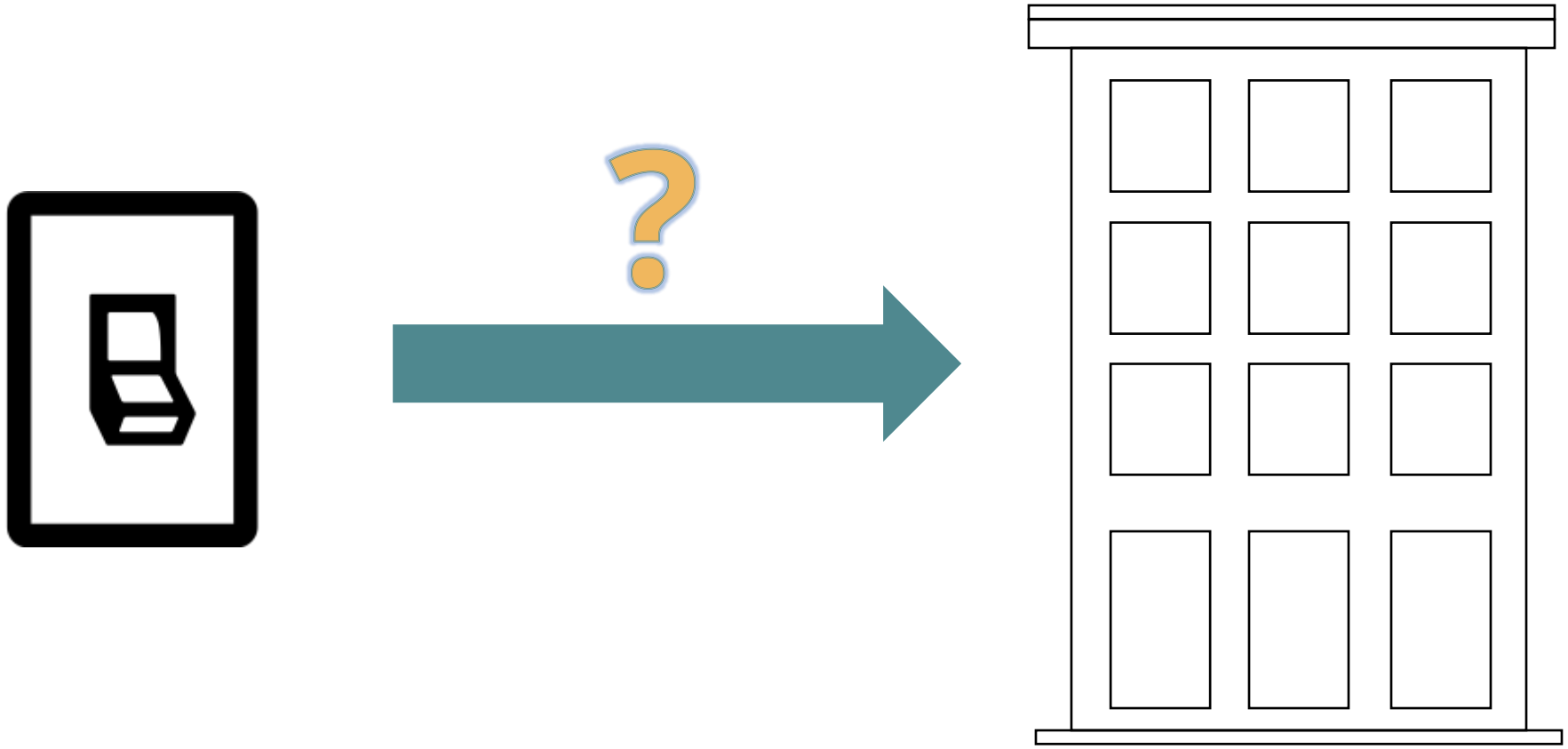
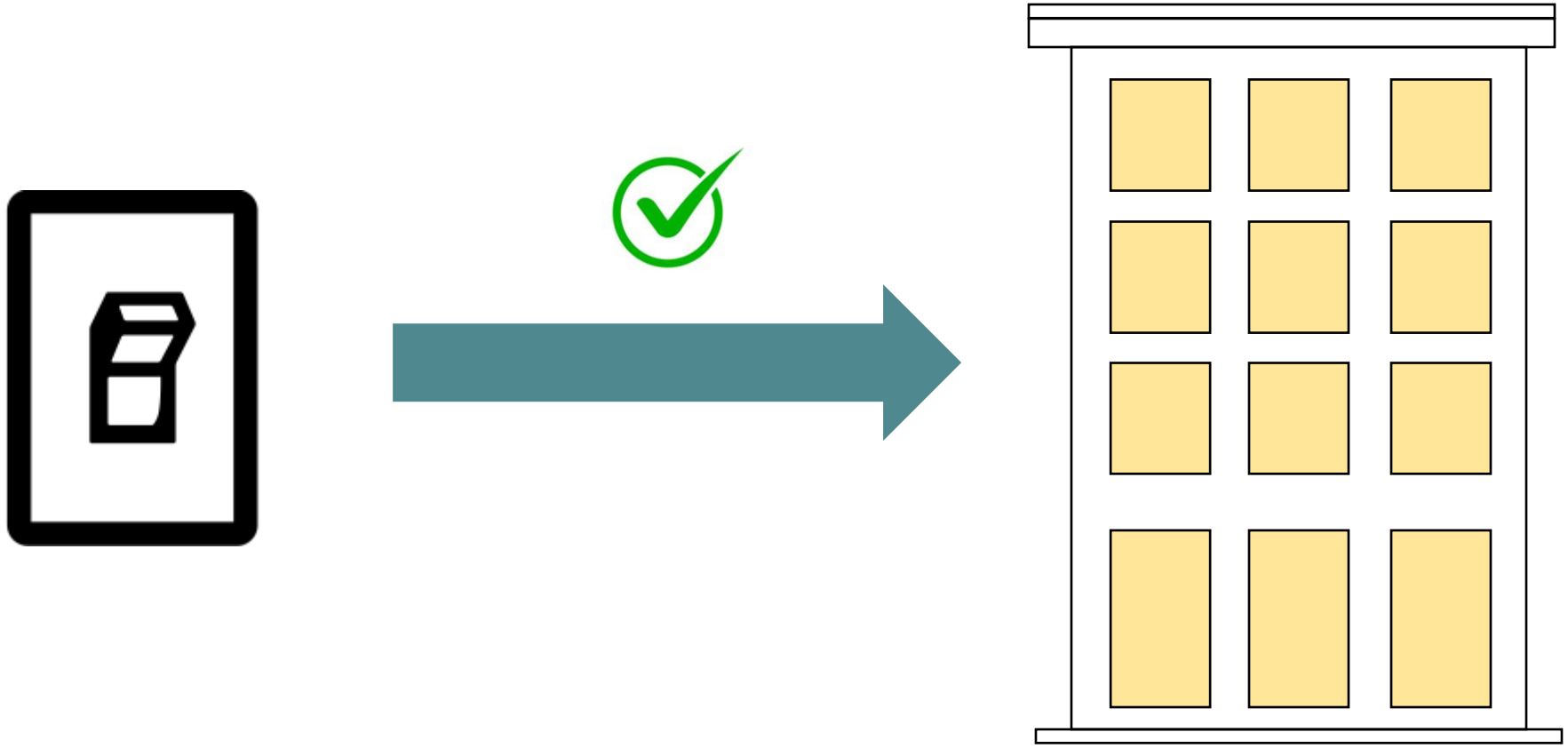
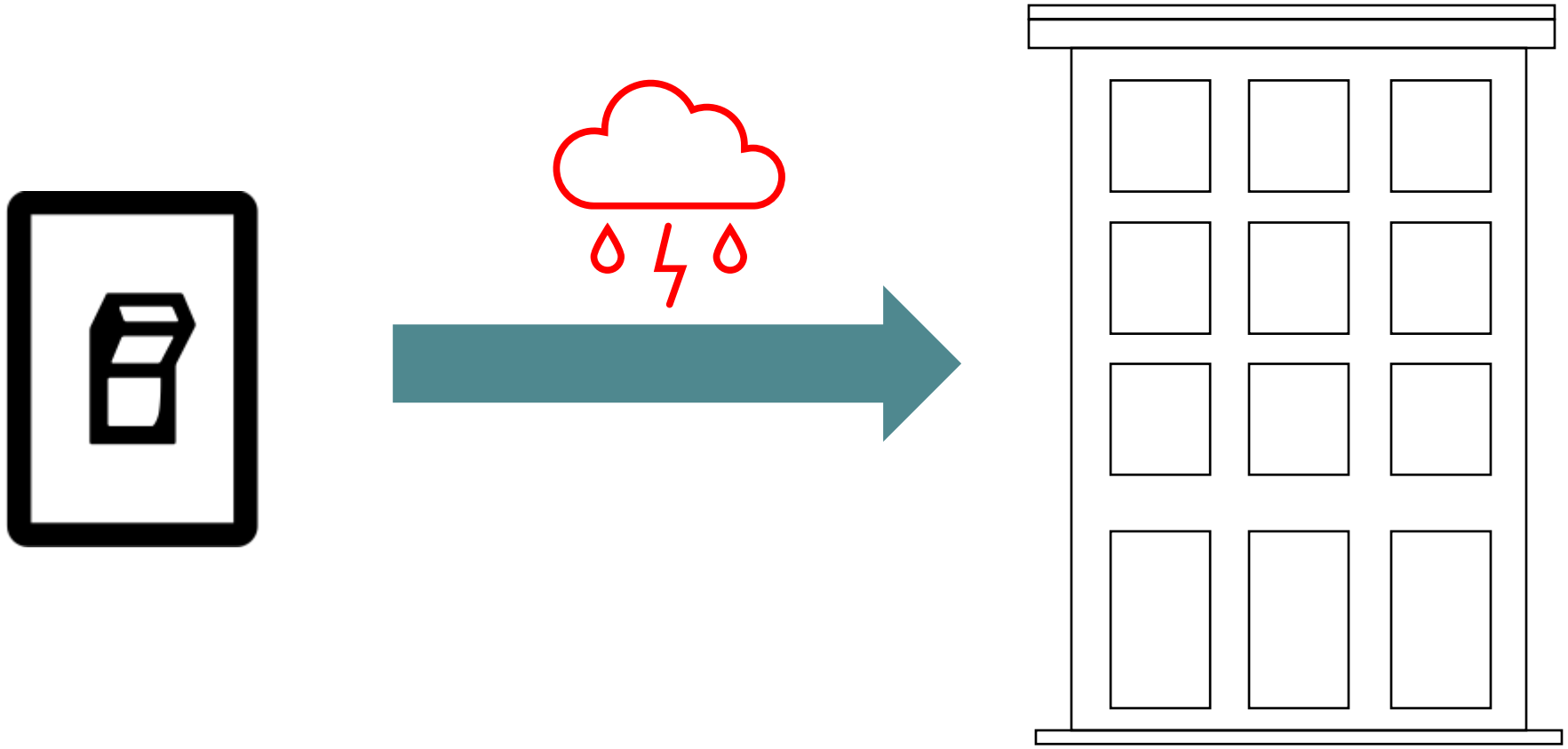
Grid-Building Interaction, Microgrids, and Passive Building

Lisa White | Phius

August 2, 2022

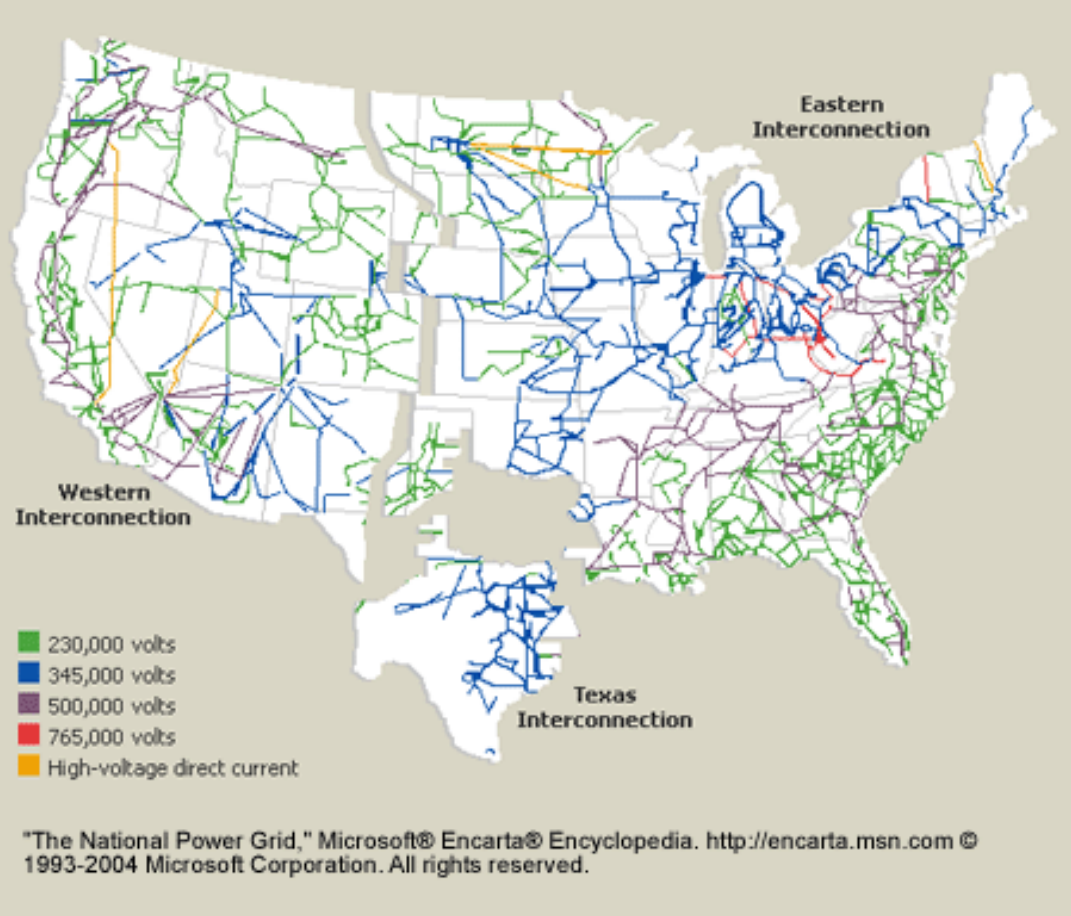




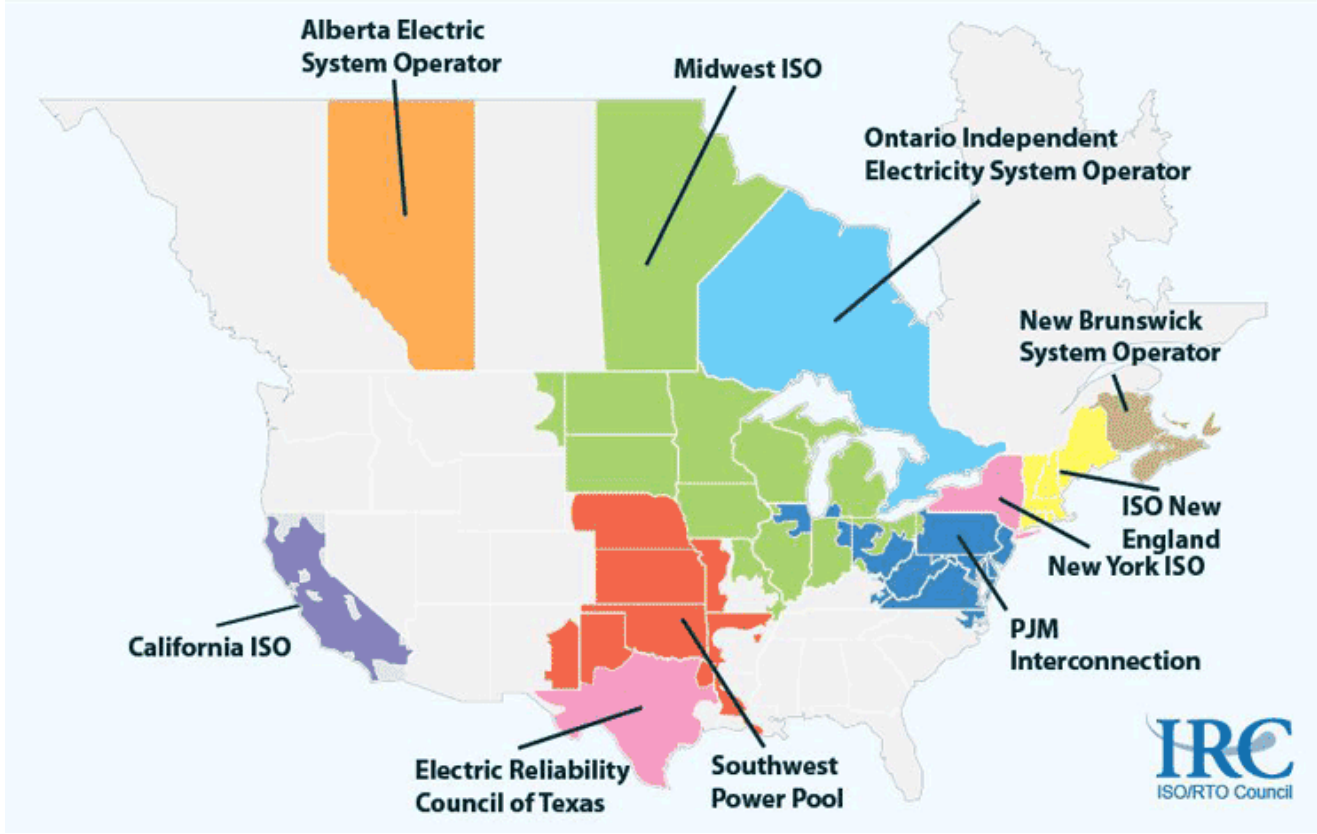



The Grid

“The biggest machine on earth”



3 Interconnections



ISO‘s (Independent Service Operators)


RECORD MONITOR
USE CORRESPONDING REMOTE PER DVD RECORDER
PREVIEW
SONY
PROGRAM
SONY
CABLE-TV
DONT FORGET TO HIT RECORD
STAGE ANNOUNCE
GLOBECASTER

