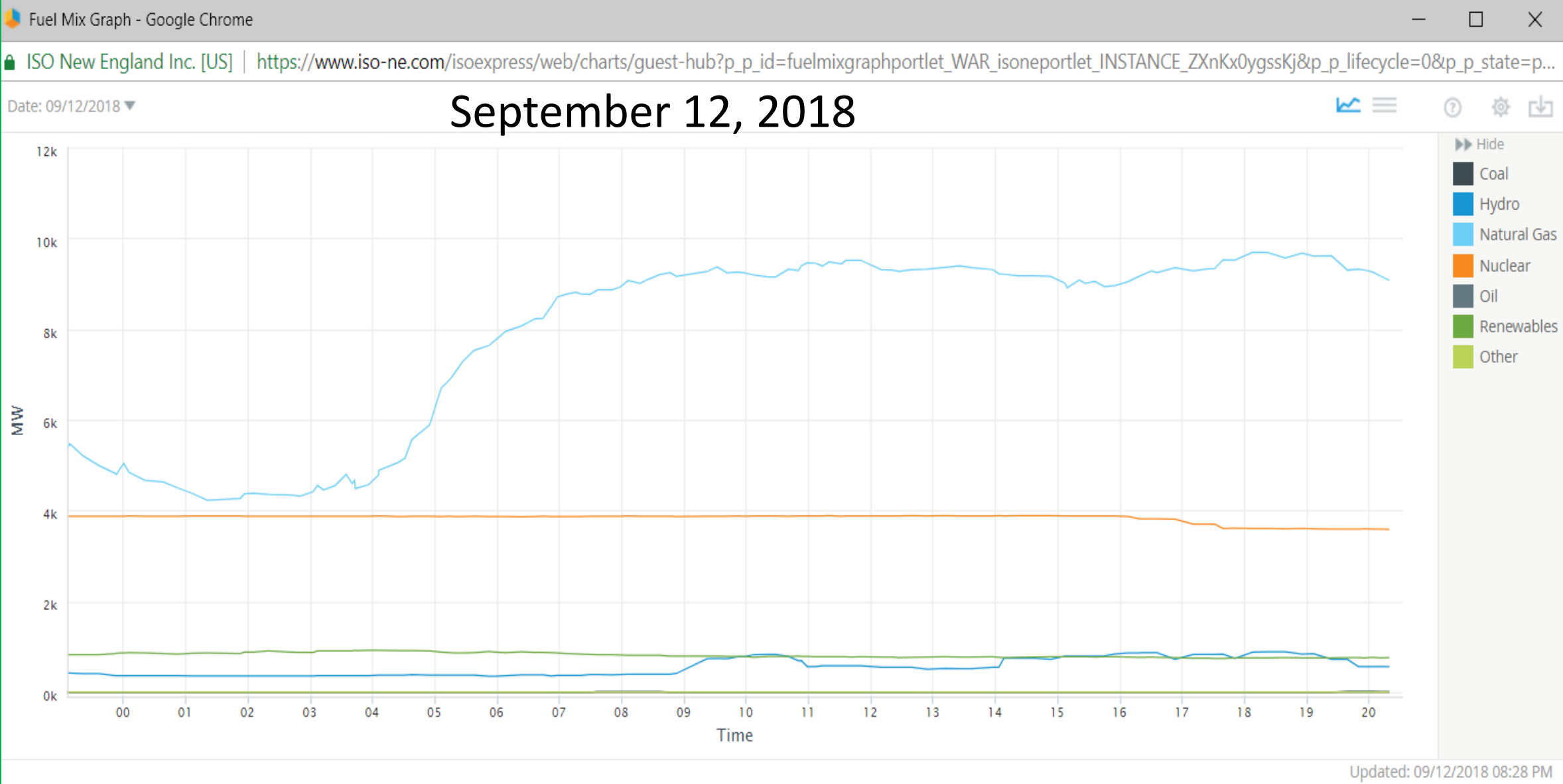
PJM Archive pricing, 2017

65_Ohio node in Chicago – 60622

Data Miner 2. PJM. Real-Time Hourly LMP's. 25 Mar 2018.

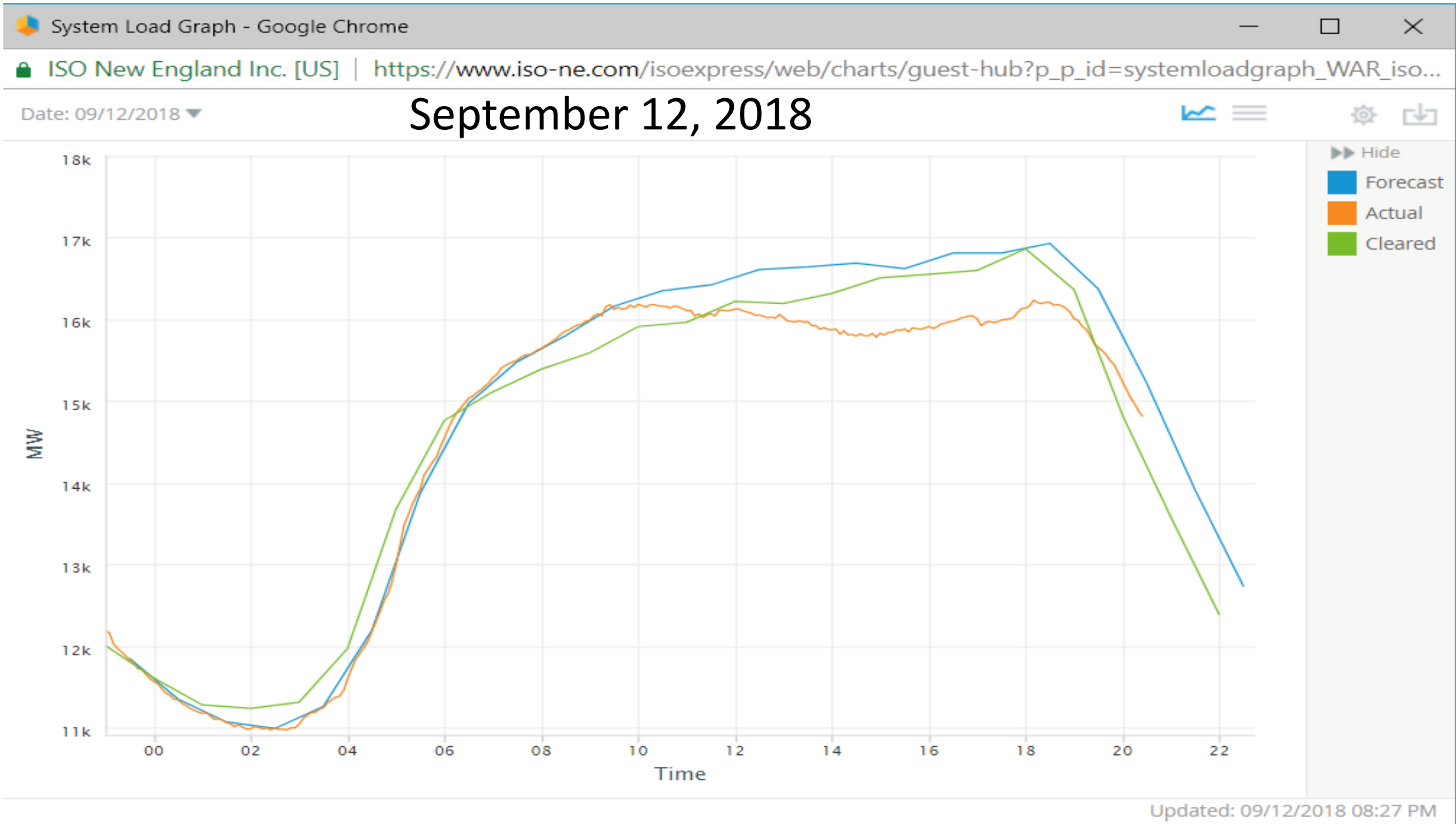
dataminer2.pjm.com/feed/rt_hrl_lmpps/definition

Datetime	Pricing	Pricing	Voltage	Equipment	Pricing	Transmission	System		Congestion	Loss	Latest	Version	Real Time
Beginning EPT	Node ID	Node Name	Level	Description	Node Type	Zone Location	Energy Price (\$/MW)	Total LMP (\$/MW)	Component for LMP (\$/MW)	Component for LMP (\$/MW)	Version	Number	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
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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
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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 21:00	36181251	65 OHIO	138 KV	TR71 12	LOAD	COMED	24.99	23.87	-0.05	-1.07	TRUE	1	0.02387
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



Updated: 09/12/2018 08:28 PM

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

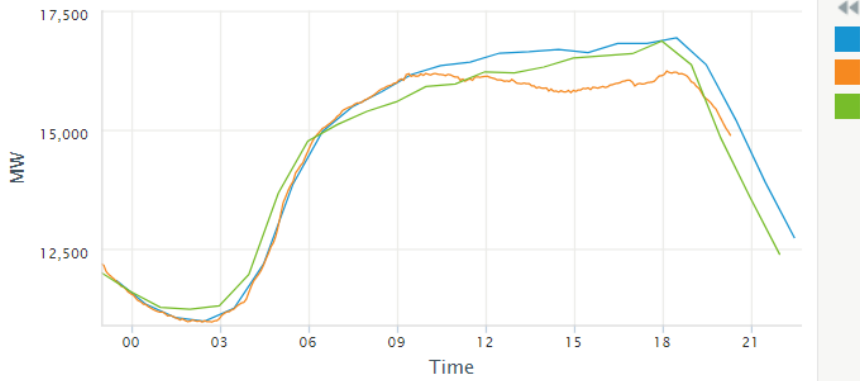


Source: <https://www.iso-ne.com/isoexpress/>

Real-Time Maps and Charts

SYSTEM LOAD GRAPH

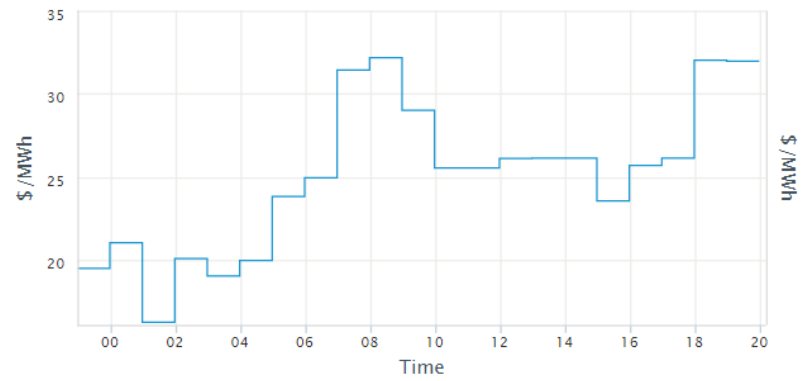
Date: 09/12/2018



Updated: 09/12/2018 08:25 PM

HOURLY LMP GRAPH

Date: 09/12/2018



Updated: 09/12/2018 08:25 PM

FIVE-MINUTE REAL-TIME LMP GRAPH

Date: 09/12/2018

40

RESERVE PRICES GRAPH

Date: 09/12/2018

0.1

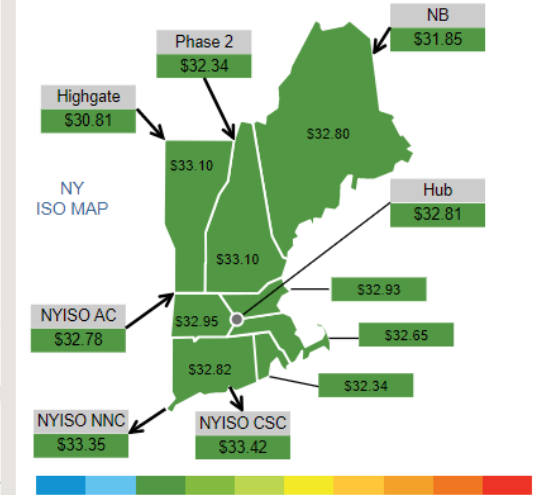
SYSTEM MONITOR

LMP MAP: REAL-TIME

Day-Ahead

Real-Time

NE Energy: \$32.84 System Demand: 14877 MW

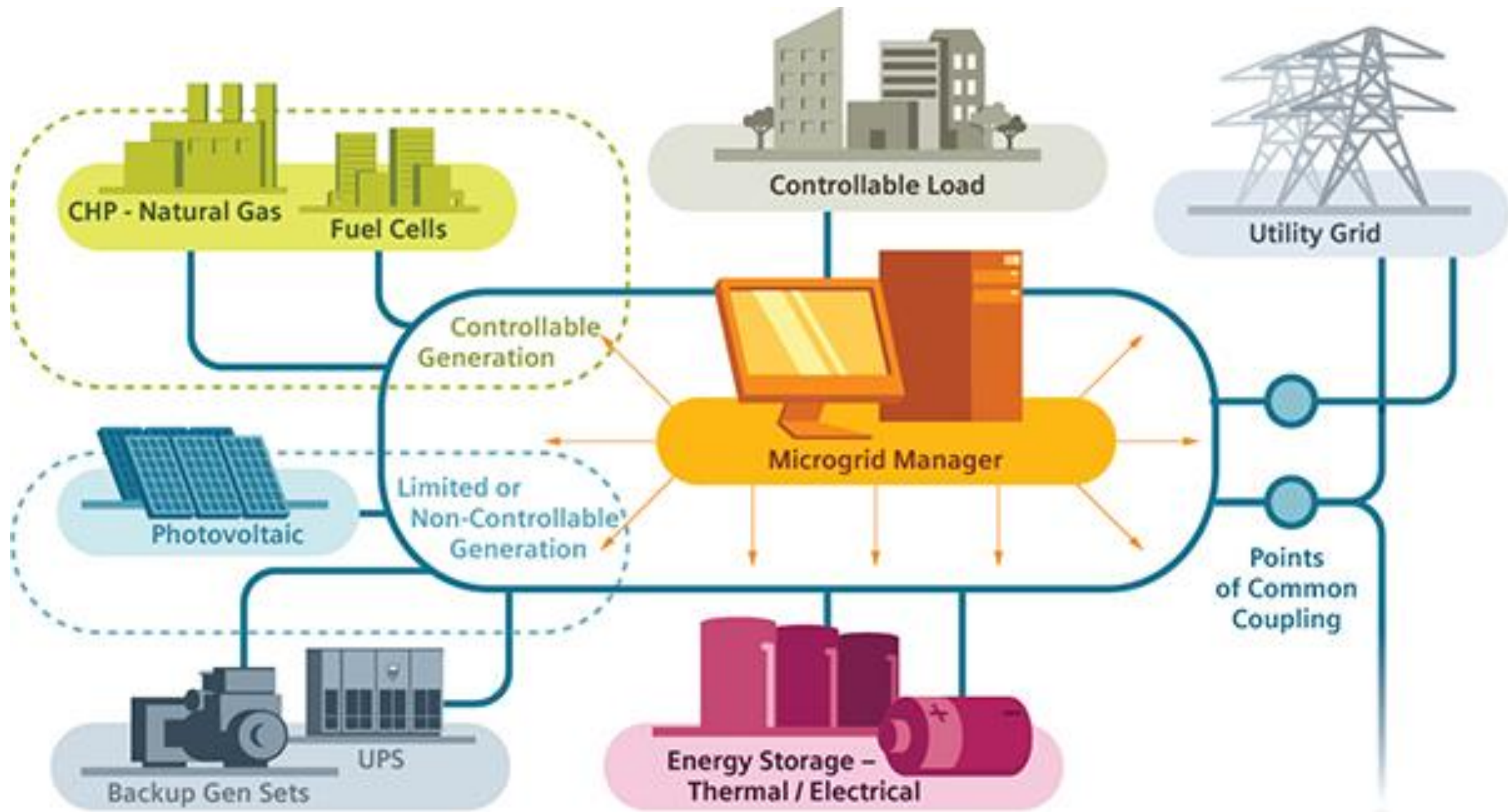


Sampling Period: 09/12/2018 08:20 PM

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

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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 sensors*) and beyond the meter (*optimization and aggregation platforms, smart appliances and devices, IoT*)

