Passive Buildings as baseline for the new grid

Lisa White, Certification Manager
Passive House Institute US

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

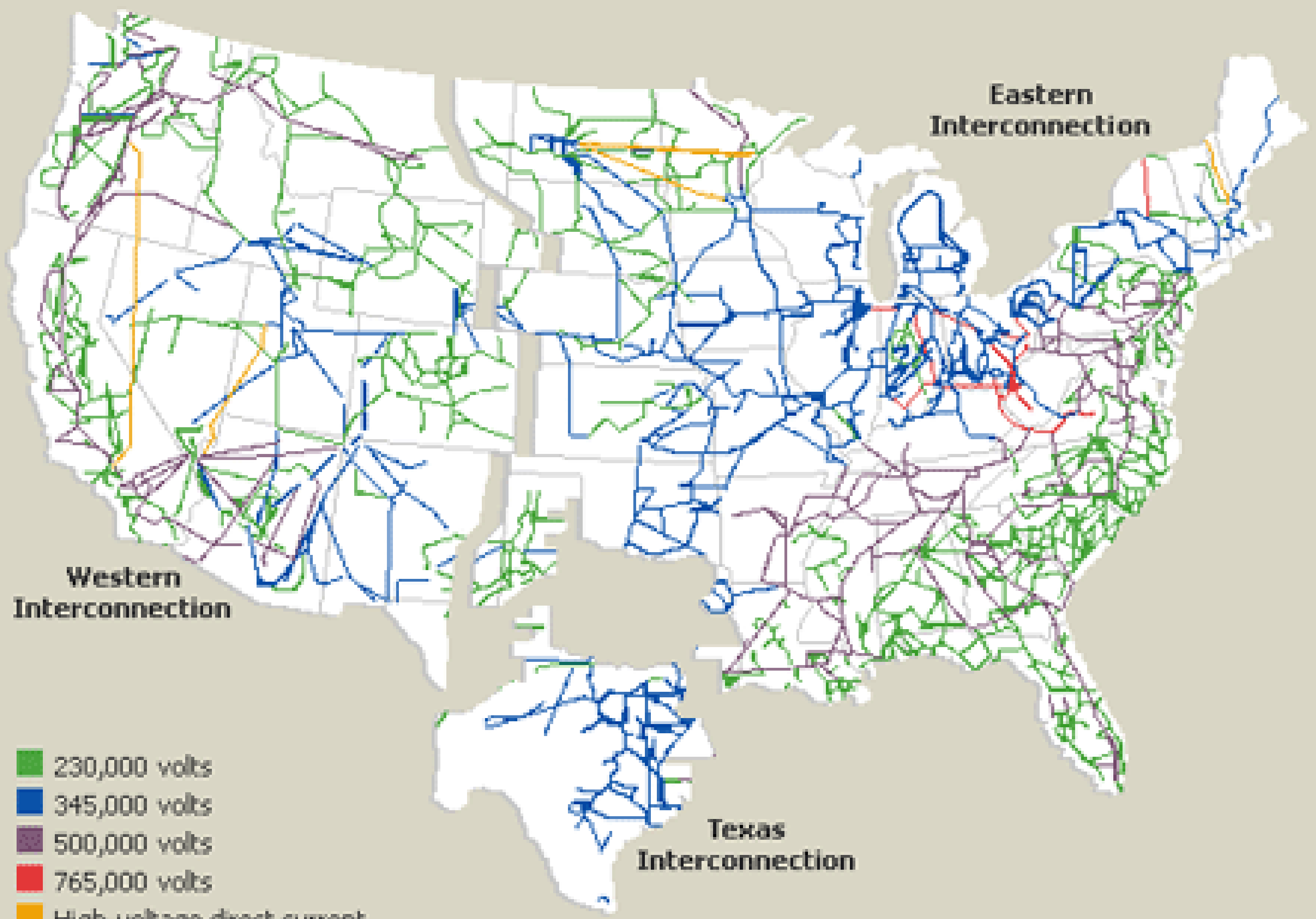
BACKGROUND *on the electric grid*

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

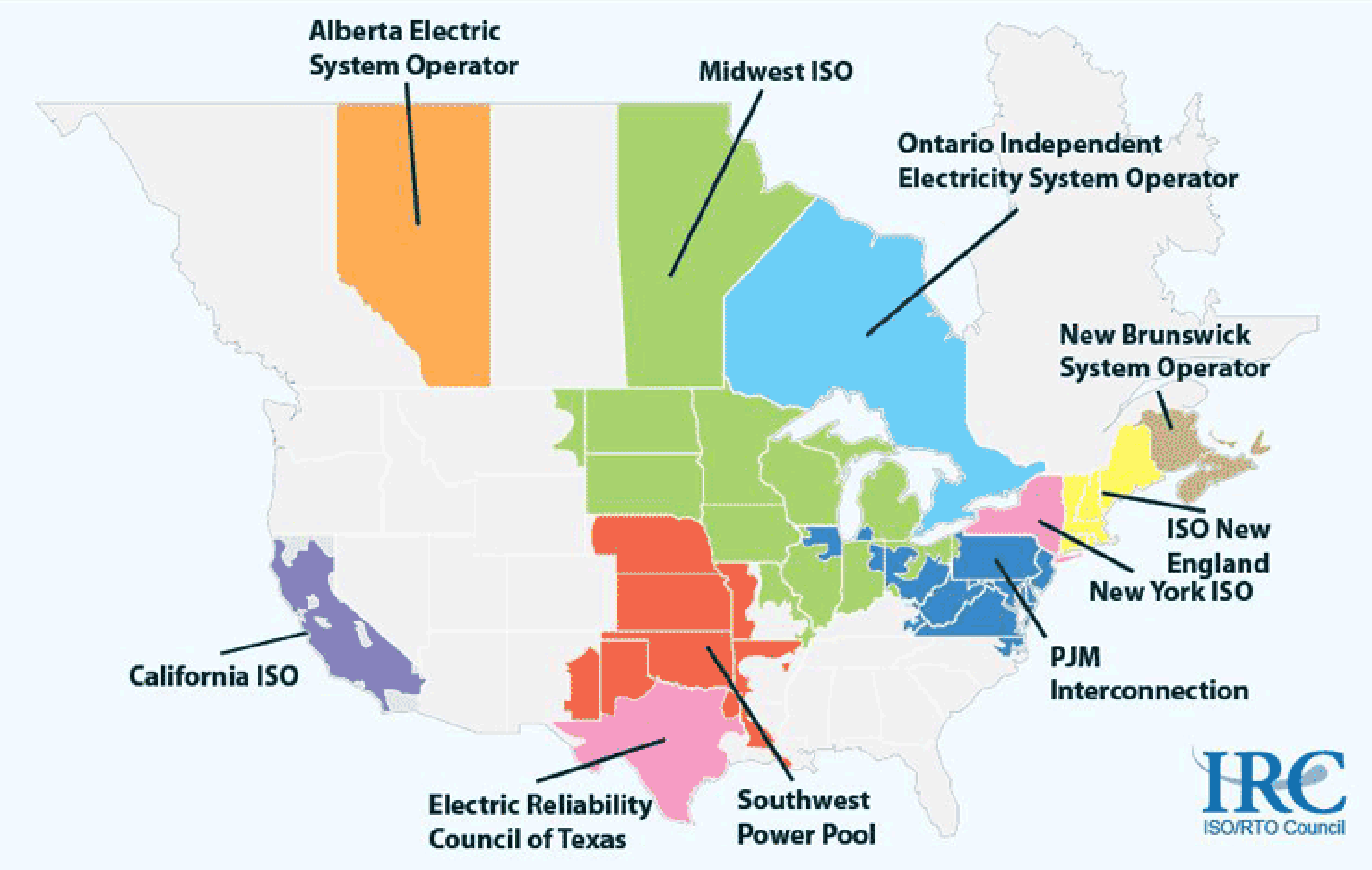
1. What it's made out of
2. Load profiles
3. Generation resources
4. Meeting the electric load

THE ELECTRIC GRID

"The biggest machine on earth"

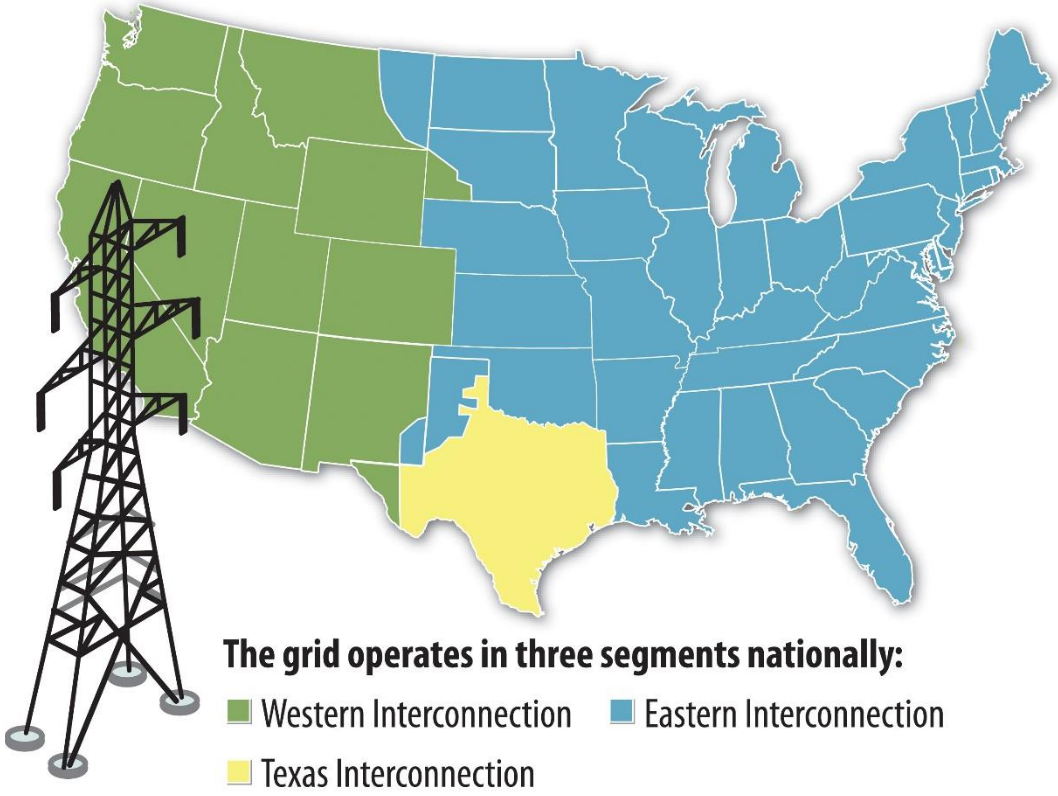


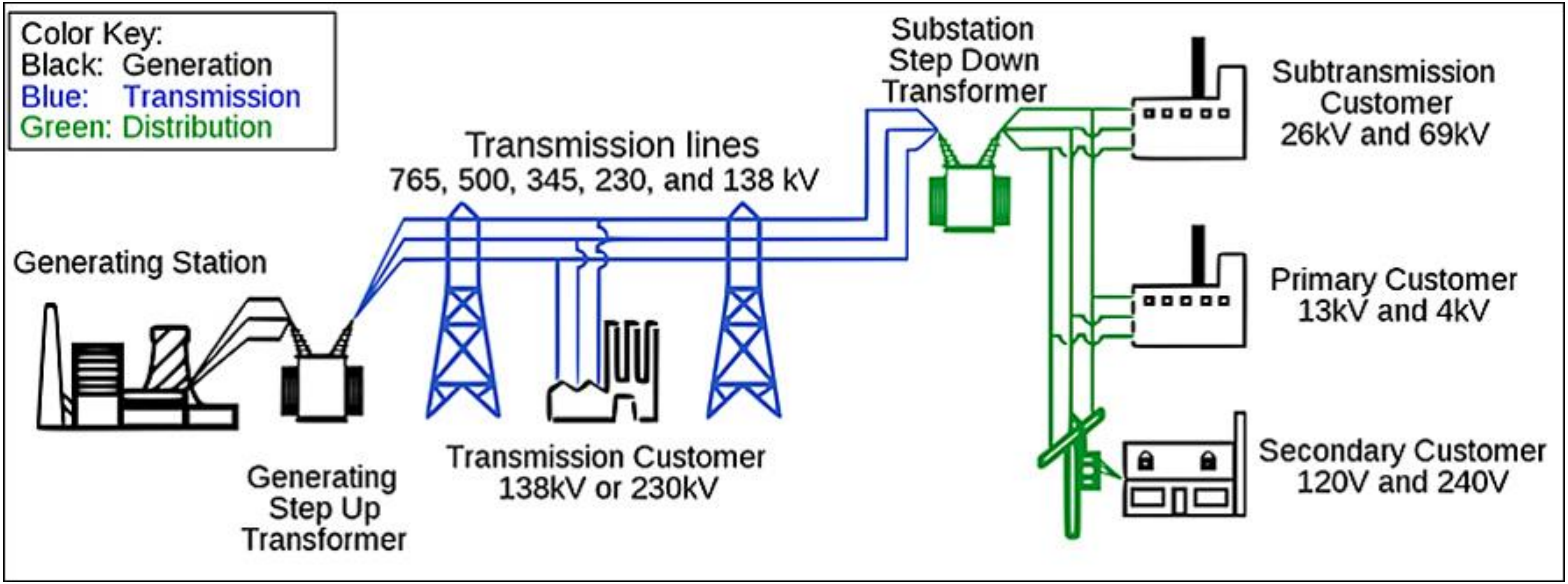
"The National Power Grid," Microsoft® Encarta® Encyclopedia. http://encarta.msn.com © 1993-2004 Microsoft Corporation. All rights reserved.



ISO‘s (Independent Service Operators)