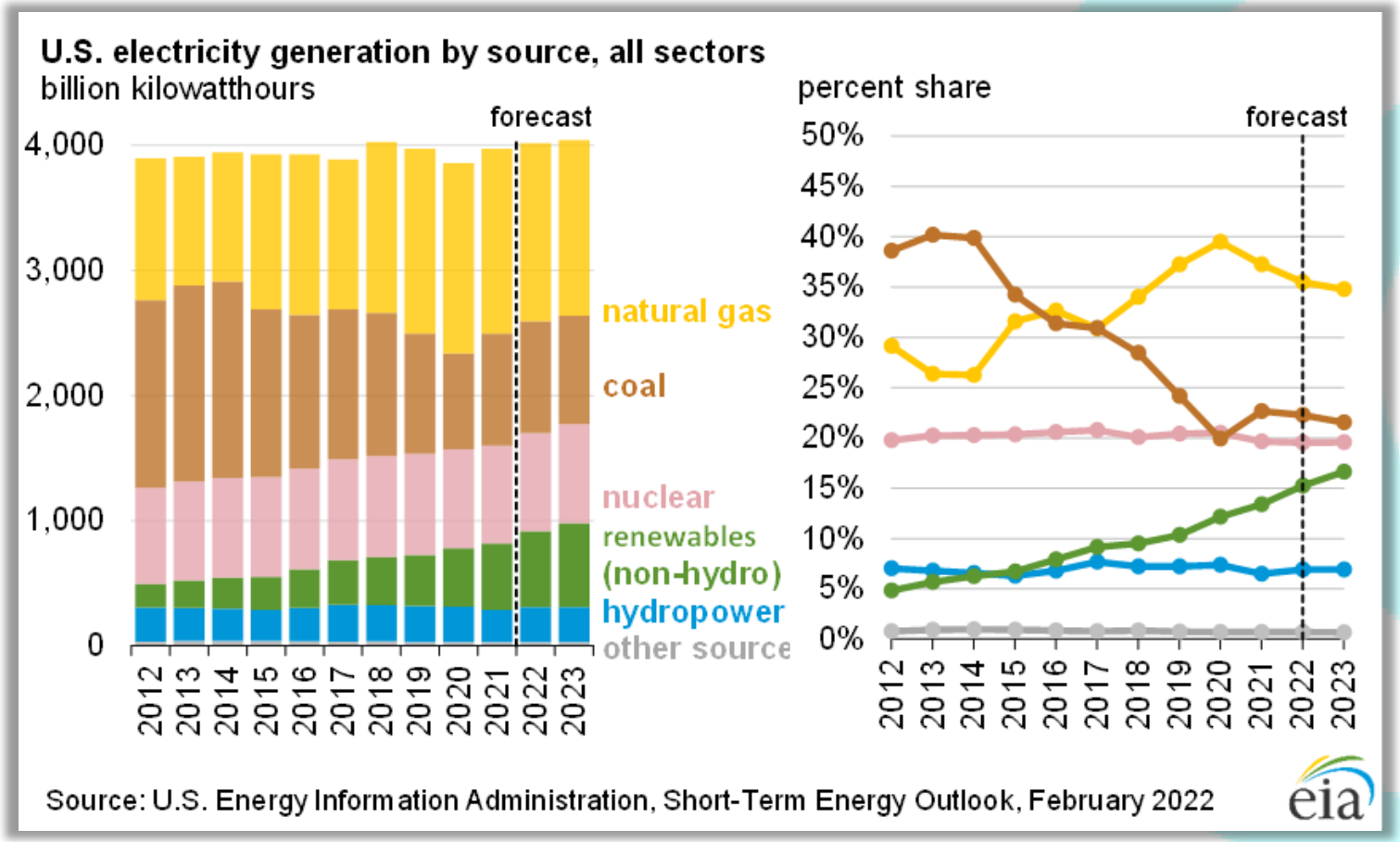
Current Electric Grid Infrastructure

Load increases (one way communication)

Power flow

Source: Adapted from National Energy Education Development Project (public domain)

GENERATION RESOURCES



35% Natural Gas

22% Coal
20% Nuclear
14% Renewables (non-hydro)

7% Hydropower

EIA forecasts renewables will be the fastest growing source of electricity generation

SEASONAL LOAD PROFILES ON GRID

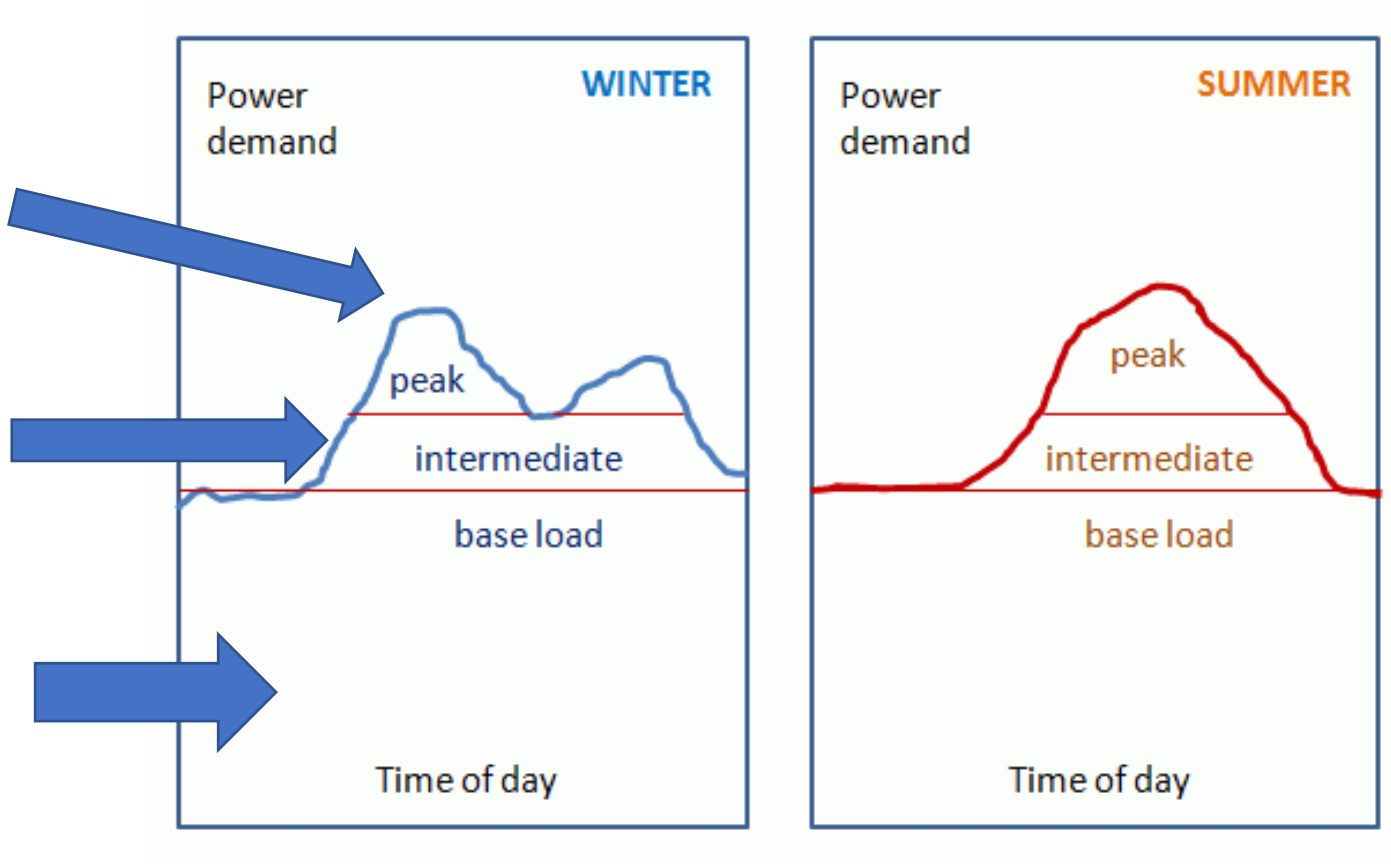
General daily patterns / grid loads are predictable, variability is mostly based on space conditioning loads.

"Peaking Load"
Natural gas "peaker plants"
Hydro

"Load Following"
Natural gas CC
Some renewables

"Baseload"
Coal
Nuclear
Some renewables

*Baseload power is mostly constrained to a constant output



Electricity Generation Sector – Load Duration Curve

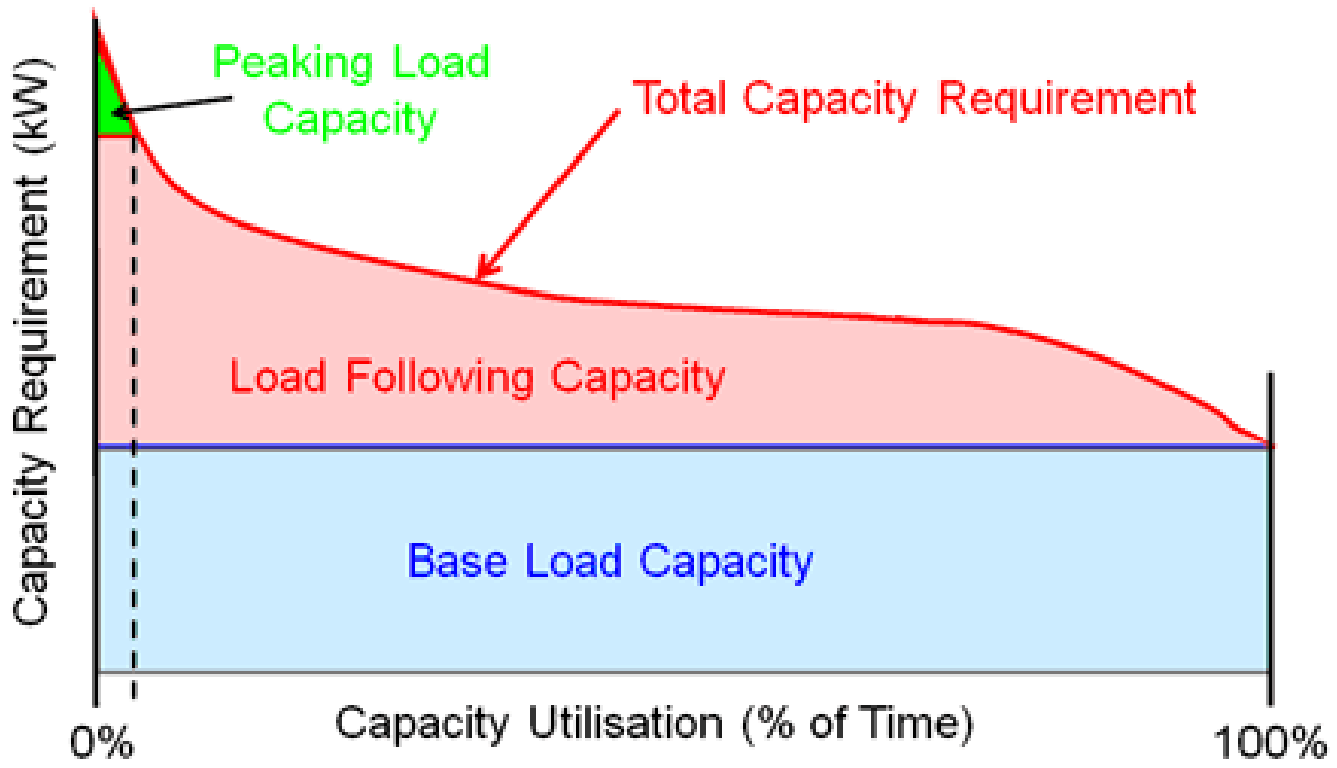
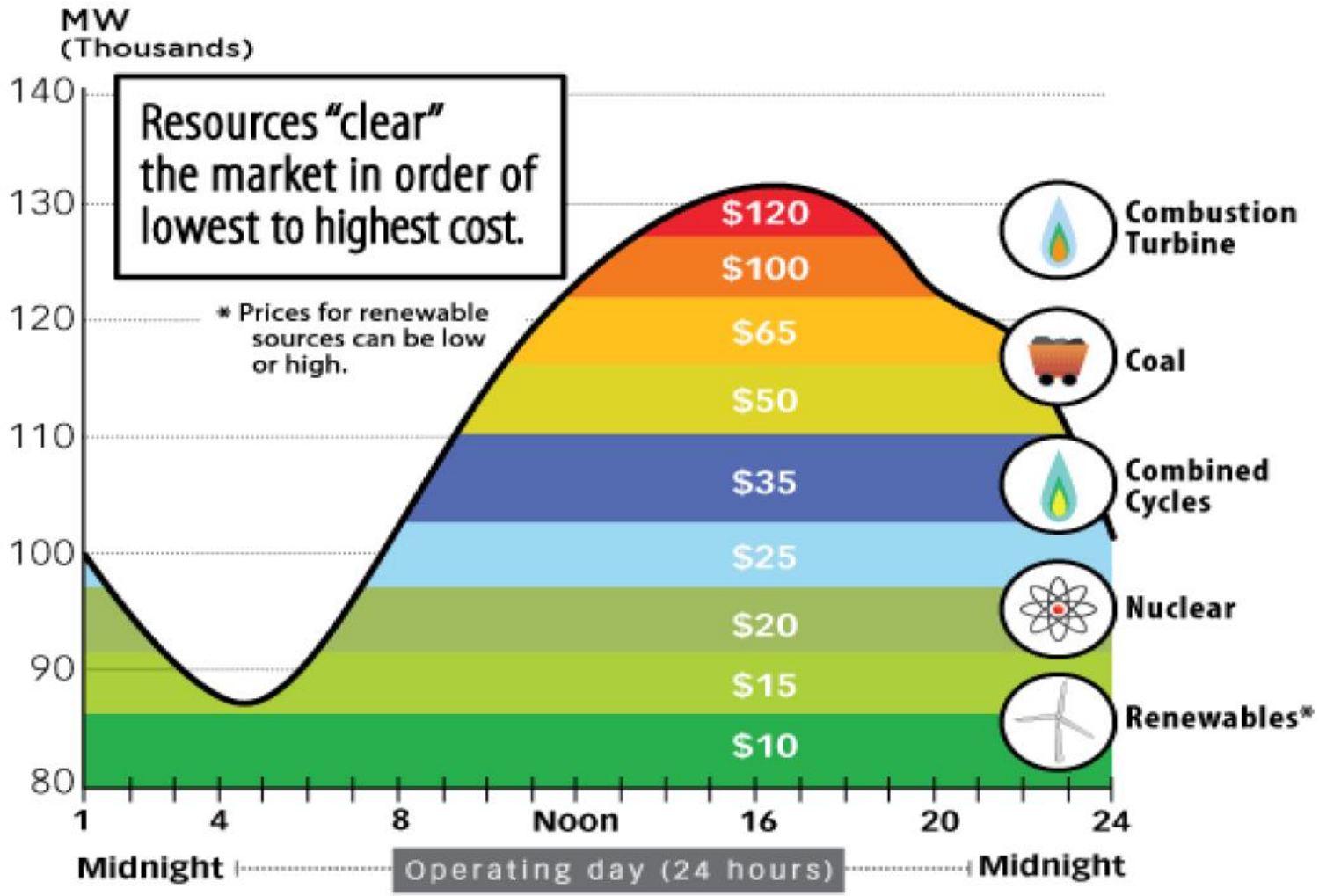


Image Source: Mark Pruitt

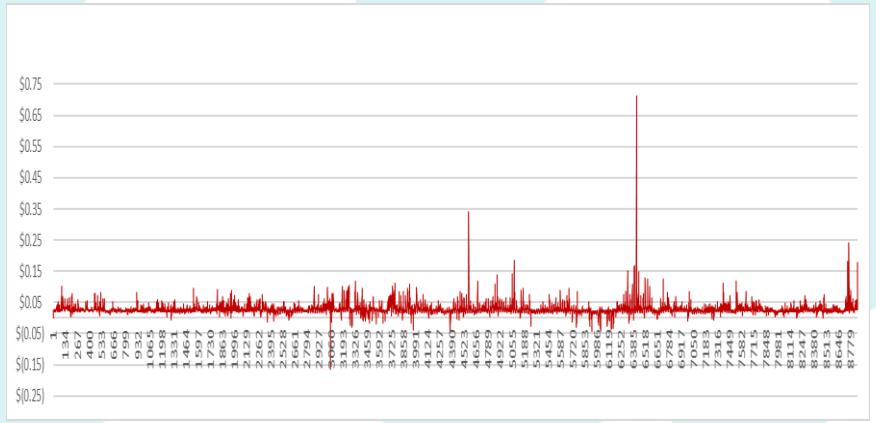
The U.S. currently has about **2.5-3 times** more generation capacity than what's used annually.