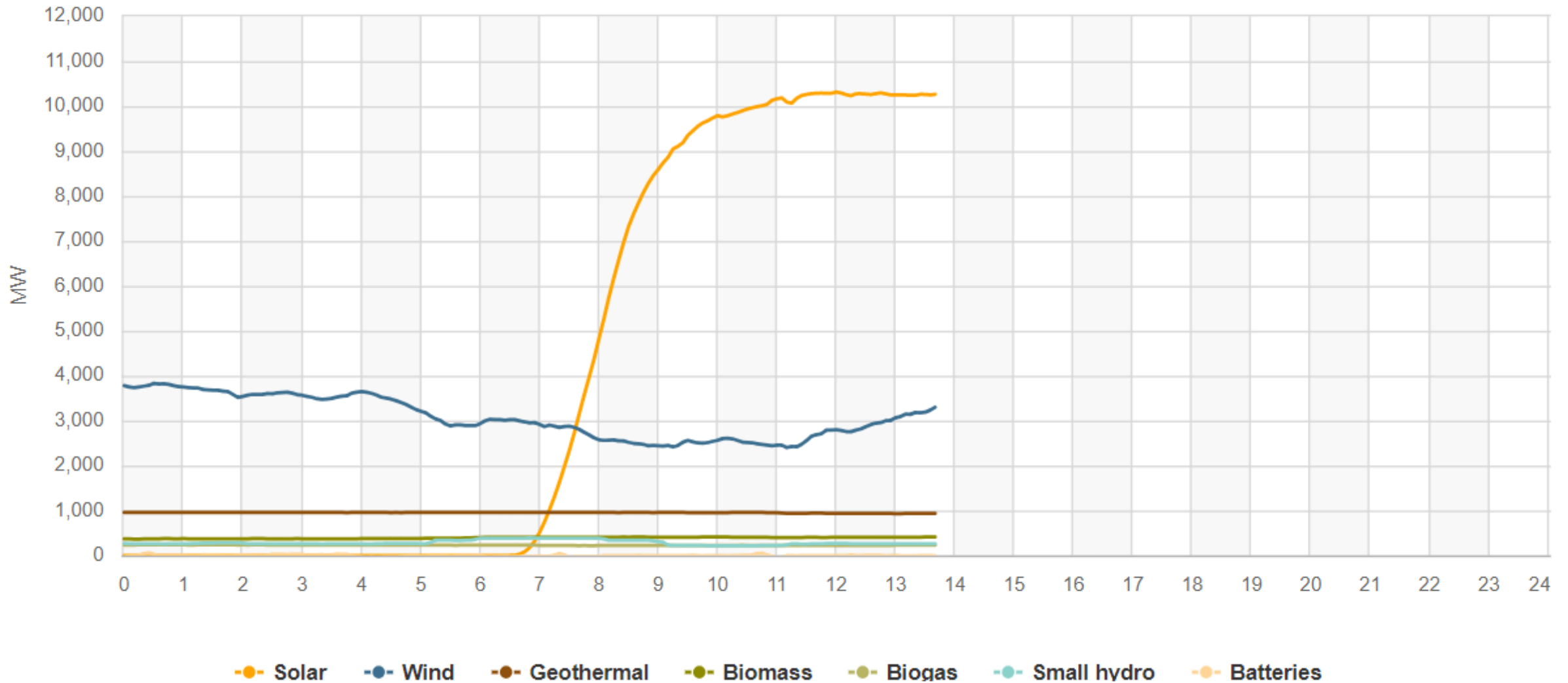


California ISO – September 12, 2018

09/12/2018 ▾

Renewables trend

Data ▾

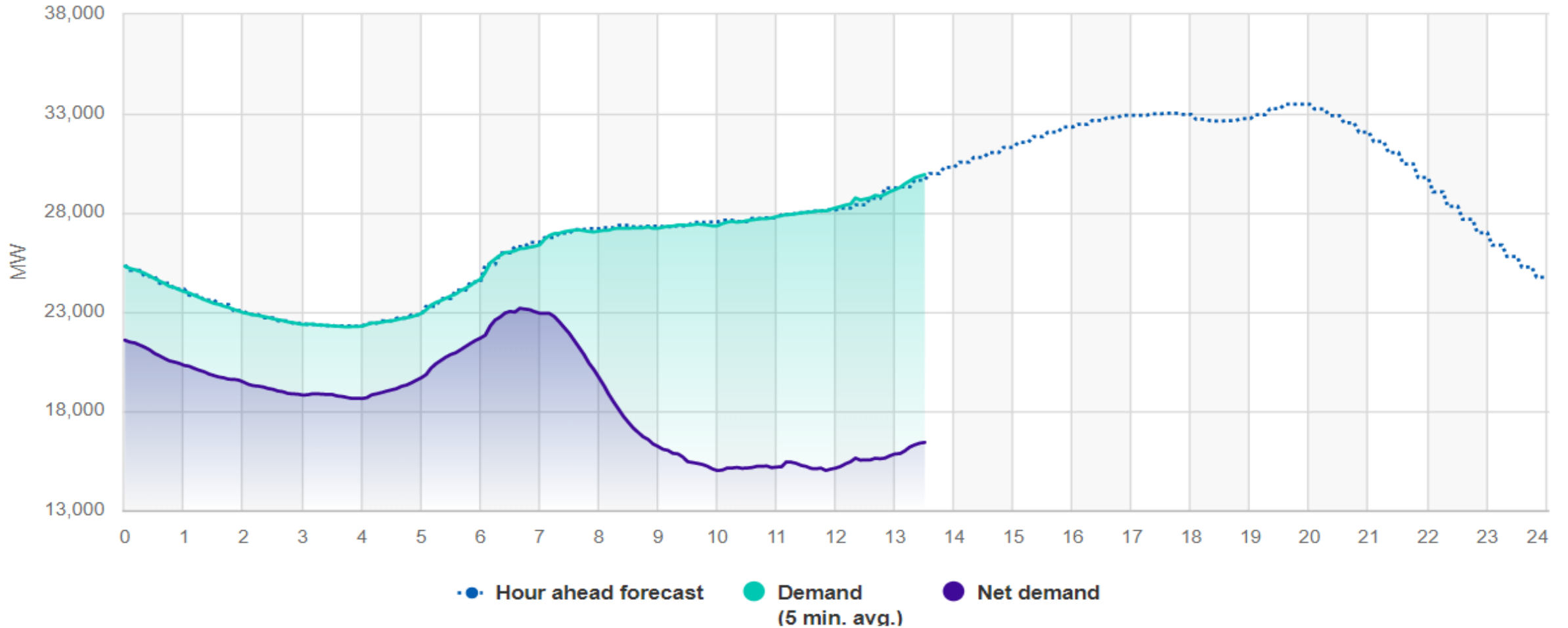


California ISO – September 12, 2018

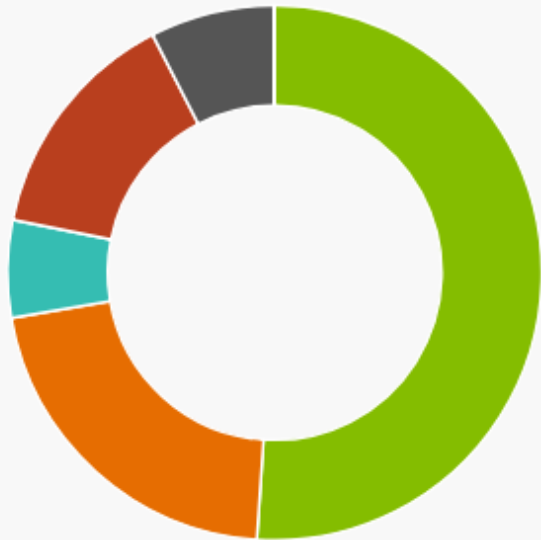
09/12/2018

Net demand trend

Data

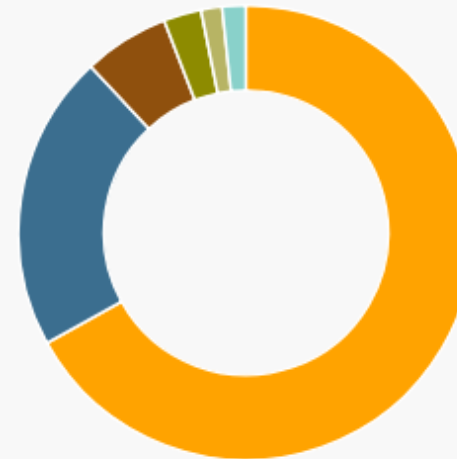


Current supply AS OF 13:35



Renewables	51.1% (15,304 MW)
Natural gas	21.2% (6,358 MW)
Large hydro	5.9% (1,764 MW)
Imports	14.3% (4,277 MW)
Nuclear	7.5% (2,248 MW)
Coal	0.1% (15 MW)
Other	0.0% (0 MW)

Current renewables AS OF 13:35



Solar	66.9% (10,250 MW)
Wind	21.1% (3,233 MW)
Geothermal	6.1% (933 MW)
Biomass	2.7% (410 MW)
Biogas	1.5% (228 MW)
Small hydro	1.7% (257 MW)
Batteries (charging)	-0.0% (-7 MW)

California ISO – September 12, 2018

1:35 PM

Today's Outlook

Demand

Supply

Prices

Emissions

AS OF 13:35 09/12/2018

Grid status

● Normal

Learn more about active alerts, warnings and emergencies

Supply and renewables

View official data in OASIS



29,964 MW

Current demand



15,304 MW

Current renewables



10,250 MW

Current solar



3,233 MW

Current wind

California ISO – September 12, 2018

7:00 PM

Today's Outlook

Demand

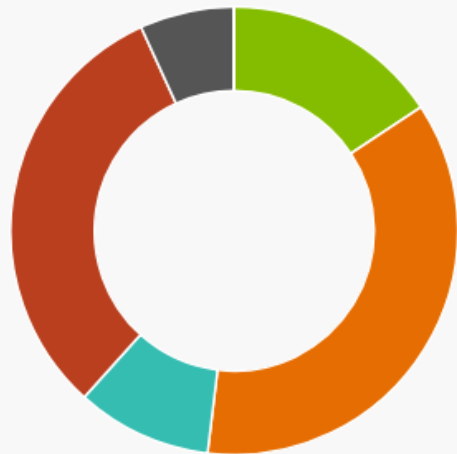
Supply

Prices

Emissions

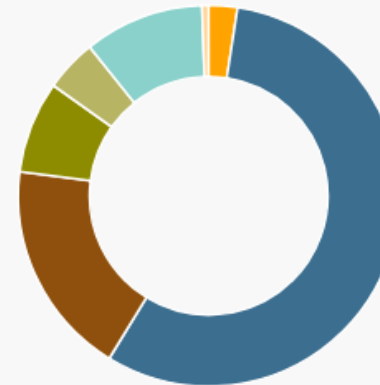
AS OF 19:00 09/12/2018

Current supply AS OF 19:00



Renewables	15.7% (5,181 MW)
Natural gas	36.2% (11,951 MW)
Large hydro	9.8% (3,225 MW)
Imports	31.5% (10,383 MW)
Nuclear	6.8% (2,241 MW)
Coal	0.0% (16 MW)
Other	0.0% (0 MW)

Current renewables AS OF 19:00



Solar	2.4% (126 MW)
Wind	56.3% (2,917 MW)
Geothermal	18.3% (948 MW)
Biomass	7.8% (404 MW)
Biogas	4.4% (230 MW)
Small hydro	10.2% (527 MW)
Batteries	0.6% (29 MW)

California ISO – September 12, 2018

7:00 PM

Today's Outlook

Demand

Supply

Prices

Emissions

AS OF 19:00 09/12/2018

Grid status

● Normal

[Learn more about active alerts, warnings and emergencies](#)

Supply and renewables

[View official data in OASIS](#)



33,038 MW

Current demand



5,181 MW

Current renewables



126 MW

Current solar



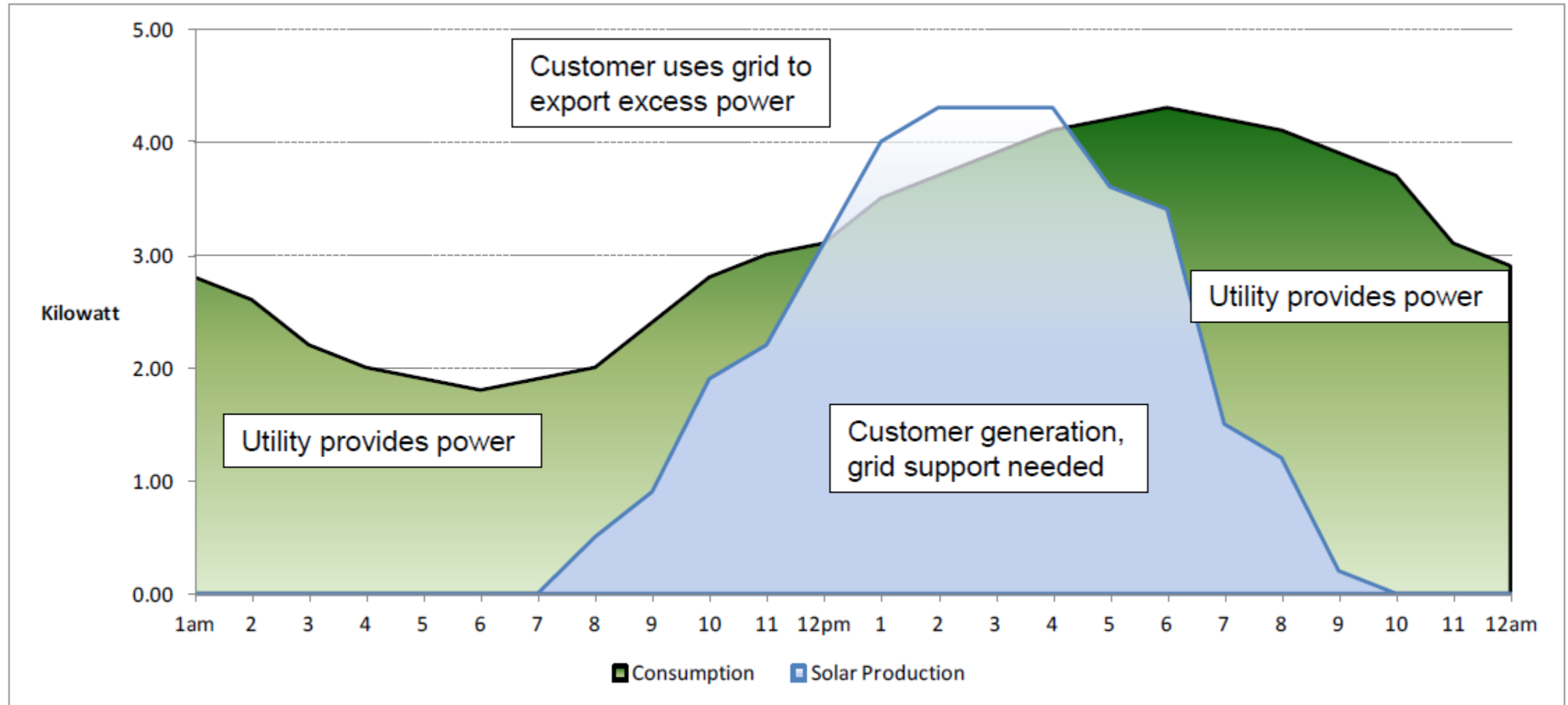
2,917 MW

Current wind

AGENDA

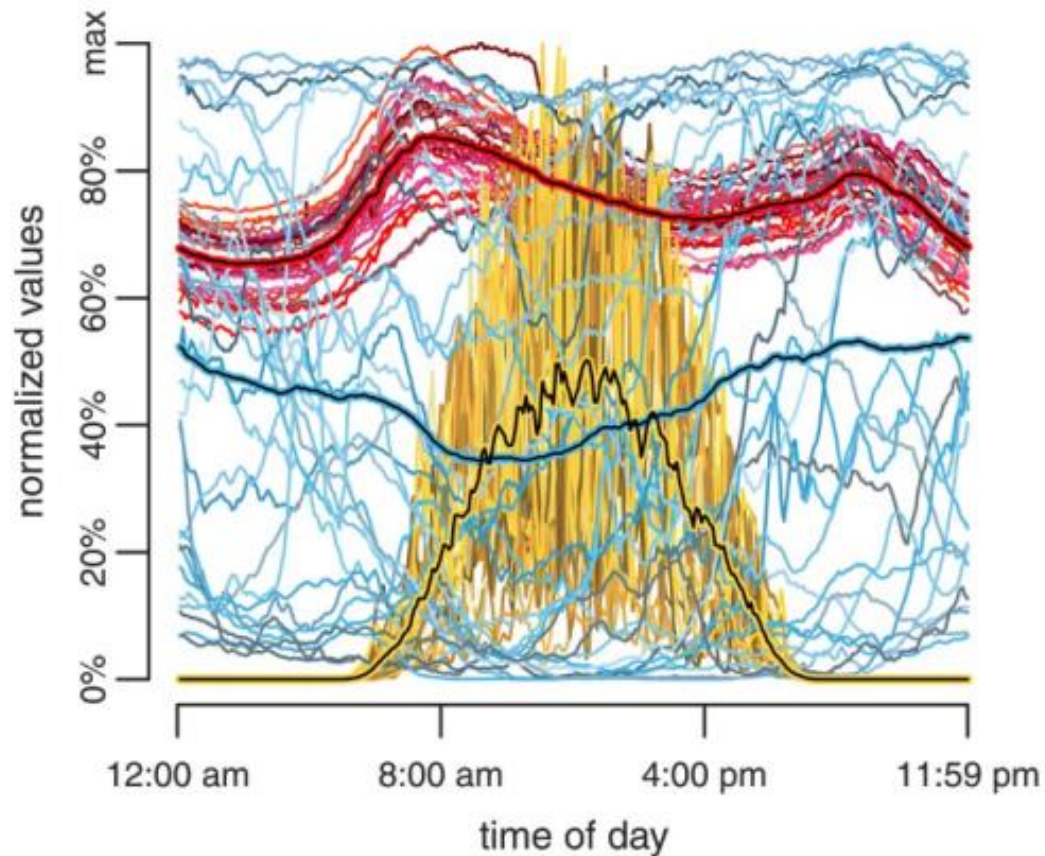
1. Overview of how the electric grid operates
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MISMATCH CHALLENGES



INTERMITTENCY

Intermittent, but not unpredictable.