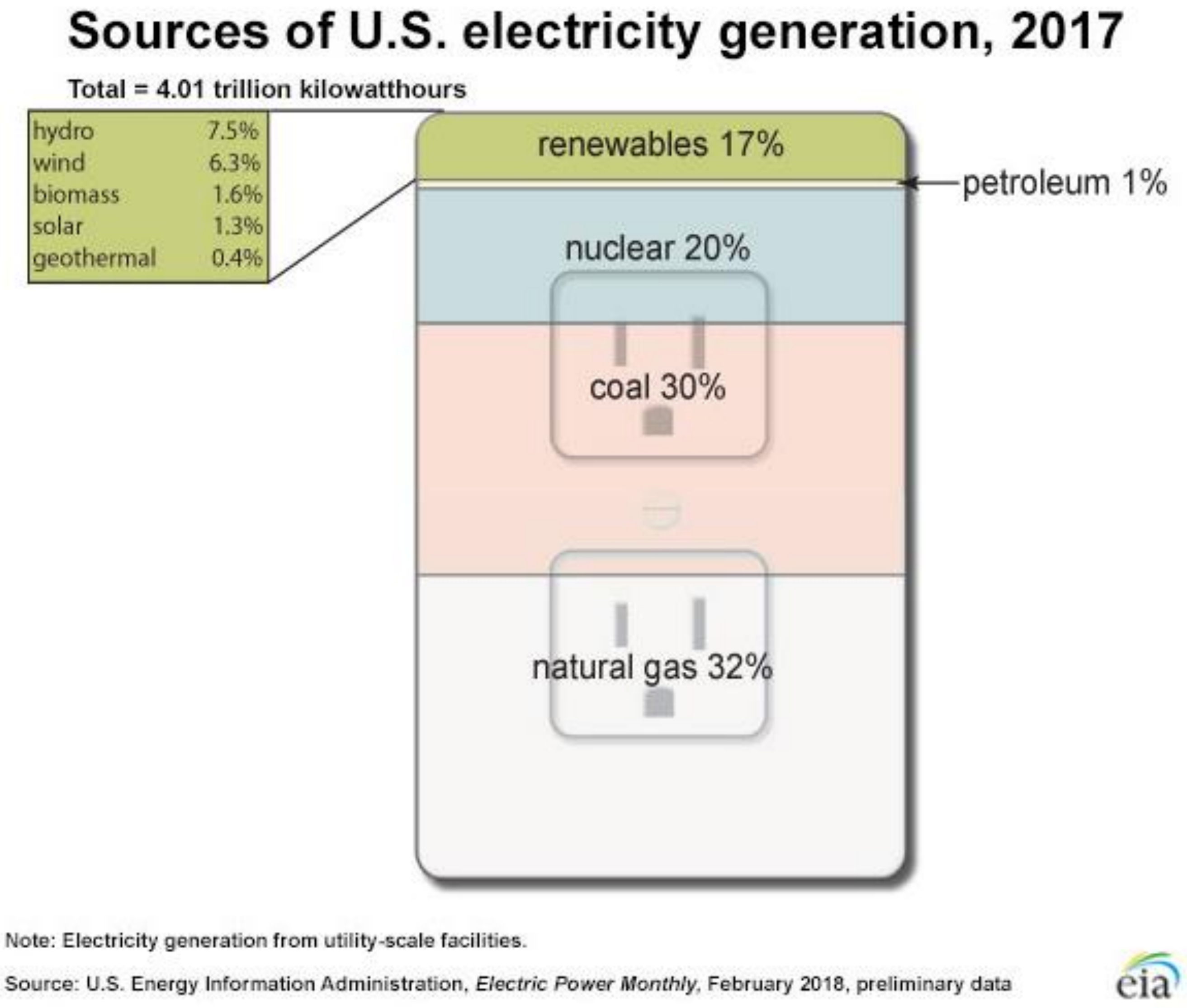
3 segments





CURRENT INFRASTRUCTURE

GENERATION RESOURCES

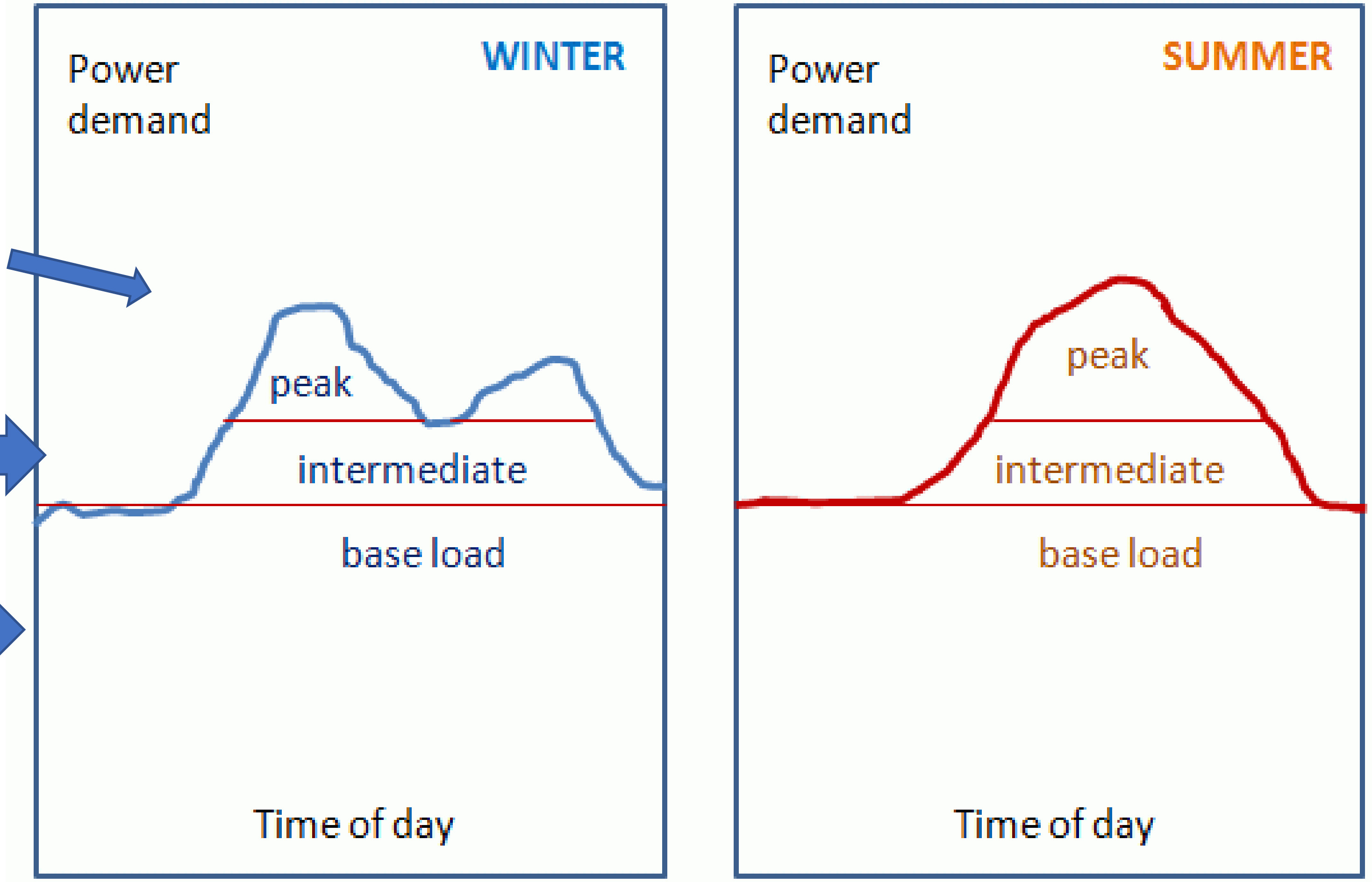


LOAD PROFILES

Natural gas "peaker plants"
Hydro

Natural gas CC
Some renewables

Coal
Nuclear
Some renewables



Electricity Generation Sector - Scheduling

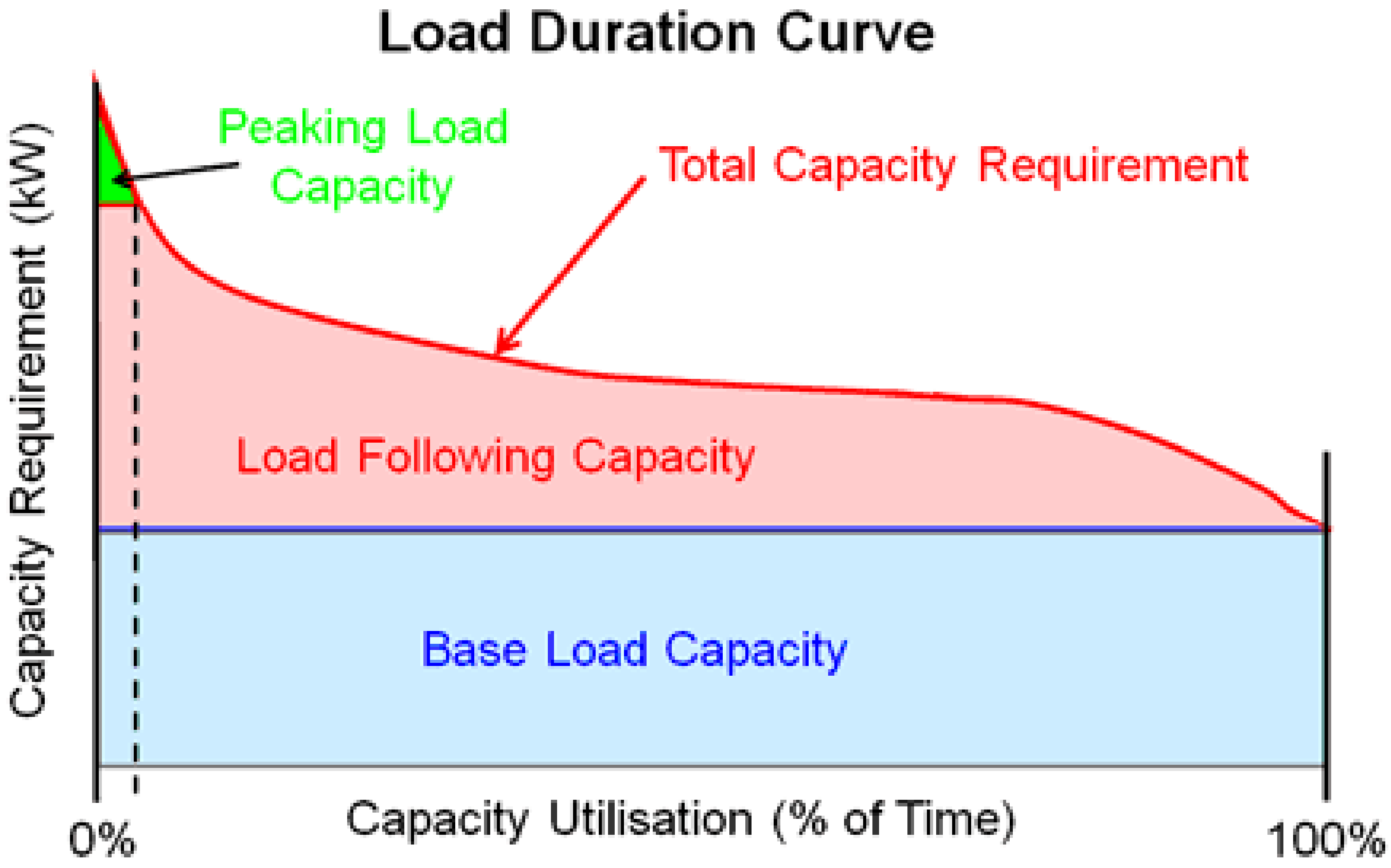
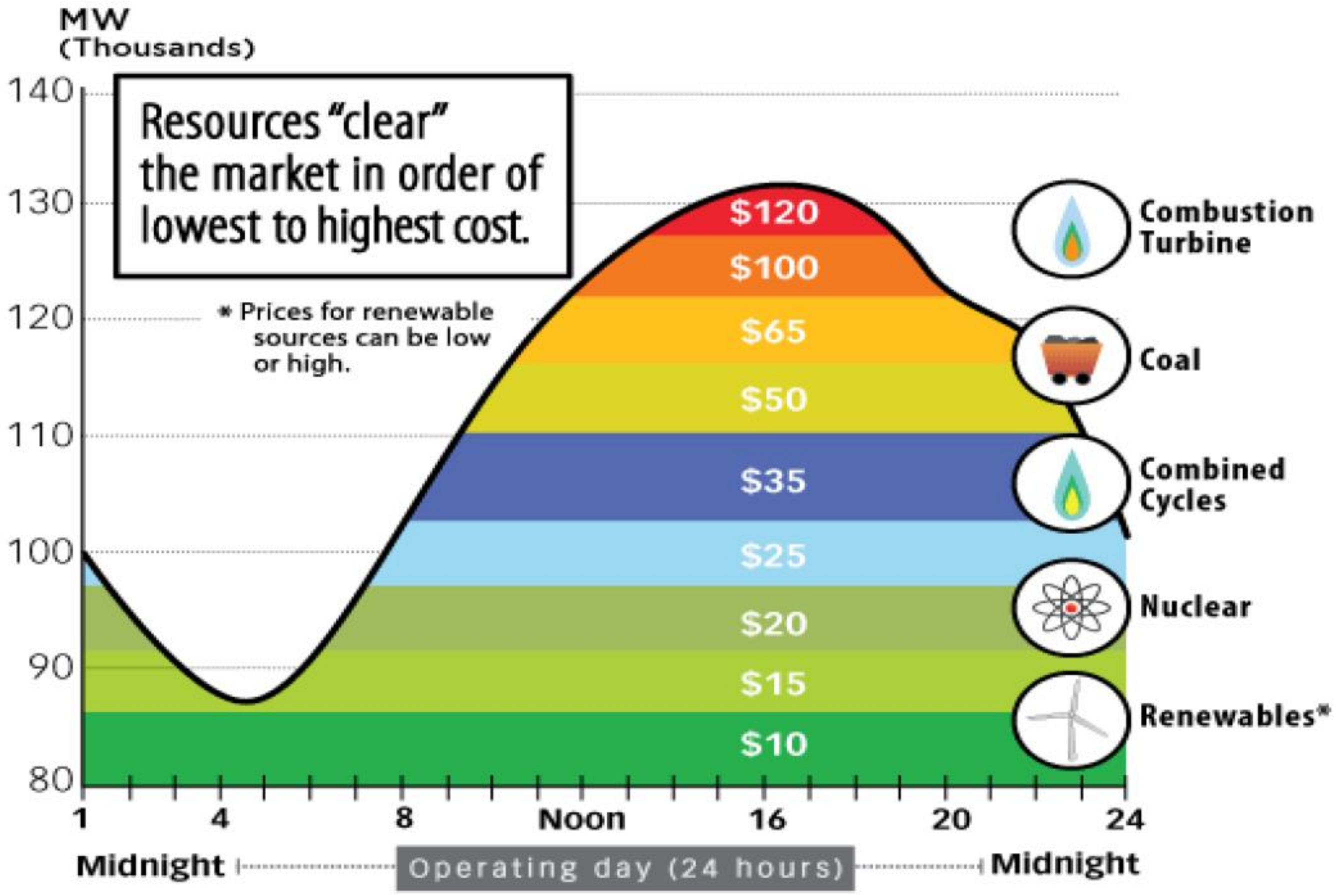


Image Source: Mark Pruitt

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

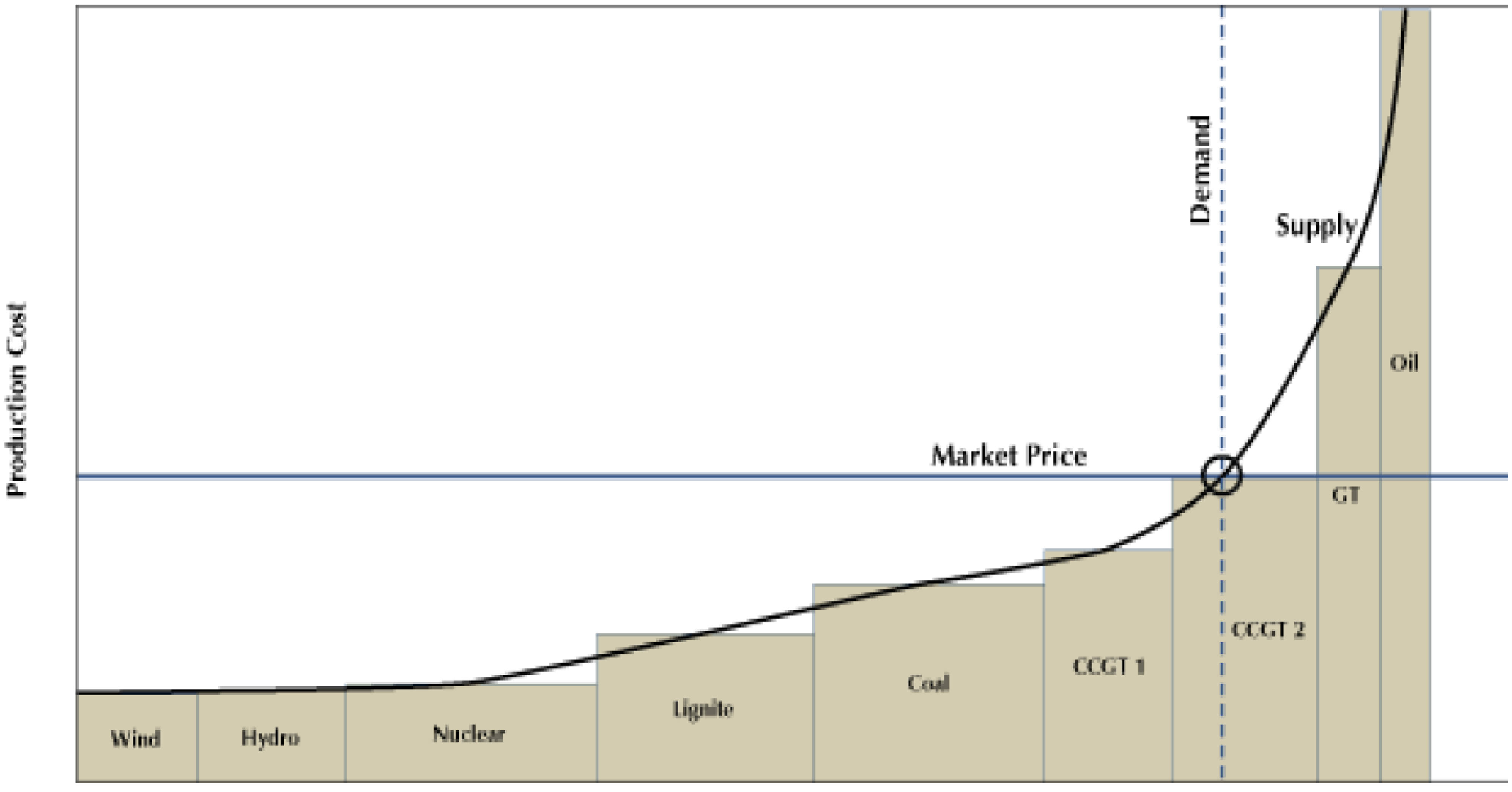
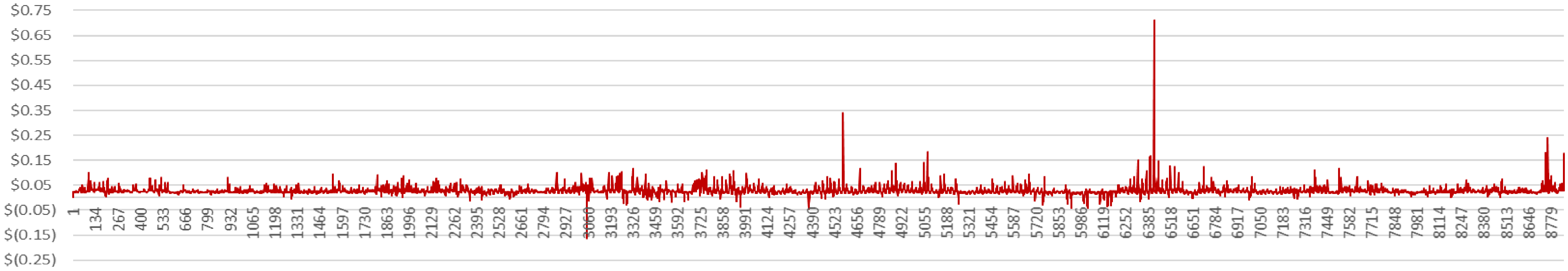


Image Source: Mark Pruitt

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_lmps/definition

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
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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
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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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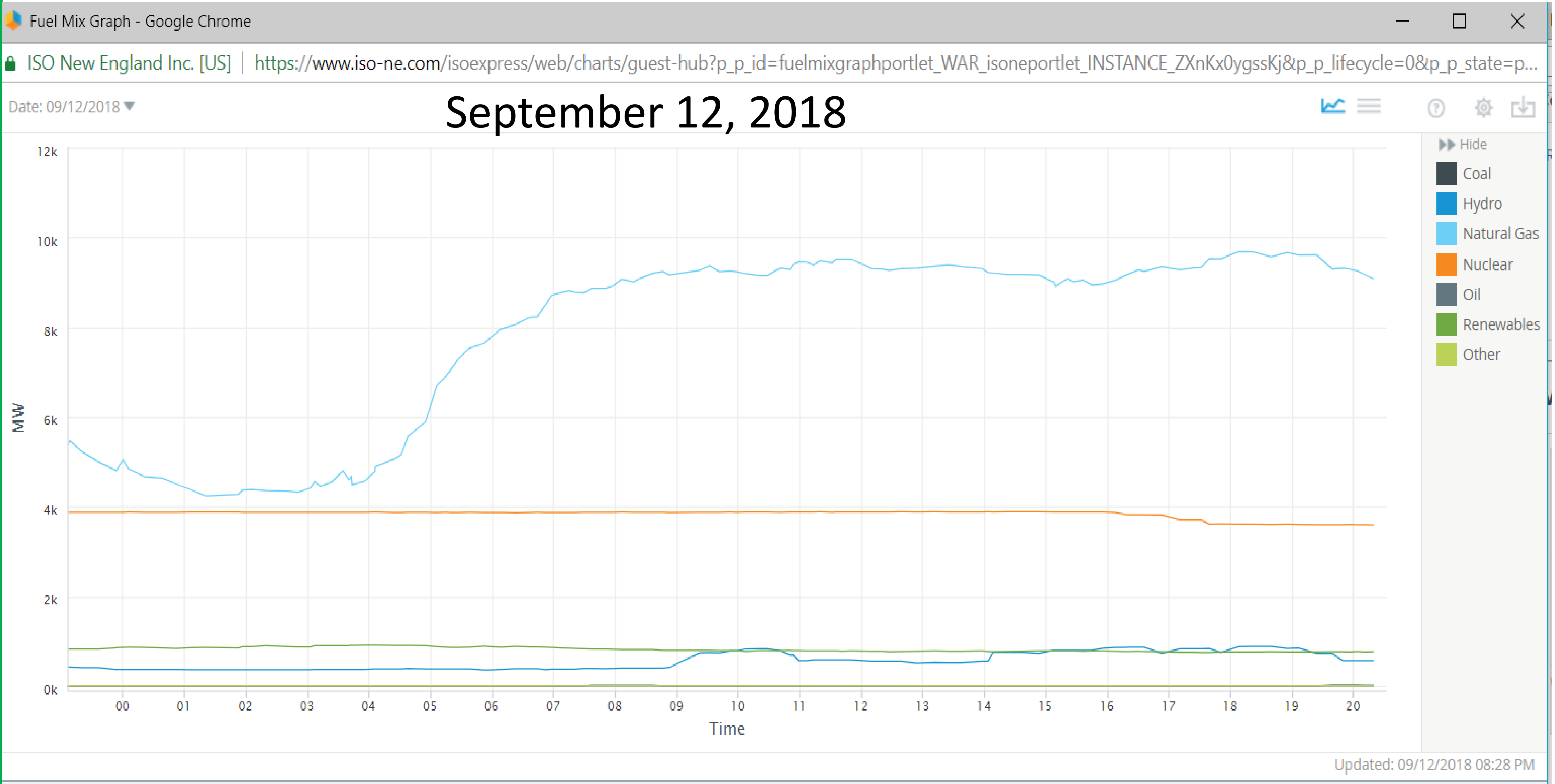
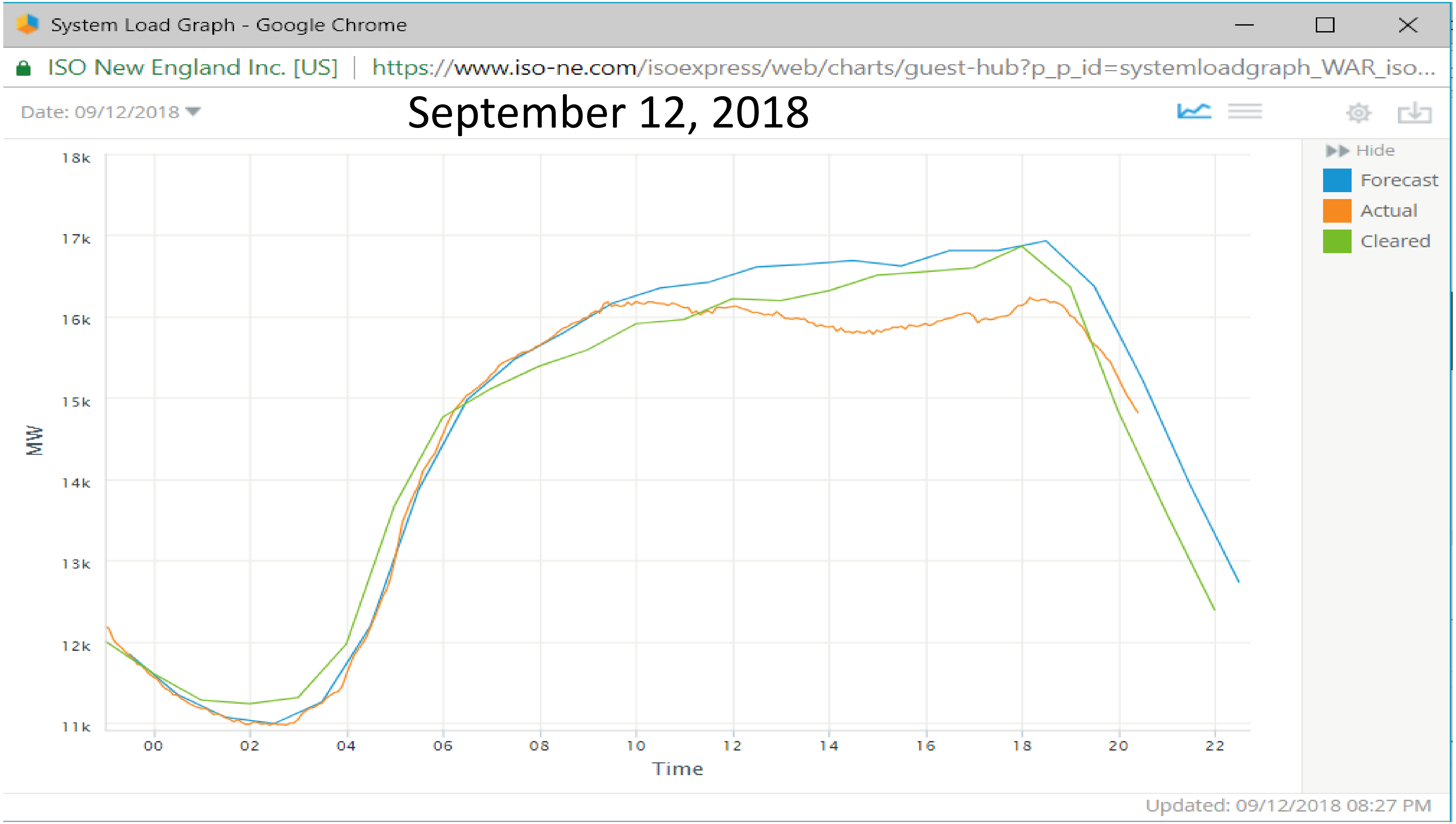
NEW ENGLAND ISO