Sized capacity based on meeting peaks = over built system

Meeting the Daily Electric Load



Electricity Generation Sector - Scheduling



REAL TIME PRICING (RTP) – Chicago, IL

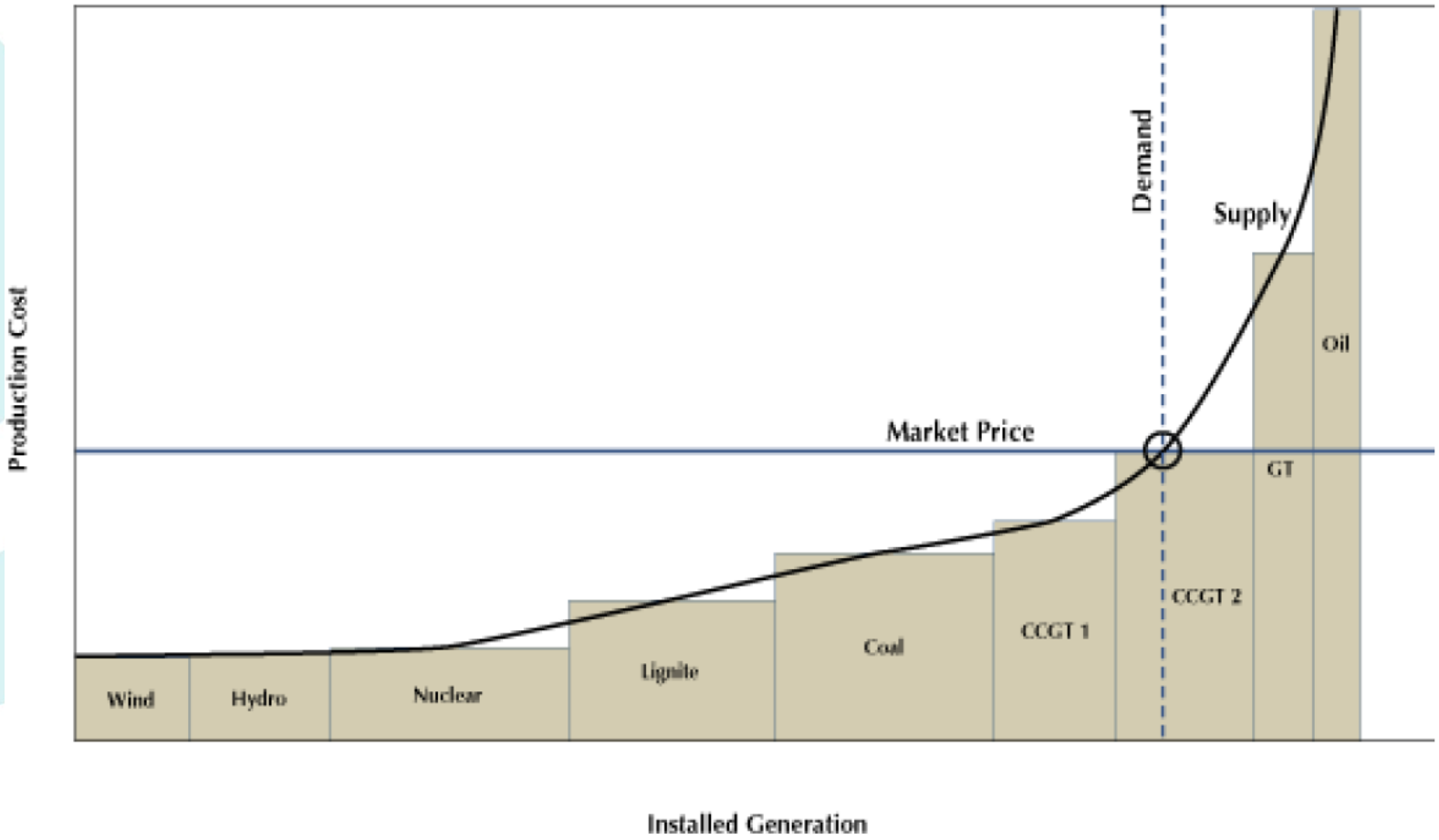
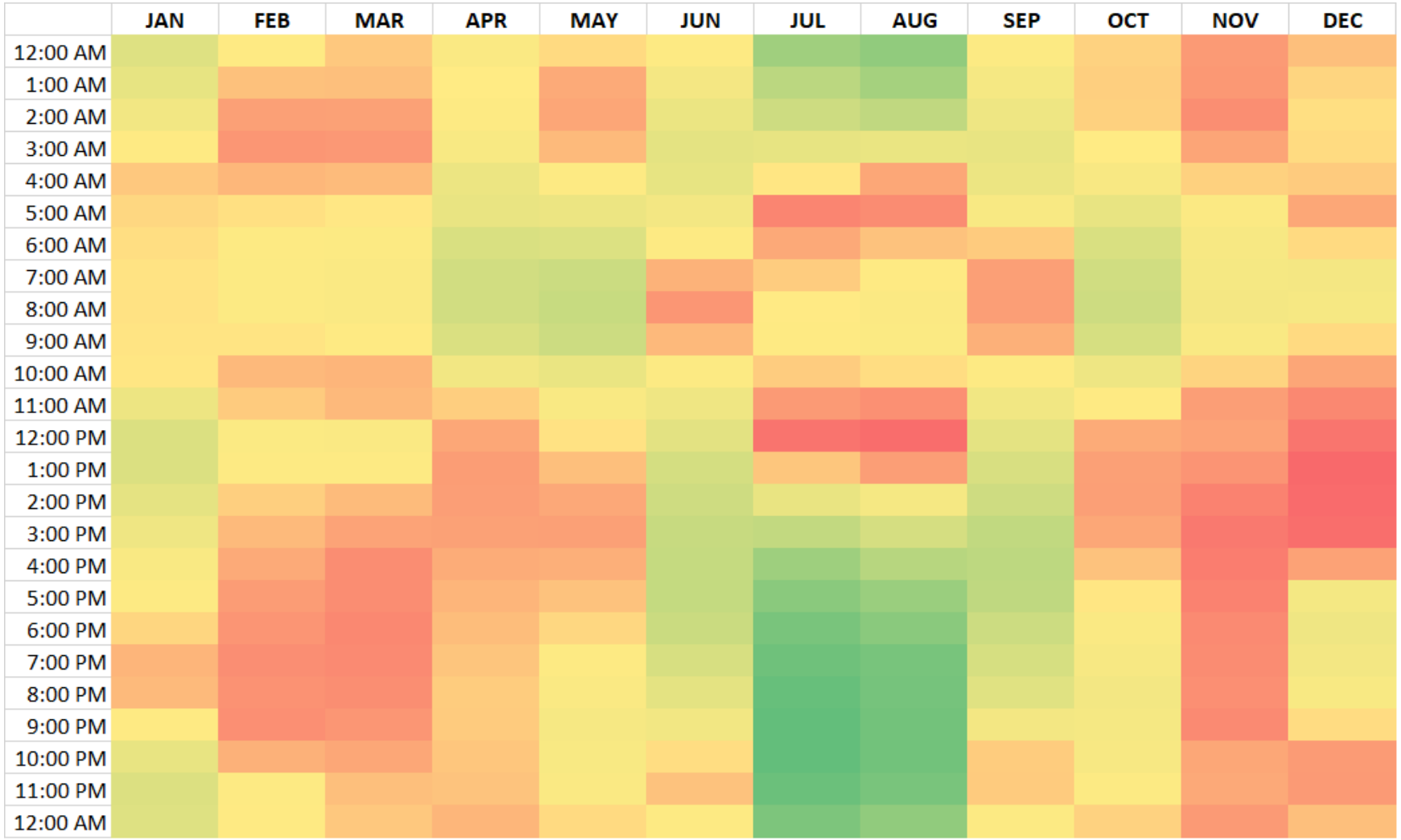


Image Source: Mark Pruitt

HOURLY MARGINAL CARBON EMISSIONS

CHICAGO, IL - 2019



Source: WattTime

Timing is important!!

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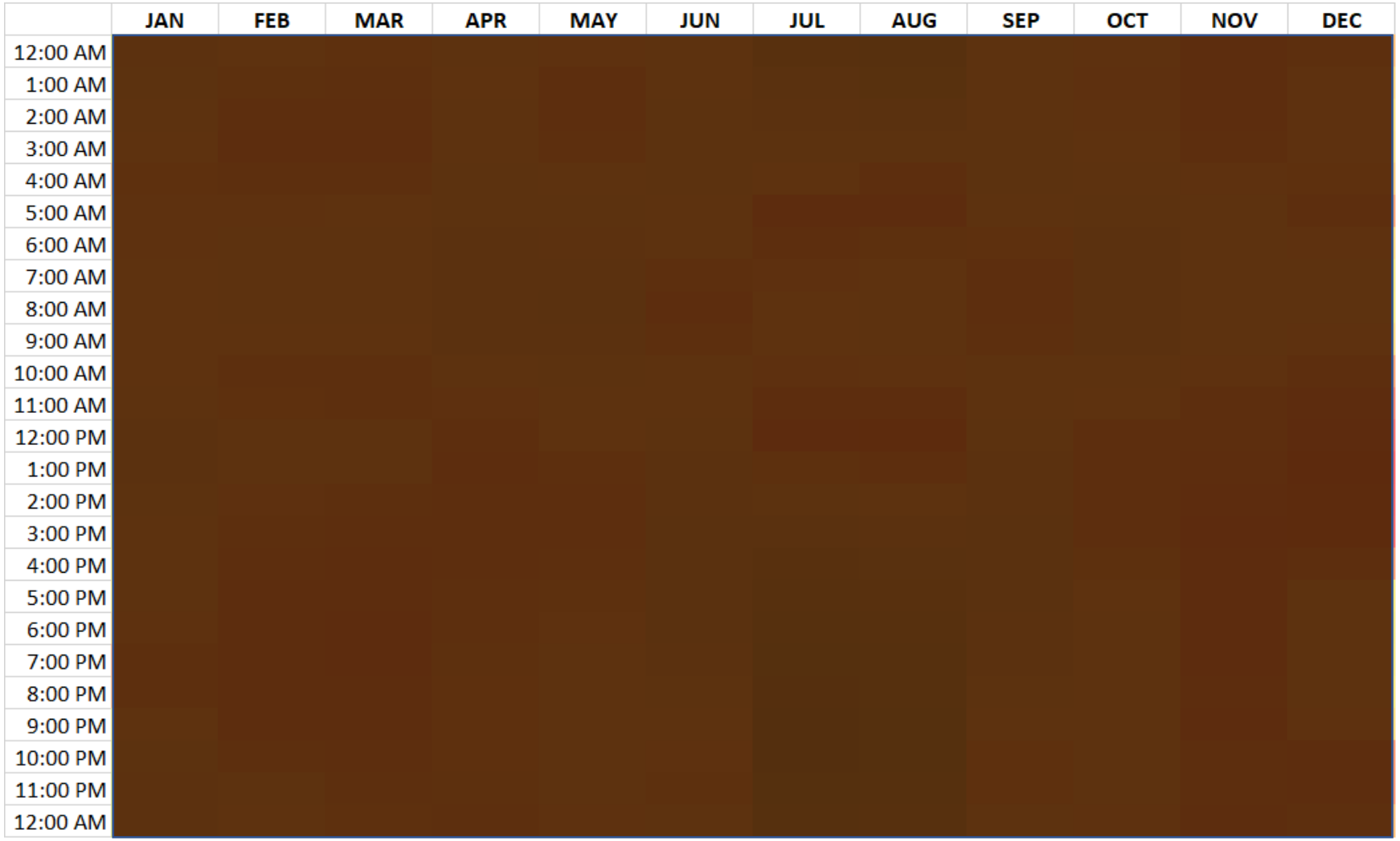
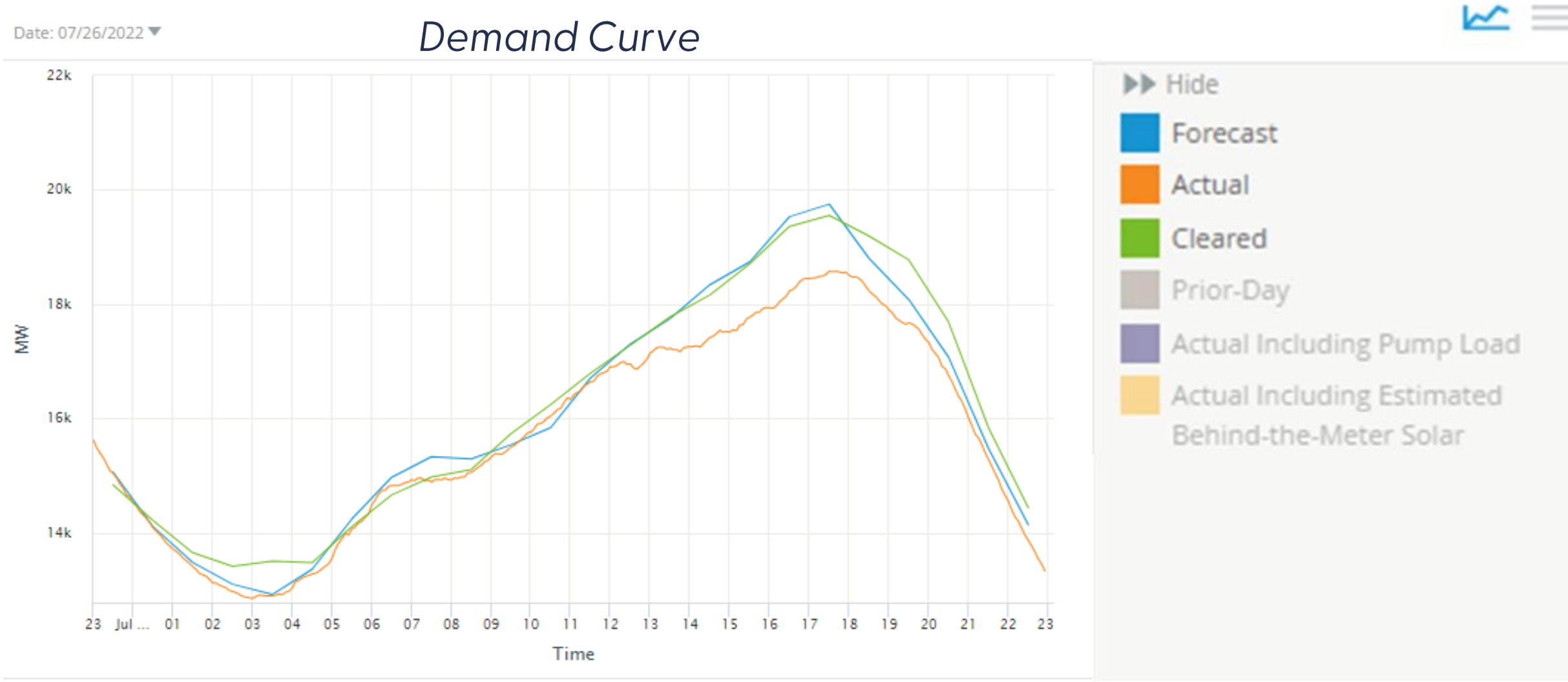
Typical Simplified Source Energy Accounting



New England ISO – July 26, 2022



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

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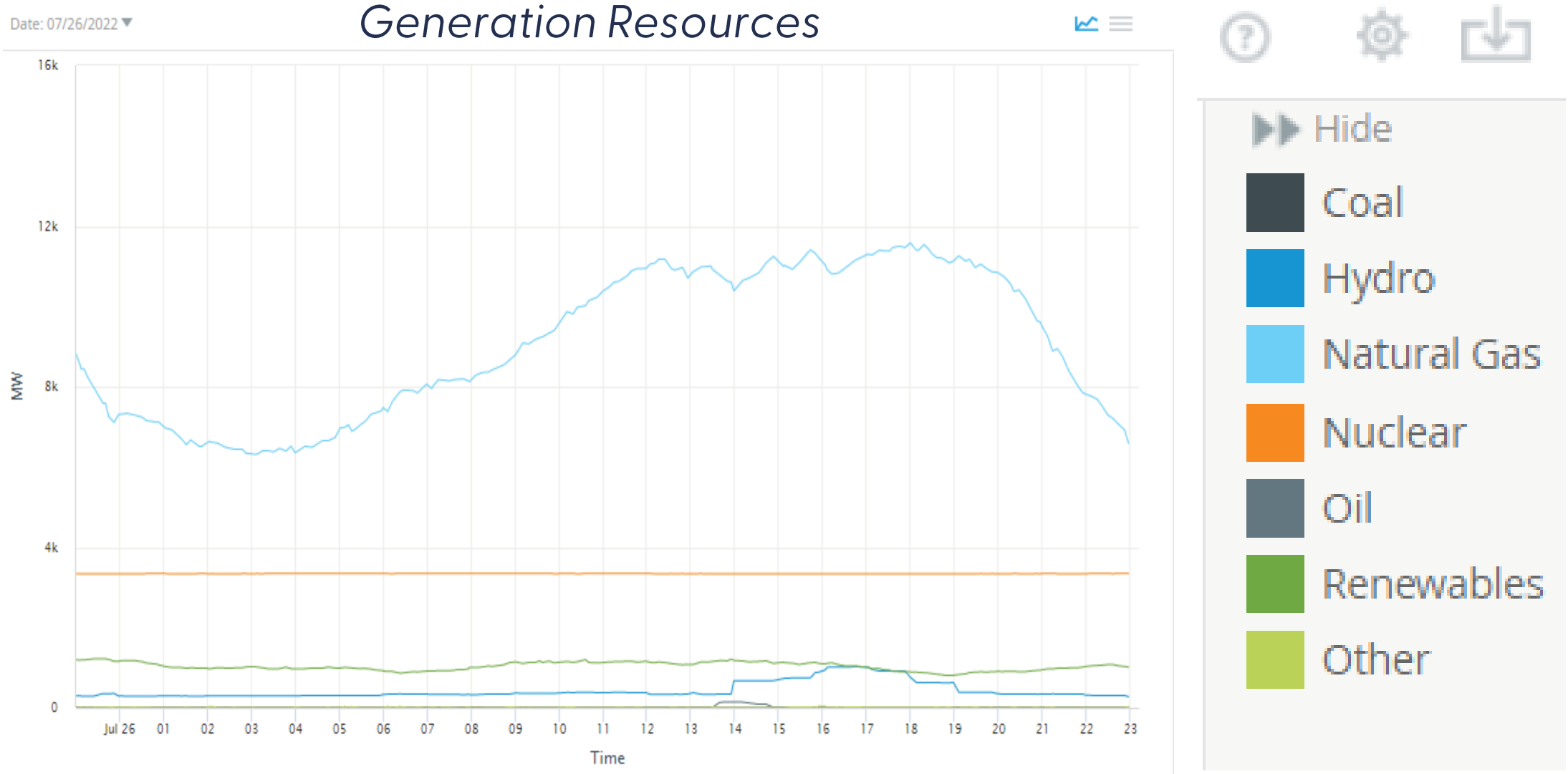
New England ISO – July 26, 2022