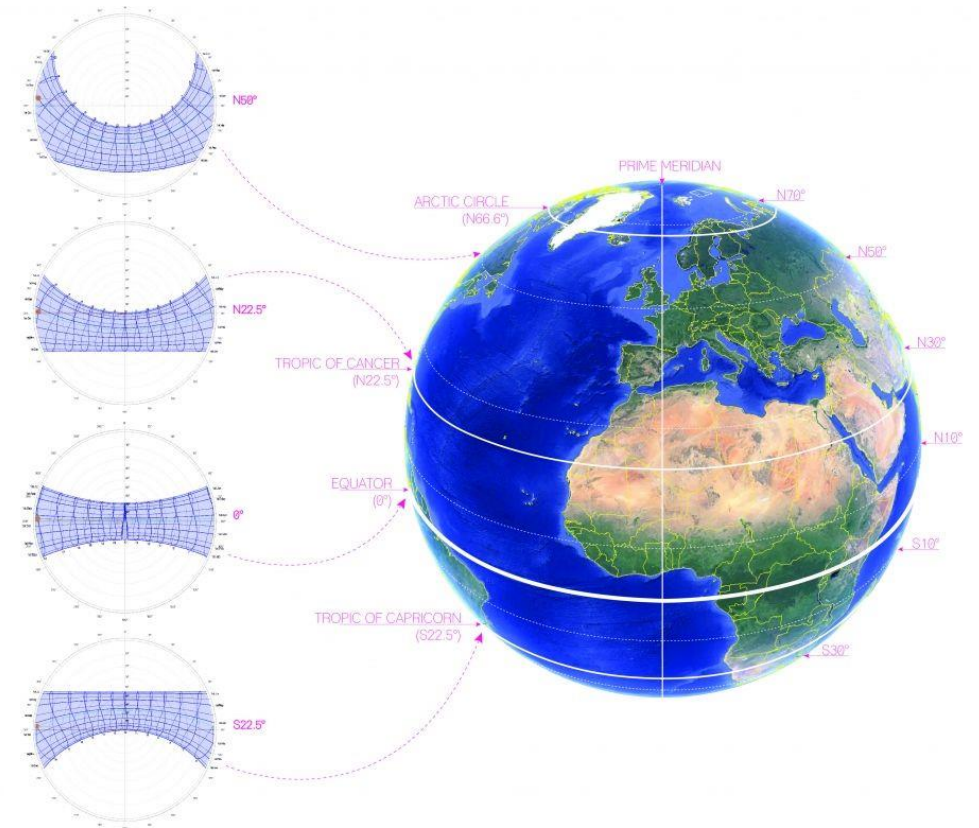


RED: POWER DEMAND

BLUE: WIND ENERGY GENERATION

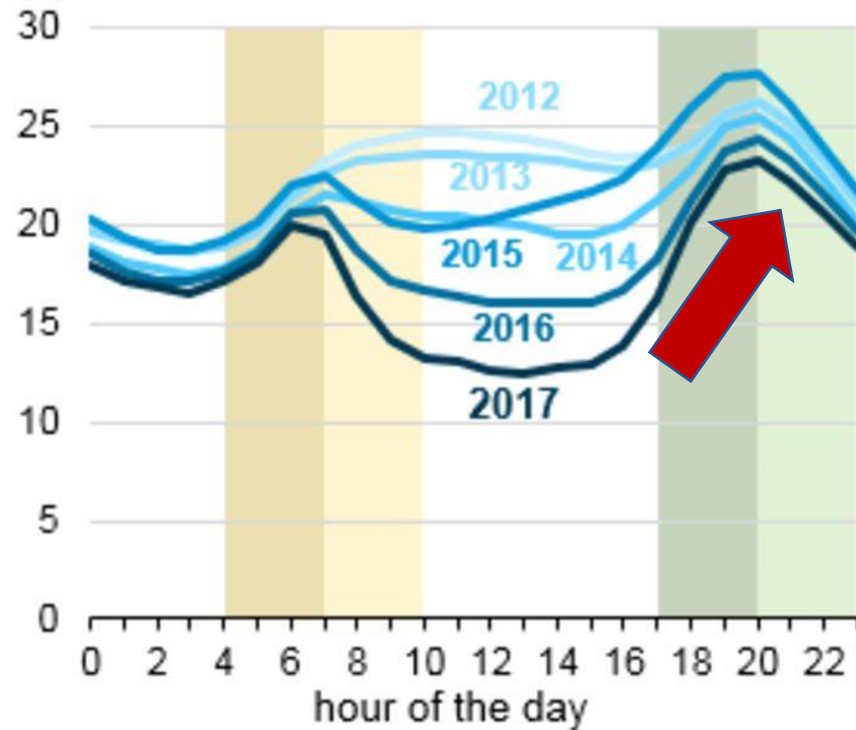
YELLOW: SOLAR INSOLATION DATA

Source: Bonneville Power Administration, April 2010

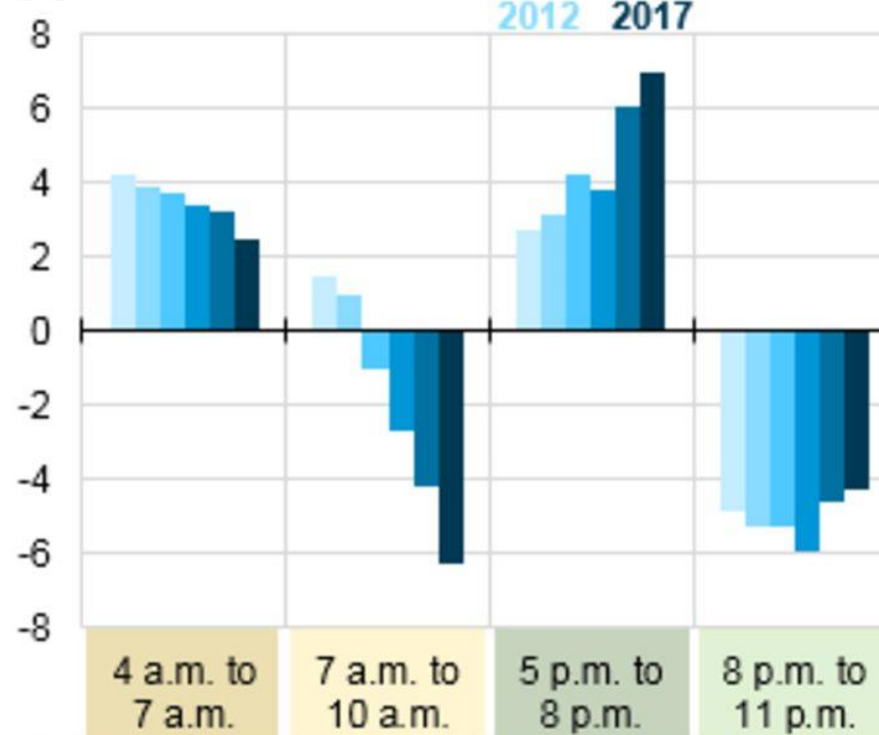


NET LOAD/RAMPING CHALLENGES

California ISO average net electric load
last week of March
gigawatts



Net load change during ramping periods
last week of March
gigawatts



Source: U.S. Energy Information Administration, based on [ABB Energy Velocity](#)

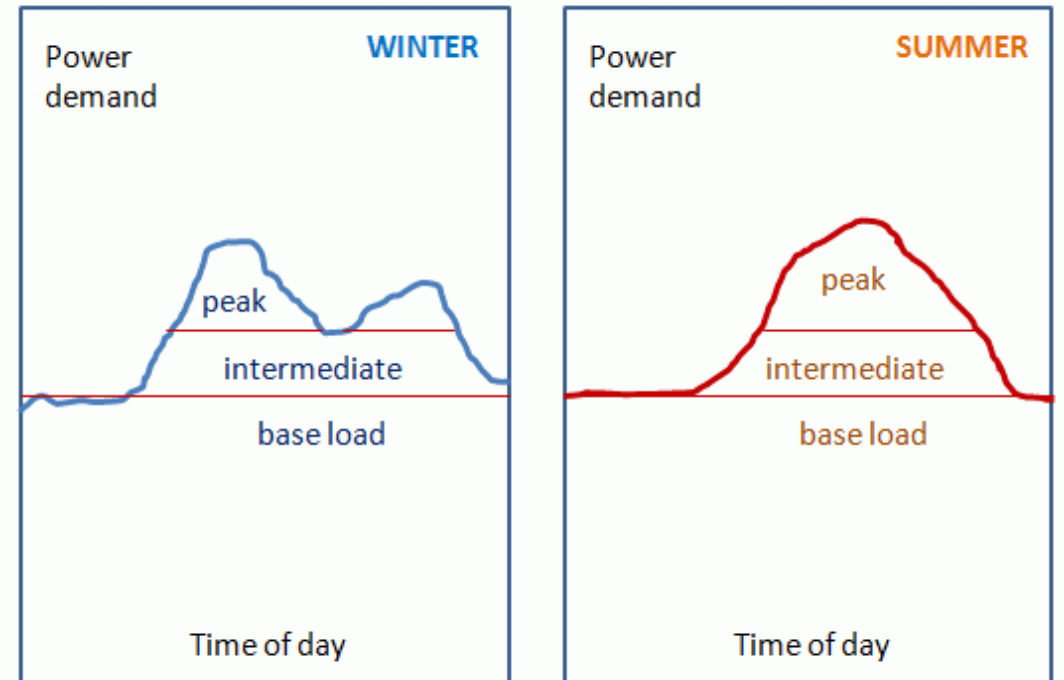
- Net Load on grid ramps dramatically as PV generation declines (sunset)
- Most generation resources cannot adjust/increase output that quickly (Natural Gas can)

BASELOAD CHALLENGES

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

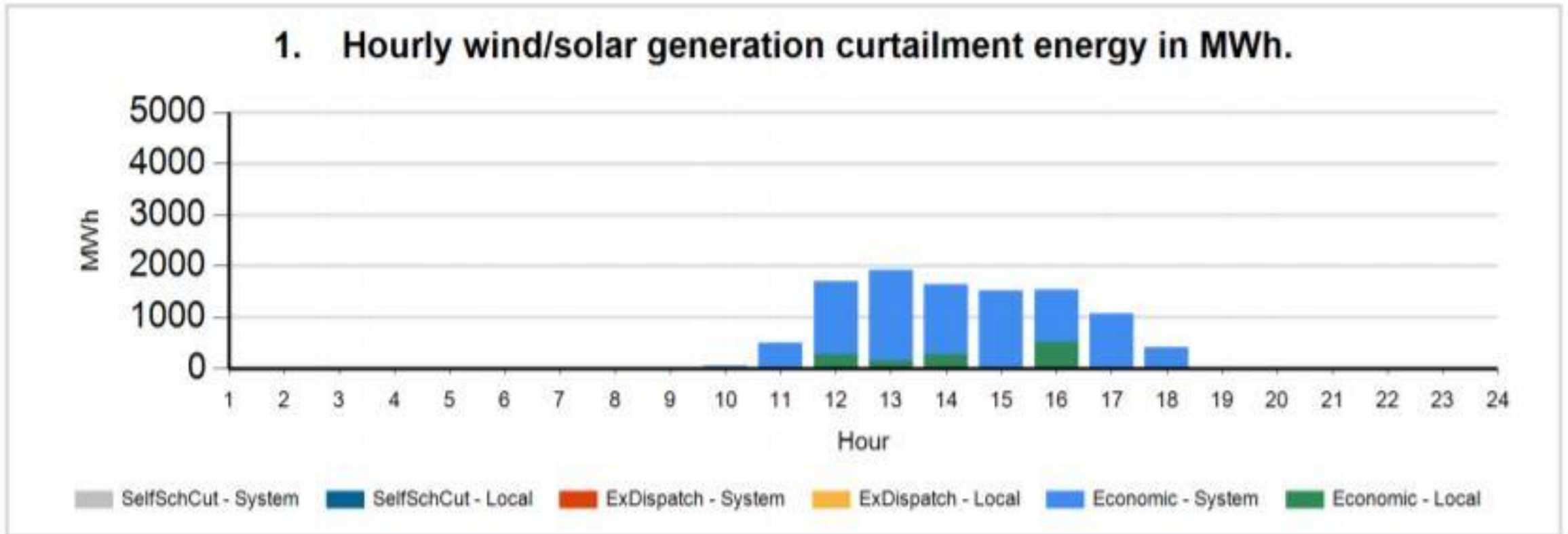
Nuclear: 80% max load minimum

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



CURTAILMENT

What if the net load on the grid is lower than or equal to the fossil-fueled baseload?



California ISO (CAISO) Curtailment on April 8, 2017.