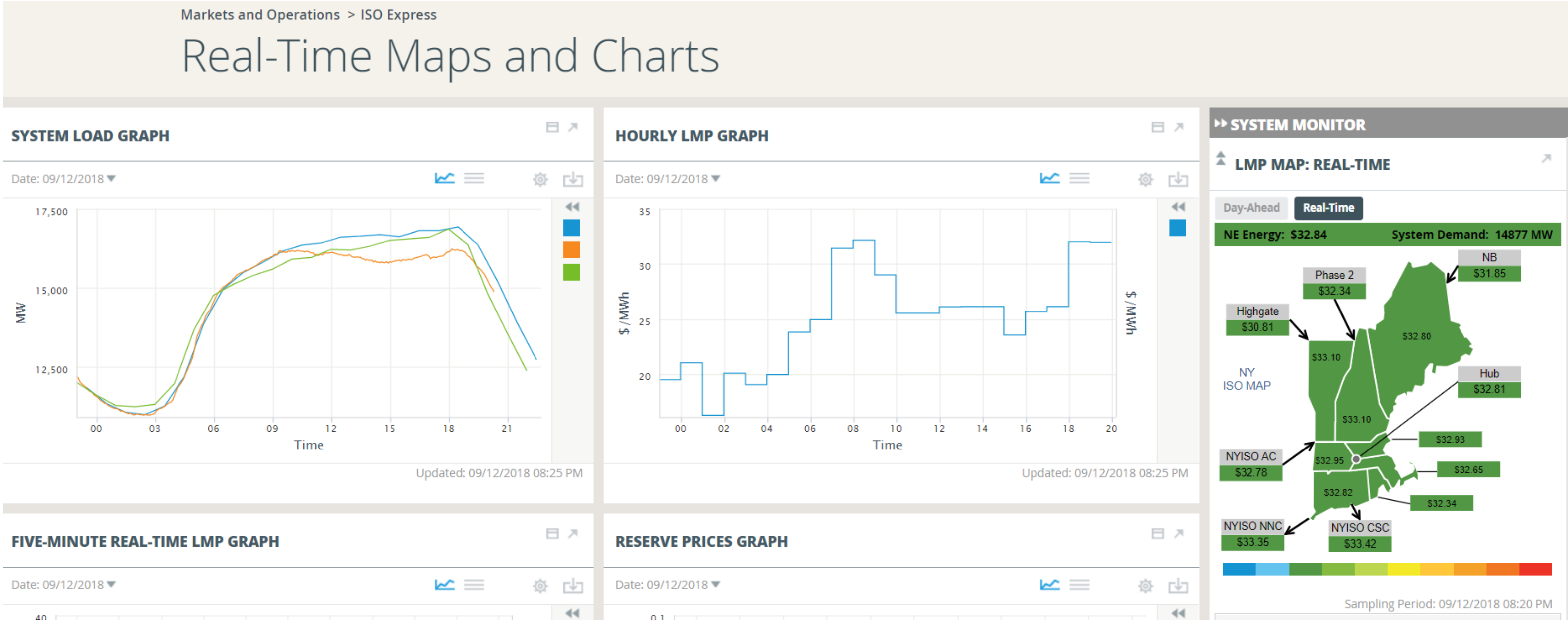
Source: https://www.iso-ne.com/isoexpress/

NEW ENGLAND ISO



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

NEW ENGLAND ISO



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

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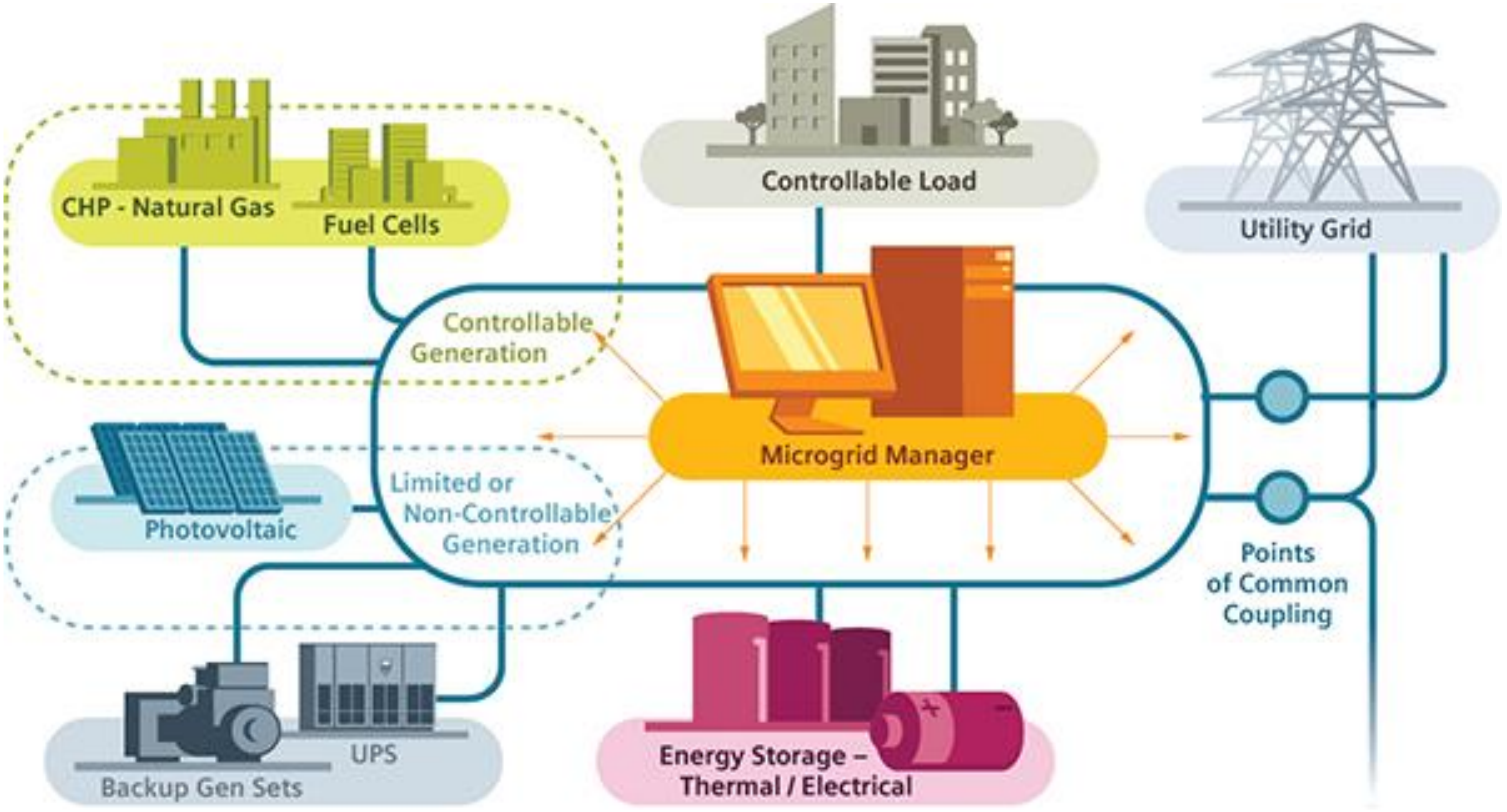
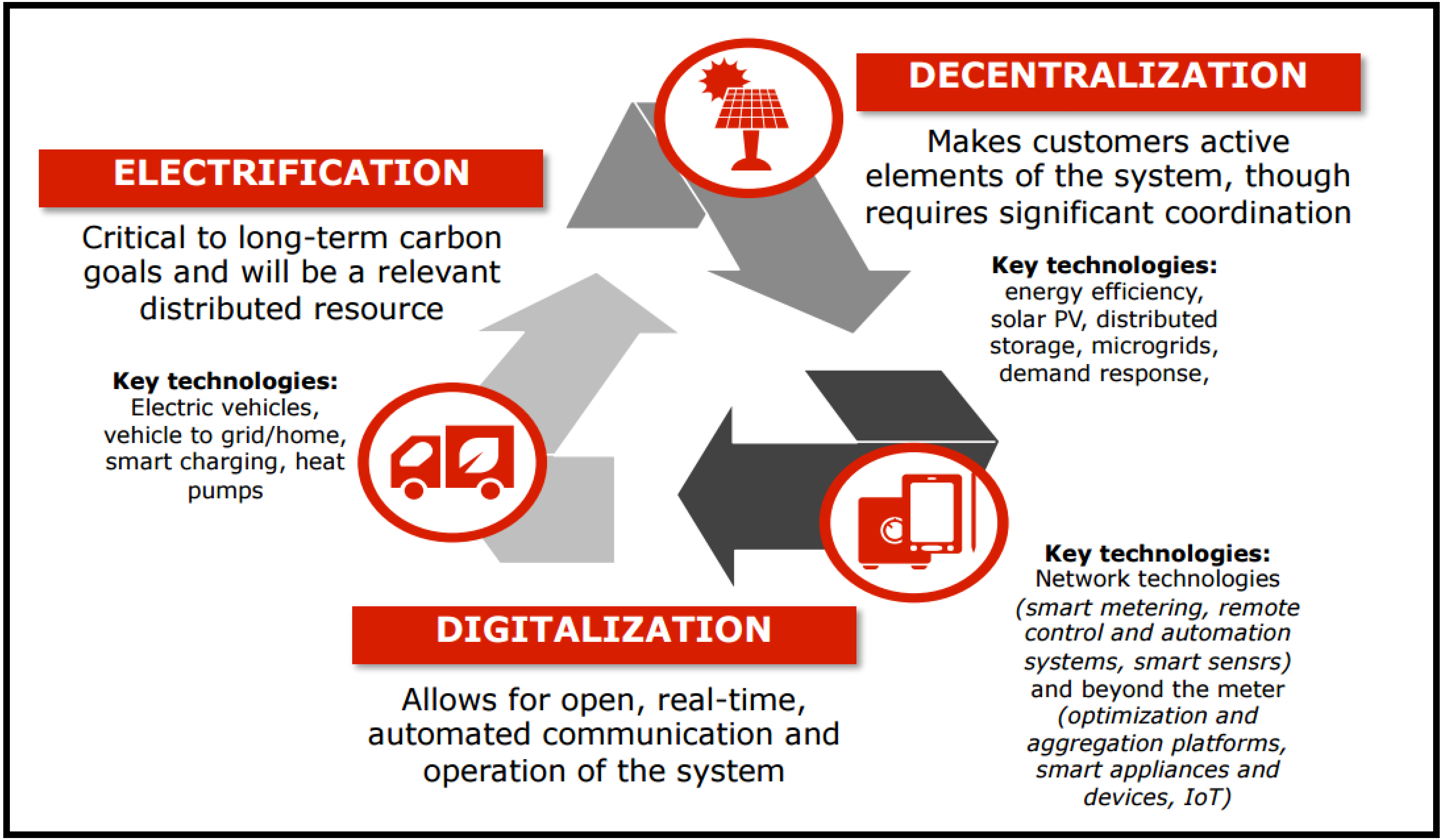
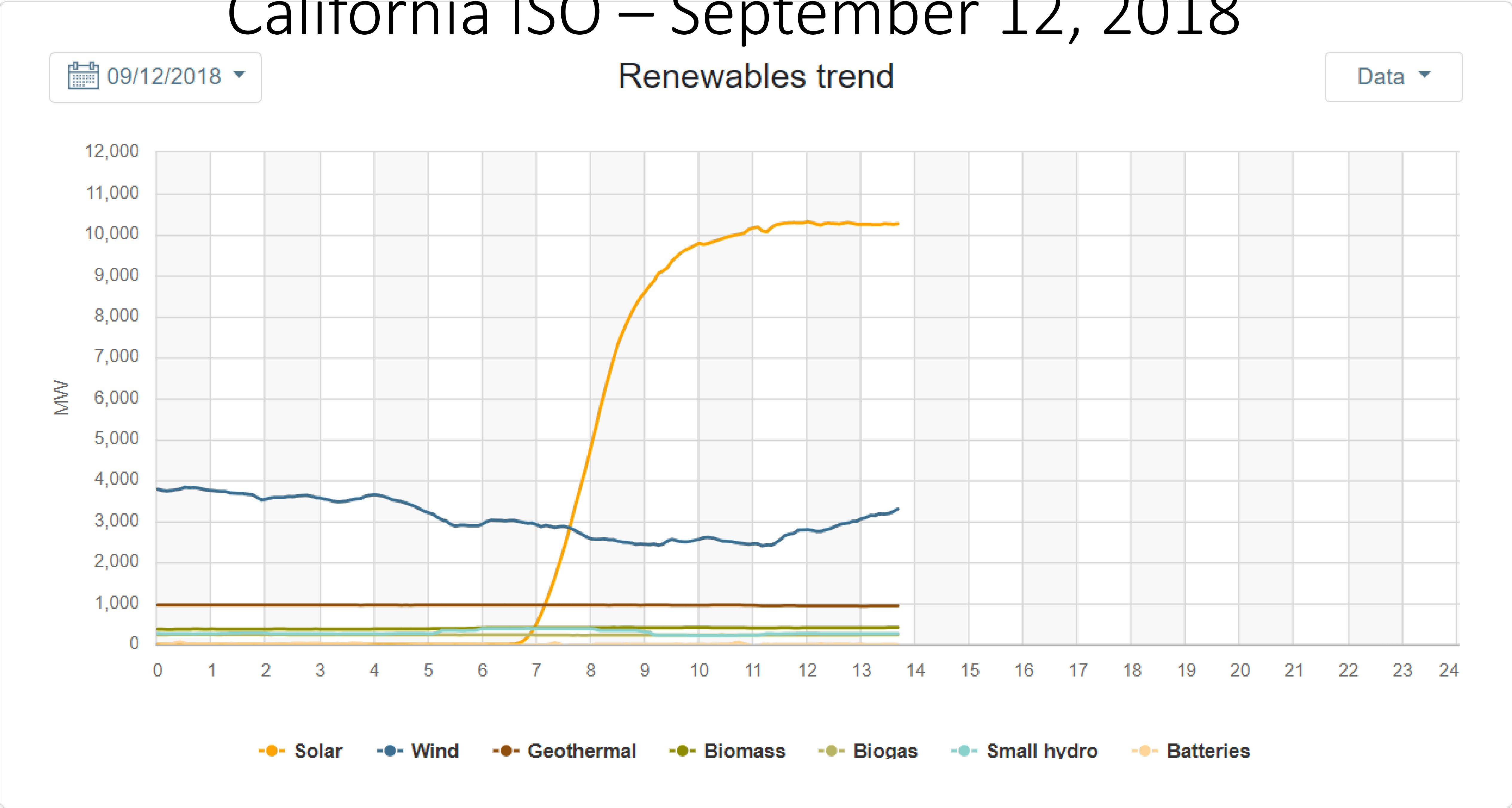
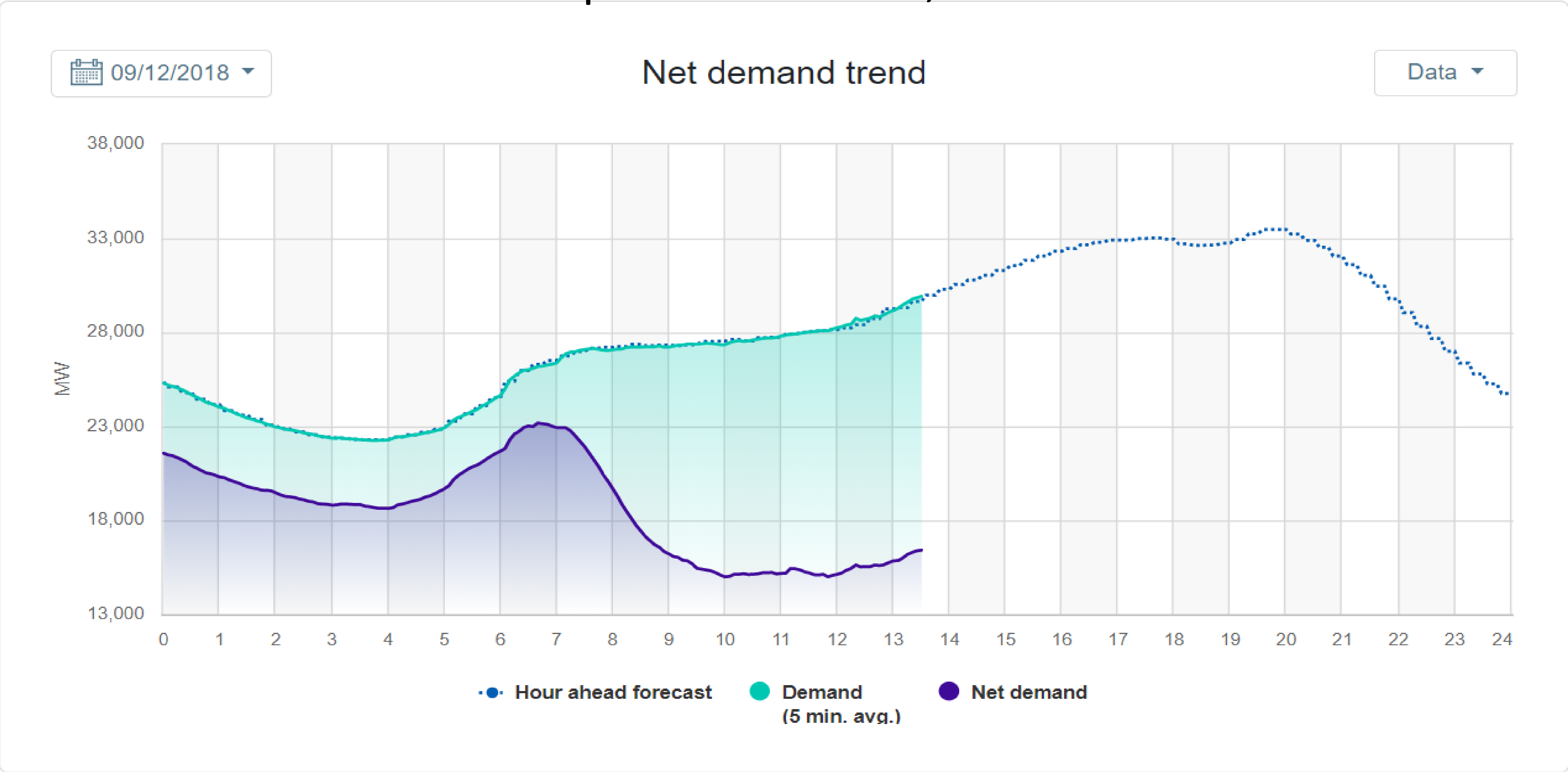

CHP - Natural Gas
Fuel Cells
Controllable Load
Utility Grid
Controllable Generation
Microgrid Manager
Photovoltaic
Limited or Non-Controllable Generation
Points of Common Coupling
UPS
Backup Gen Sets
Energy Storage – Thermal / Electrical


DECENTRALIZATION
Makes customers active elements of the system, though requires significant coordination
Key technologies:
energy efficiency, solar PV, distributed storage, microgrids, demand response,
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
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 – September 12, 2018