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

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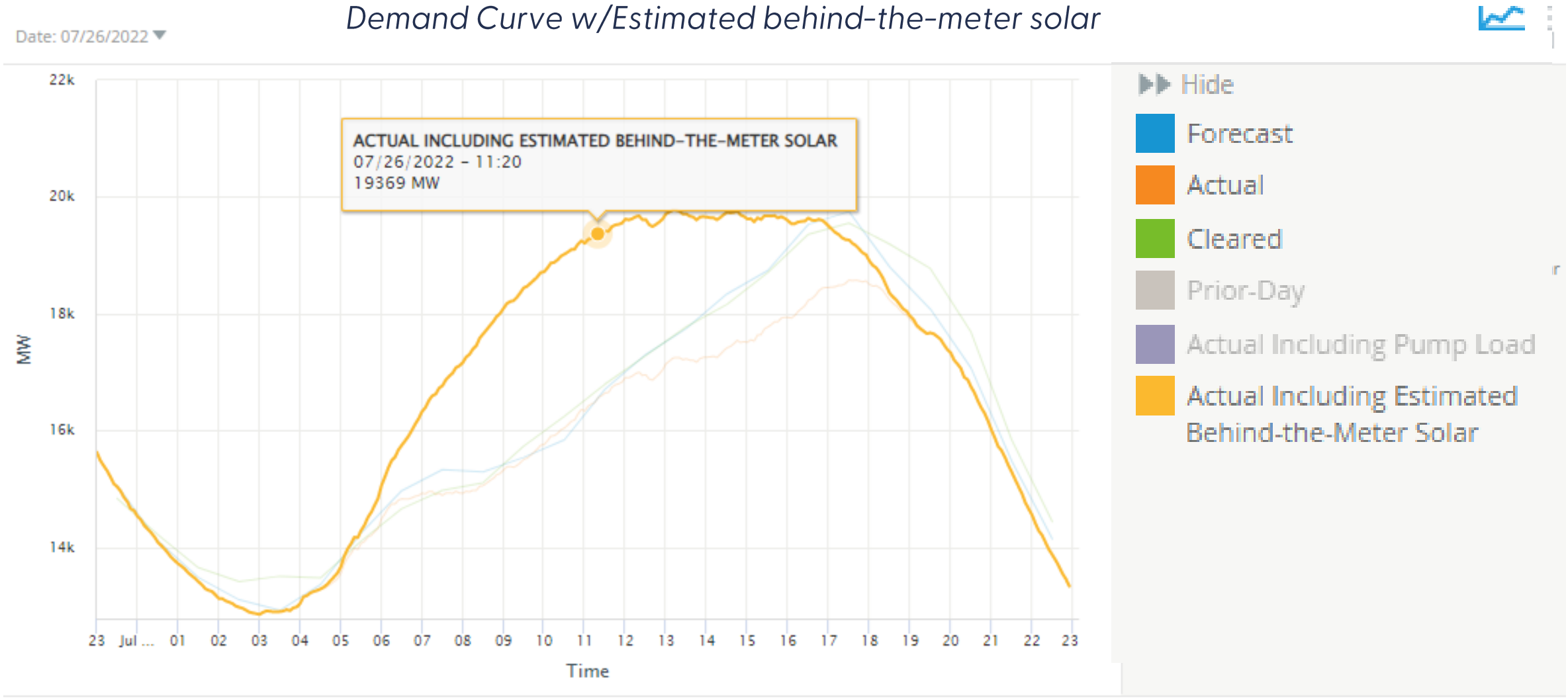
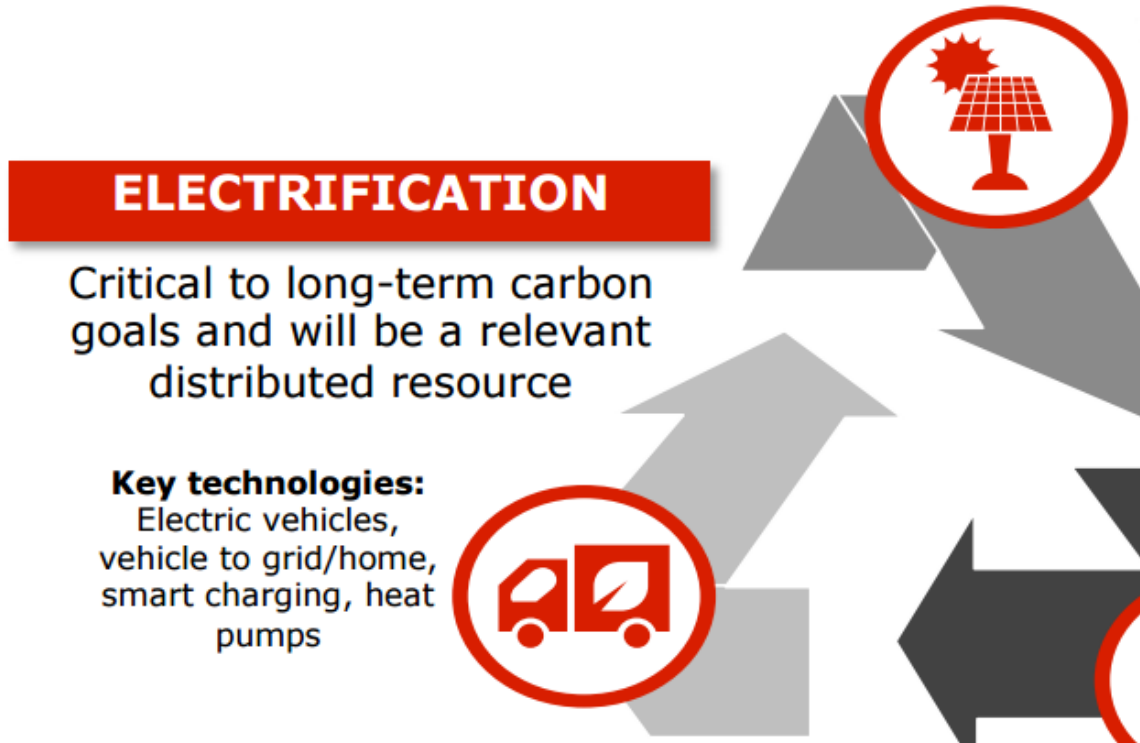
New England ISO – July 26, 2022

Demand Curve w/Estimated behind-the-meter solar



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

THE GRID IS CHANGING



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

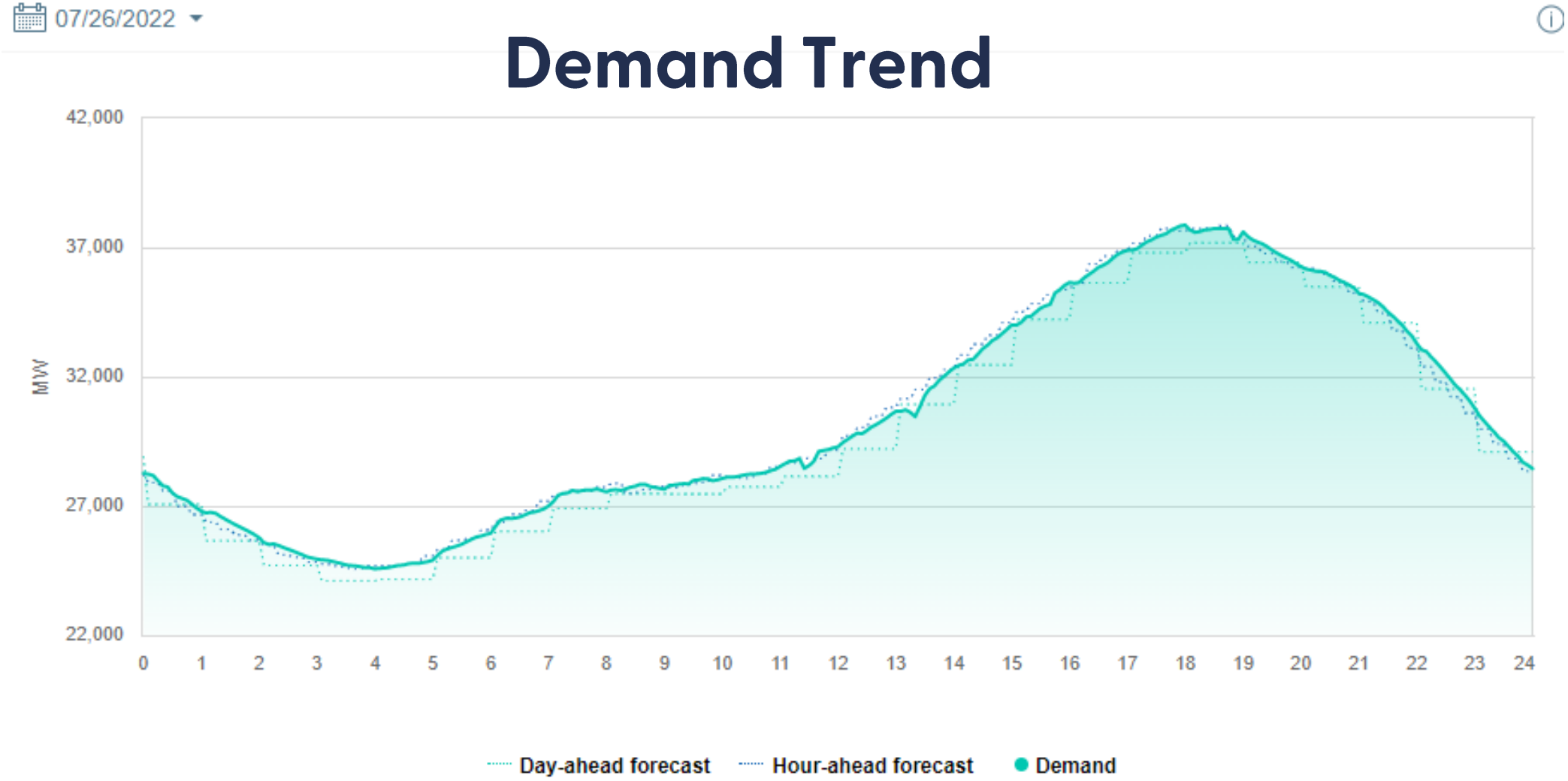
Key technologies:
Electric vehicles, vehicle to grid/home, smart charging, heat pumps

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 (CAISO) – July 26, 2022

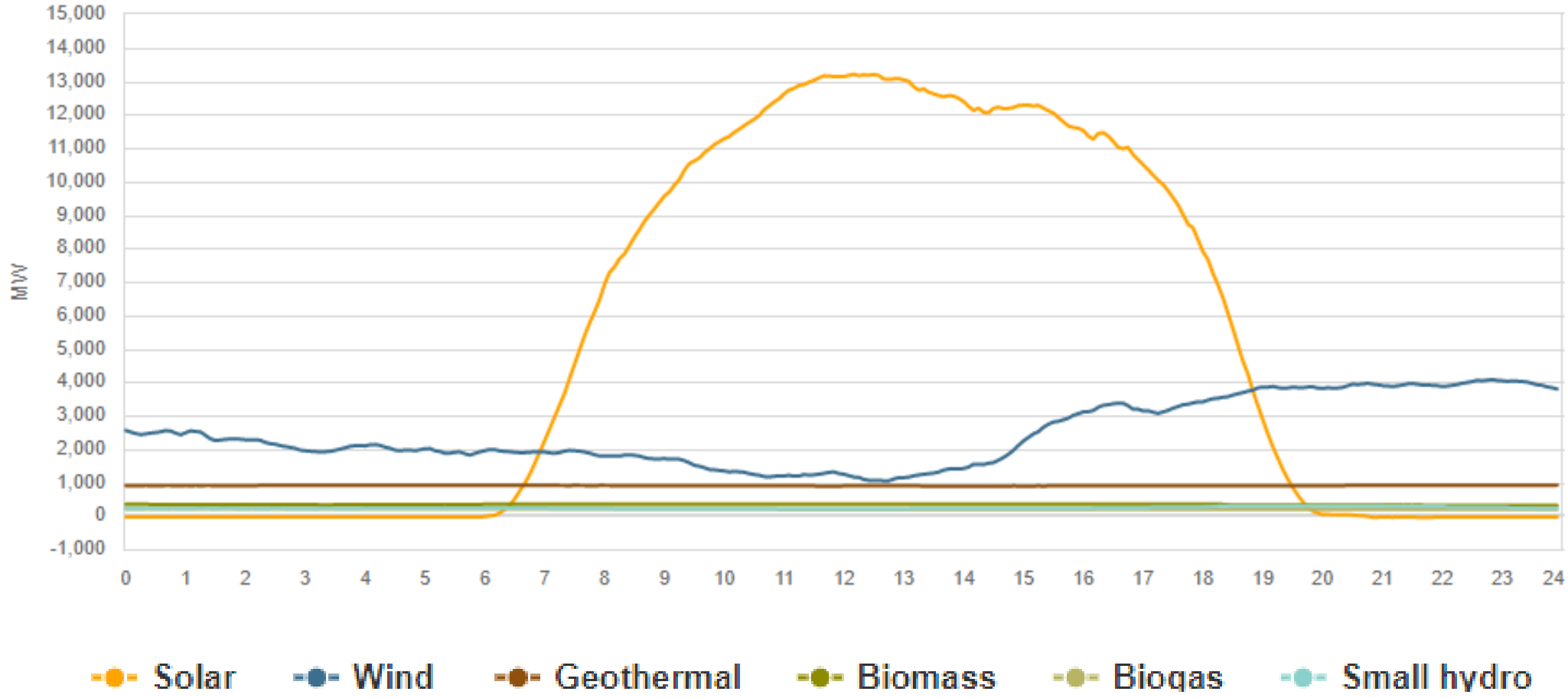


http://www.caiso.com

California ISO (CAISO) – July 26, 2022

07/26/2022

Renewables Trend

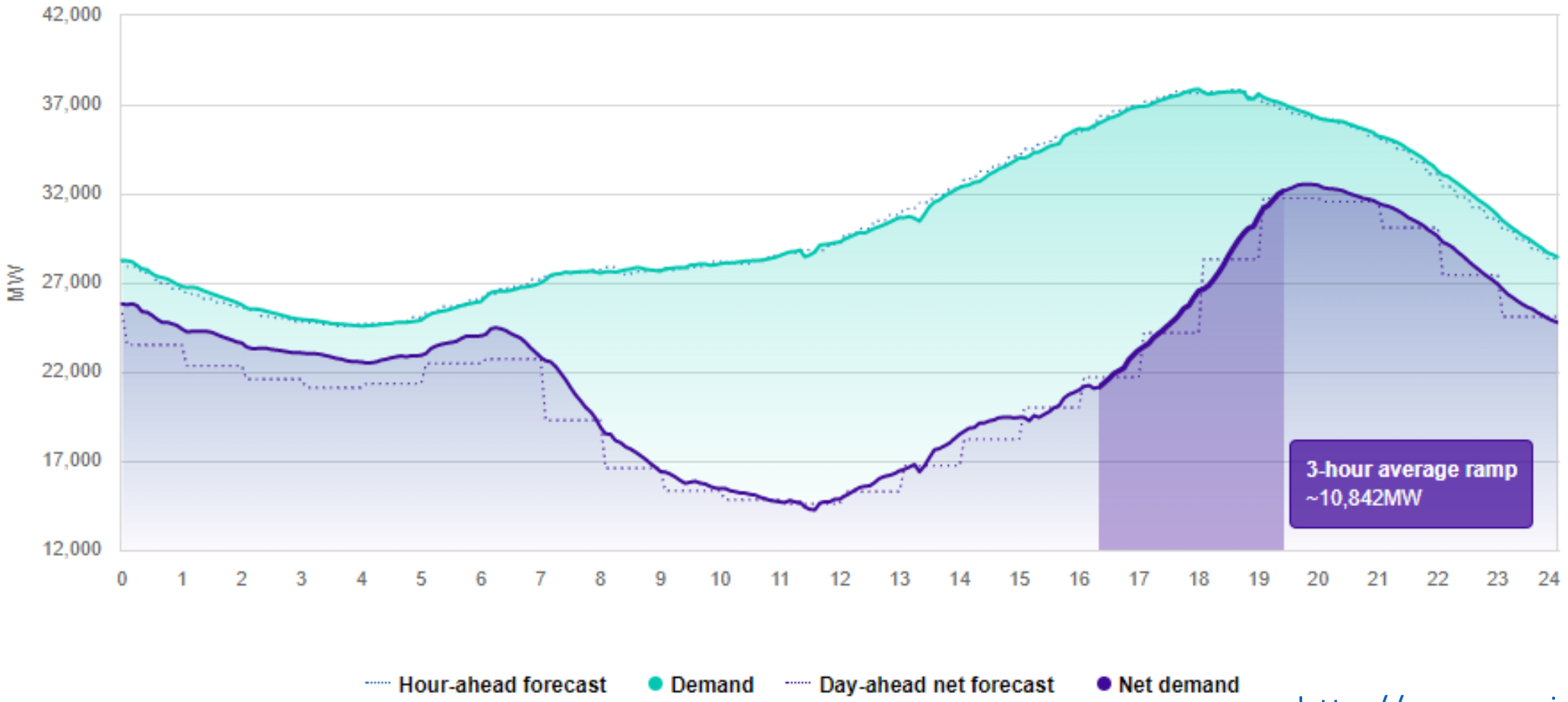


http://www.caiso.com

California ISO (CAISO) – July 26, 2022

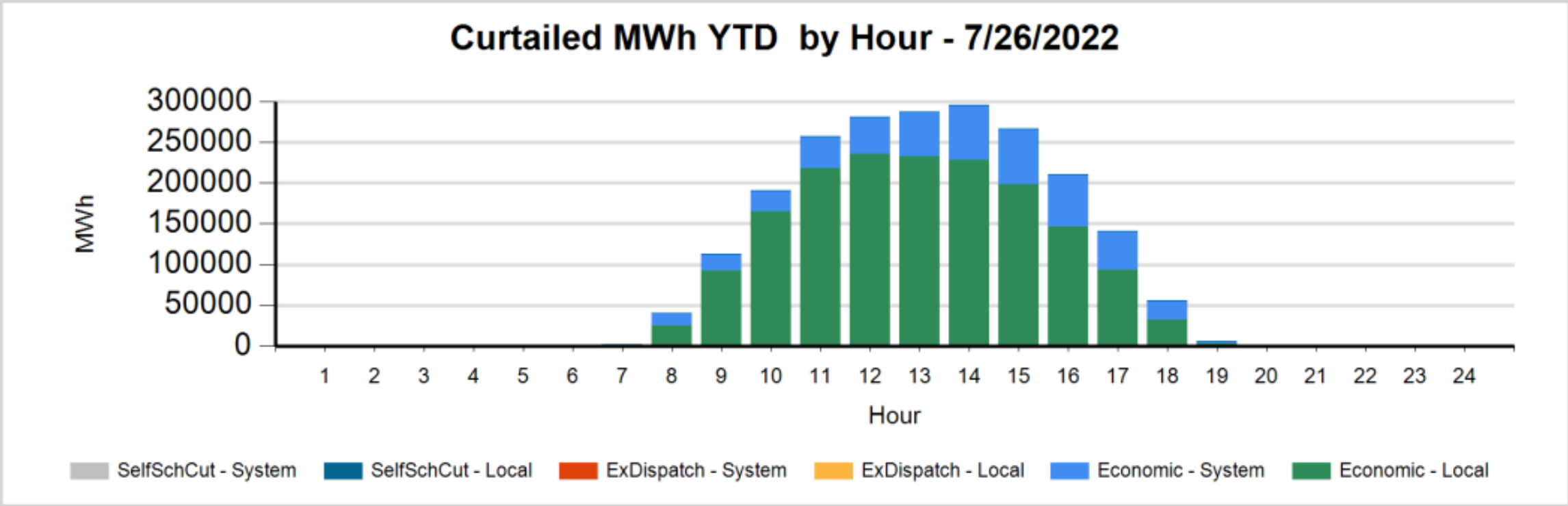
07/26/2022

Net Demand



http://www.caiso.com

Transmission Congestion

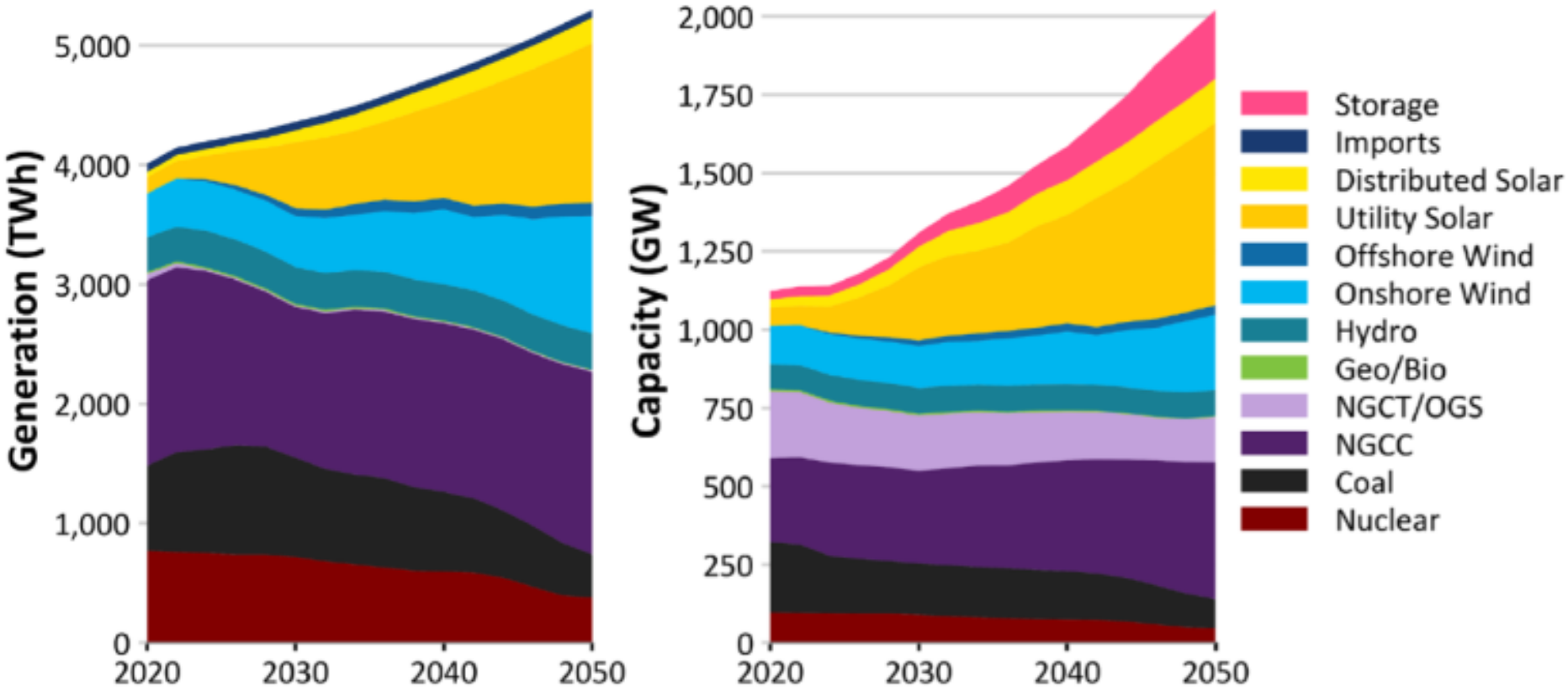


Economic – Local: *Market dispatch over generators with economic bids to mitigate local congestion**