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 2. **Other strategies**

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 buildings than conventional
5. Control electric water heaters
Electric water heaters common in passive buildings
6. Control other major appliances

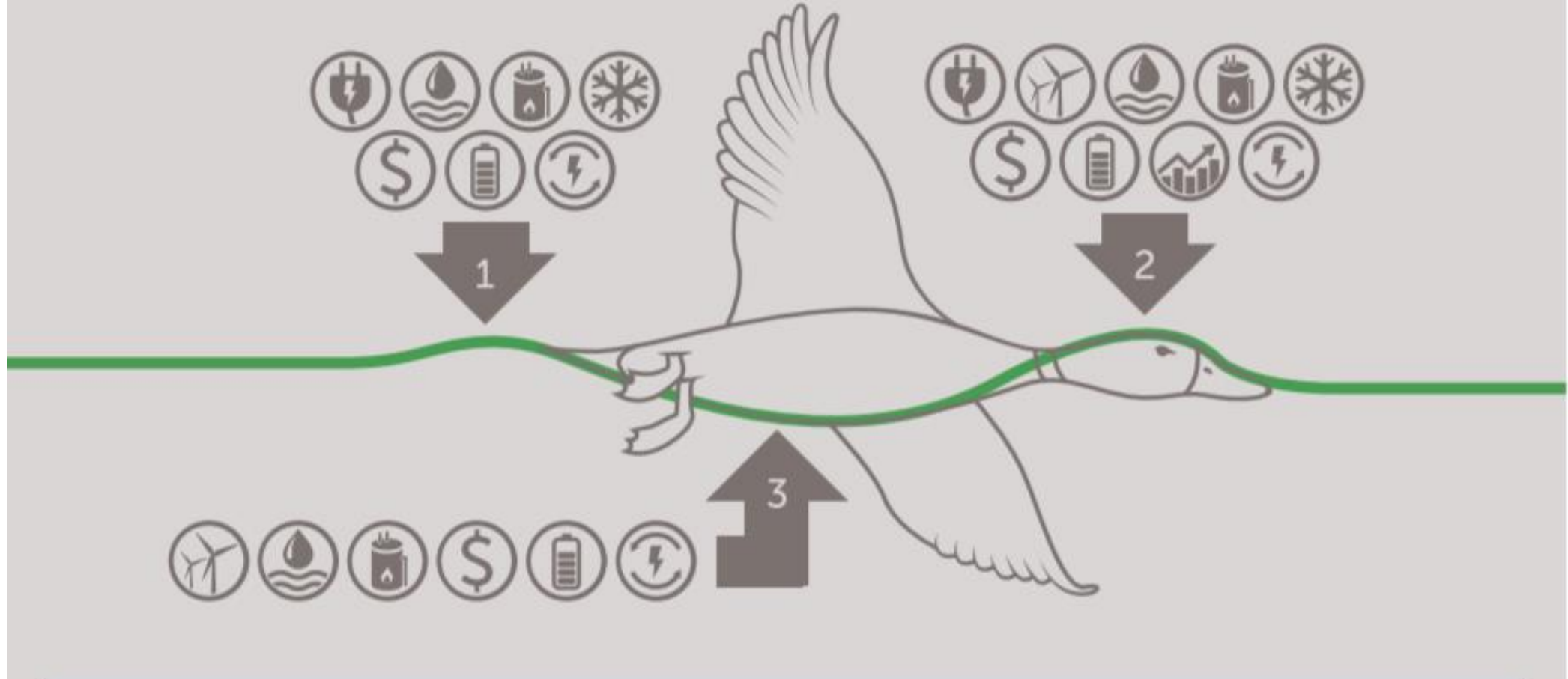


TEACHING THE DUCK TO FLY

Image Source: Jim Lazar (RAP)

Teaching the "Duck" to Fly:

10 strategies to control generation, manage demand, & flatten the Duck Curve



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. ↓ 2



Peak-Oriented Renewables

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



Manage Water Pumping

Run pumps during periods of low load or high solar output, curtailing during ramping hours. ↓ 2 3



Control Electric Water Heaters

Increase usage during night & mid-day hours, & decrease during peak demand periods. ↓ 2 3



Ice Storage for Commercial AC

Convert commercial AC to ice or chilled-water storage operated during non-ramping hours. ↓ 2



Rate Design

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



Targeted Electric Storage

Deploy storage to reduce need for transmission & distribution, & to enable intermittent renewables. ↓ 2 3



Demand Response

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



Inter-Regional Power Exchange

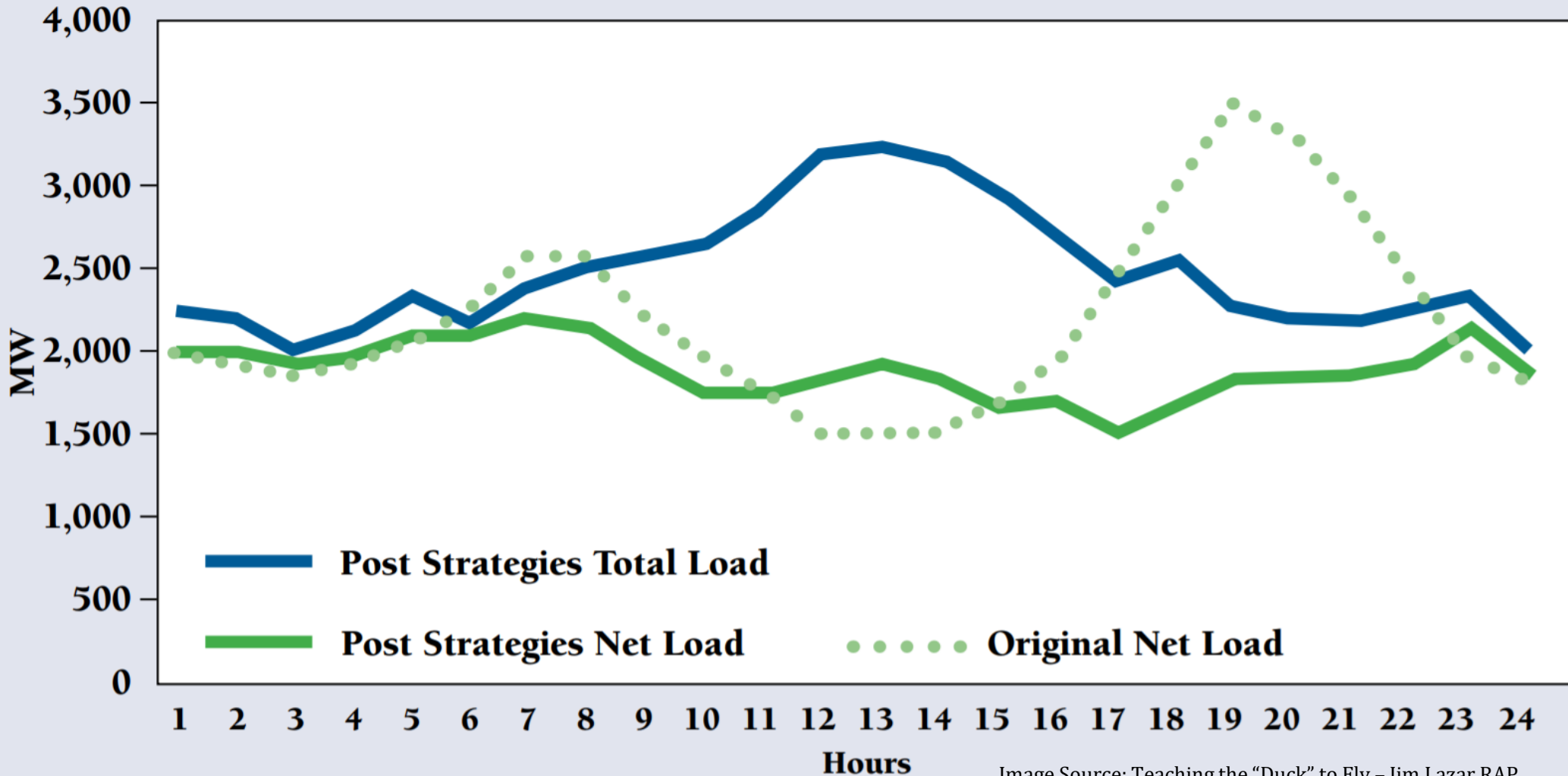
Import power from & export power to other regions with different peaking periods. ↓ 2 3



Retire Inflexible Generating Plants

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

Duck Curve With All Ten Strategies Compared to Original Load

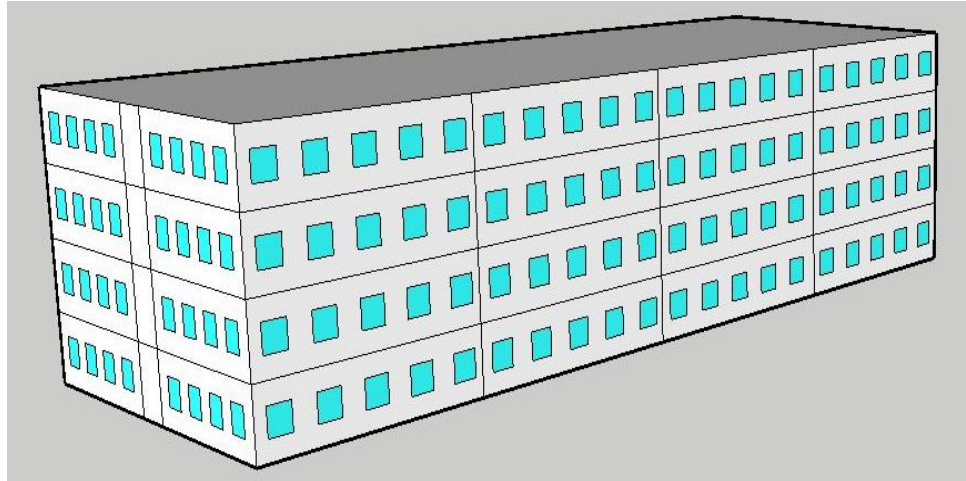


Load Factor: 63.6% → 86.5%

Max Hourly Ramp: 350 MW → 198 MW

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

'NET ZERO' CASE STUDY



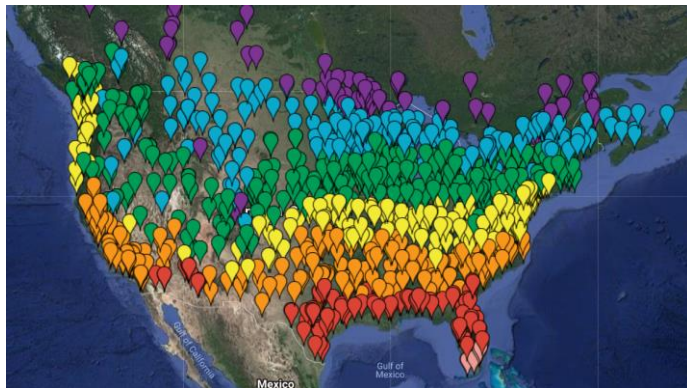
Multifamily Building – DOE Prototype

Location: Chicago, IL

32 units, 96 occupants, ~35,000 sf

All Electric

Energy Model: BeOpt (Energy Plus engine)



Two 'Net Zero' buildings studied:

1. Baseline "Renewable Oriented" (code compliant):

290 kW PV Array

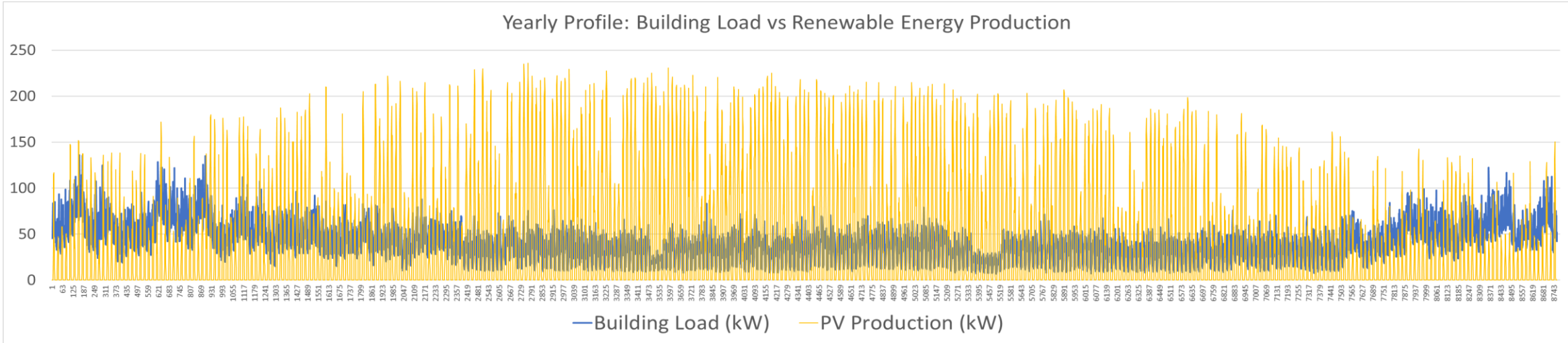
All south facing, 10 degree tilt

2. Passive building (PHIUS+ 2015 compliant):

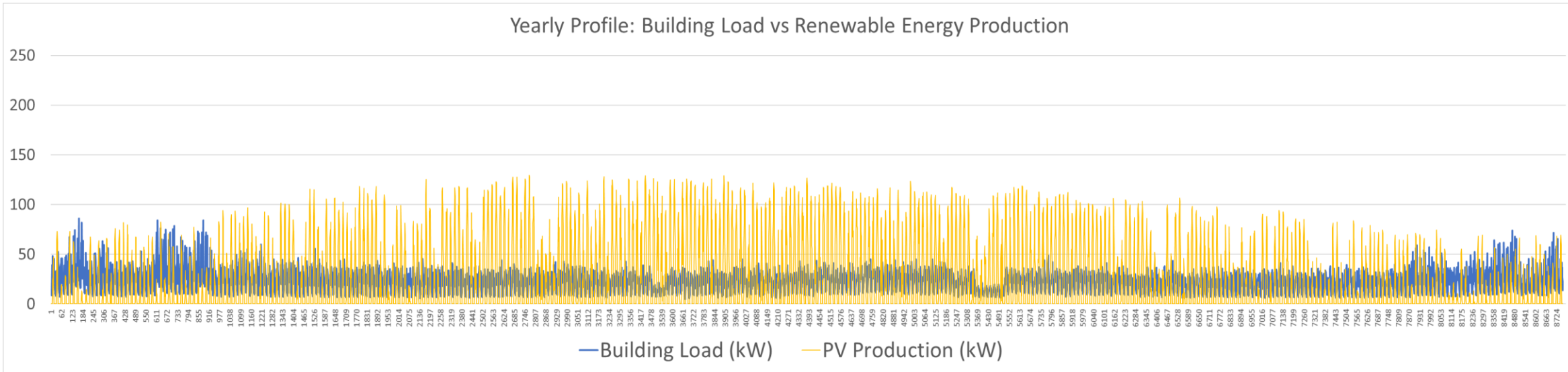
166 kW PV Array

50% South Facing, 25% E, 25% W, 10 degree tilt

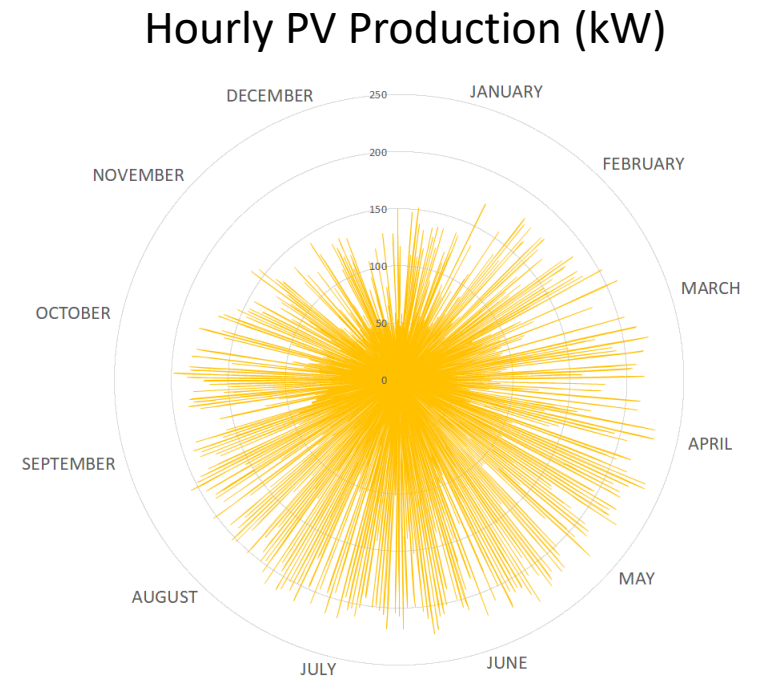
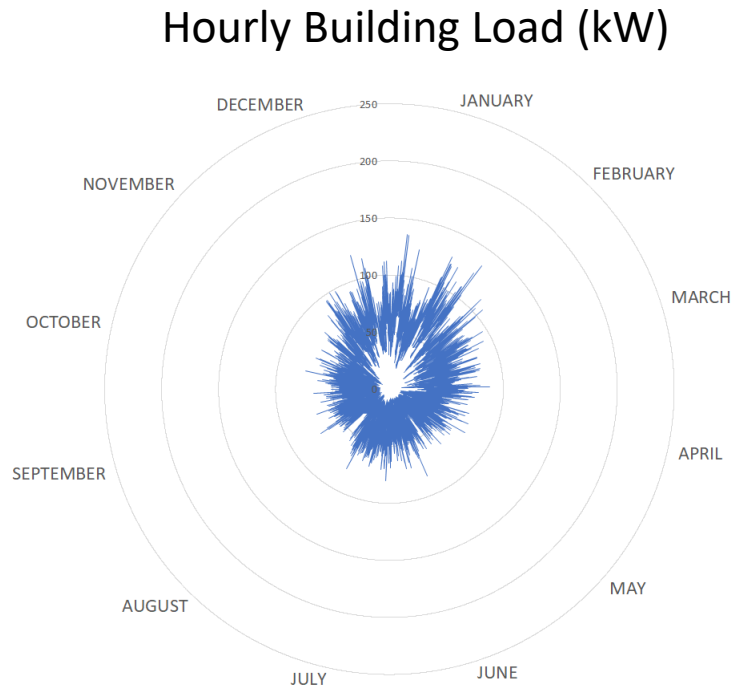
Baseline building