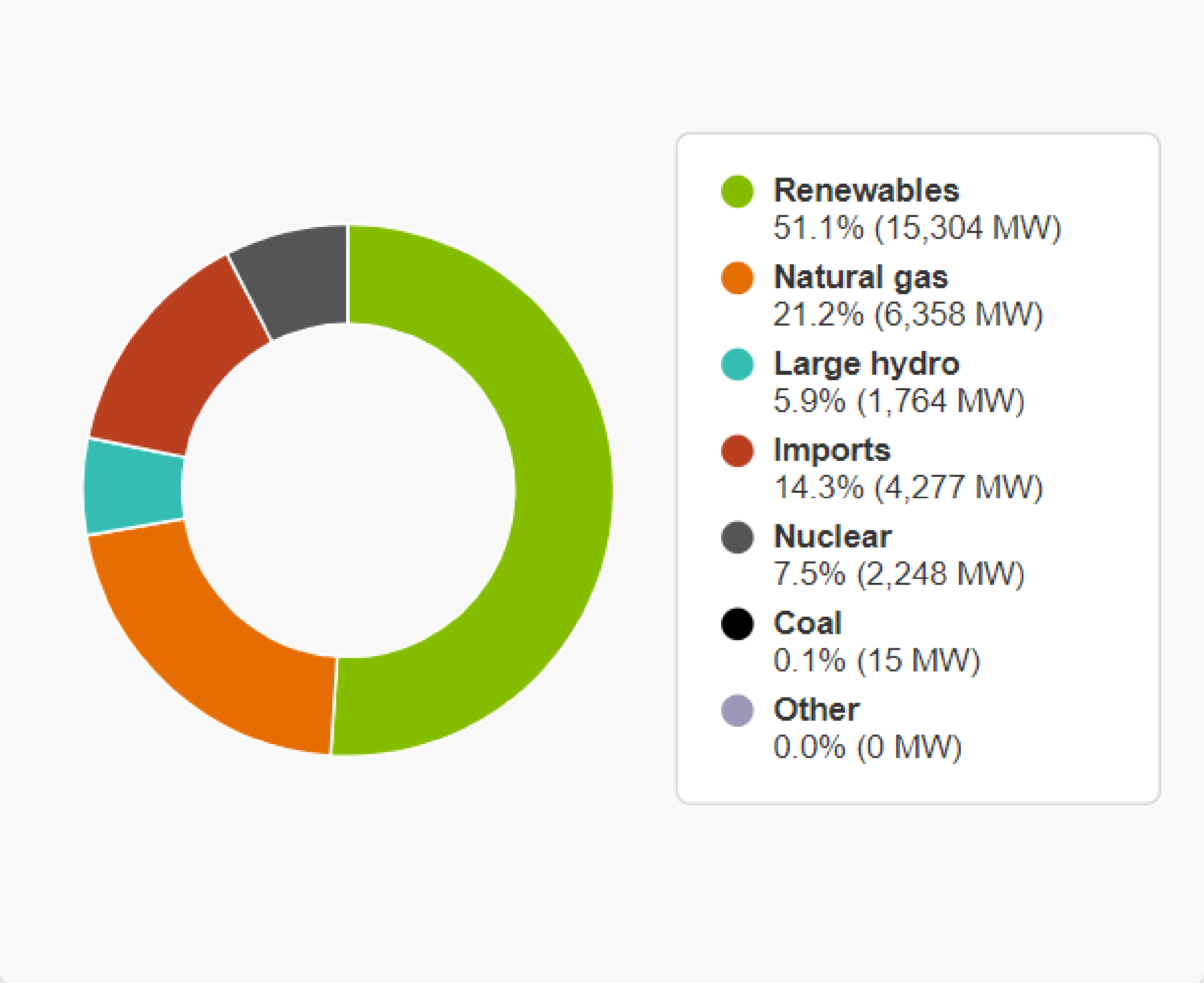


California ISO – September 12, 2018

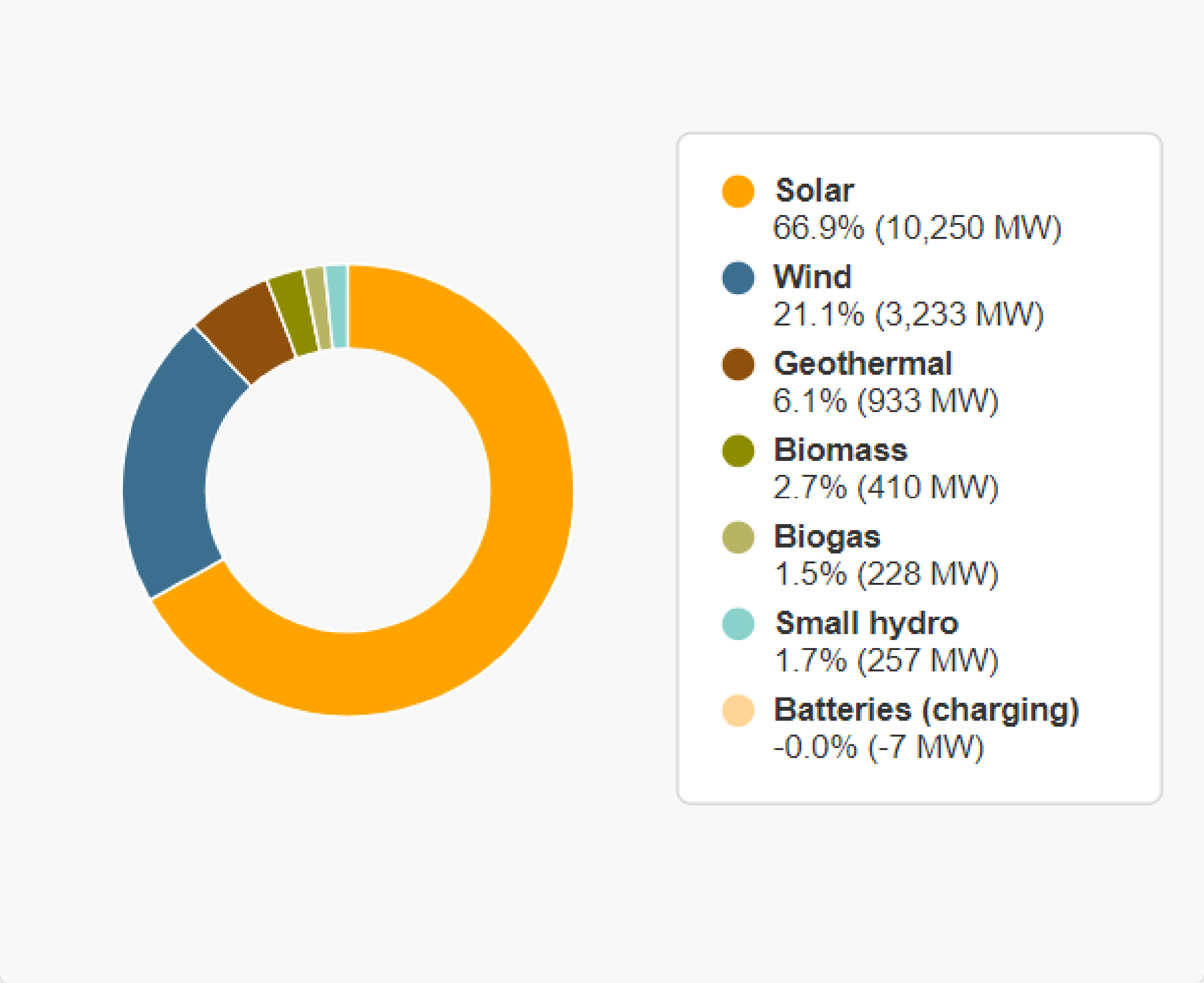


California ISO – September 12, 2018 1:35 PM

Current supply AS OF 13:35



Current renewables AS OF 13:35



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

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

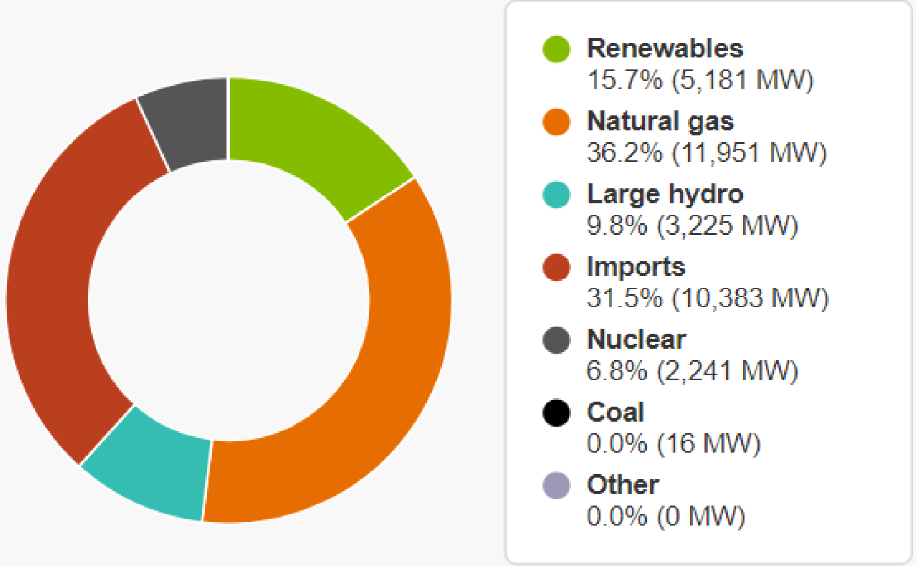
29,964 MW	**15,304 MW**	**10,250 MW**	**3,233 MW**
Current demand	Current renewables	Current solar	Current wind

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

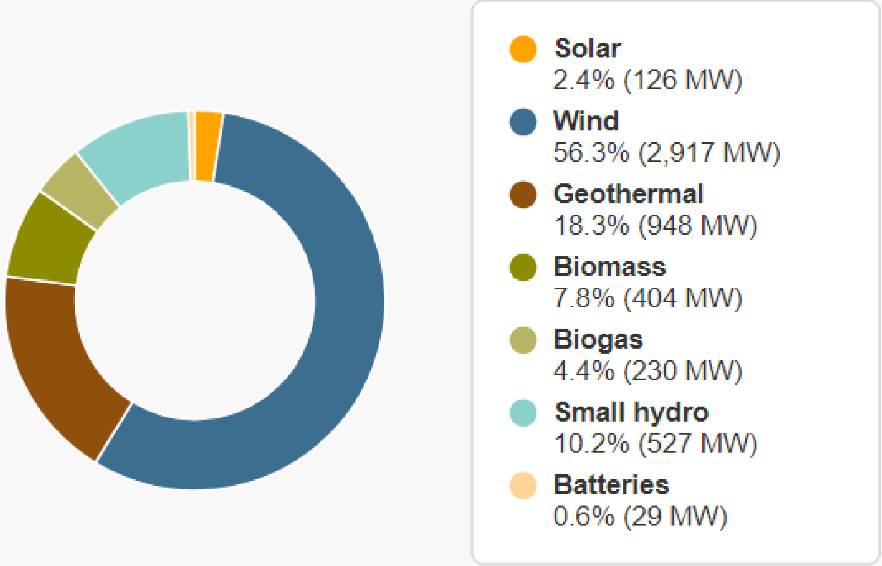
California ISO – September 12, 2018 7:00 PM

Today's Outlook Demand **Supply** Prices Emissions AS OF **19:00 09/12/2018**

Current supply AS OF 19:00



Current renewables AS OF 19:00



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

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	**5,181** MW	**126** MW	**2,917** MW
Current demand	Current renewables	Current solar	Current wind

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

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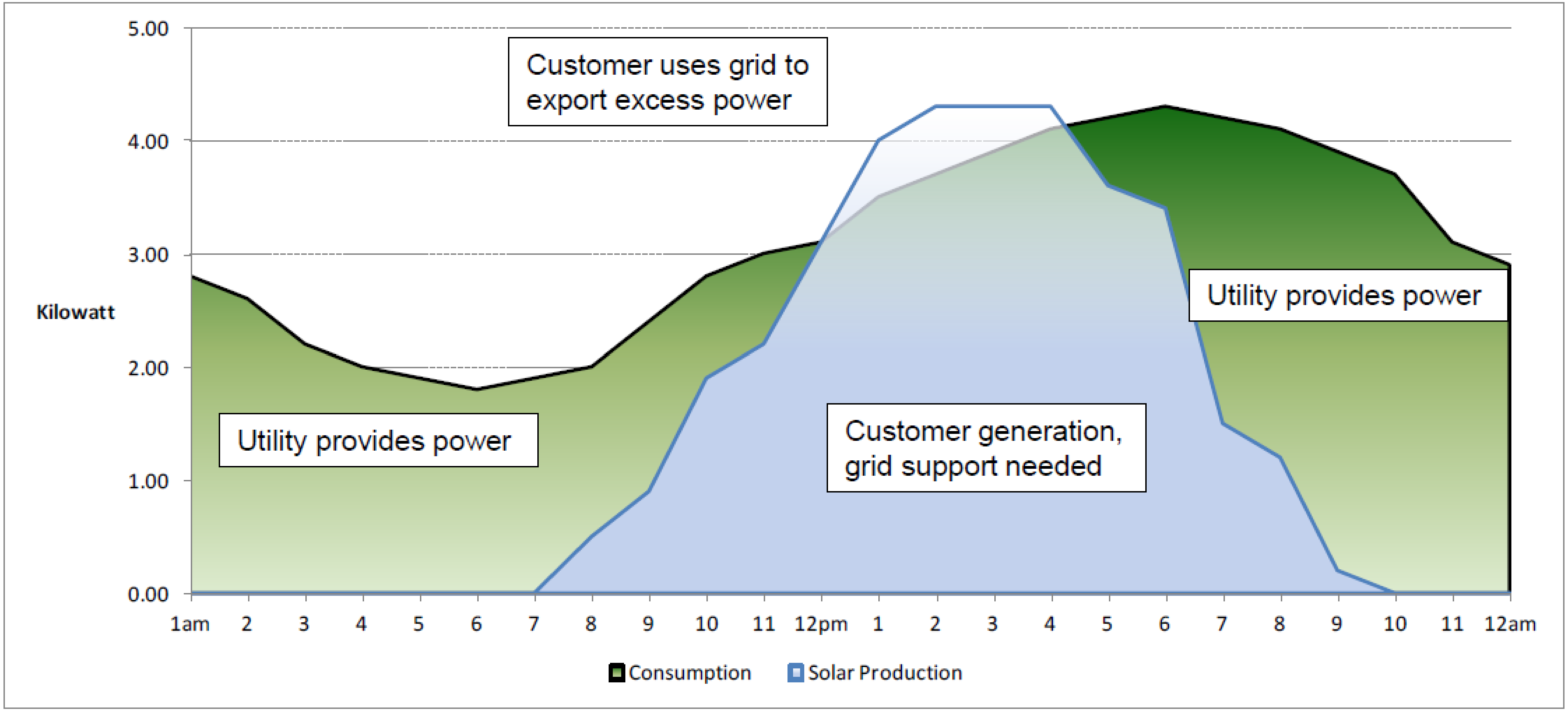
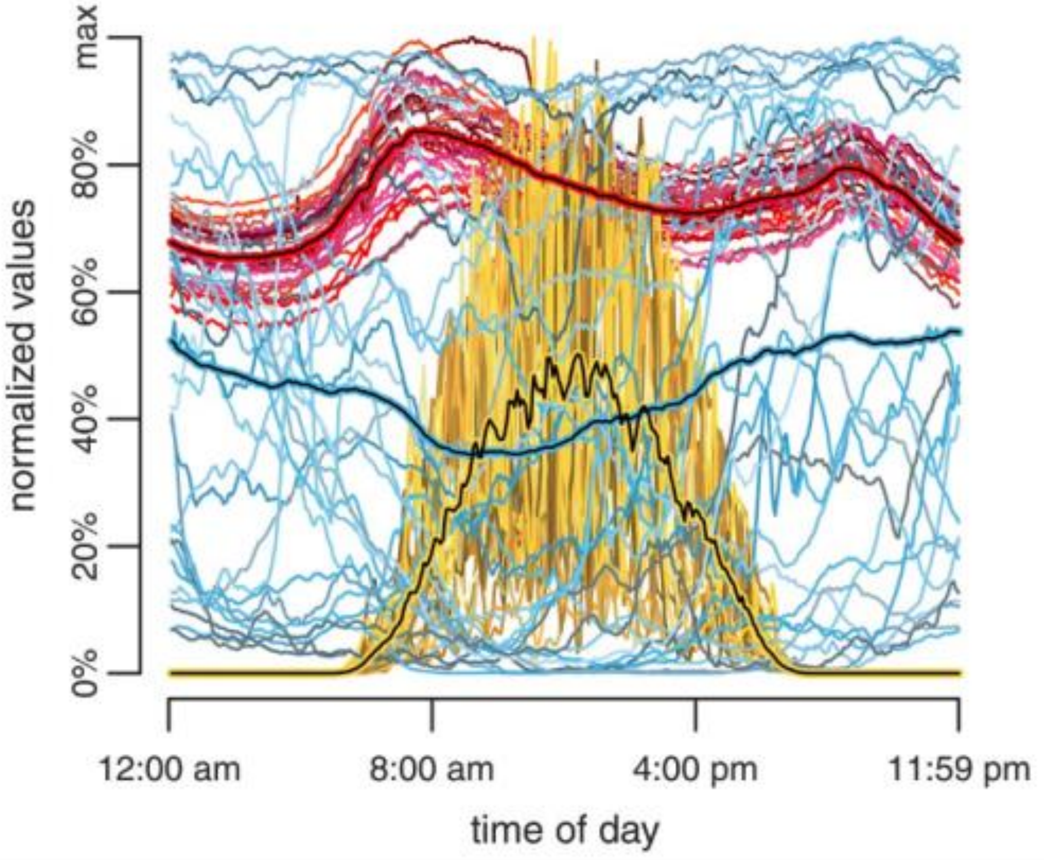
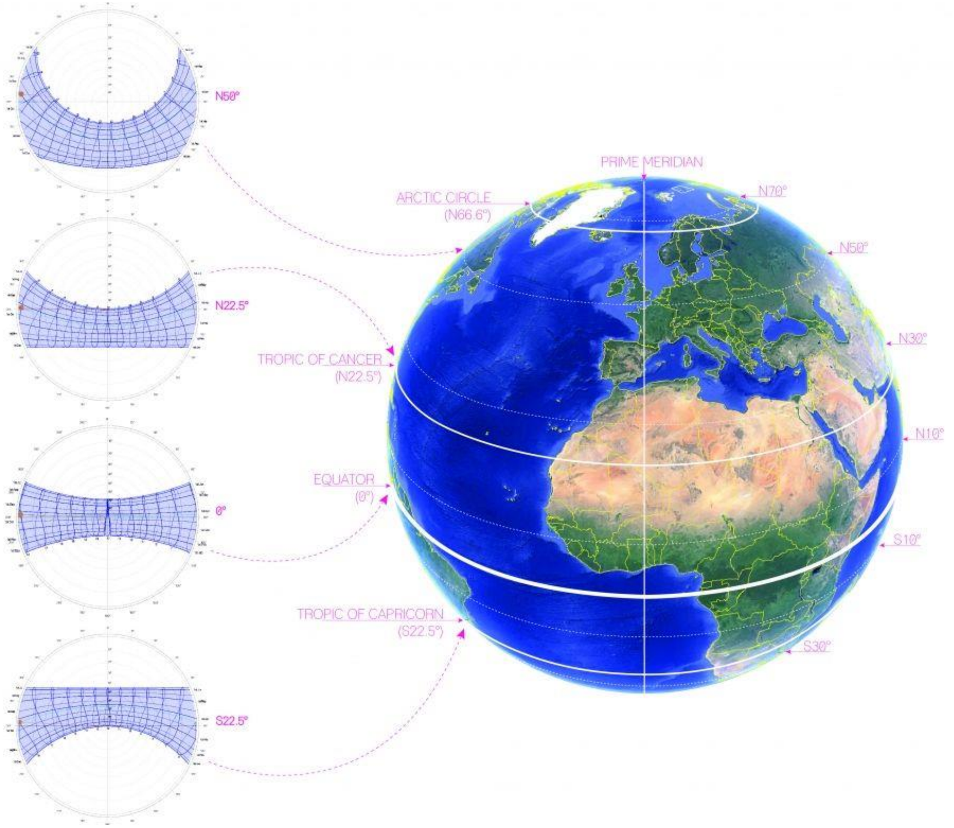
MISMATCH CHALLENGES



INTERMITTENCY

Intermittent, but not unpredictable.