**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.*

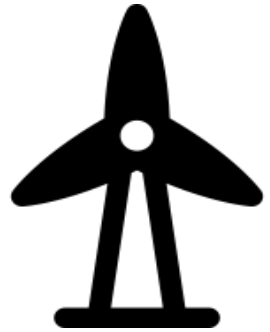
Economic – System*: Market dispatch of generators with economic bids to mitigate system-wide oversupply*

NREL Cambium Model – 2050 Mid Case Scenario for US Grid Electricity Capacity and Generation Mix



The Transition to a Renewable Future

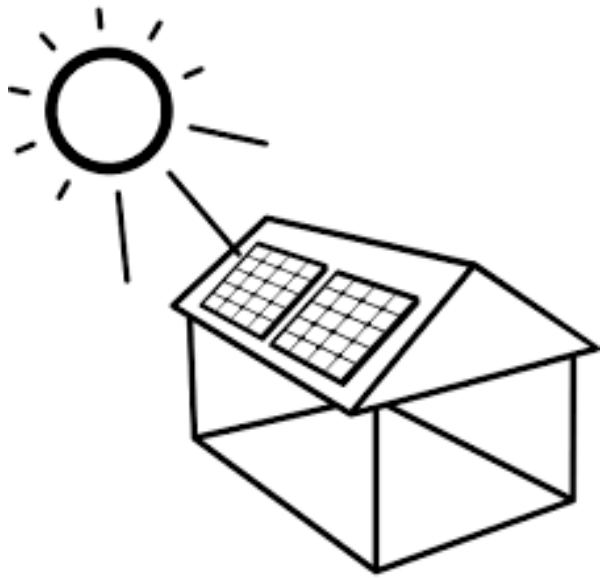
Requires Systems Level Thinking



How do the decisions at this scale… **Impact the decisions at this scale?**

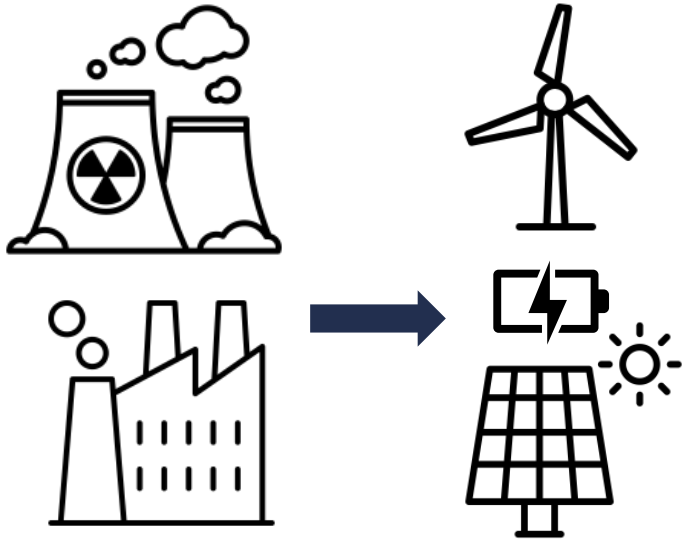
Changes & Challenges

Decarbonization Movement



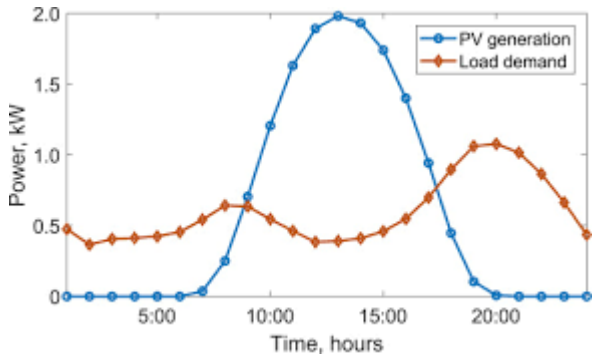
Net-Zero Buildings

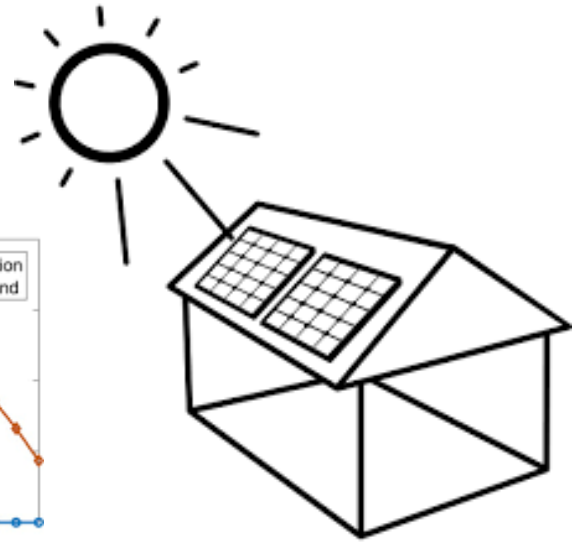
Electrification Movement



Dispatchable fossil fueled power generation shifting to variable renewable resources

Timing is important.



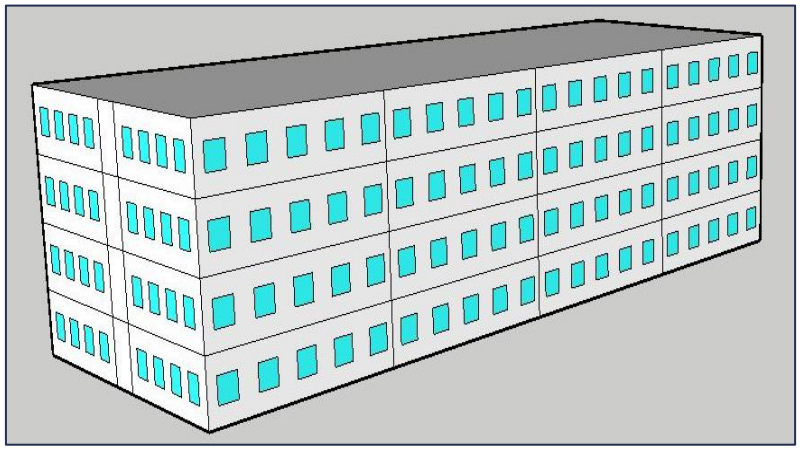


“Net Zero”

≠

“Zero Impact”
“Zero Grid Reliance”
“Zero Operating Emissions”

Two types of Net ZERO



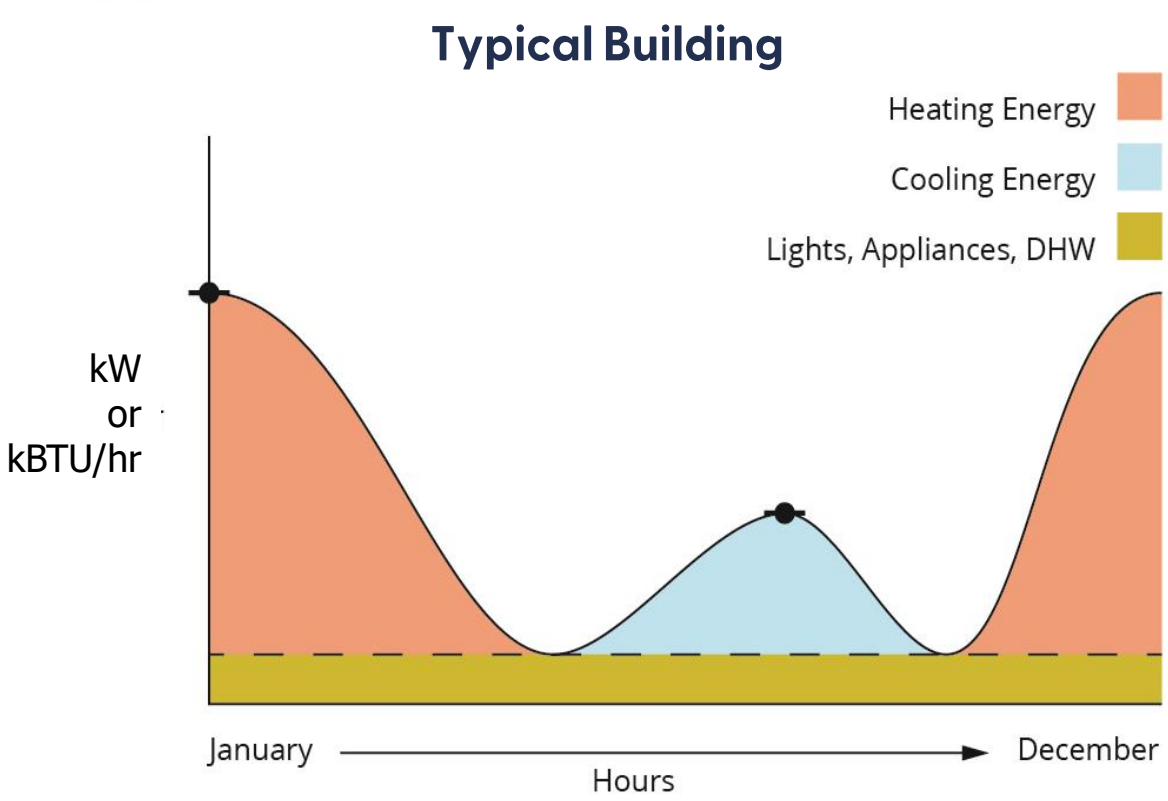
Multifamily Building – DOE Prototype
Location: Chicago, IL
32 units, 96 occupants, ~35,000 sf iCFA
All Electric

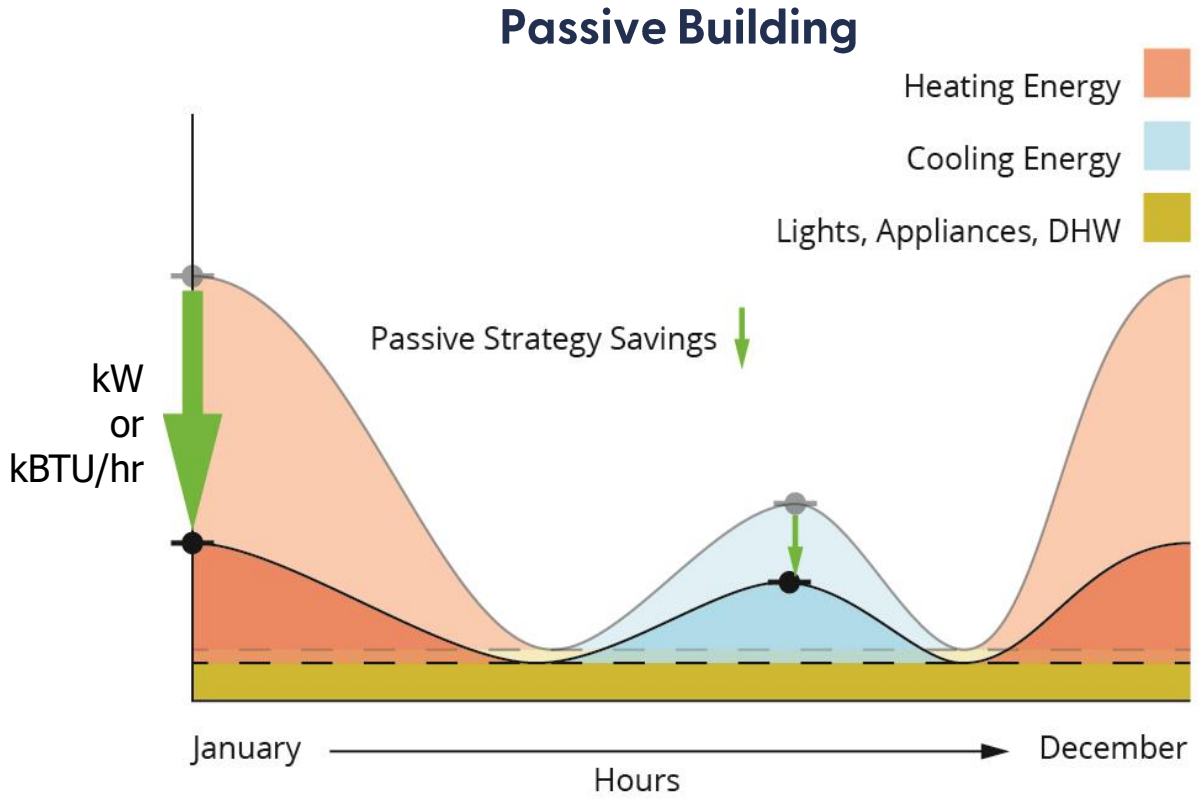
Two ‘Net Zero’ buildings studied:

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

2. Passive building (Phius certifiable):
159 kW PV Array
All south facing, 10 degree tilt

Passive Building

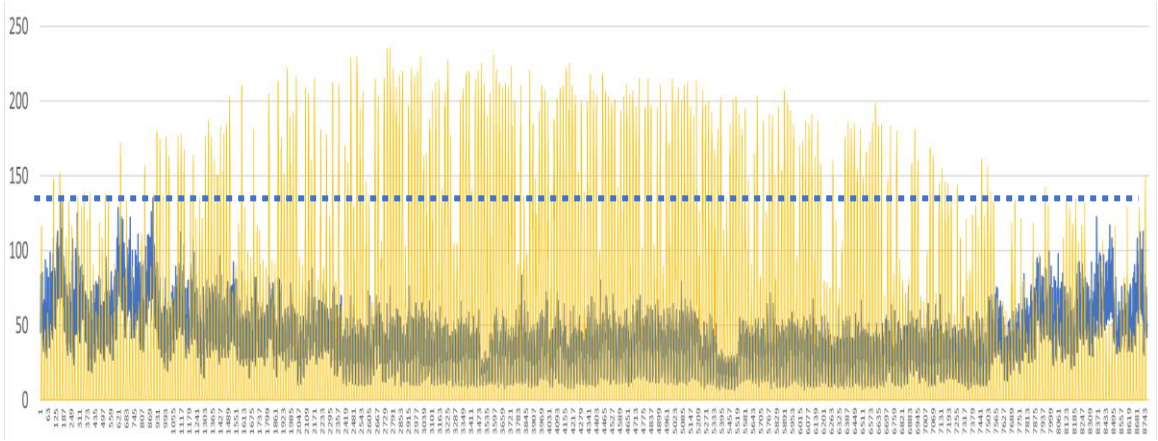




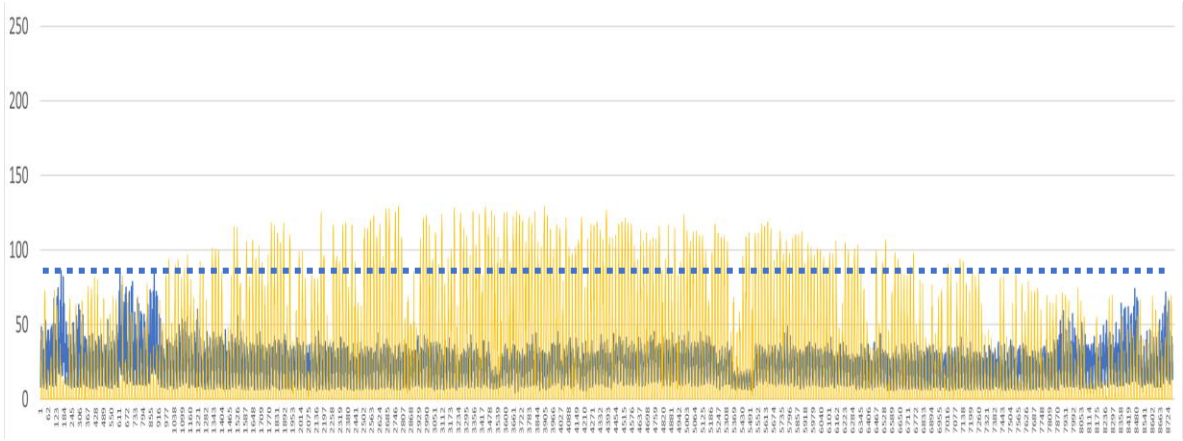
Annual Energy = kWh/yr (or kBTU/yr) → area under the curve
Peak Power = kW (or kBTU/hr) → point at top of curve