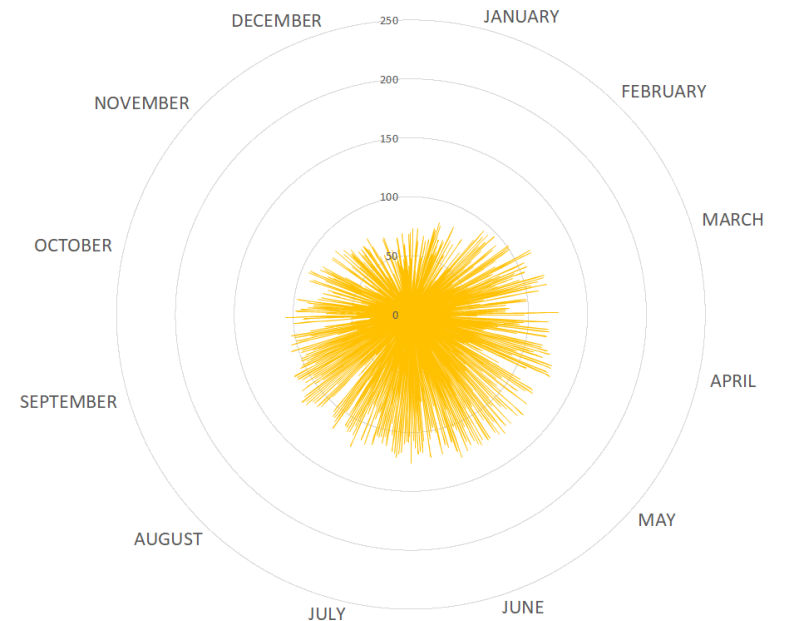
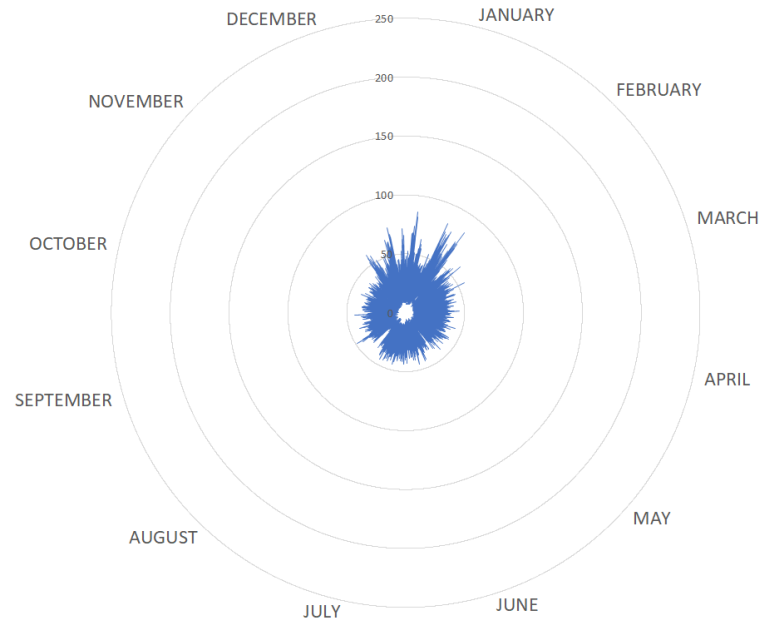
Passive building



Baseline building



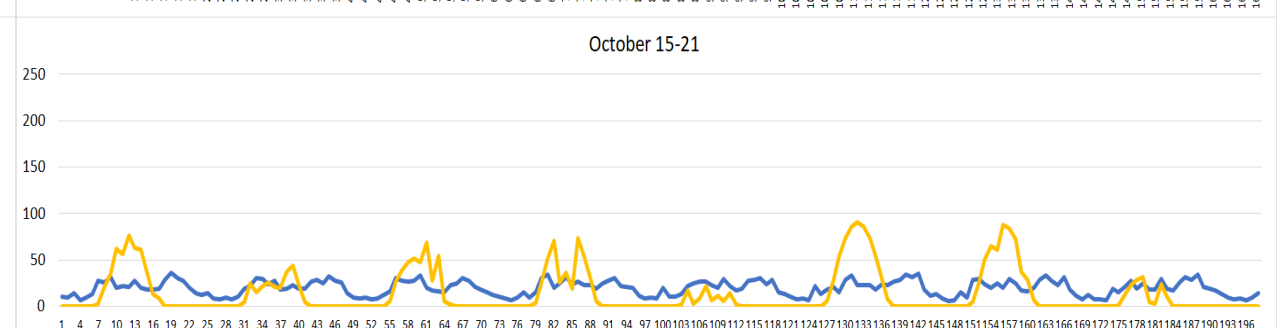
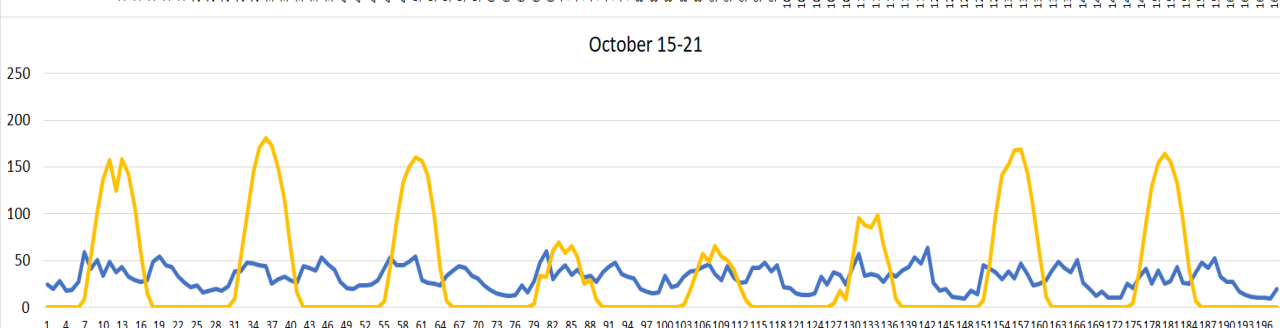
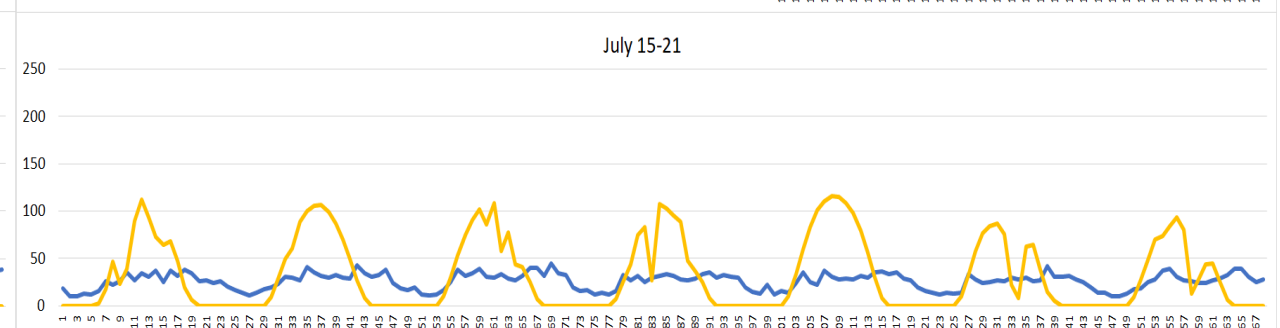
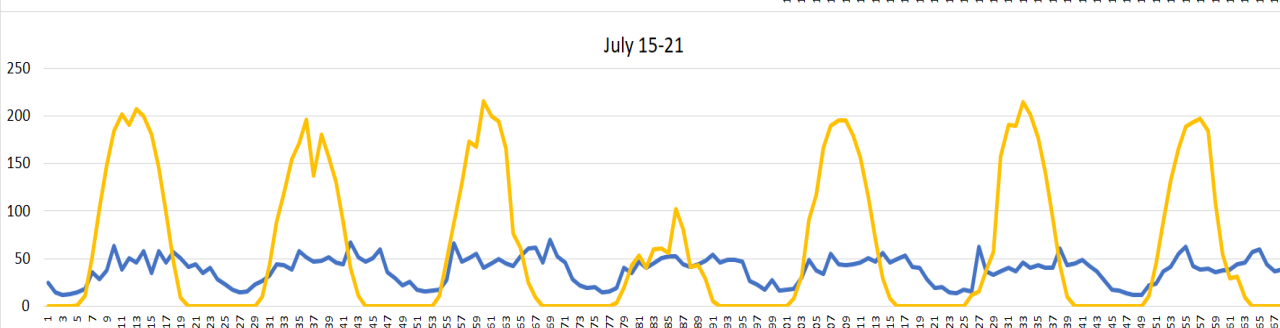
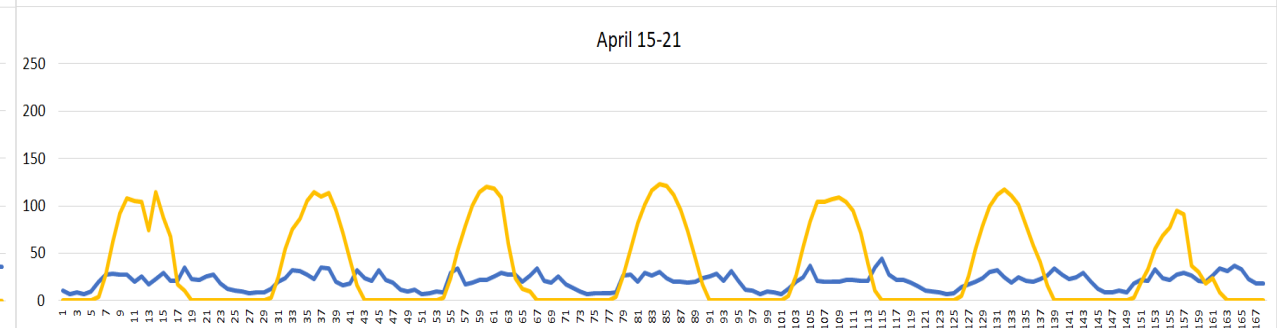
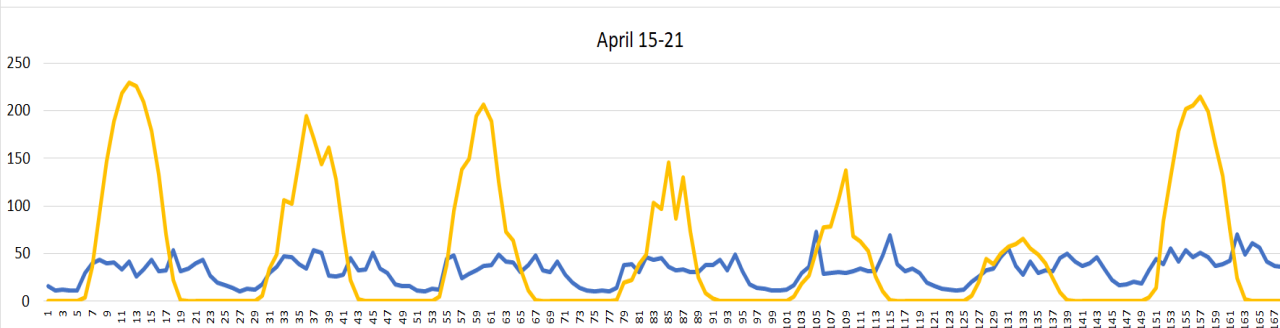
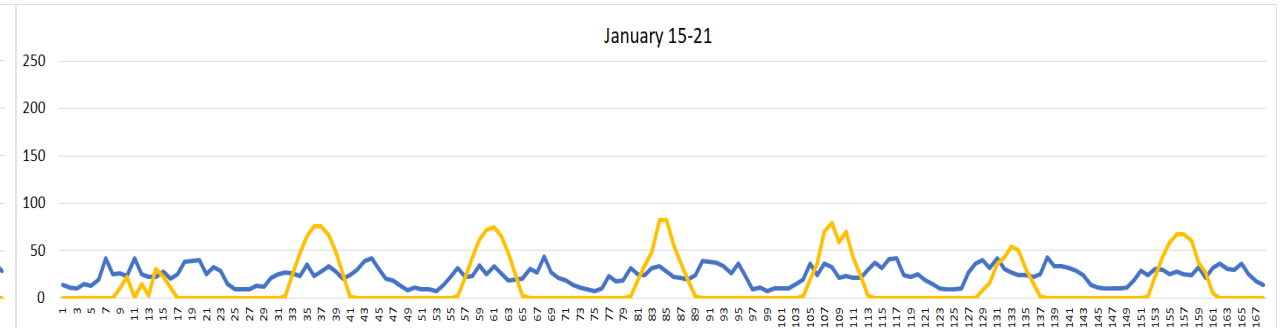
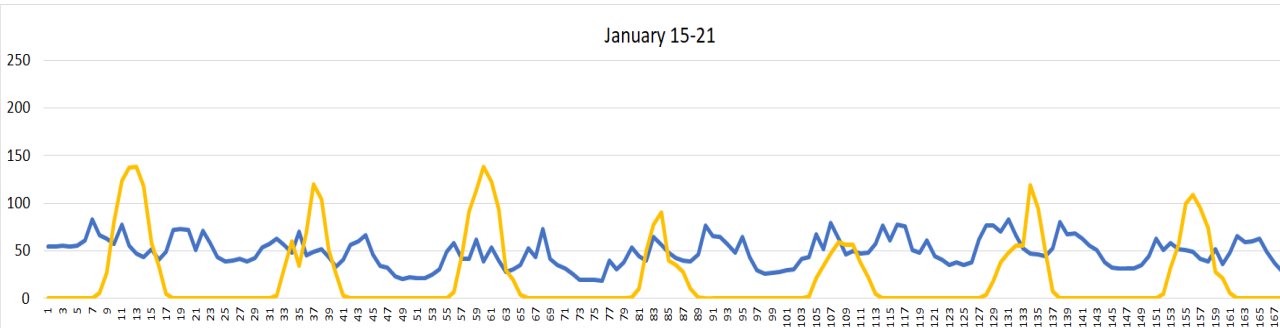
Passive building