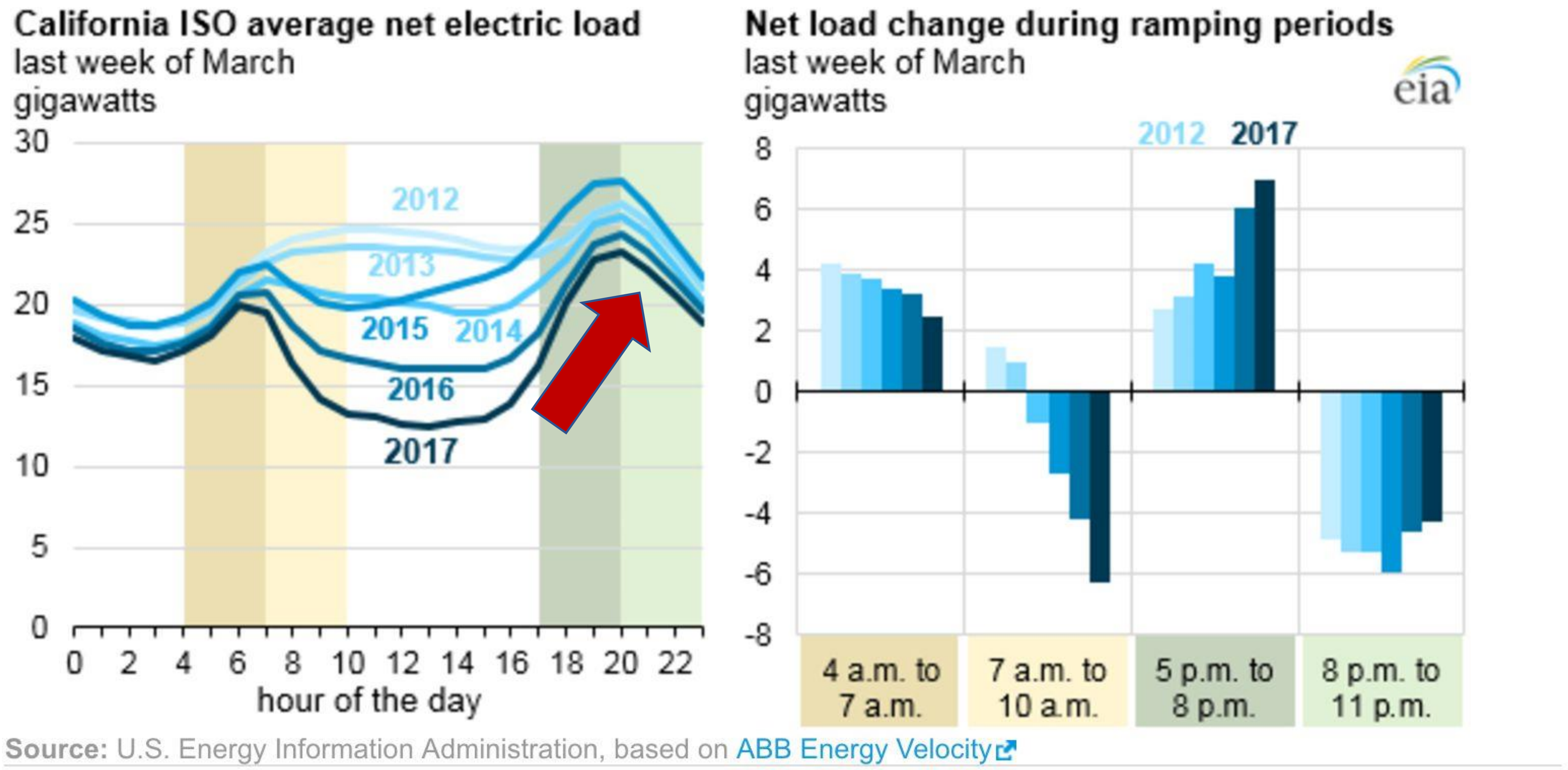




RED: POWER DEMAND
BLUE: WIND ENERGY GENERATION
YELLOW: SOLAR INSOLATION DATA

Source: Bonneville Power Administration, April 2010

NET LOAD/RAMPING CHALLENGES

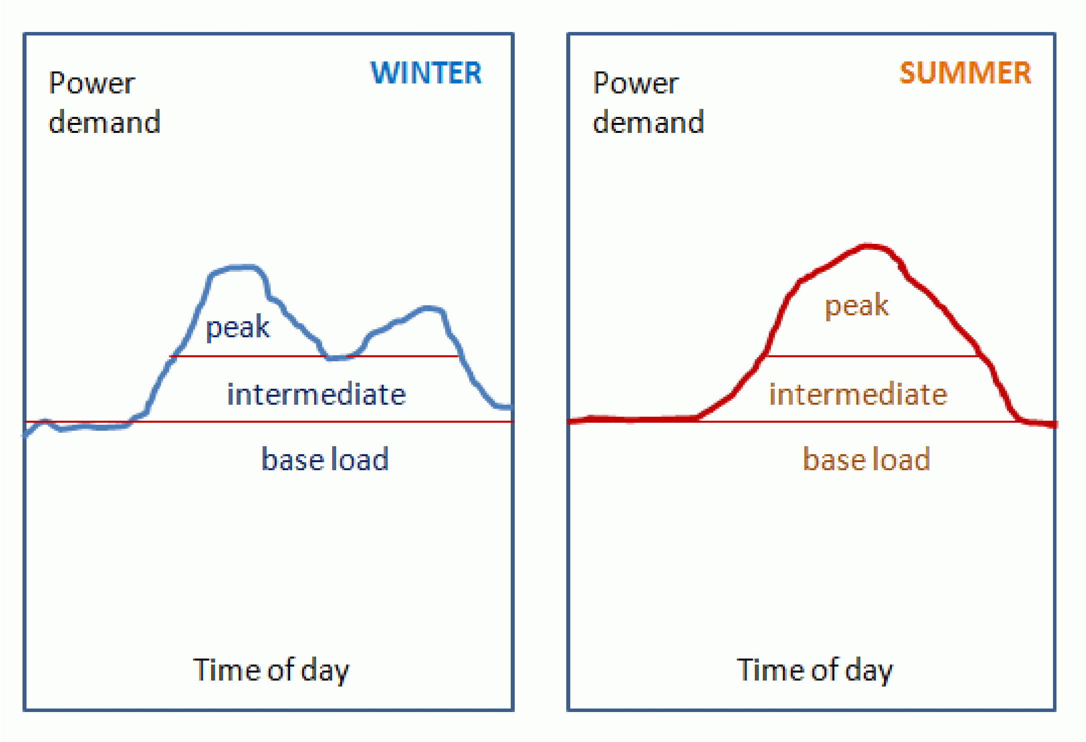


- Net Load on grid ramps dramatically as PV generation declines (sunset)
- Most generation resources cannot adjust/increase output that quickly (Natural Gas can)

BASELOAD CHALLENGES

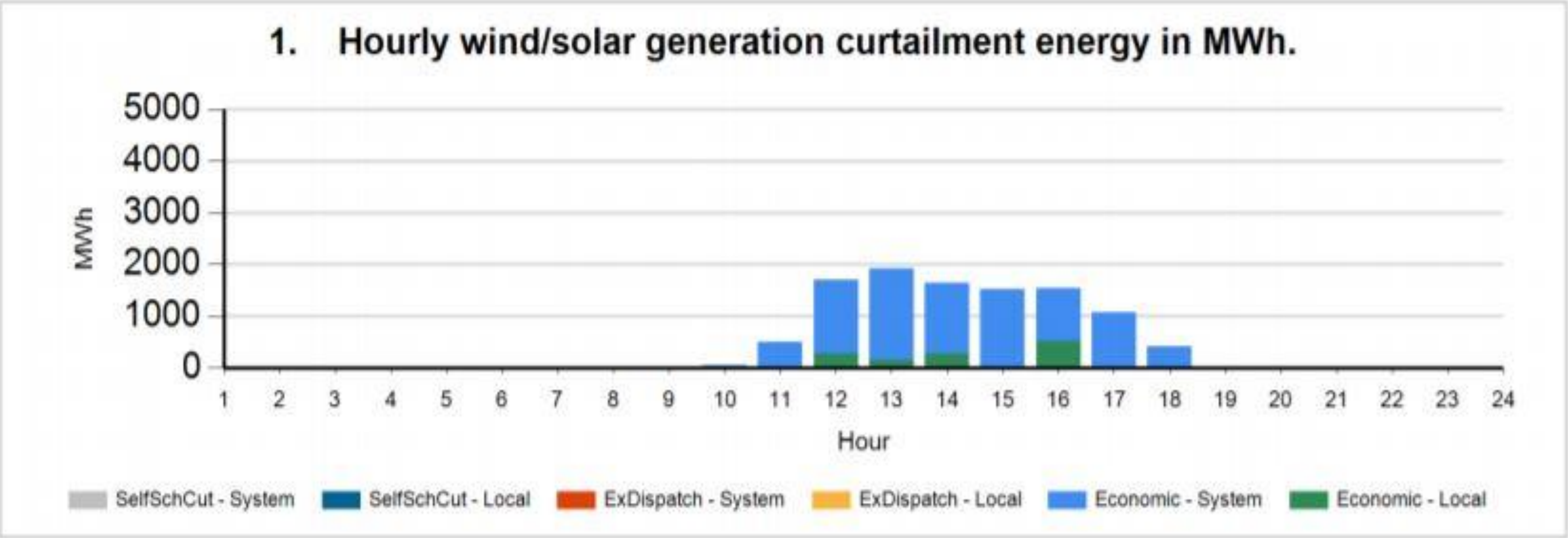
Similarly to difficulty in quickly increasing load, some baseload resources cannot ‘turn down’.

Nuclear: 80% max load minimum
Coal: Varies, but takes hours to lower output, and days to re-start if brought down to 0.



CURTAILMENT

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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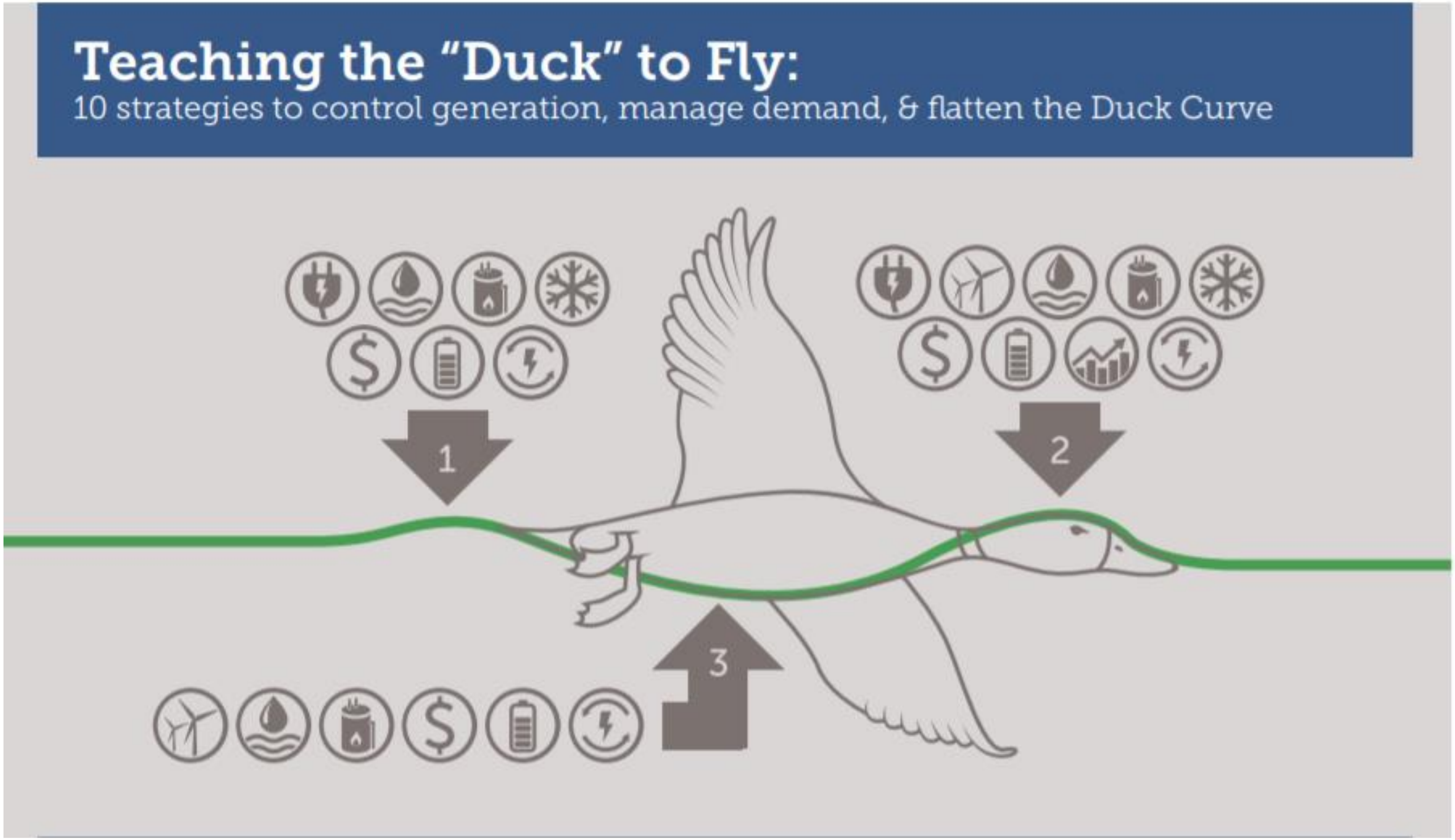
GRID INTEGRATION STRATEGIES

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)

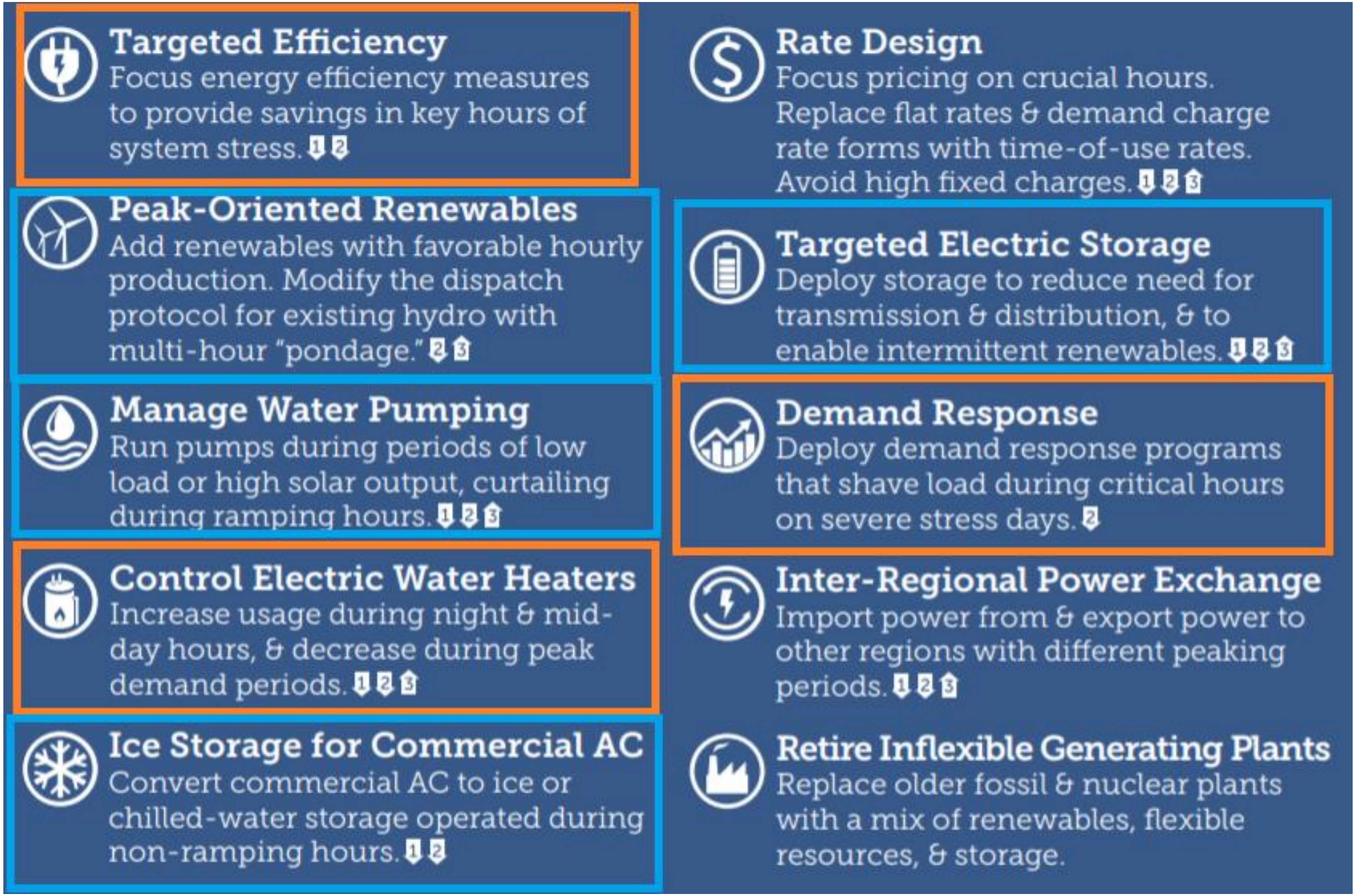
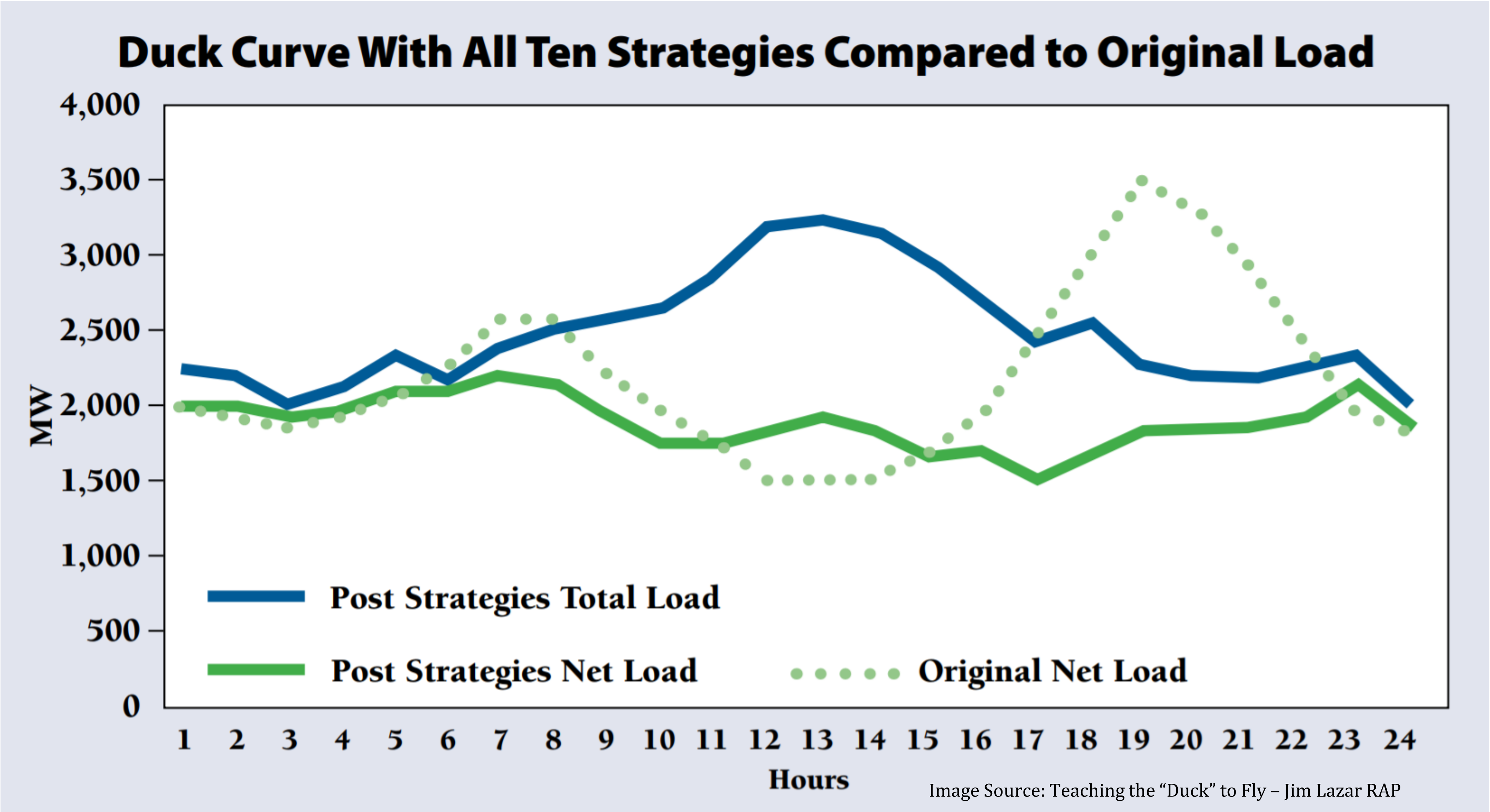
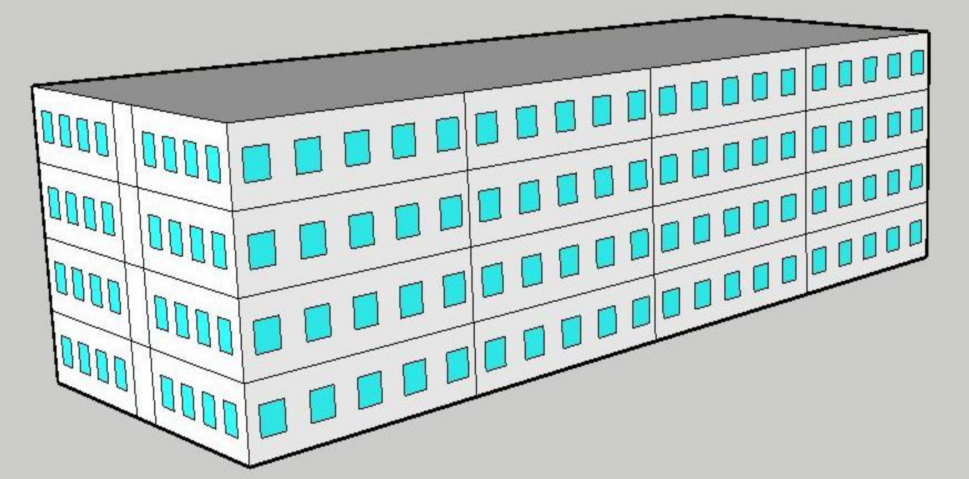