NET ZERO CASE STUDY

Baseline Building



Passive (Phius Compliant) Building



Yearly Profile: Building Load vs. Solar Energy Production

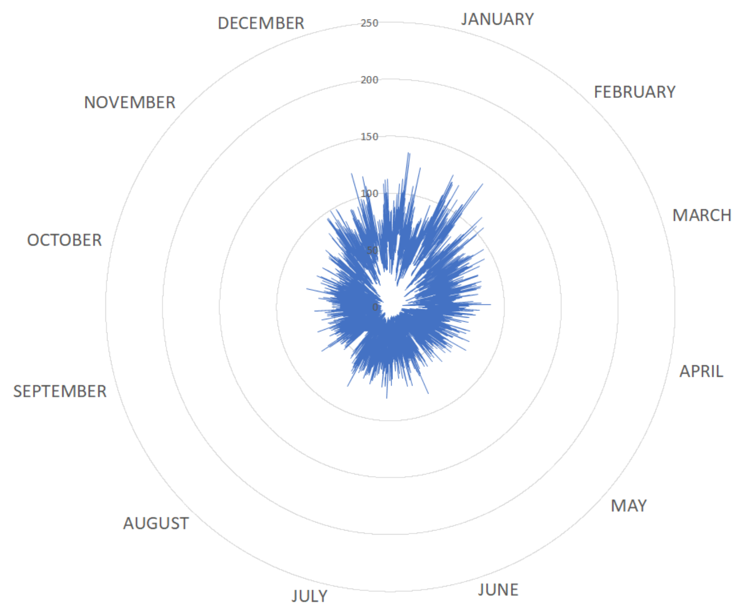
Building Load (kW)

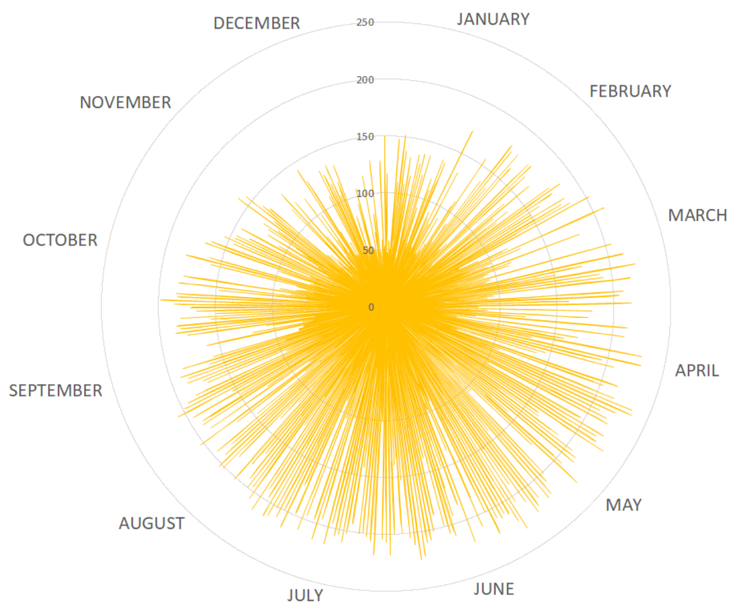
PV Output (kW)

NET ZERO CASE STUDY

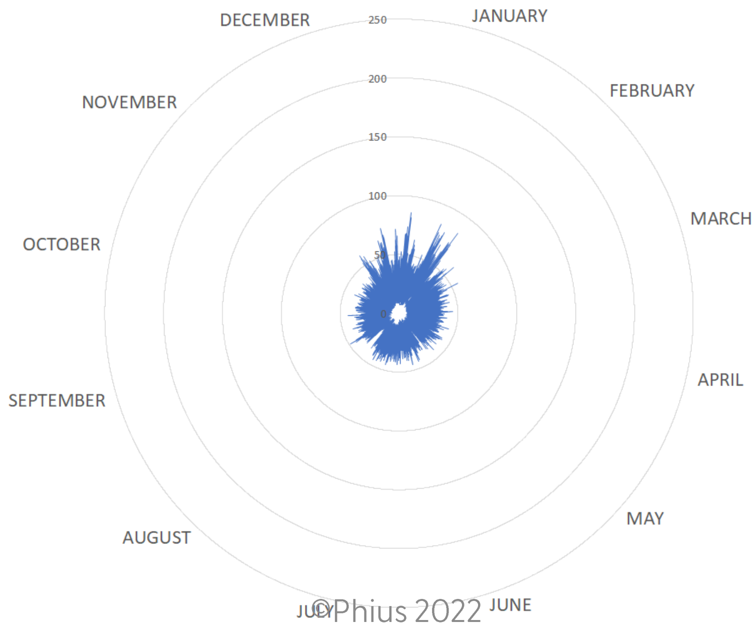
Hourly Building Load (kW) | Hourly PV Production

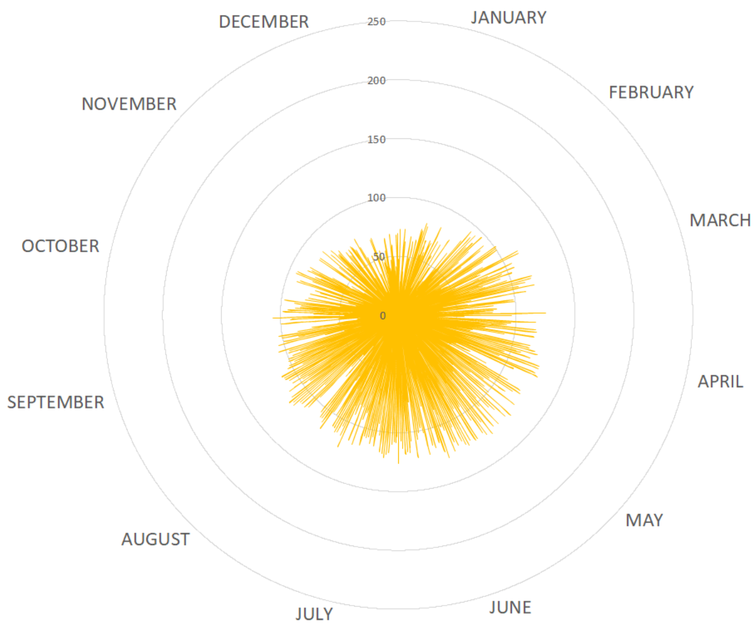
Baseline building





Passive building



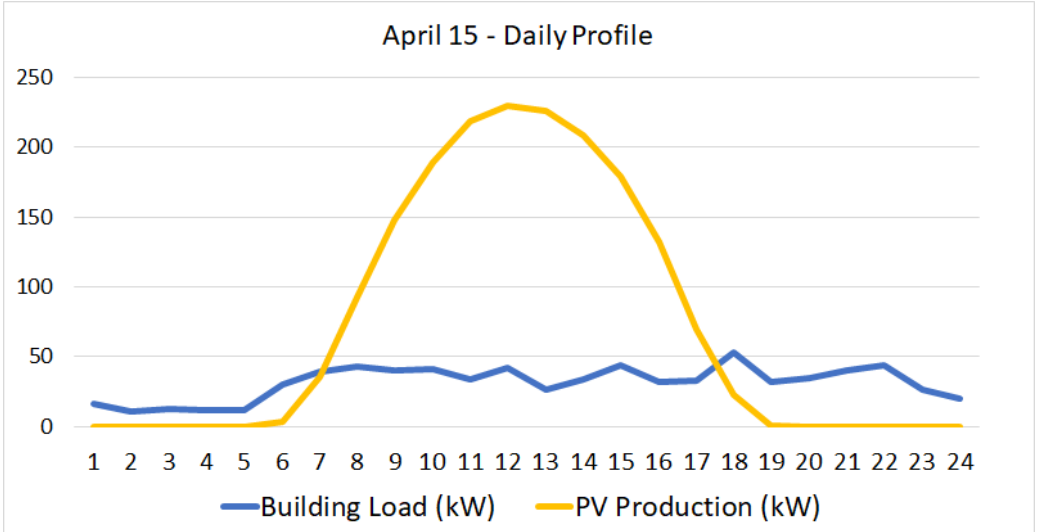


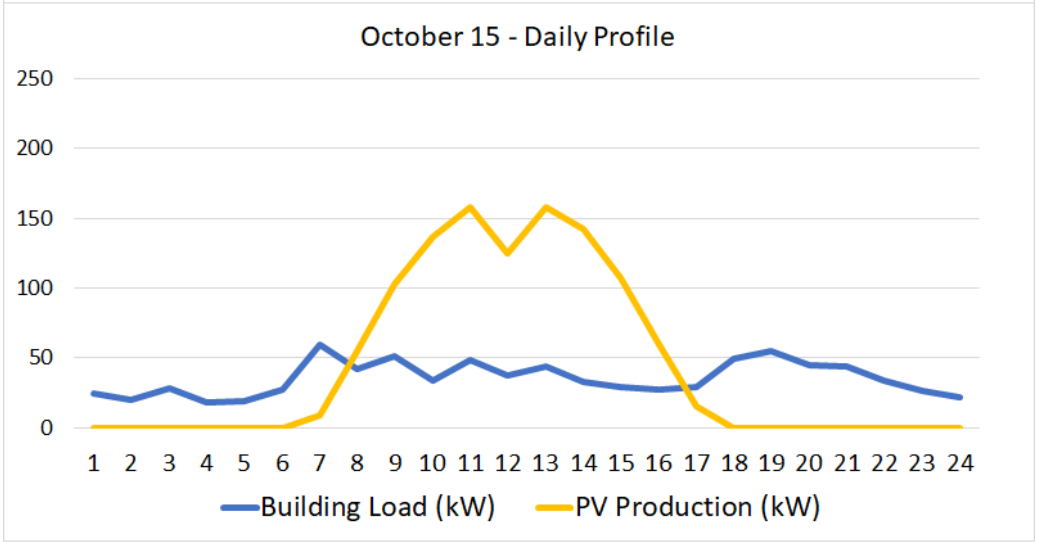
Daily Loads & PV Production

Spring & Fall

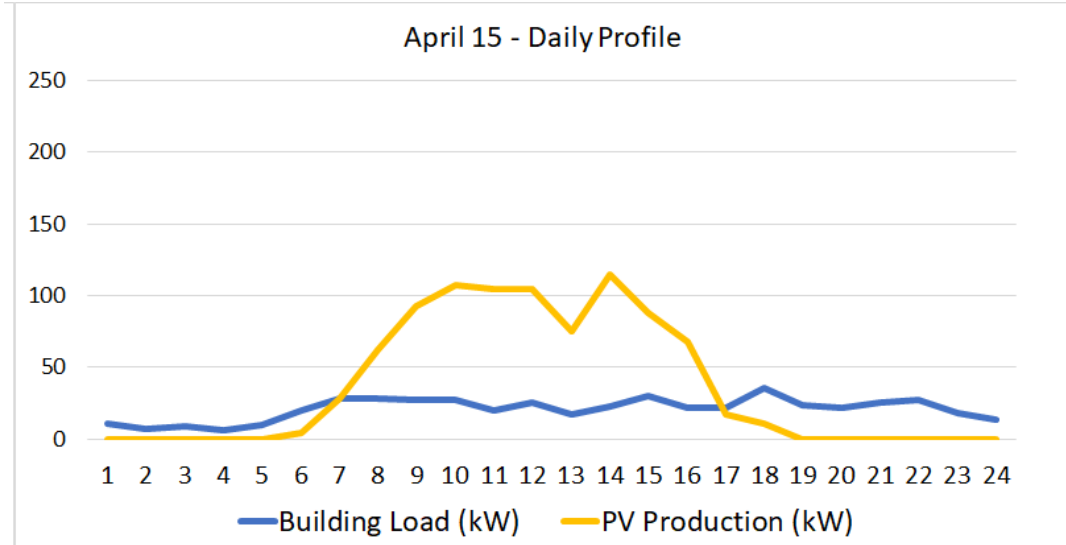
April 15

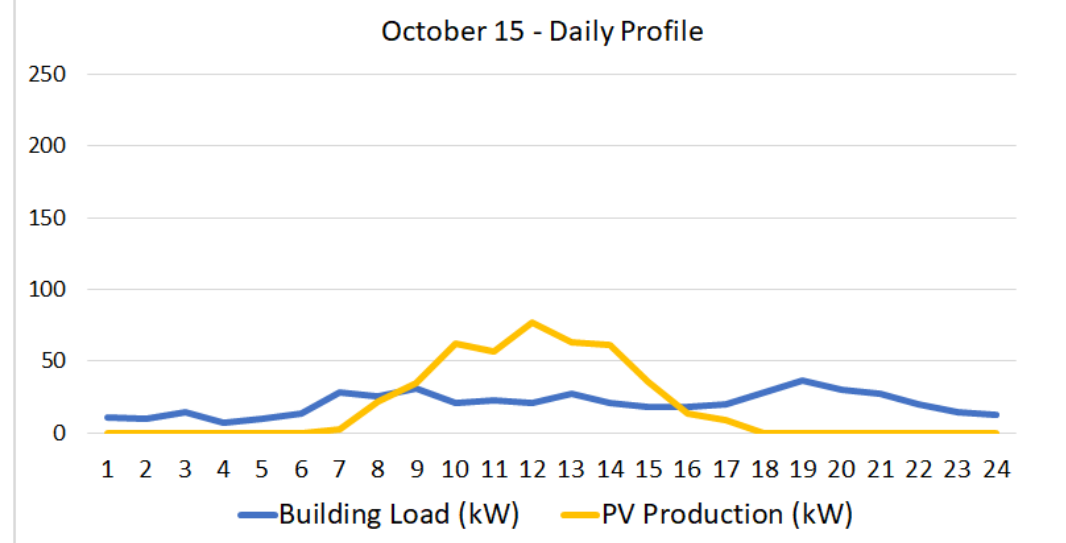
October 15





Baseline building





Passive building

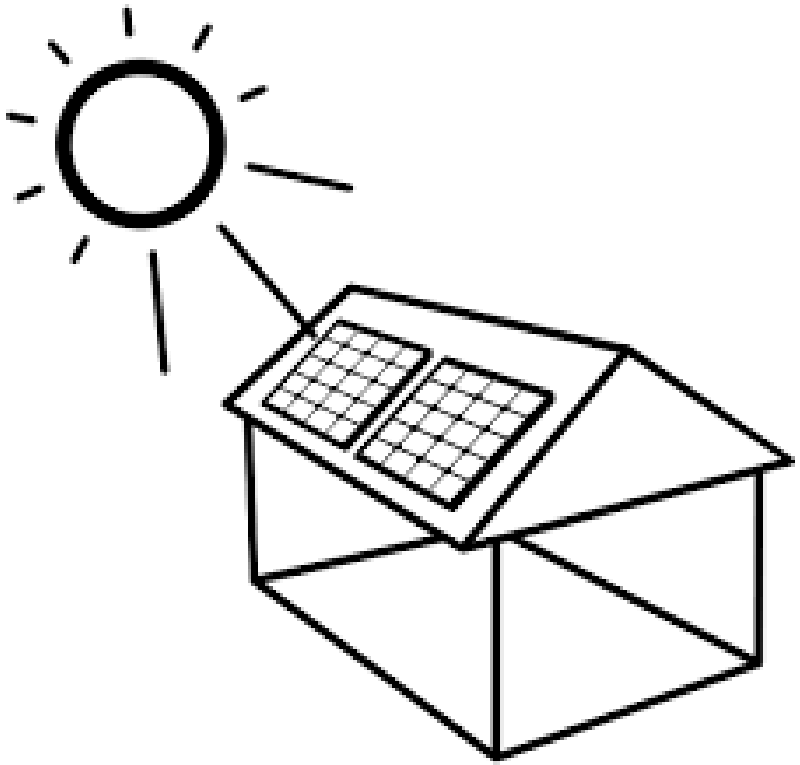
Some findings…

Passive or not, net zero buildings that rely solely on PV to offset their annual energy use, grid support is still required for about ~2/3 of the energy supply.

BUT in the passive case, that's ½ the annual energy that must be provided by the grid (relative to the code baseline).

- Also in the passive case: Less renewables were required, building peaks and annual loads aligned better with PV output.

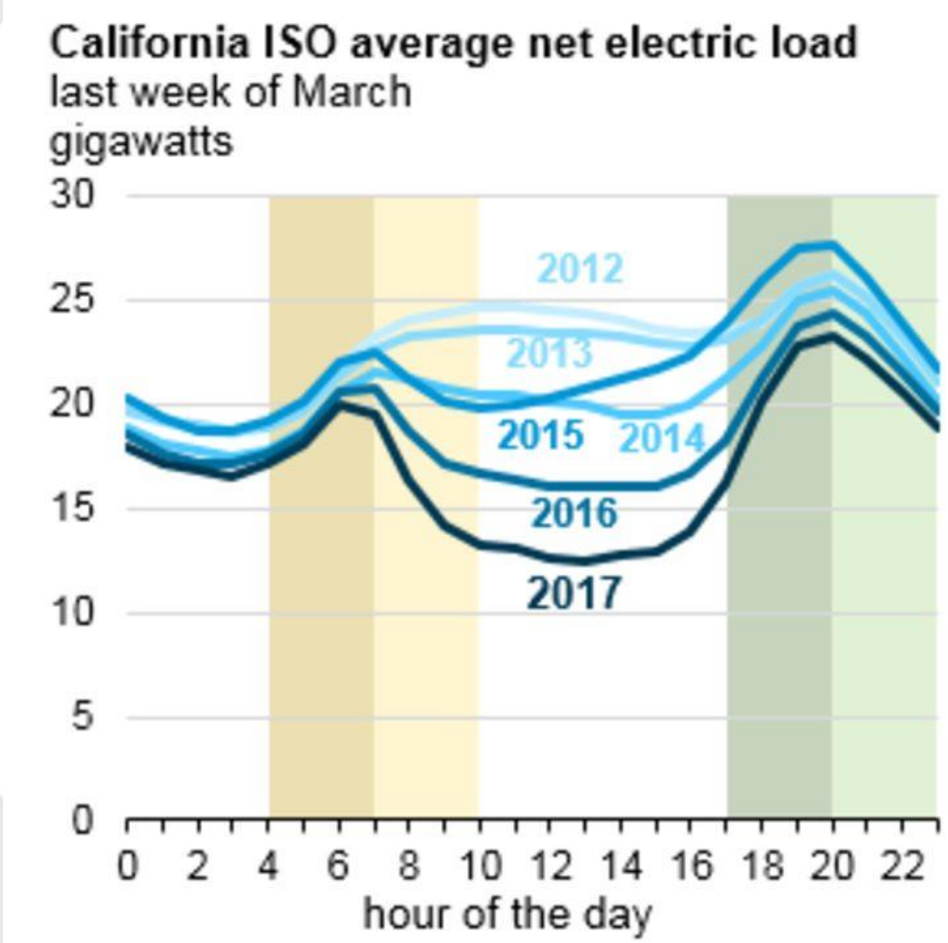
Consumers are becoming *producers + widespread solar energy*