Baseline building

WEEKLY MISMATCH – ON SITE PRODUCTION vs USE

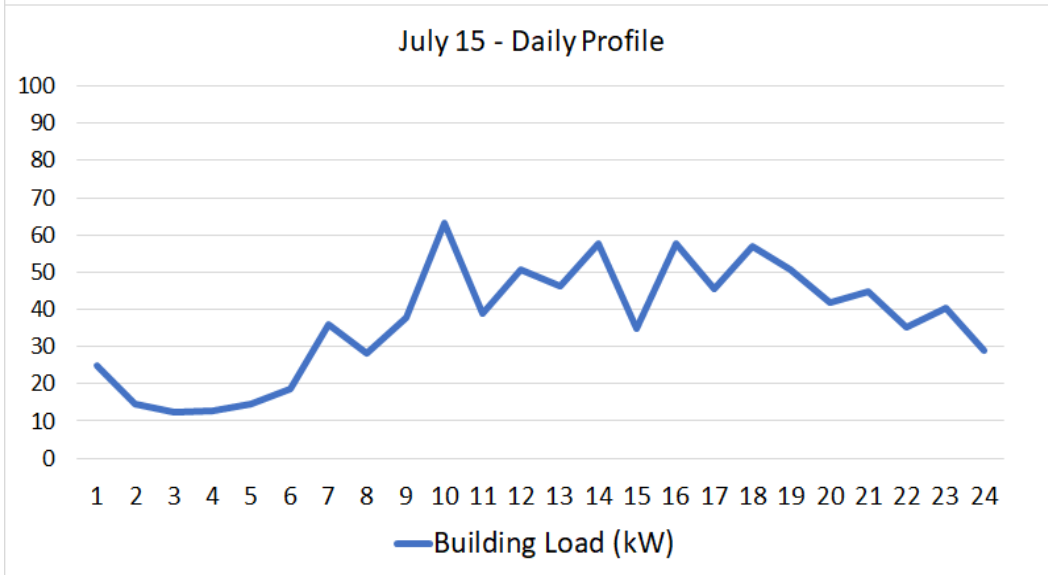
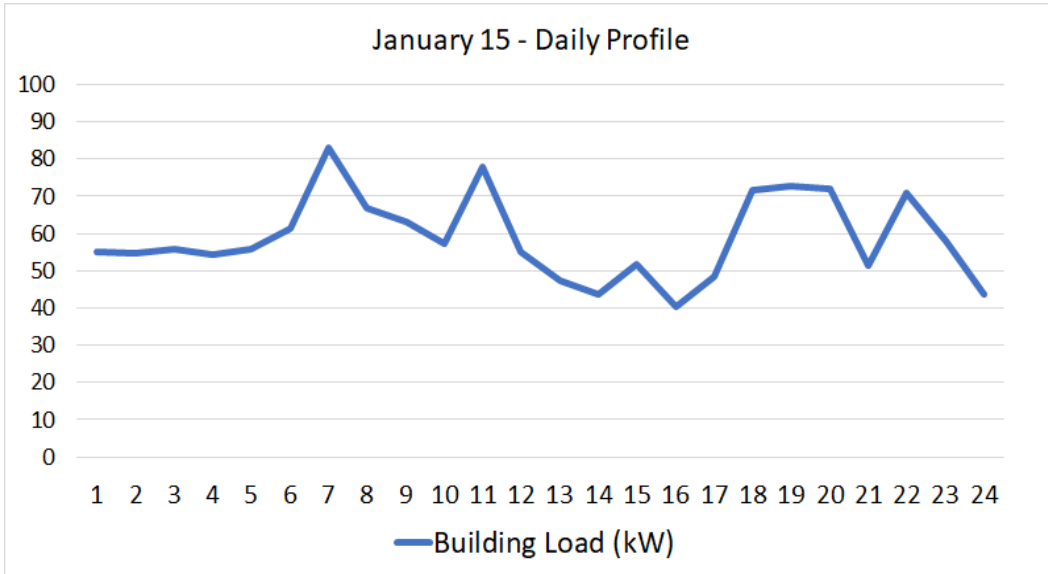
Passive building



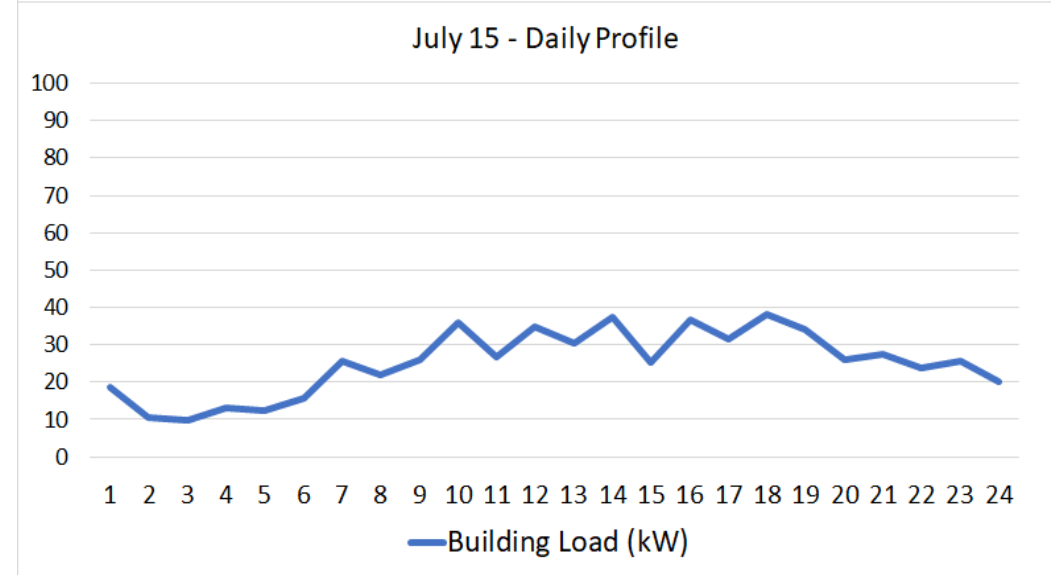
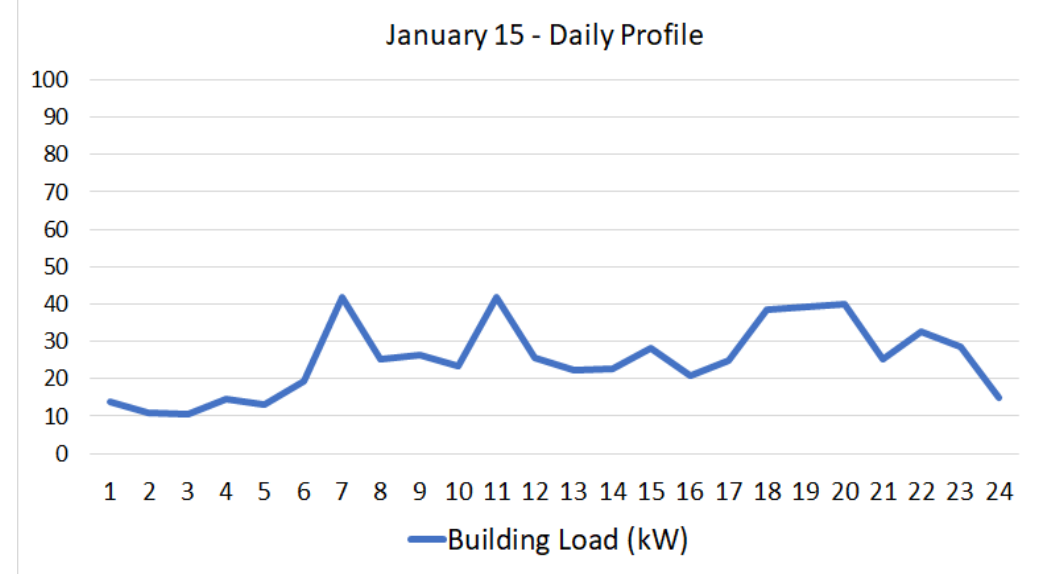
— Building Load (kW) — PV Generation (kW)

— Building Load (kW) — PV Generation (kW)

Daily Analysis – January & July



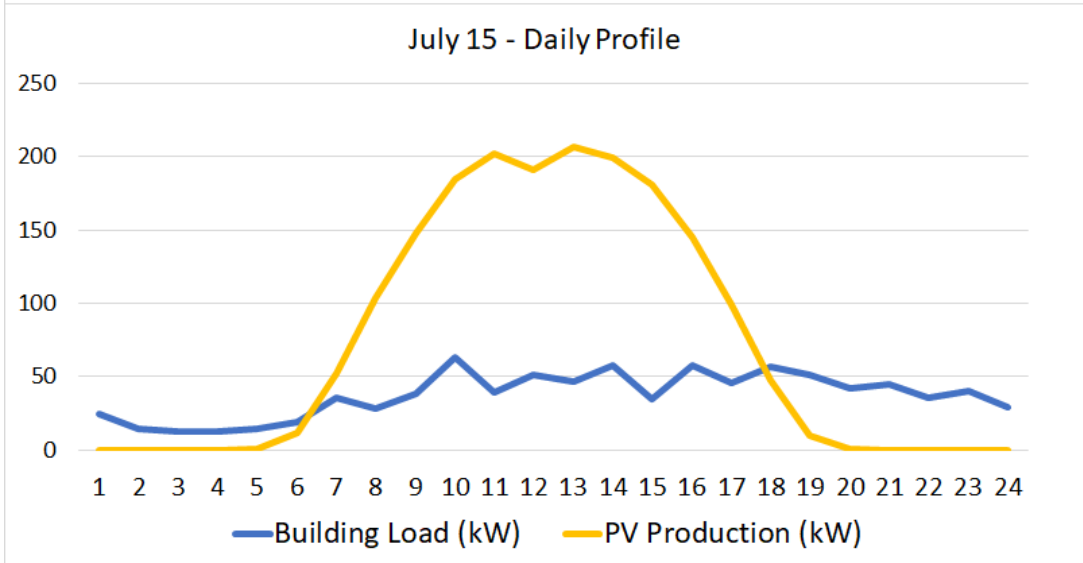
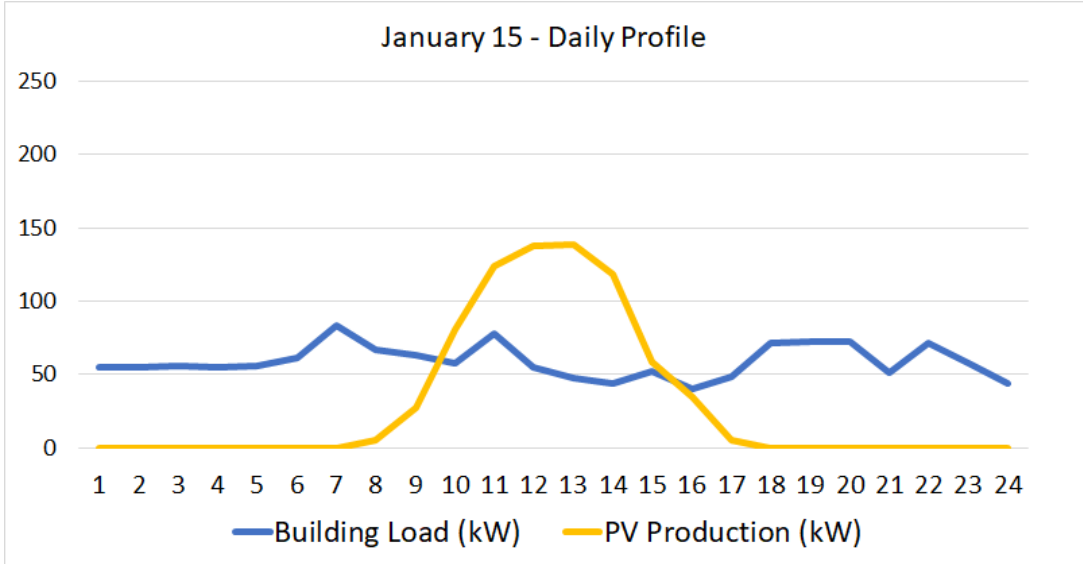
Baseline building



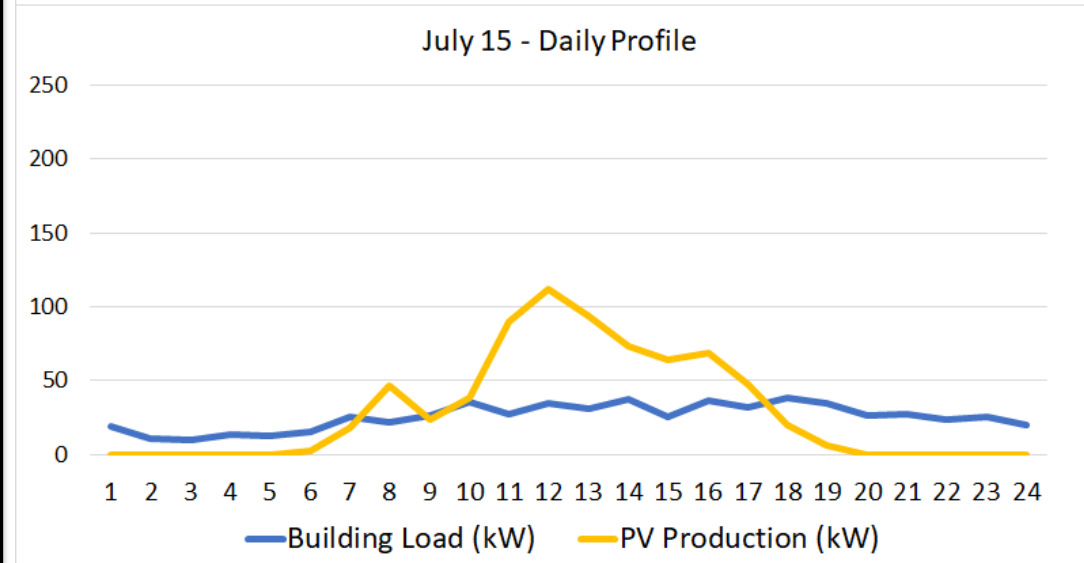
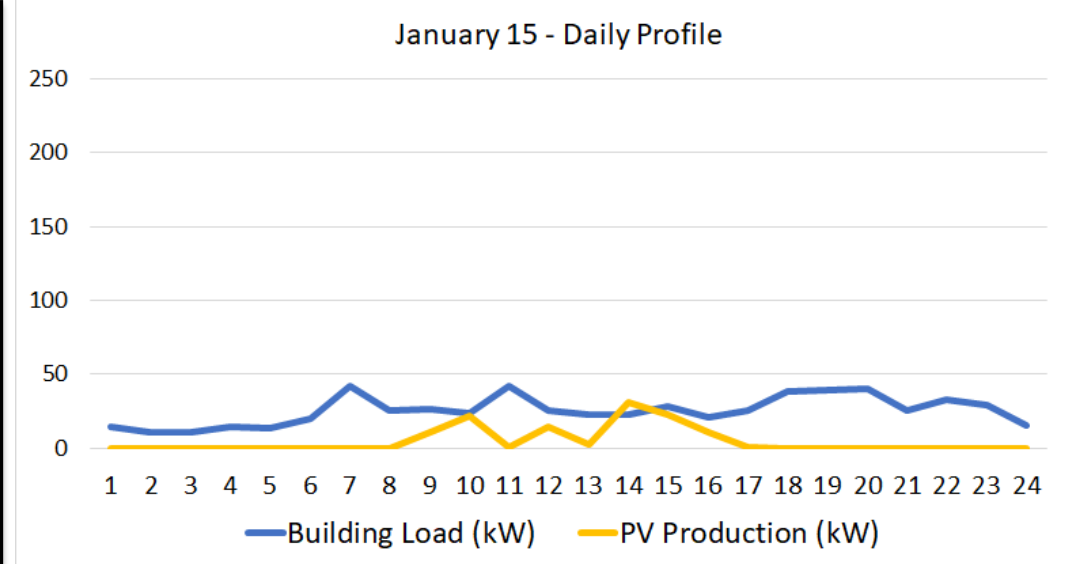
Passive building