Image Source: Teaching the "Duck" to Fly – Jim Lazar RAP

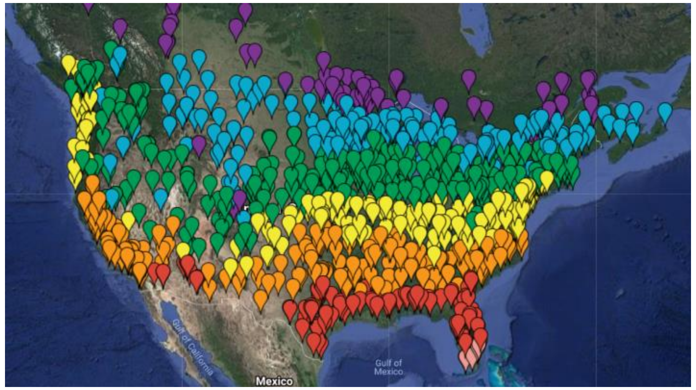


Load Factor: 63.6% → 86.5%
Max Hourly Ramp: 350 MW → 198 MW
Total Difference Between Highest and Lowest Hour: 2000 MW → 600 MW

‘NET ZERO’ CASE STUDY



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



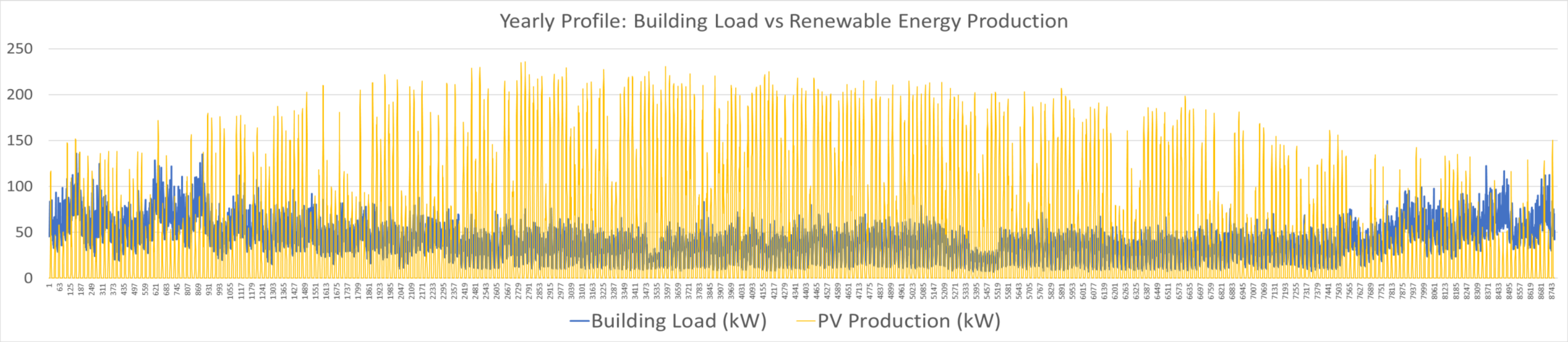
<u>Two ‘Net Zero’ buildings studied:</u>

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

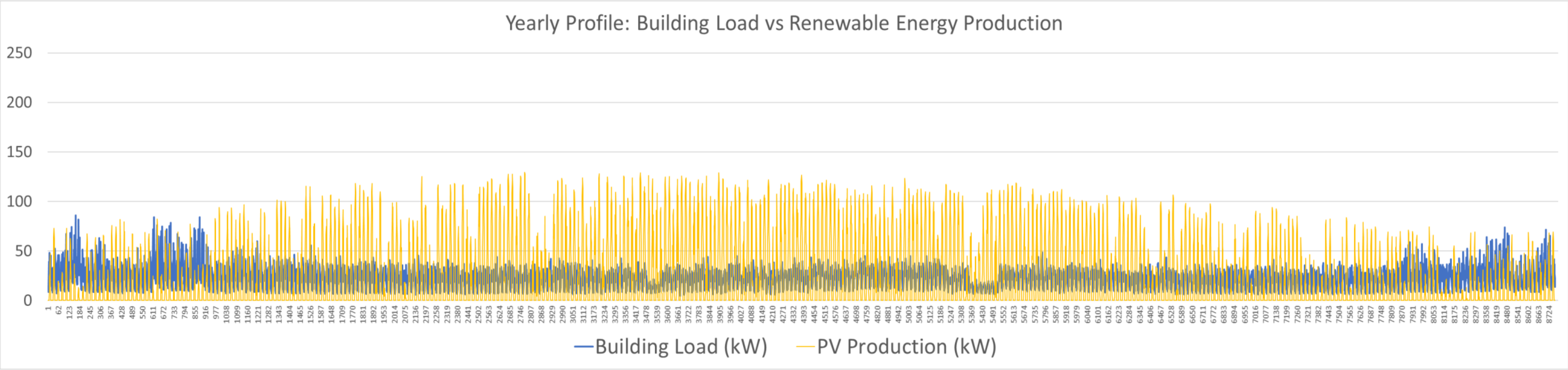
2. Passive building (PHIUS+ 2015 compliant):
166 kW PV Array
50% South Facing, 25% E, 25% W, 10 degree tilt

CASE STUDY

Baseline building



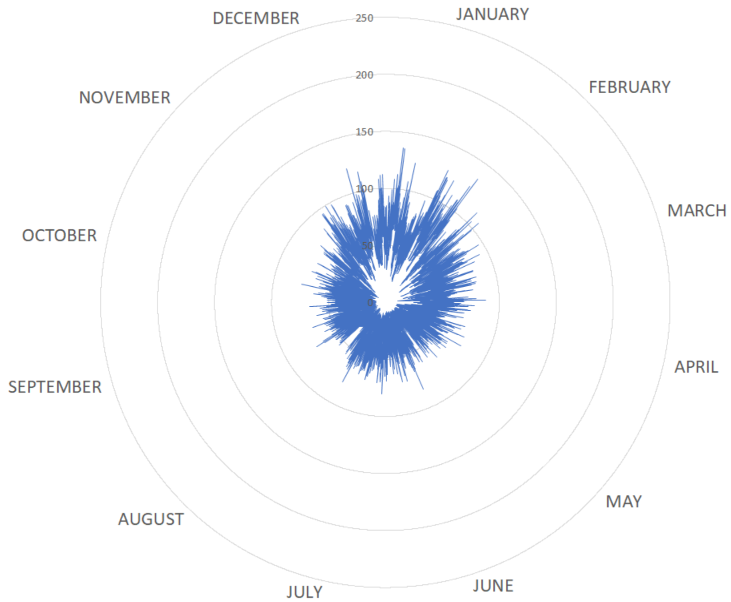
Passive building

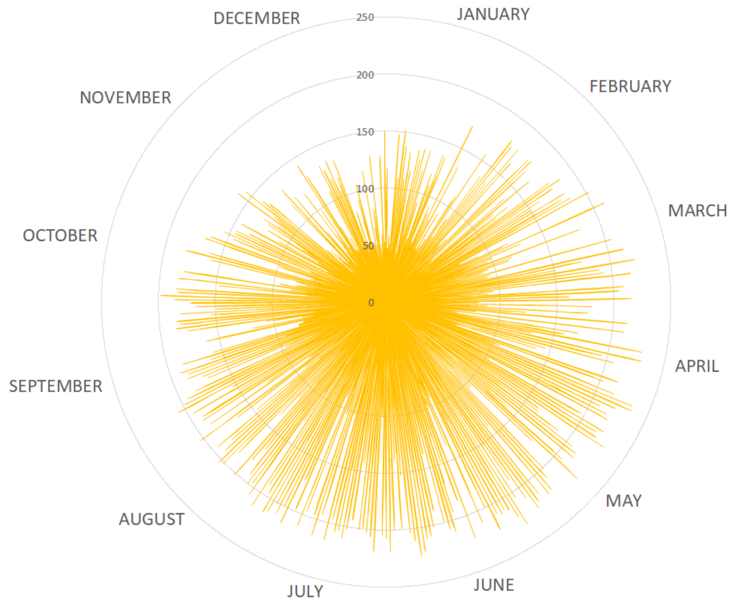


CASE STUDY

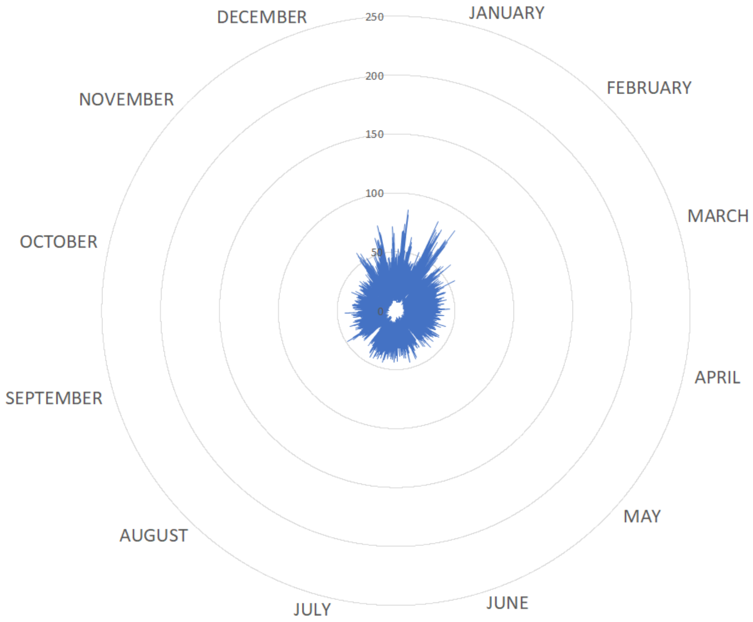
Hourly Building Load (kW) | Hourly PV Production (kW)

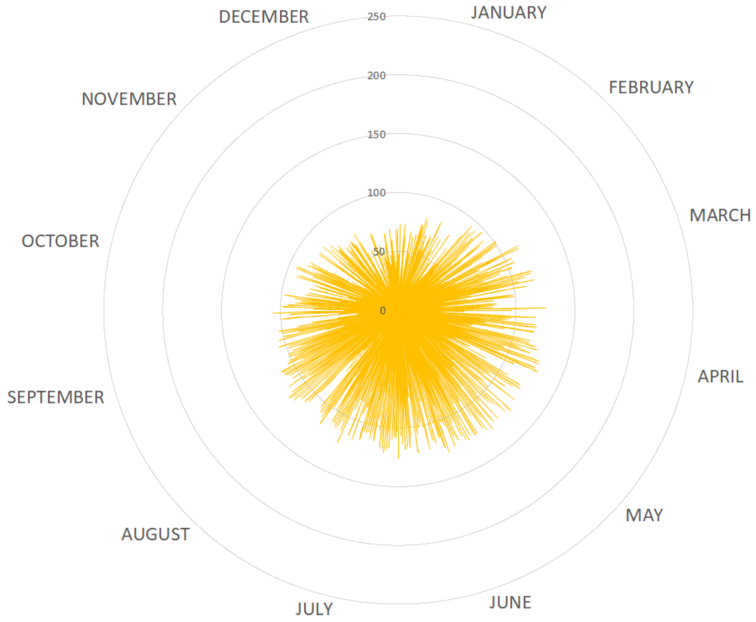
Baseline building



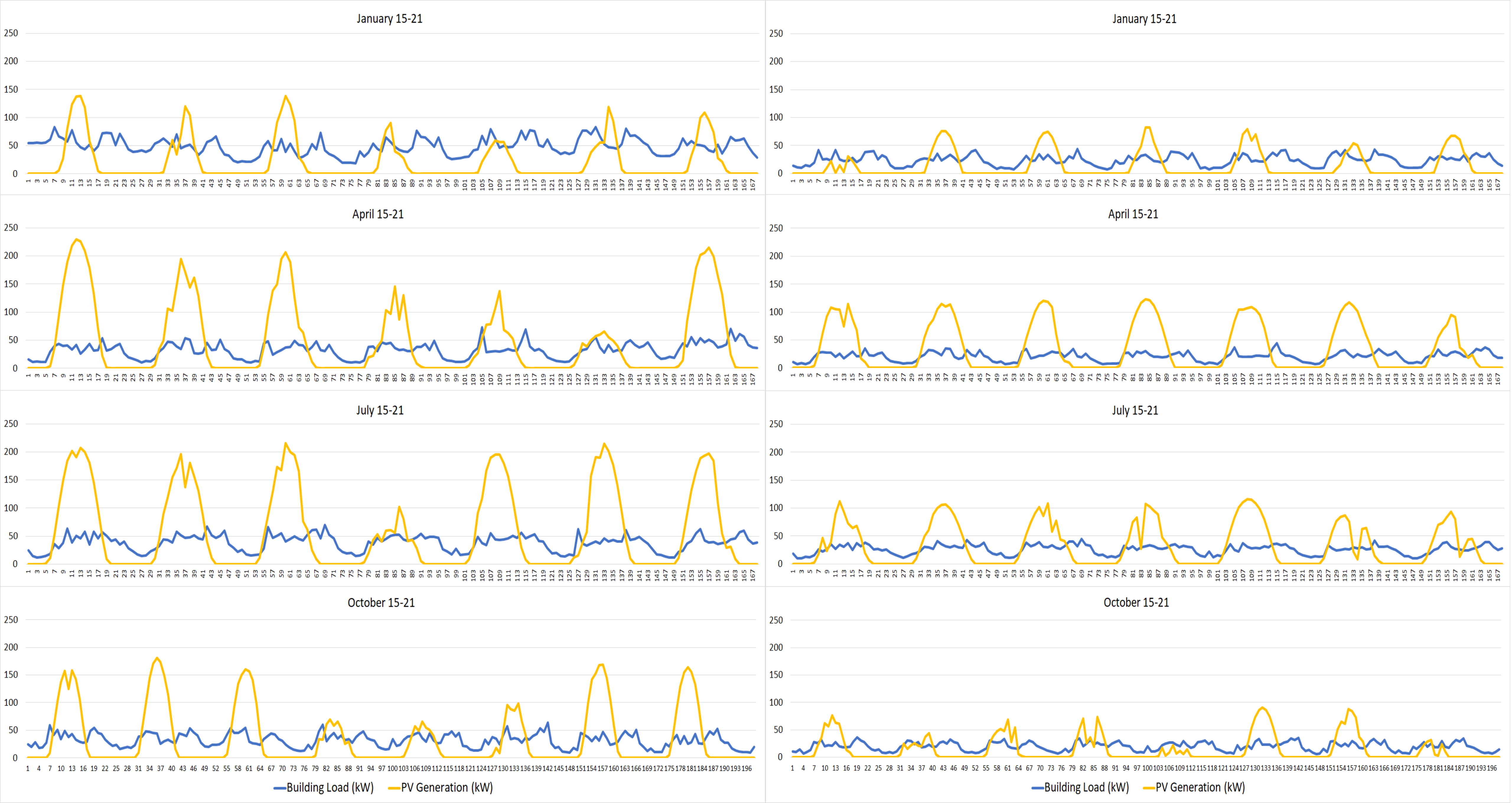


Passive building



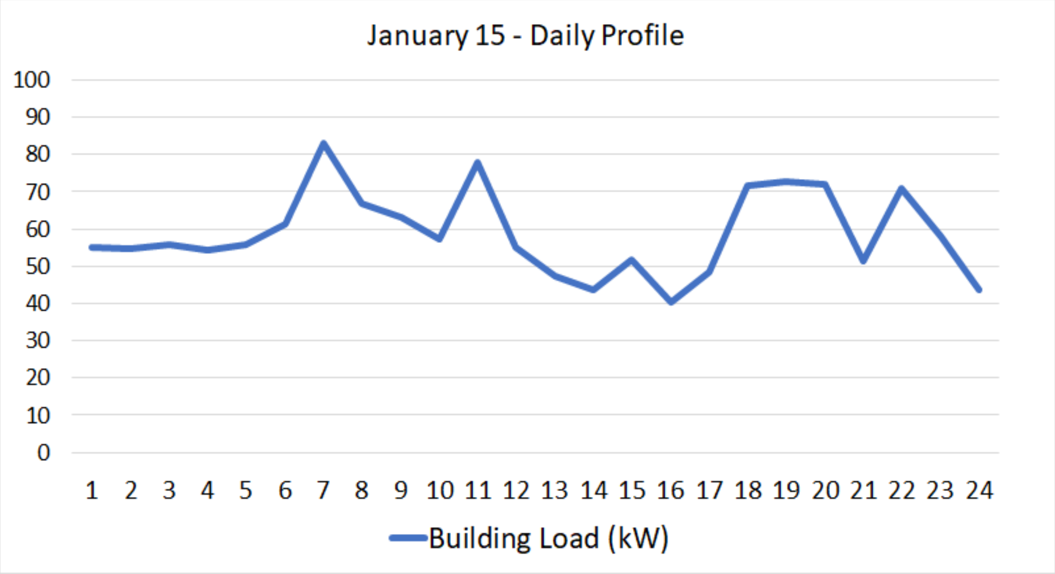


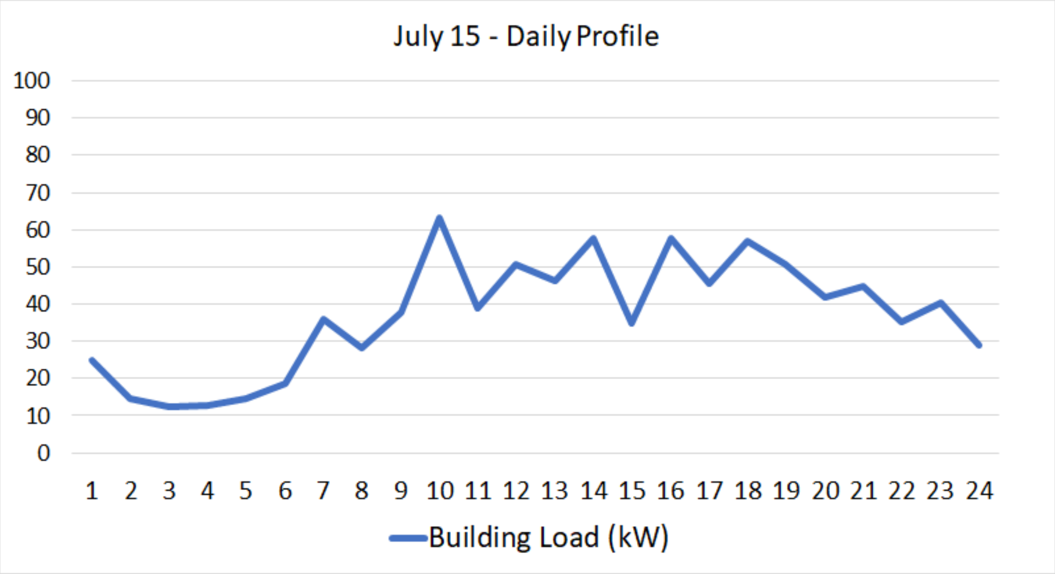
Baseline building **WEEKLY MISMATCH – ON SITE PRODUCTION vs USE** *Passive building*