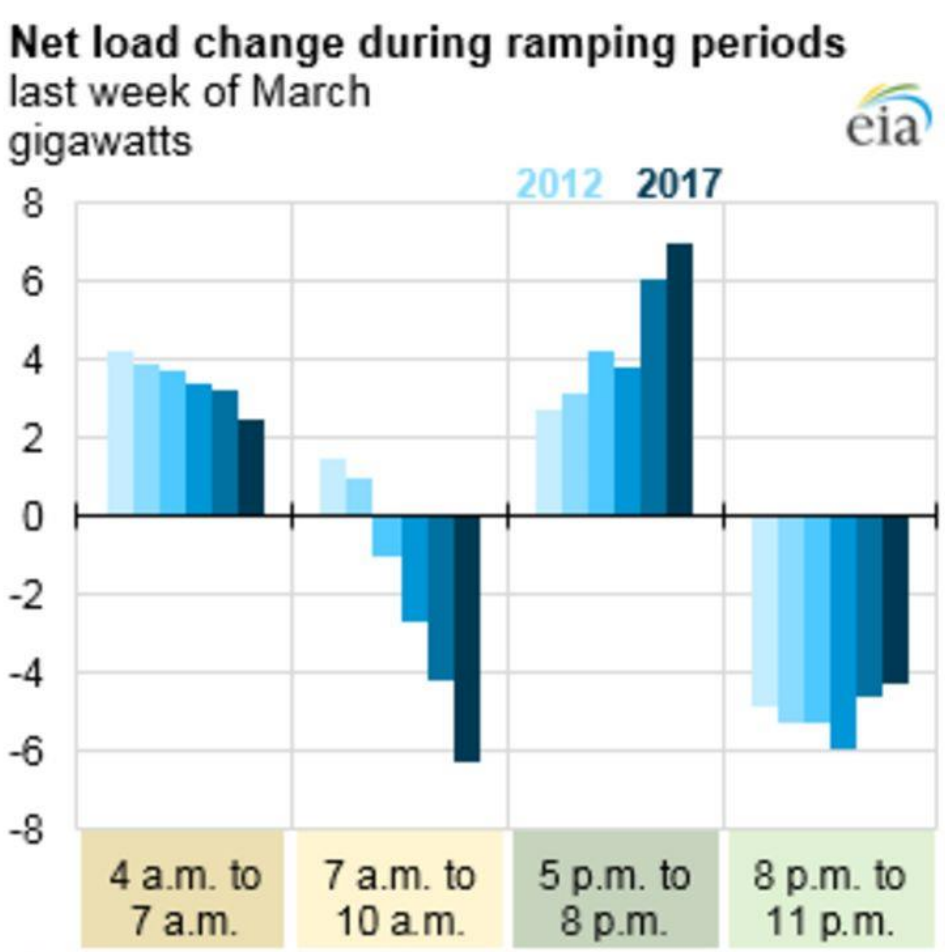


“DER”

(Distributed **E**nergy **R**esources**)**

Net Load & Ramping Challenges (CA)

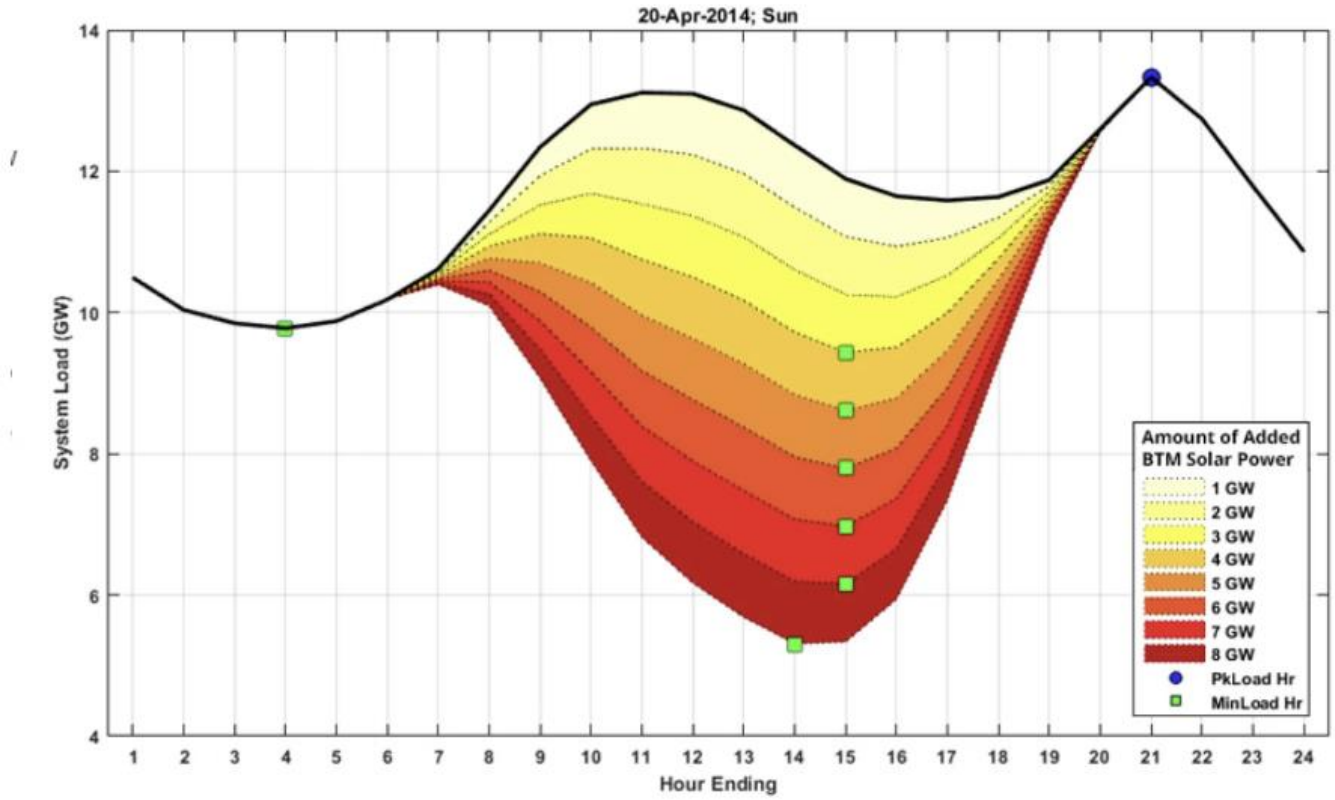




Source: U.S. Energy Information Administration, based on ABB Energy Velocity

Net Load & Ramping Challenges (MA)

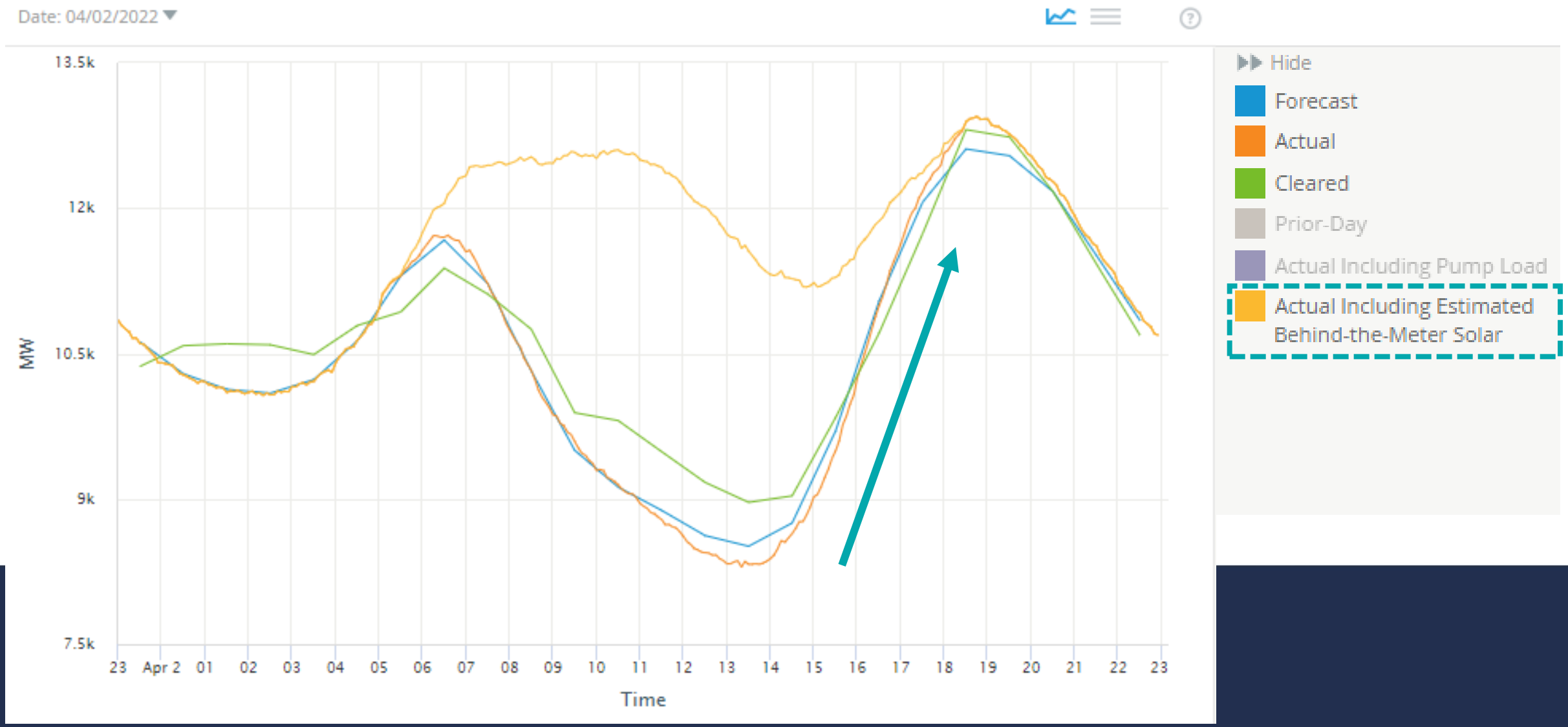
Spring/Autumn Load Profile with Increasing Behind-the-Meter Solar Power



Source: ISO New England

ISO New England will hit the 3-gigawatt level by 2019, driving down the minimum load level. (Image credit: ISO-NE)

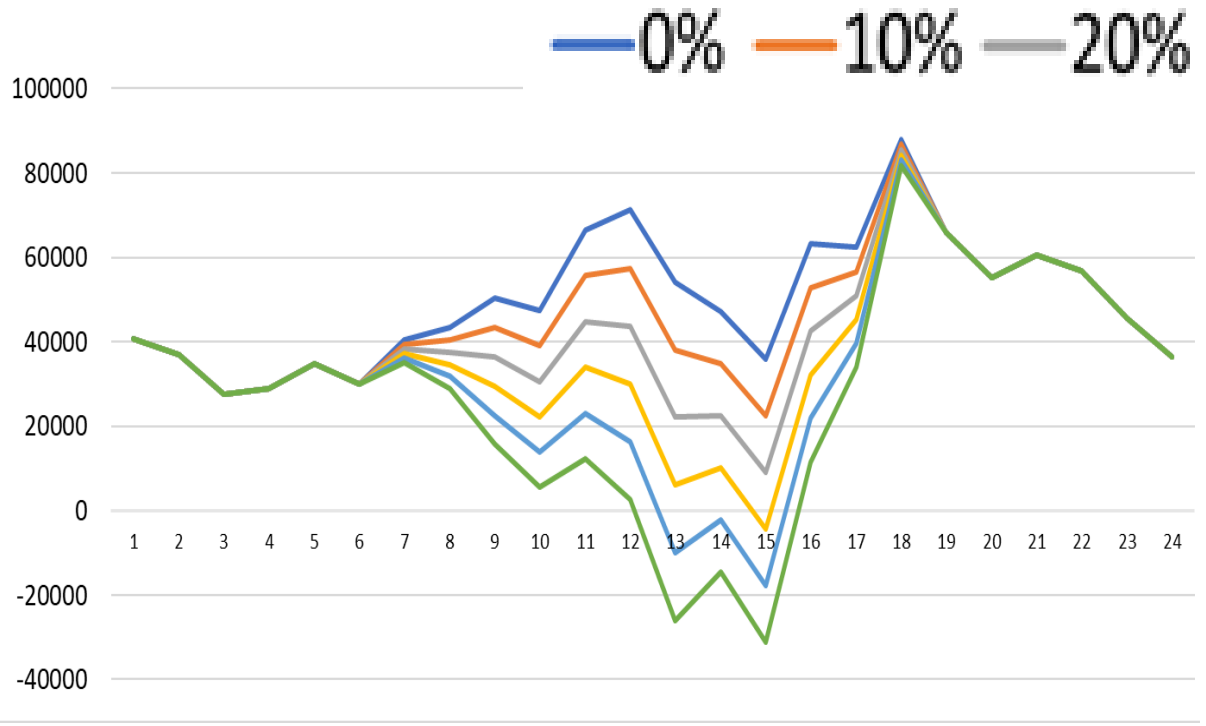
New England ISO – April 2, 2022

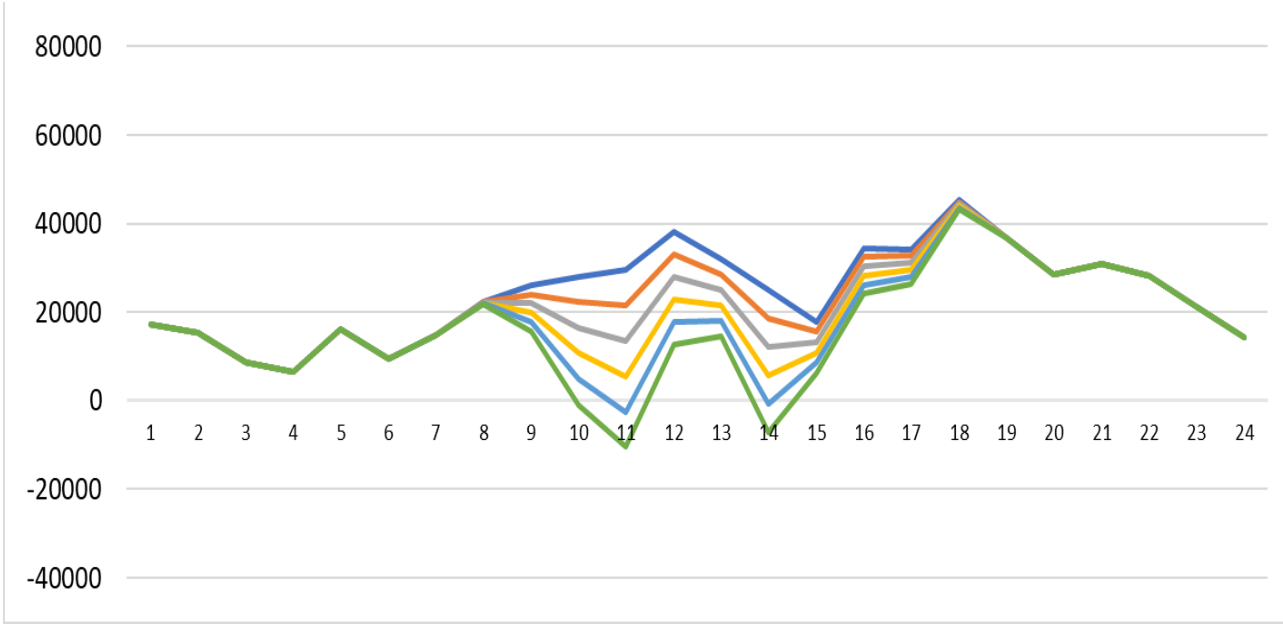


Net Load on Grid/Ramping Analysis

*Community Scale – **1000 Multifamily Prototype Buildings in Chicago***

March 31: Net Load with Varying %'s of NZE Case Study Buildings





Baseline building

Passive building

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

Ramp must be met with dispatchable energy (peakers or storage)

More findings…

Passive buildings *dampen the issue* but don't fully eliminate it.

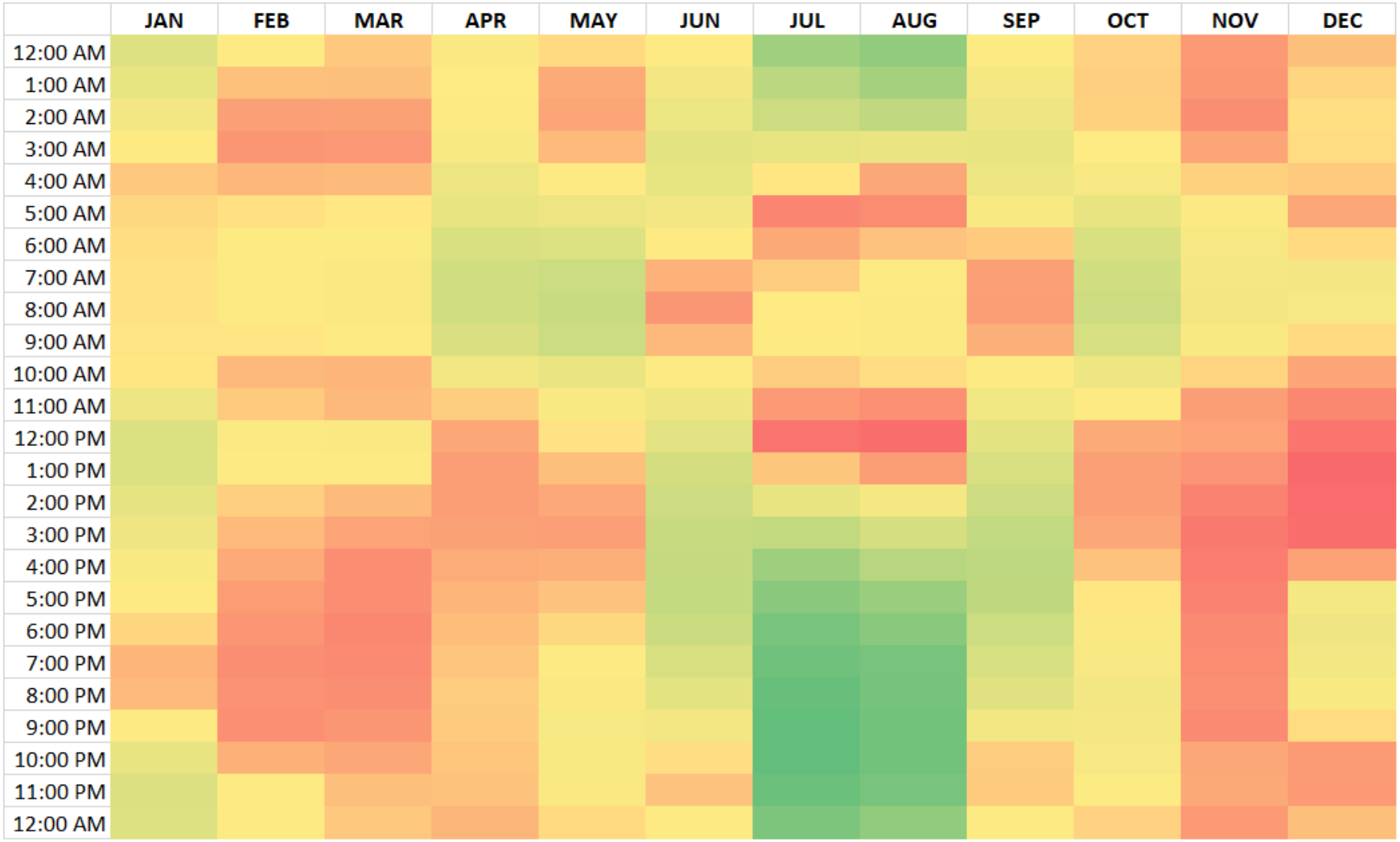
Behind-the-meter energy production is hard for utilities to plan for. They can't "see" it or rely on it in the same way as other generation resources.