Daily Analysis - January & July

CASE STUDY



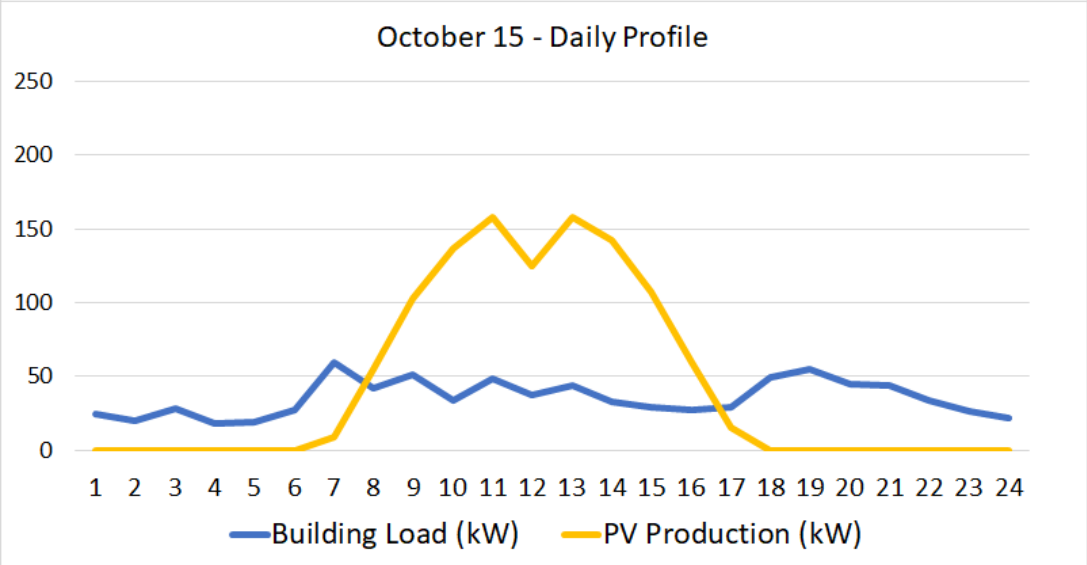
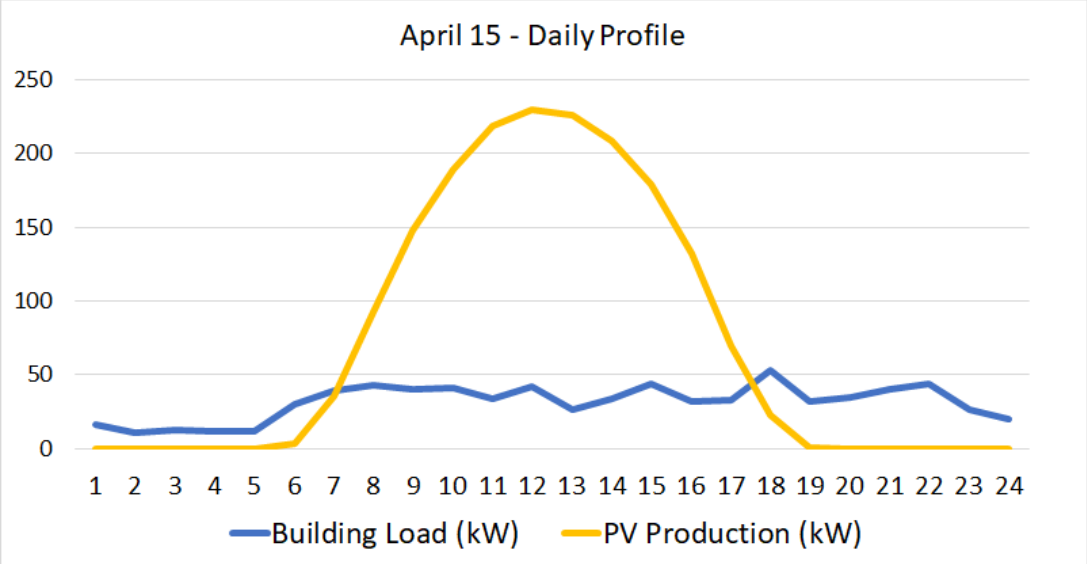
Baseline building



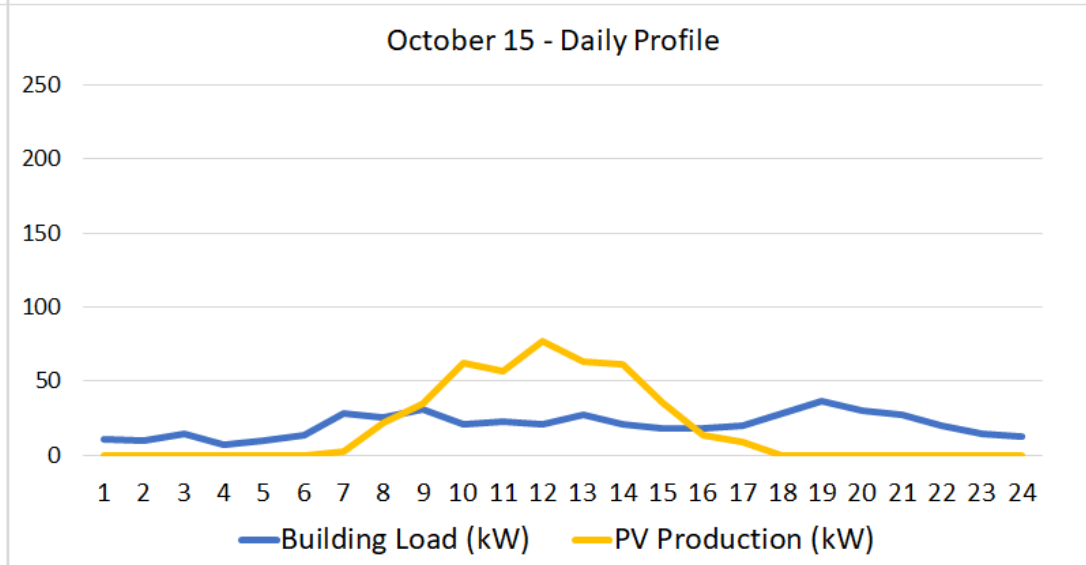
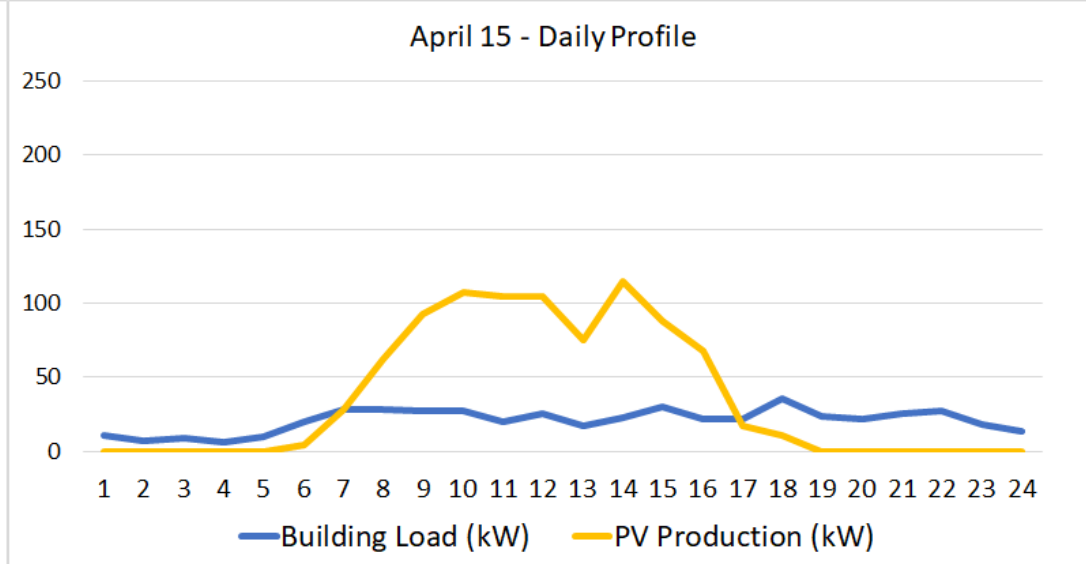
Passive building

Daily Analysis - April & October

CASE STUDY



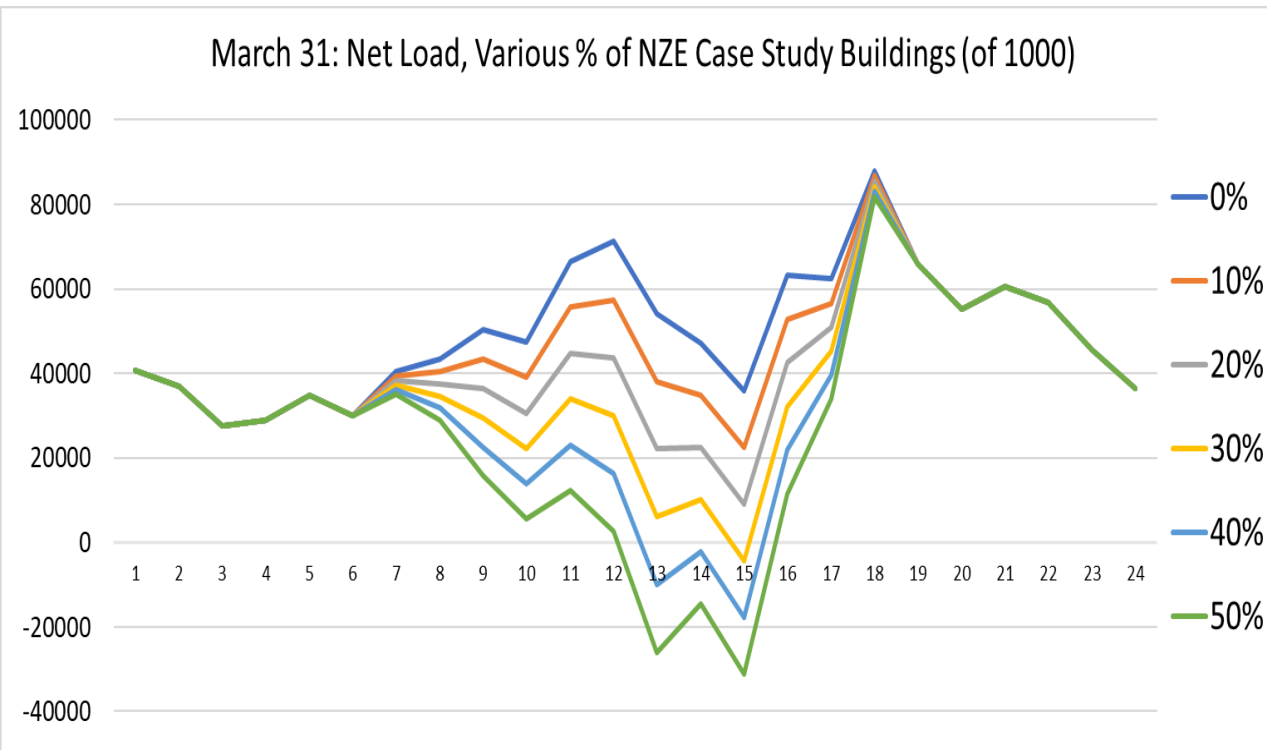
Baseline building



Passive building

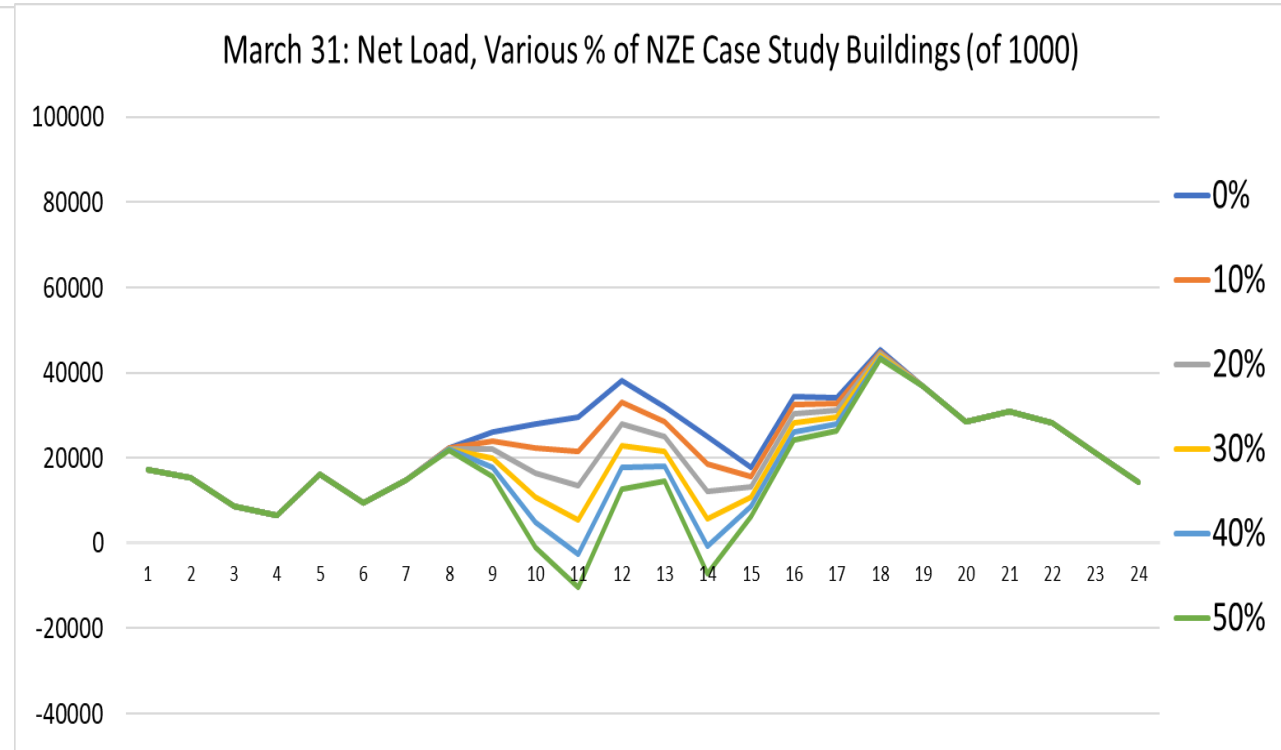
Net Load/ Ramping Analysis

- Few energy generation types can match this ramp.
- Curtailment occurs when 'net load' hits the flat-line baseload.