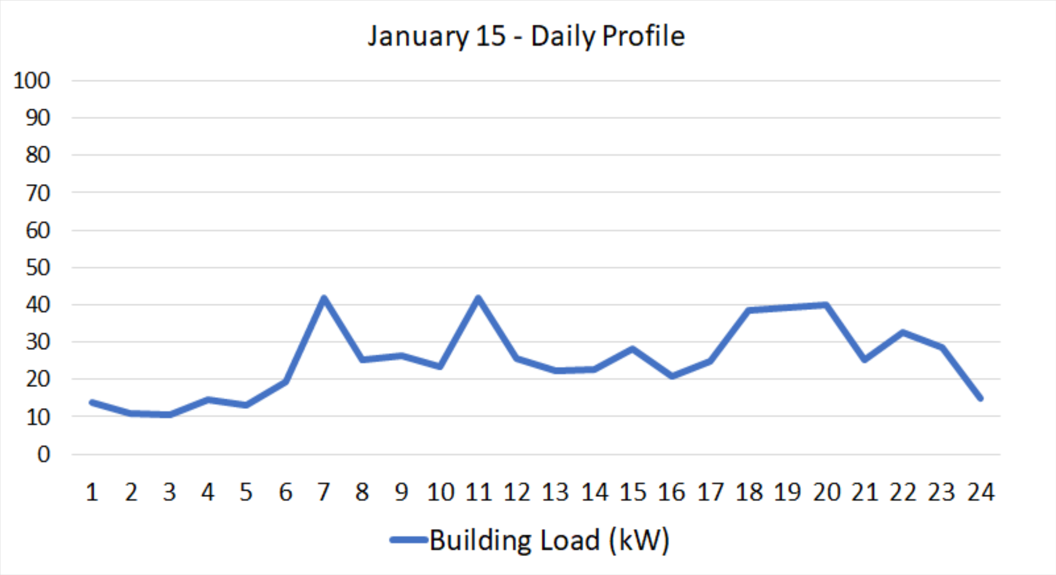
CASE STUDY

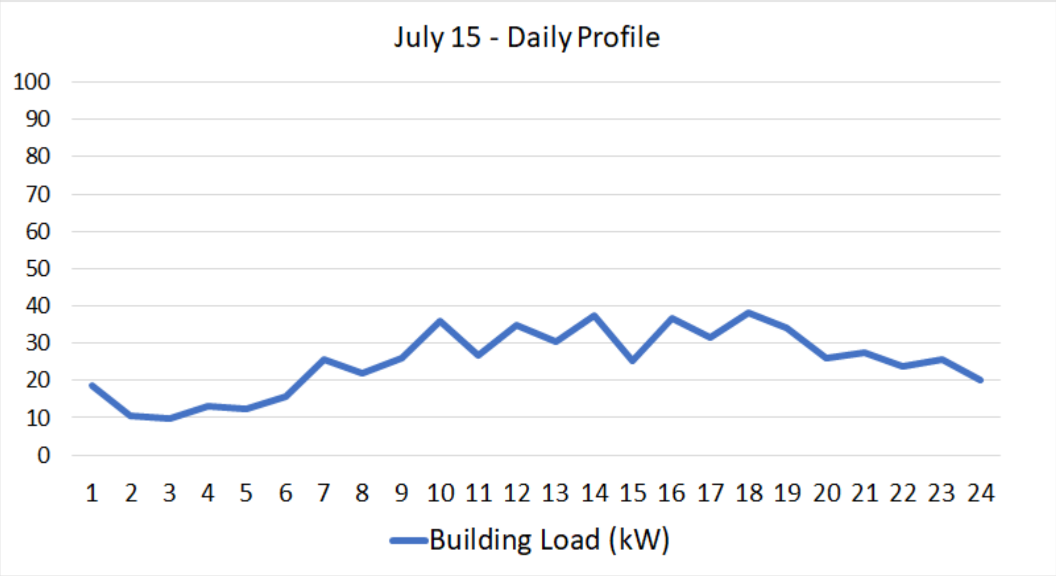
Daily Analysis – January & July





Baseline building





Passive building

CASE STUDY

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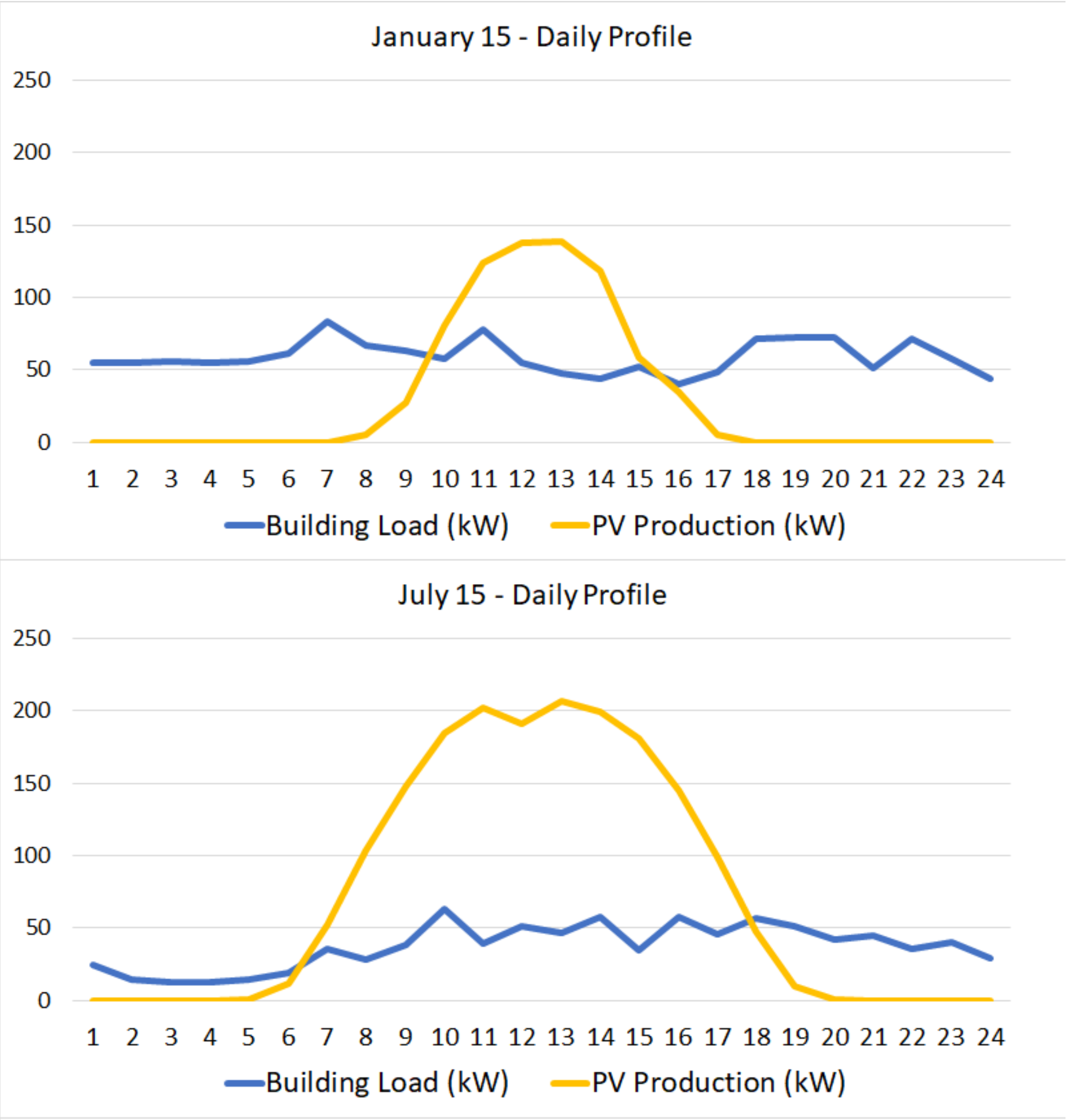
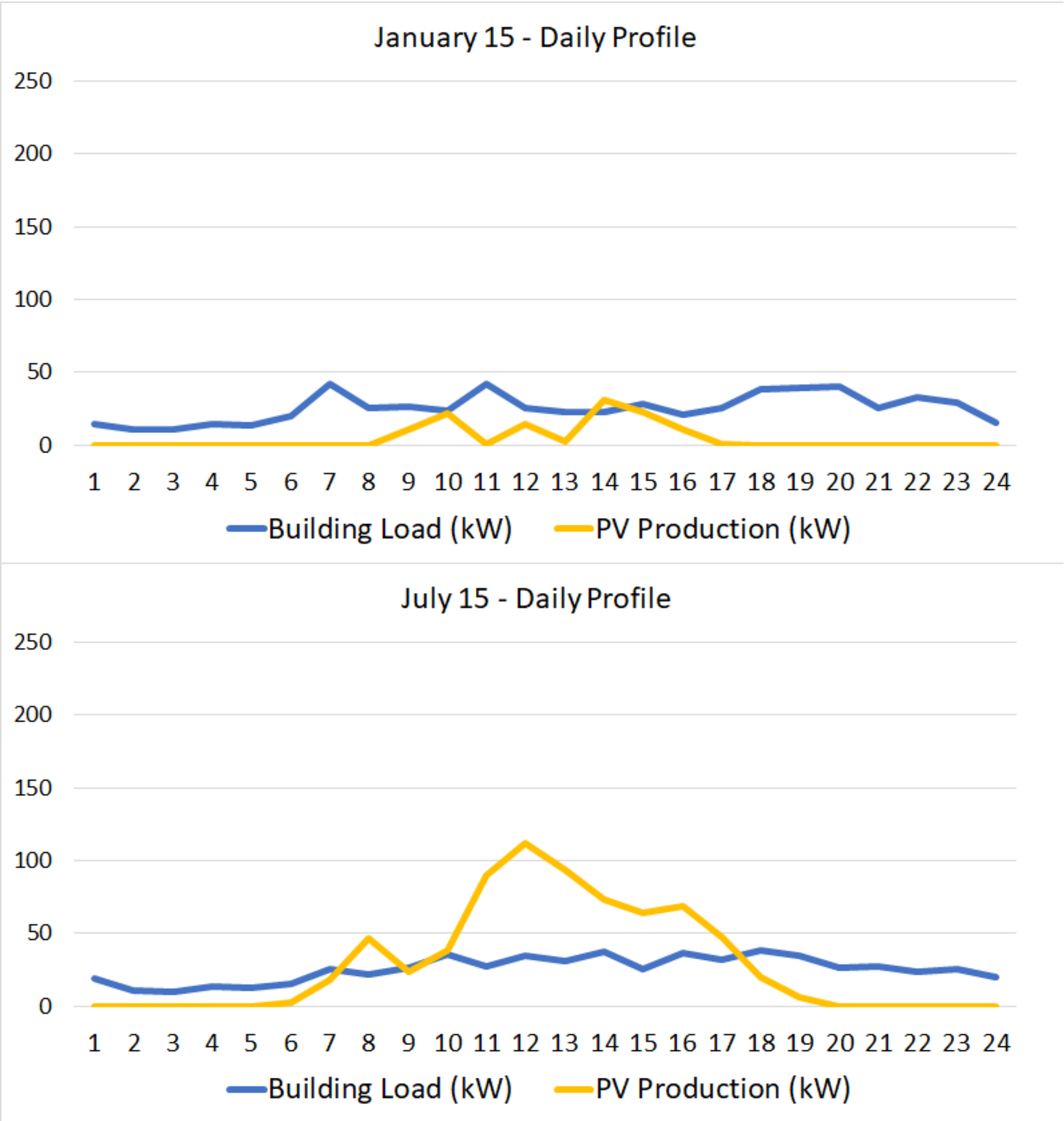