Baseline building

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

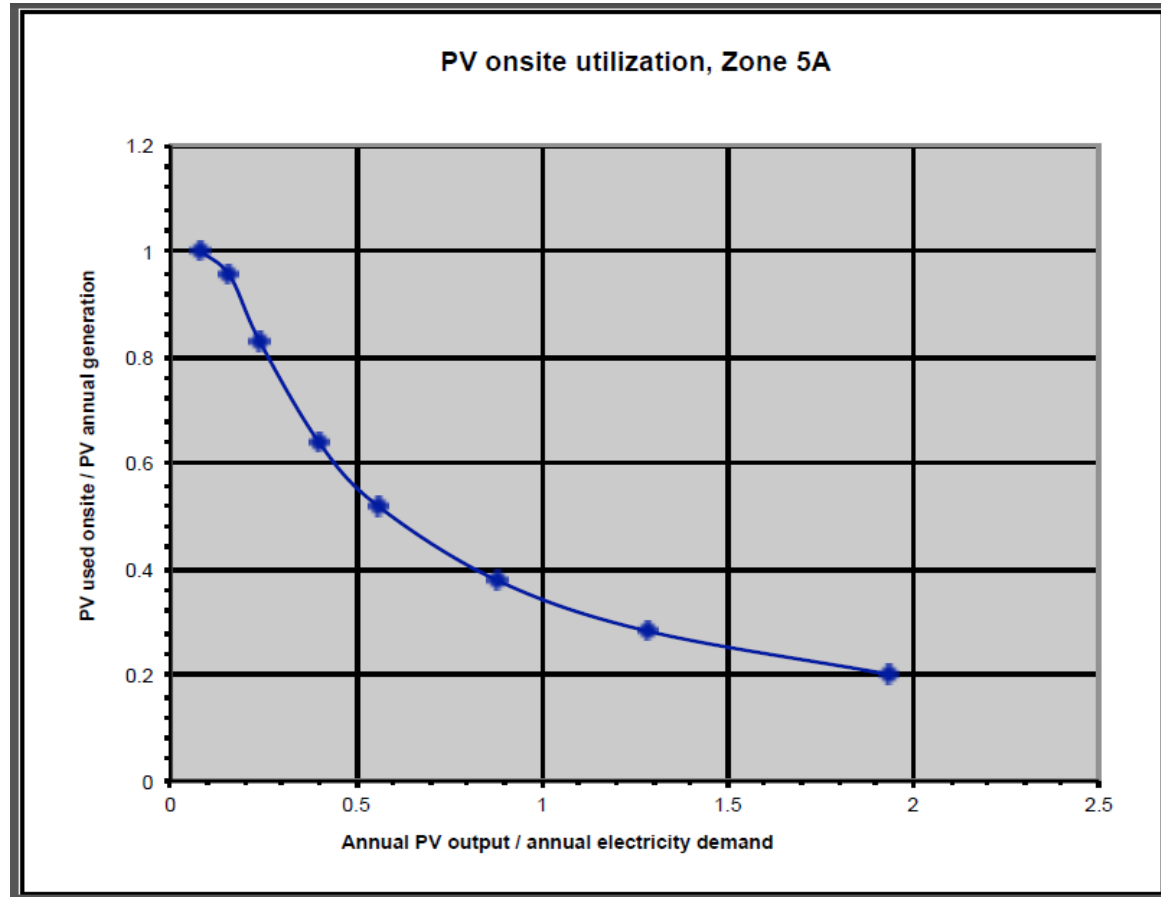


Passive building

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



DIFFERENCE
covered by grid
99,102 kWh/yr

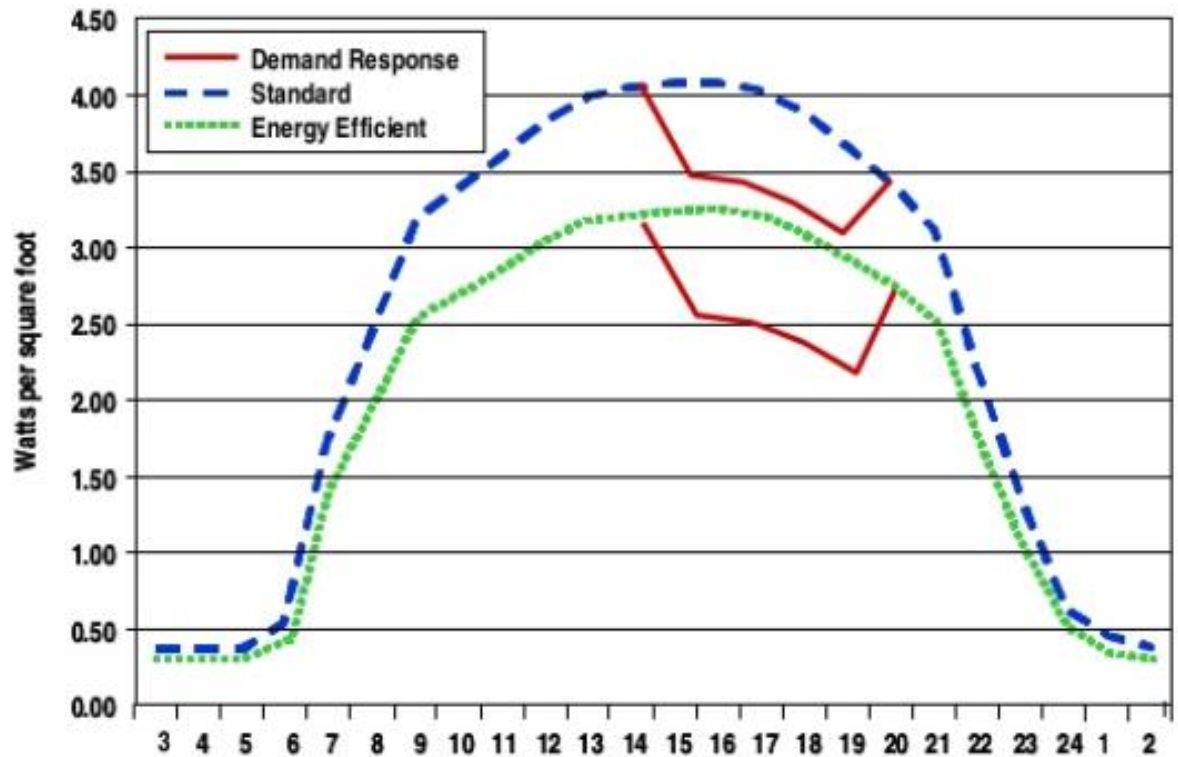
DEMAND RESPONSE

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 vs. Energy Efficiency

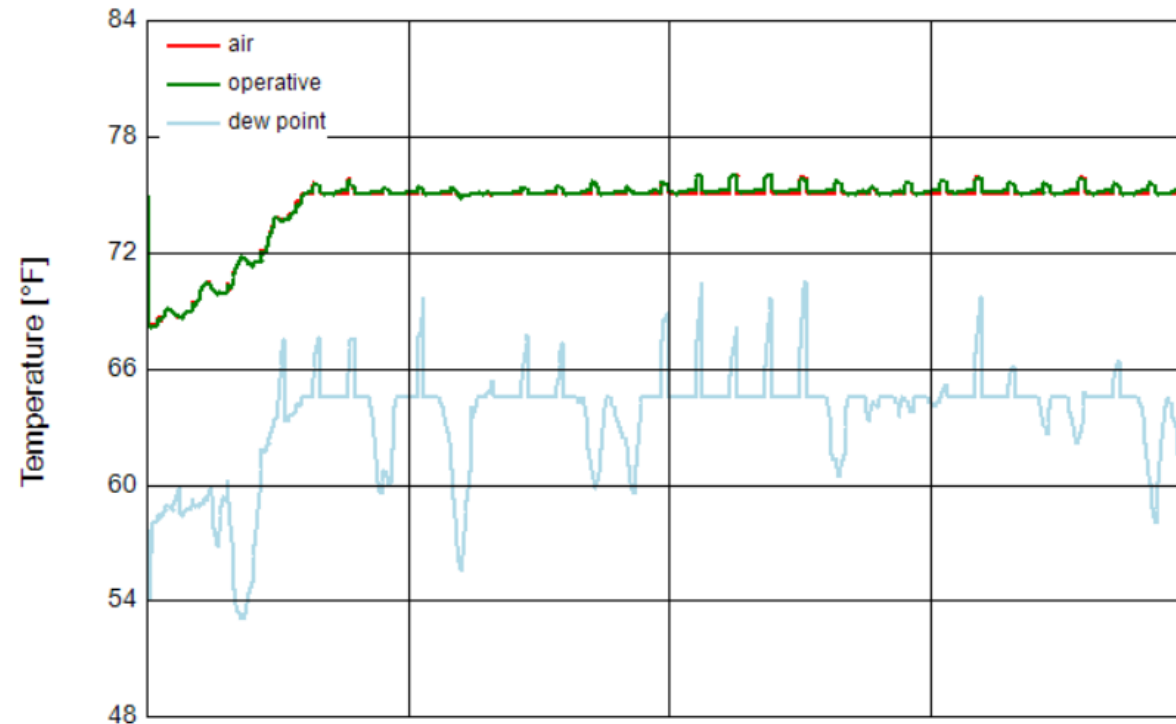


Source: Public Interest Energy Research (PIER) Demand Response Research Center

DEMAND RESPONSE

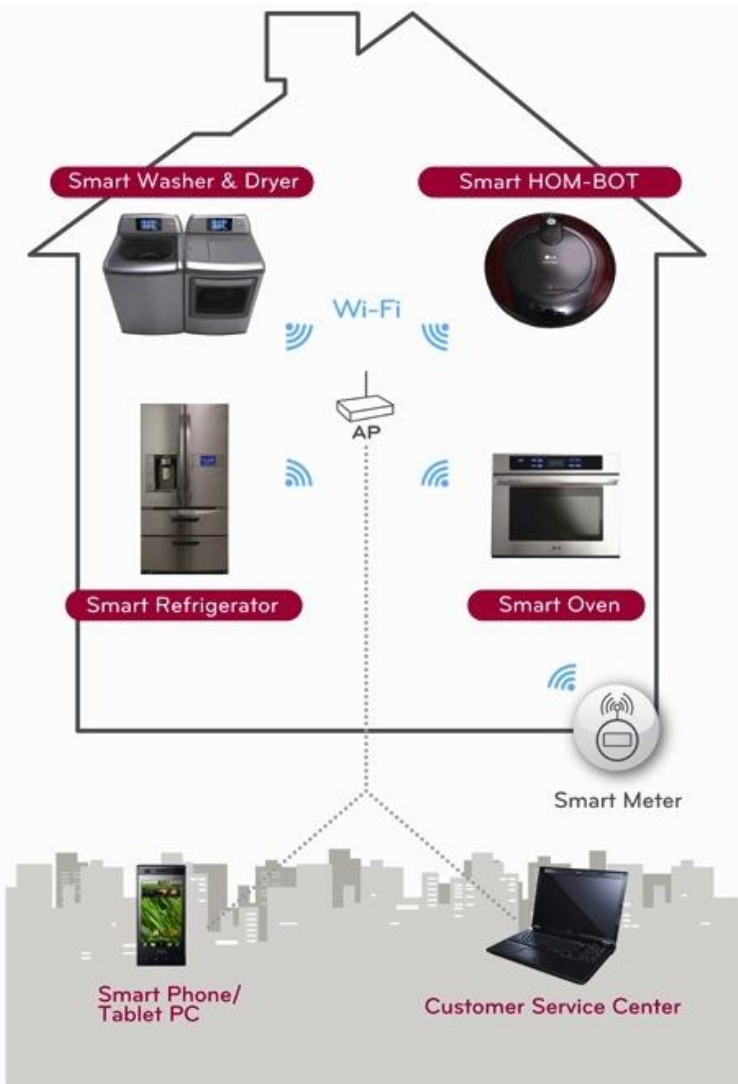
BUT – Passive buildings can potentially shift and change the load shape!

PH - Allow for adjustments in space conditioning based on grid responses, and float through peak times with little to no impact on comfort.



Ex WUFIplus simulation: Remove space cooling/dehumidification capacity from 5pm-10pm, July 1-July 31 – Chicago, IL, single SW corner unit of study building

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.

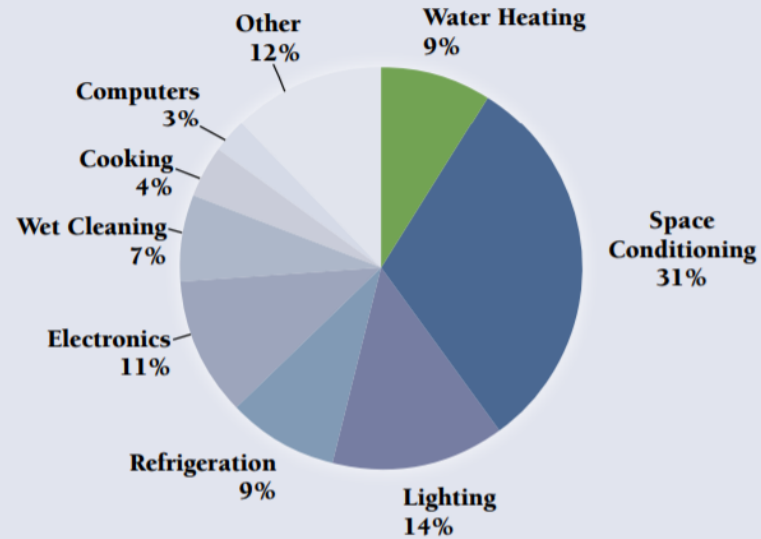


Sure, it's smart, but is it a good conversationalist?

CONTROL ELECTRIC WATER HEATERS

© Passive House Institute US

Residential Electricity Demand by End-Use



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

Water heating = 9% of total elec load in residential application
Can be 50% or more in passive buildings!

Water heater control can act to stabilize intermittent renewable energy generation and also act as storage and provide ancillary services for the grid.

Example calc:

Water Heater: 4000 kWh/yr

1 kW Wind: ~2000 kWh/yr

1 grid-controlled WH provides balancing for 2 kW wind power.

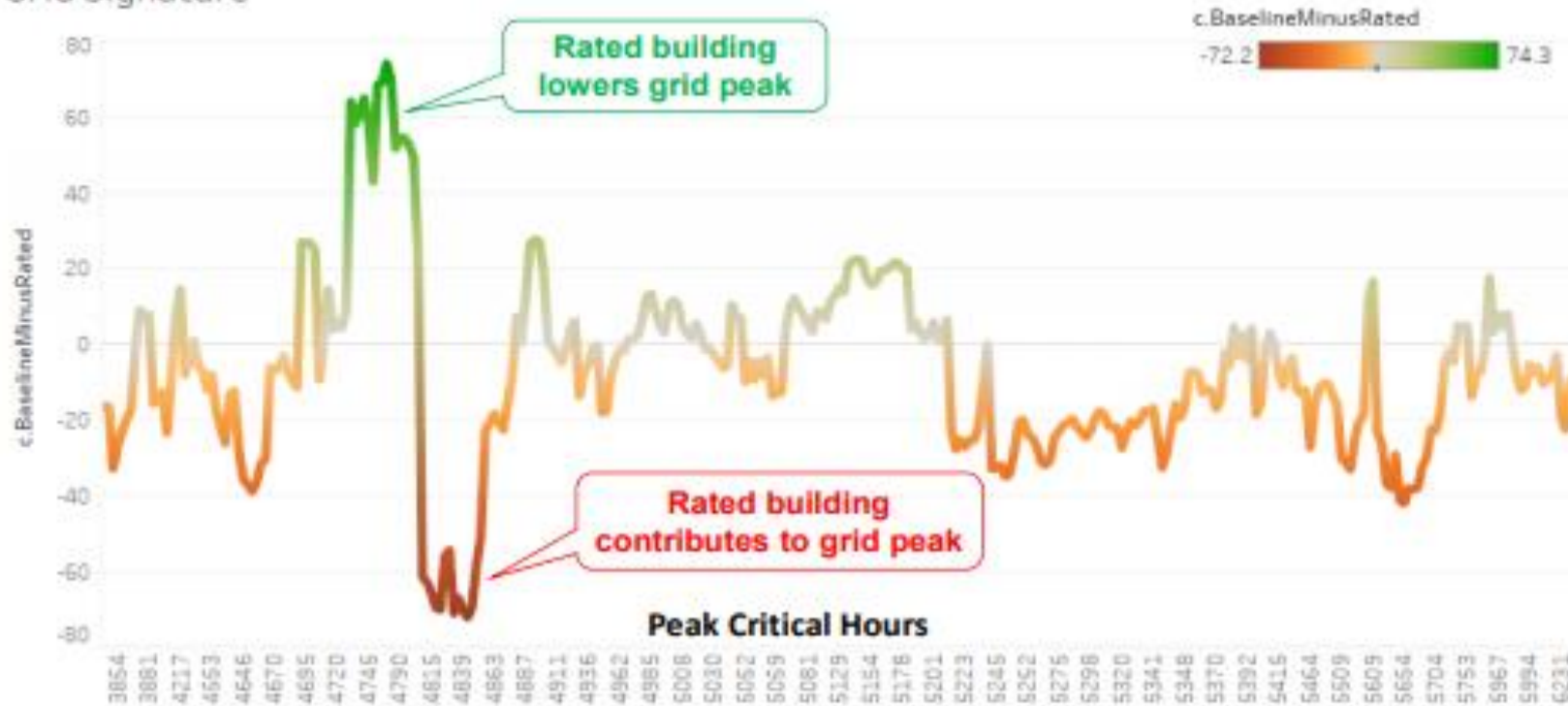
U.S. Water Heaters by Region (×1,000)

	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%

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

GridOptimal™: Grid Signature

Grid Signature



nbi new buildings institute



New Buildings Institute © 2017

Provides value to all stakeholders.

Four steps for GridOptimal scoring:

1. Identify critical hours from grid signature, peak, and negative peak
2. Compare rated building to baseline building demand during critical hours
3. Weight, aggregate, and score demand variance above/below baseline building
4. Adjust scoring based on other building characteristics (optional)

KEY TAKEAWAYS

- Current operation of the grid is complicated, and is getting more complex due to consumers acting as generators
- Allowing a building communication and response to grid signals is critical
- Quick response time is critical
- 'Net Zero' buildings that favor conservation should be favored by utilities, rather than renewable-oriented style.
- Communication between the grid and building for large appliances and water heaters has a lot of potential.
- Passive buildings have the ability to shed space conditioning loads when called upon (demand response) and minimally impact comfort in the space.
- Passive buildings decrease the mis-match between on-site energy generation and use when designing for net zero buildings, and depend less on the grid overall.