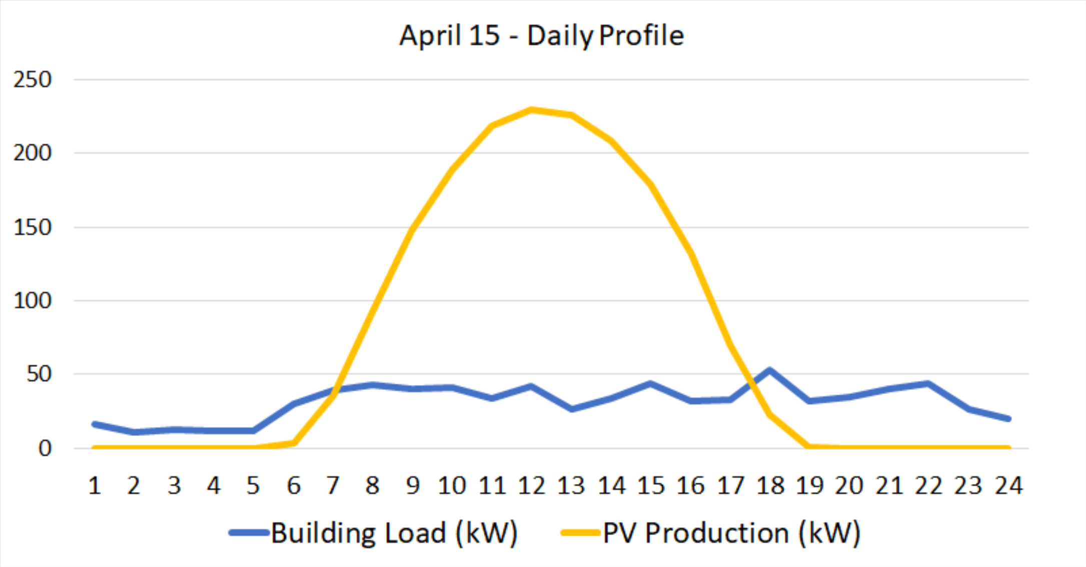
Baseline building

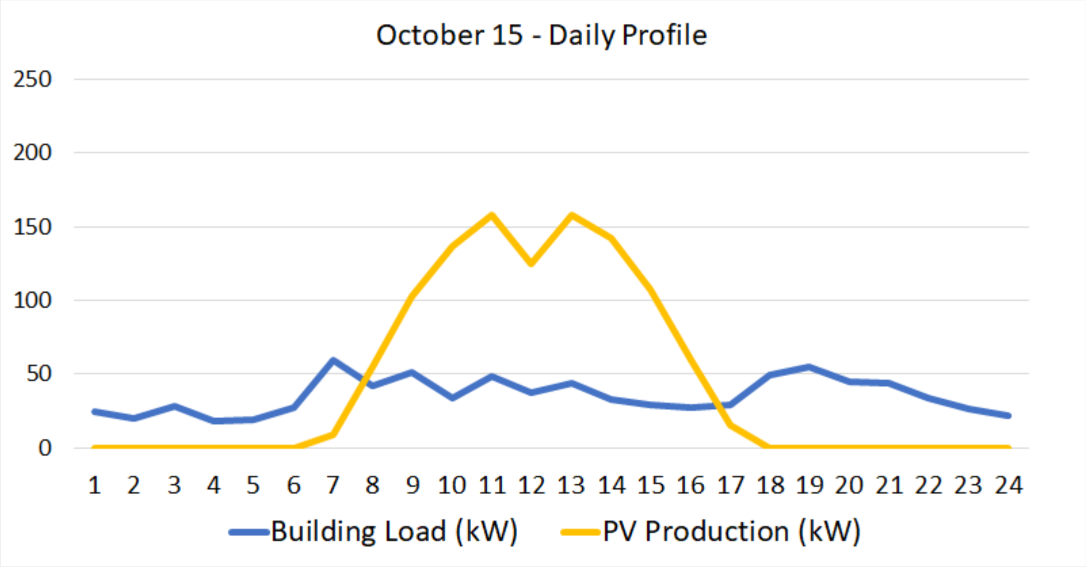


Passive building

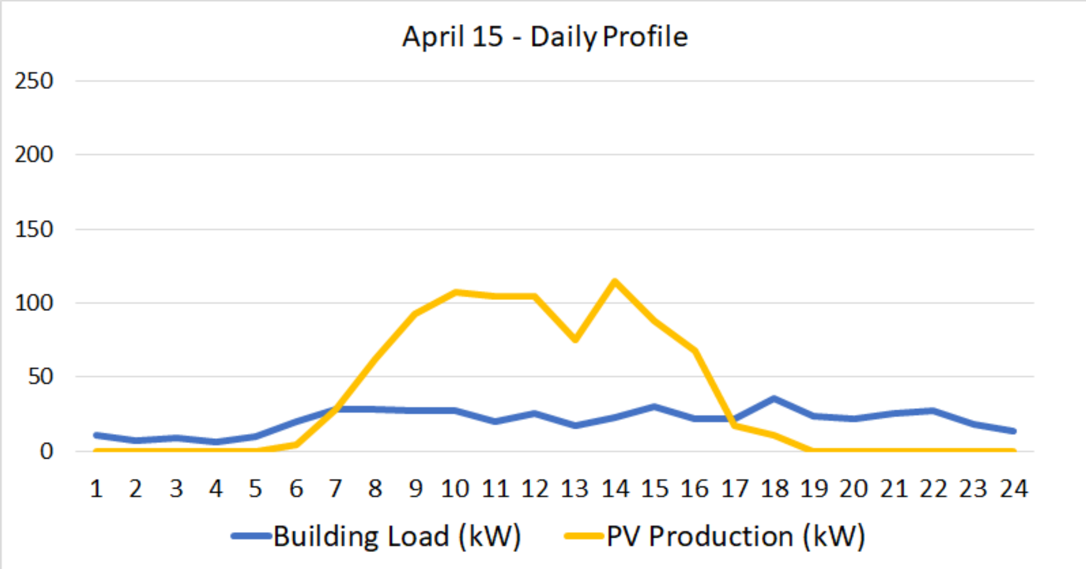
CASE STUDY

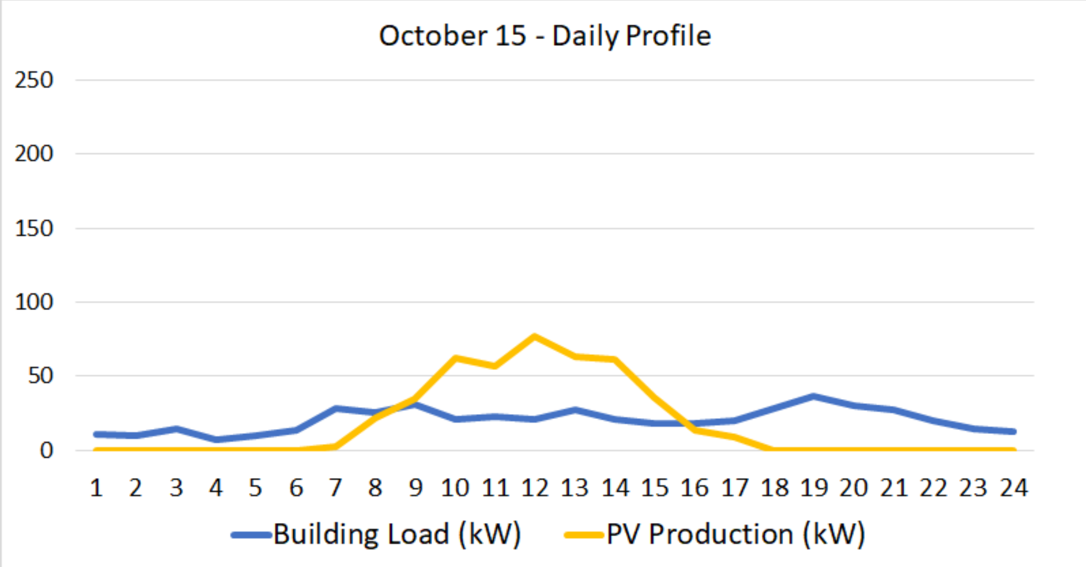
Daily Analysis – April & October





Baseline building

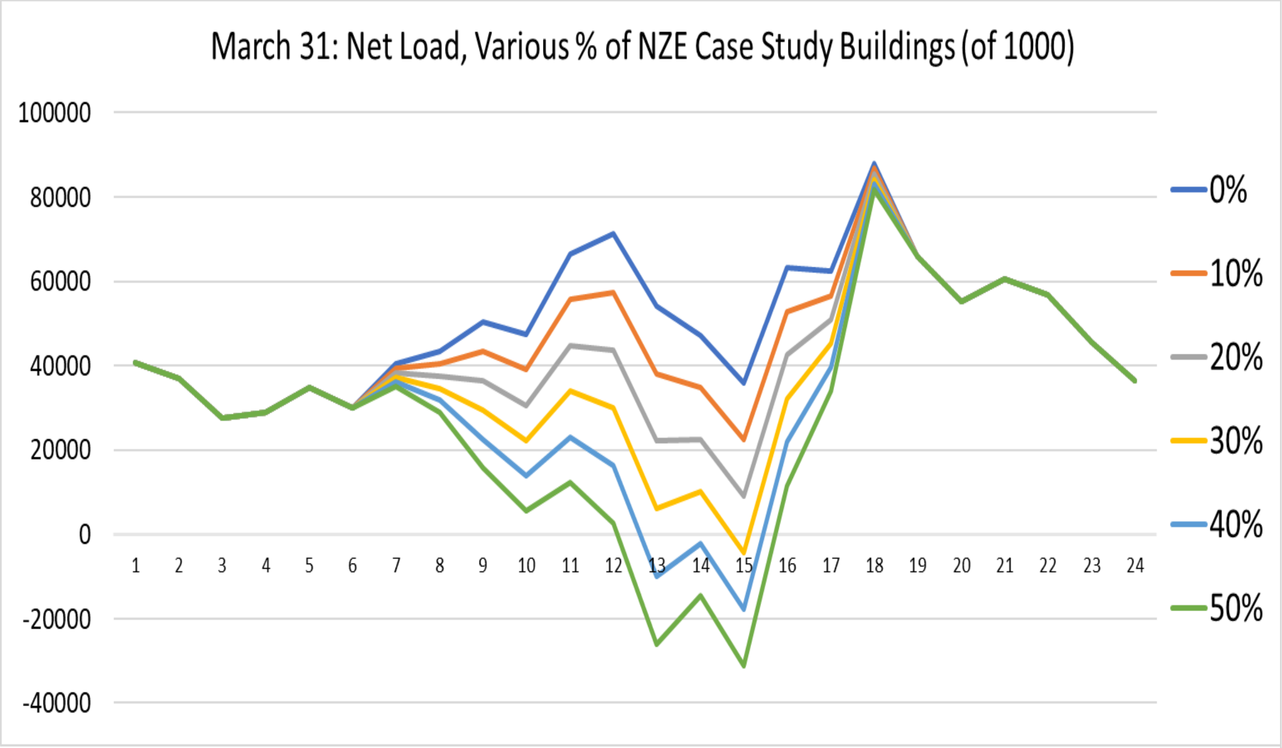




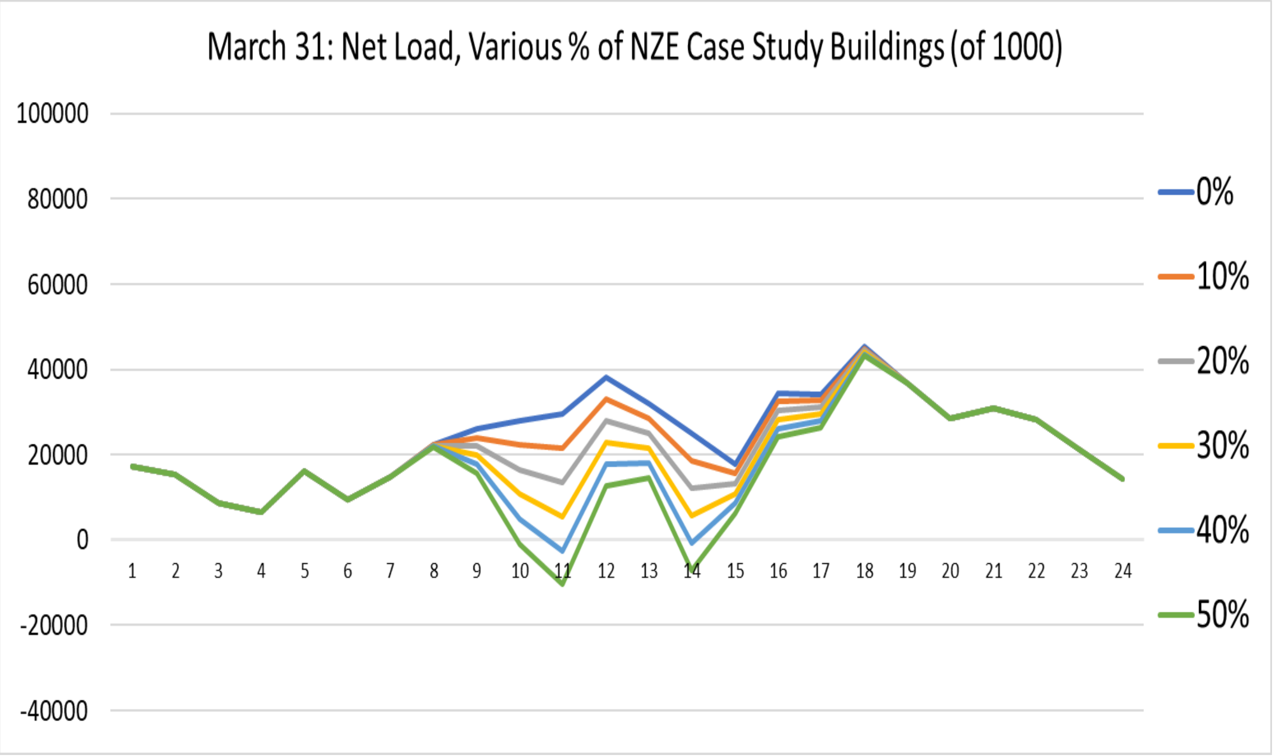
Passive building

Net Load/ Ramping Analysis

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



Baseline building



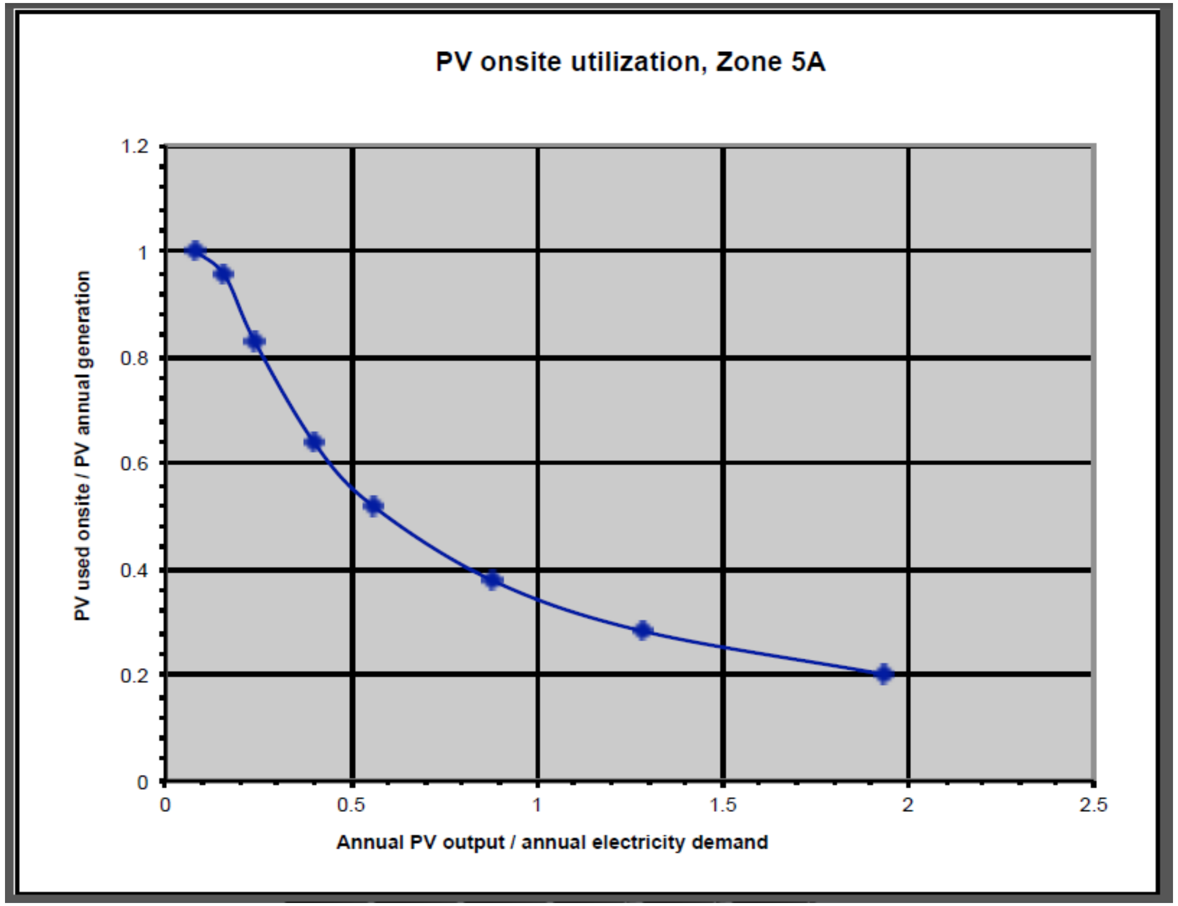
Passive building

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



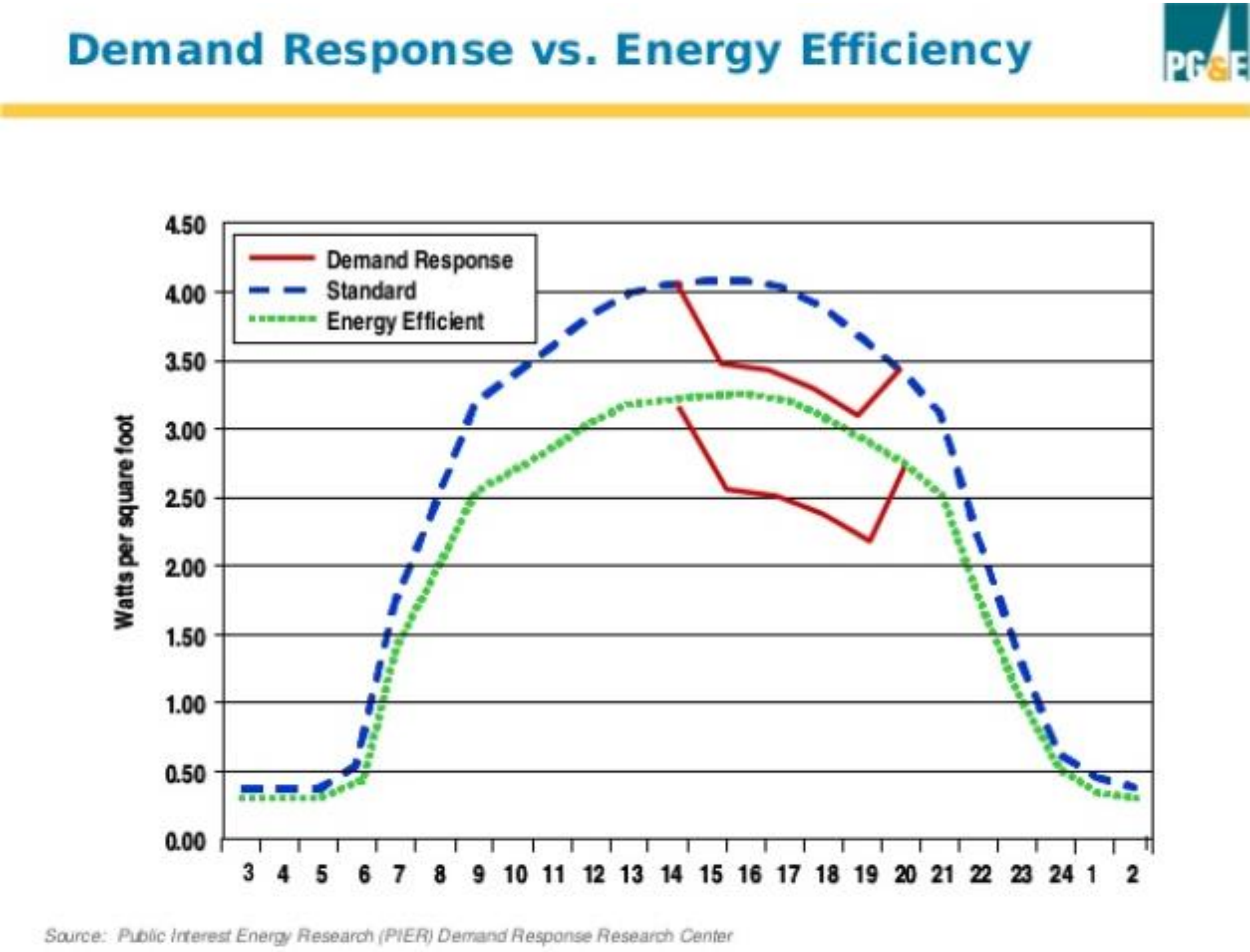
DIFFERENCE
covered by grid
99,102 kWh/yr

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.

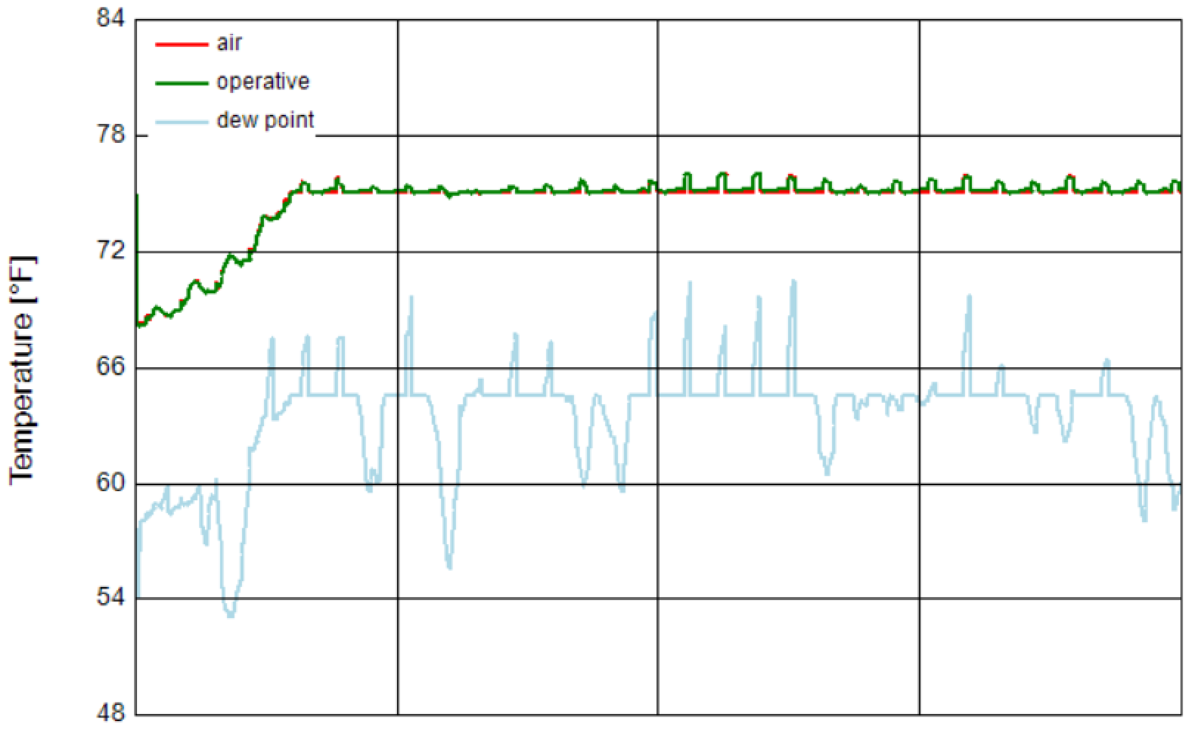
Customers are paid significant $ to sign on to these programs, as it reduces the need for the grid to start up "peaker plants" - $$



DEMAND RESPONSE

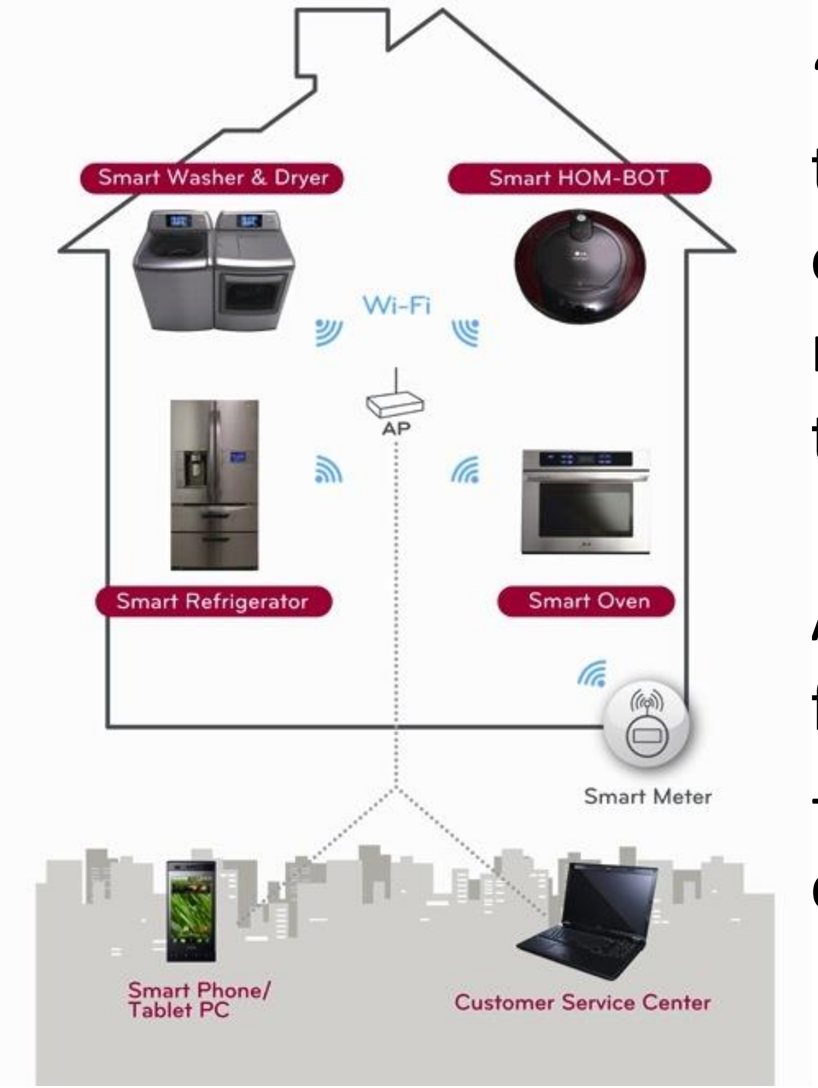
BUT – Passive buildings can potentially shift and change the load shape!

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



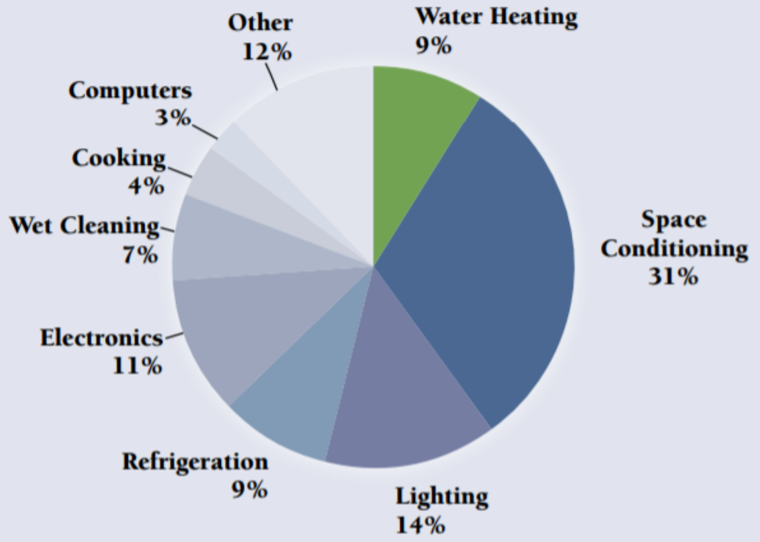
'Smart' appliances, connected to networks, allow grid operators to re-work and manage the demand side of the equation.

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

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%

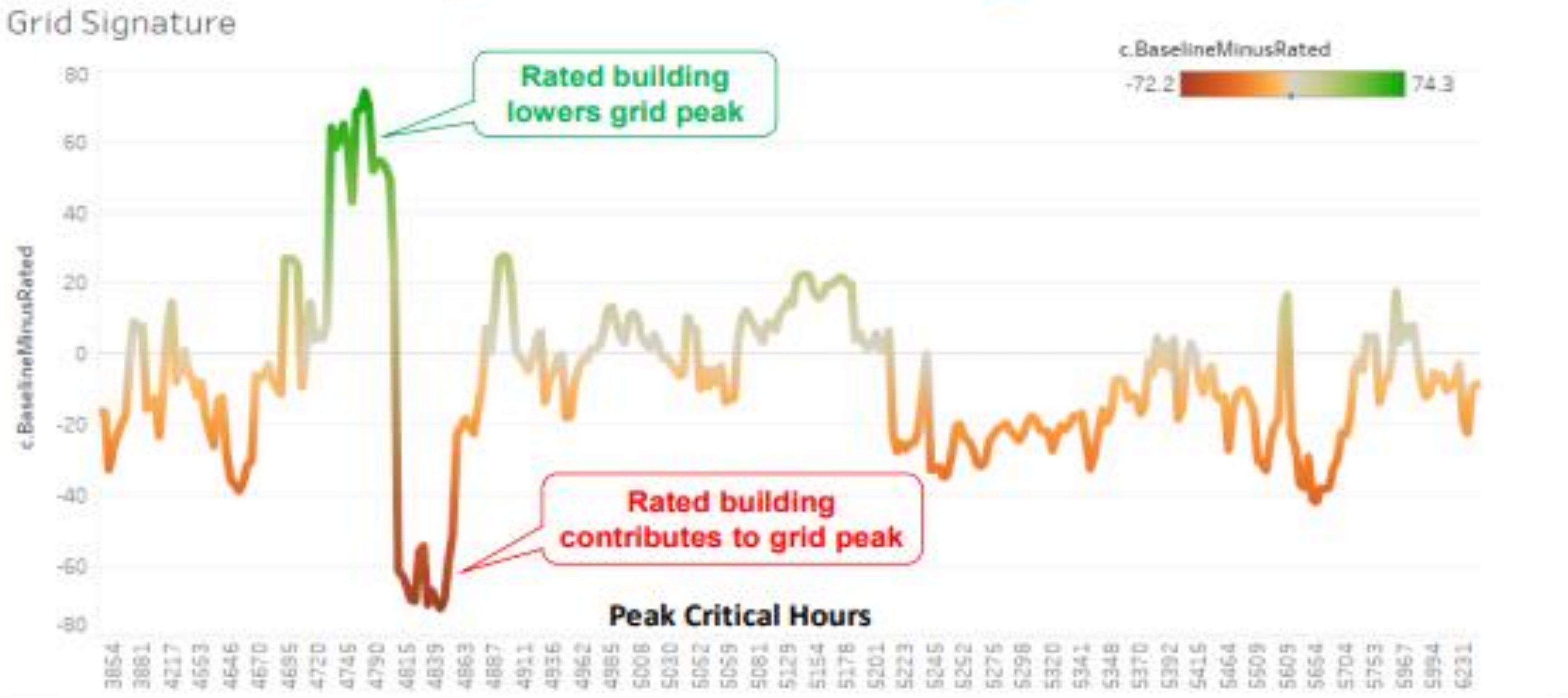
Water heating = 9% of total elec load in residential application
Can be 50% or more in passive buildings!

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

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

GridOptimal™: Grid Signature



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.