Communication & visibility to data is key.

Not all kWh's (used and produced) are equal

Hourly Marginal Carbon Emissions will continue to be dynamic.

Price to meet peak grid loads will remain dynamic.

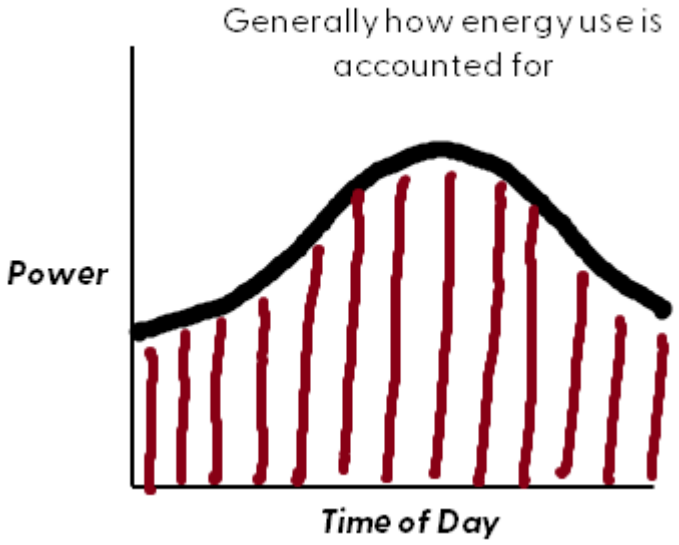


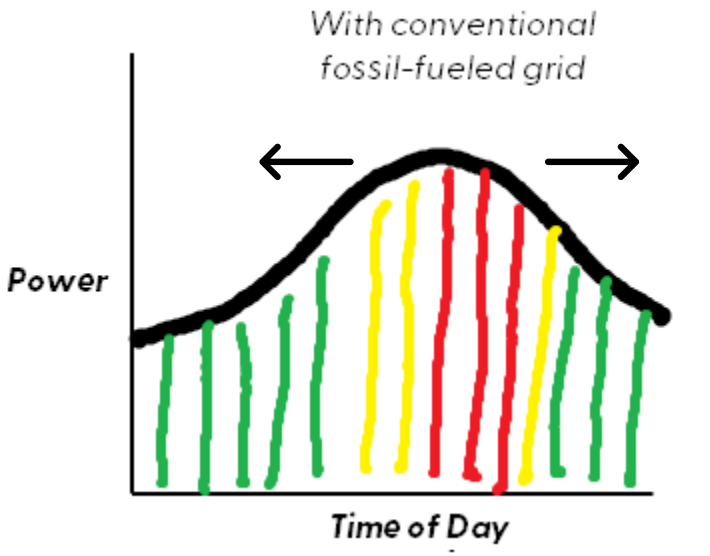
Source: WattTime

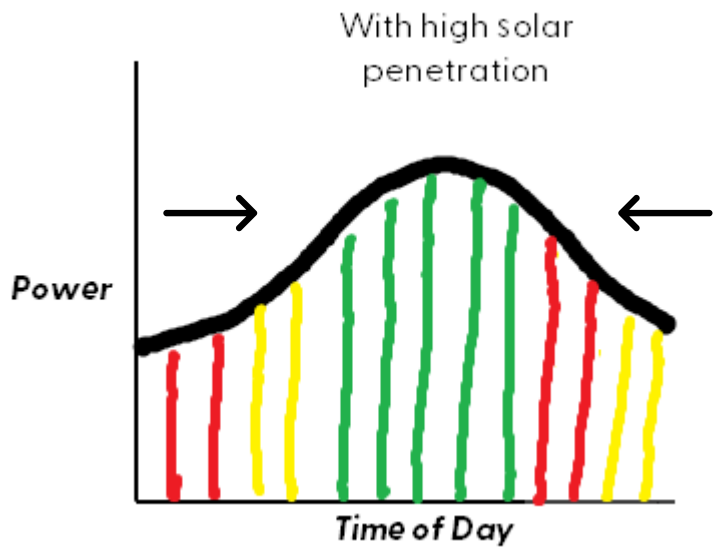
CHICAGO, IL - 2019

phius

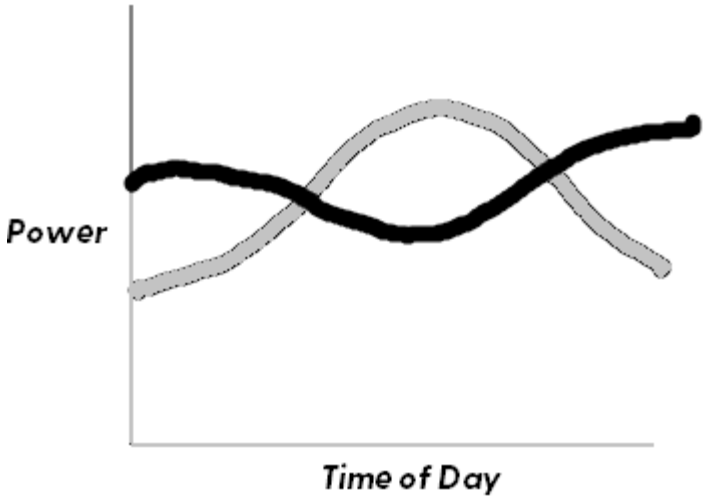
Net Zero = focus is on “how much” instead of “when”…

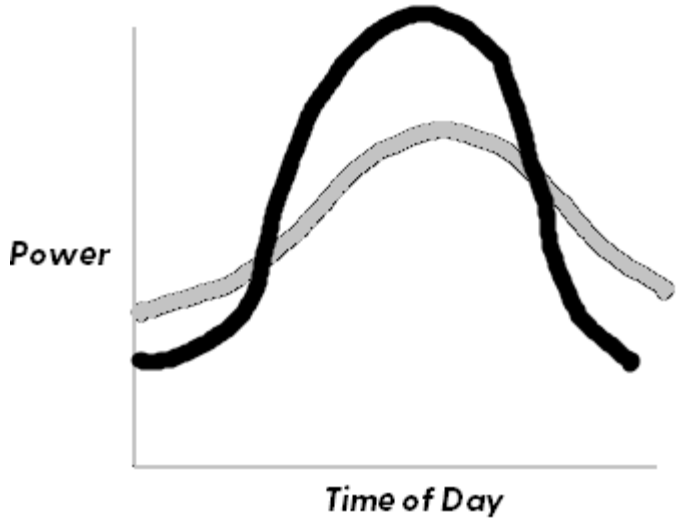






But there are varying emission factors based on load profile and grid mix





Enable the building loads to be “smart” & responsive to signals

GEB =

Grid-Interactive
Efficient
Building

GEB Integration, Optimization, Communication & Control
at the building level

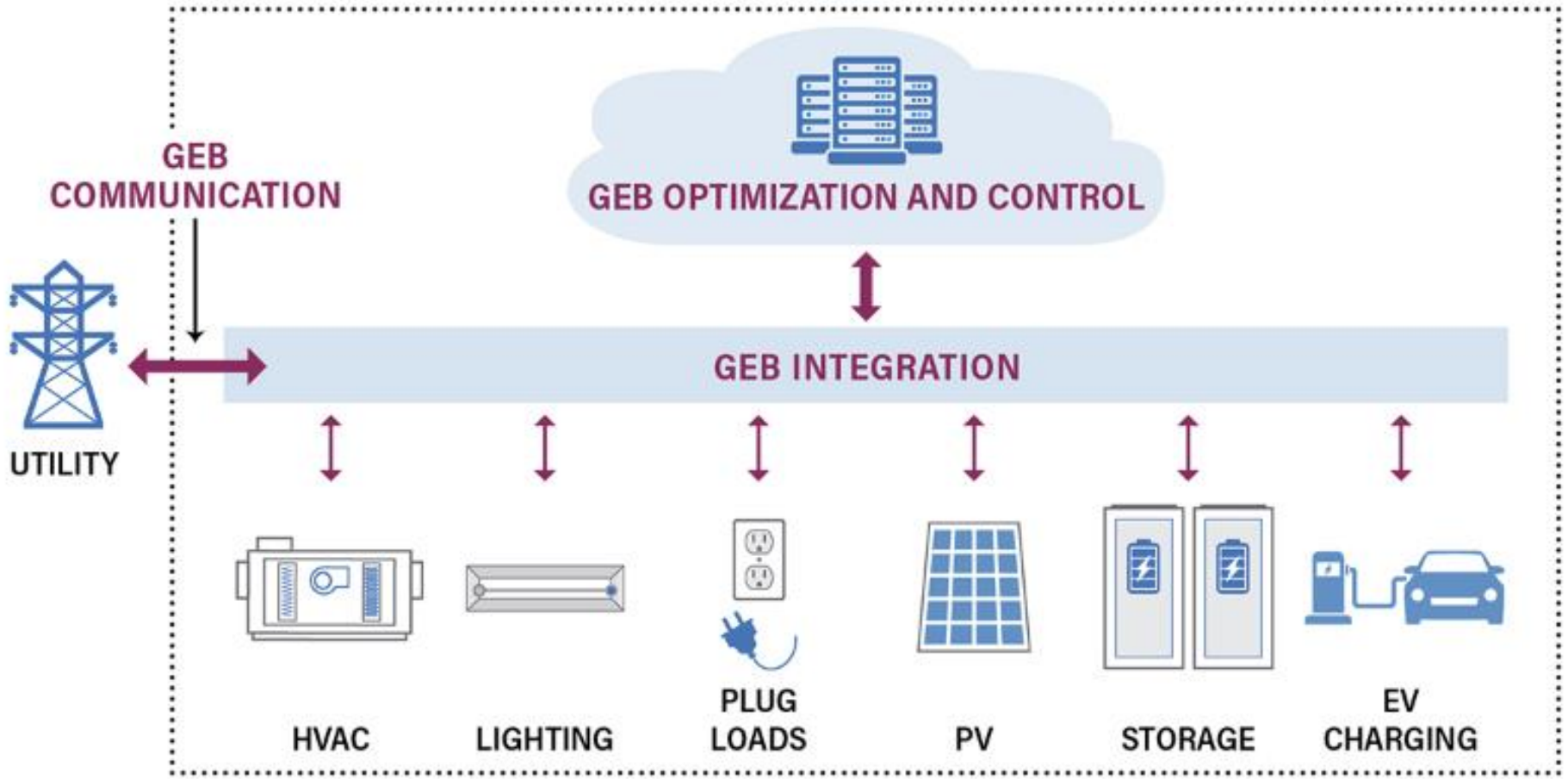
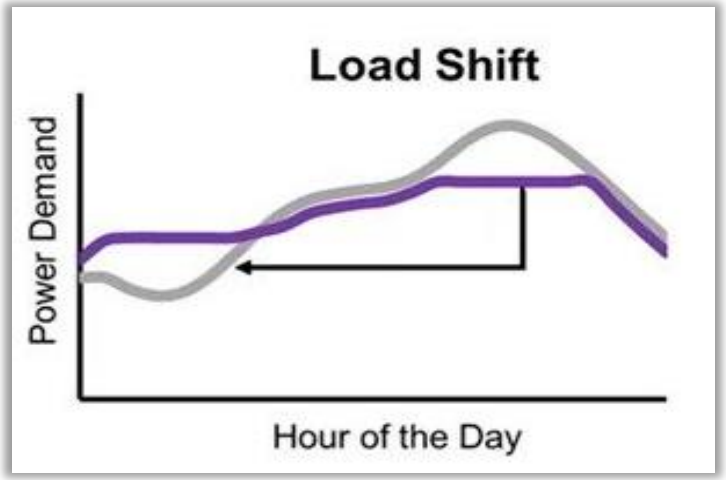
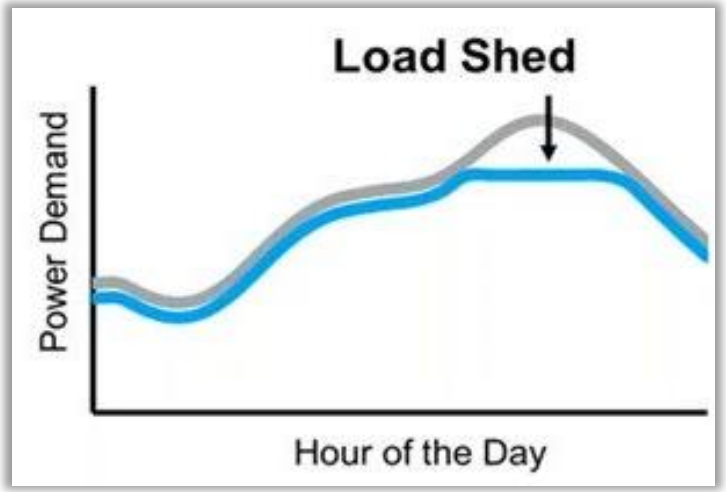


Image Source: Slipstream

GEBs Toolkit: Load Shifting & Shedding

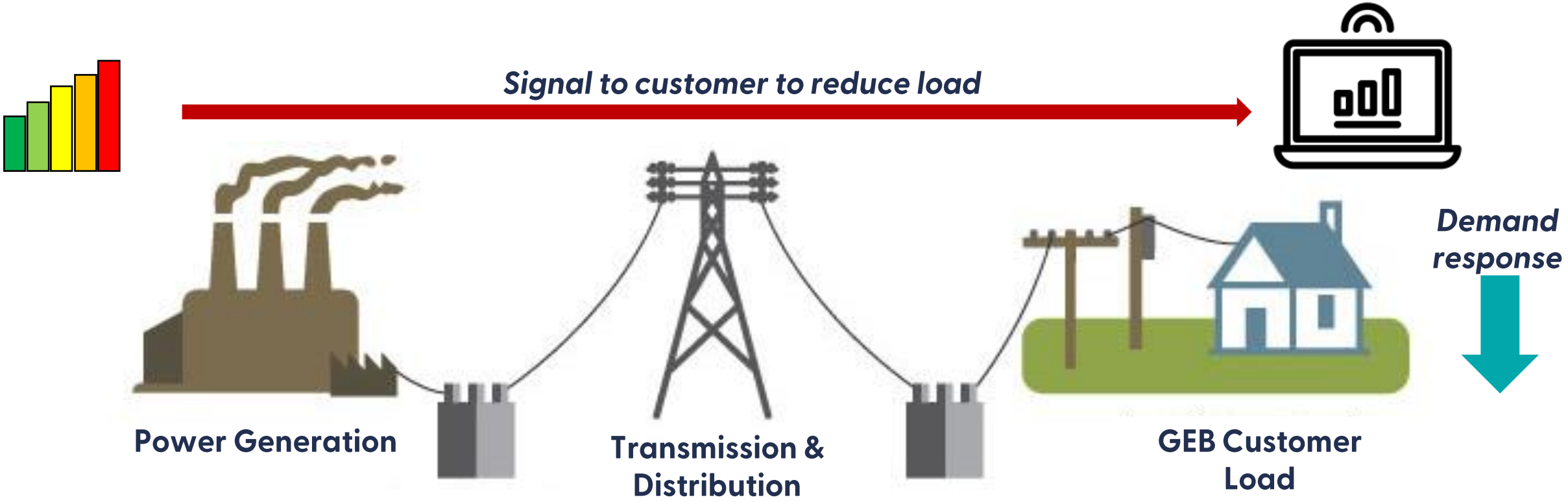


Focus to on **when** buildings are consuming energy as opposed to **how much** energy is being consumed.



Reduce energy use at peaks / times of high grid stress based on response signals.

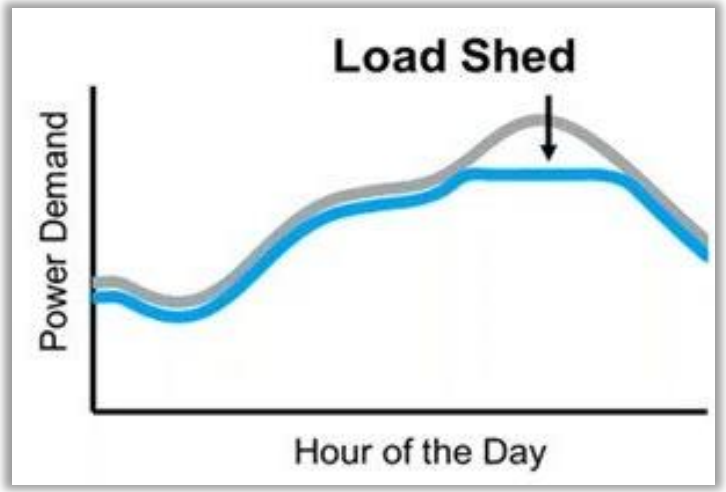
GEB Scenario

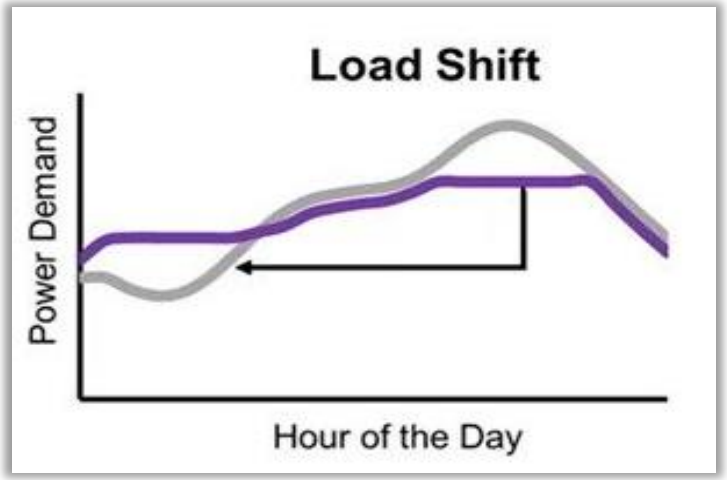


Source: Adapted from National Energy Education Development Project (public domain)

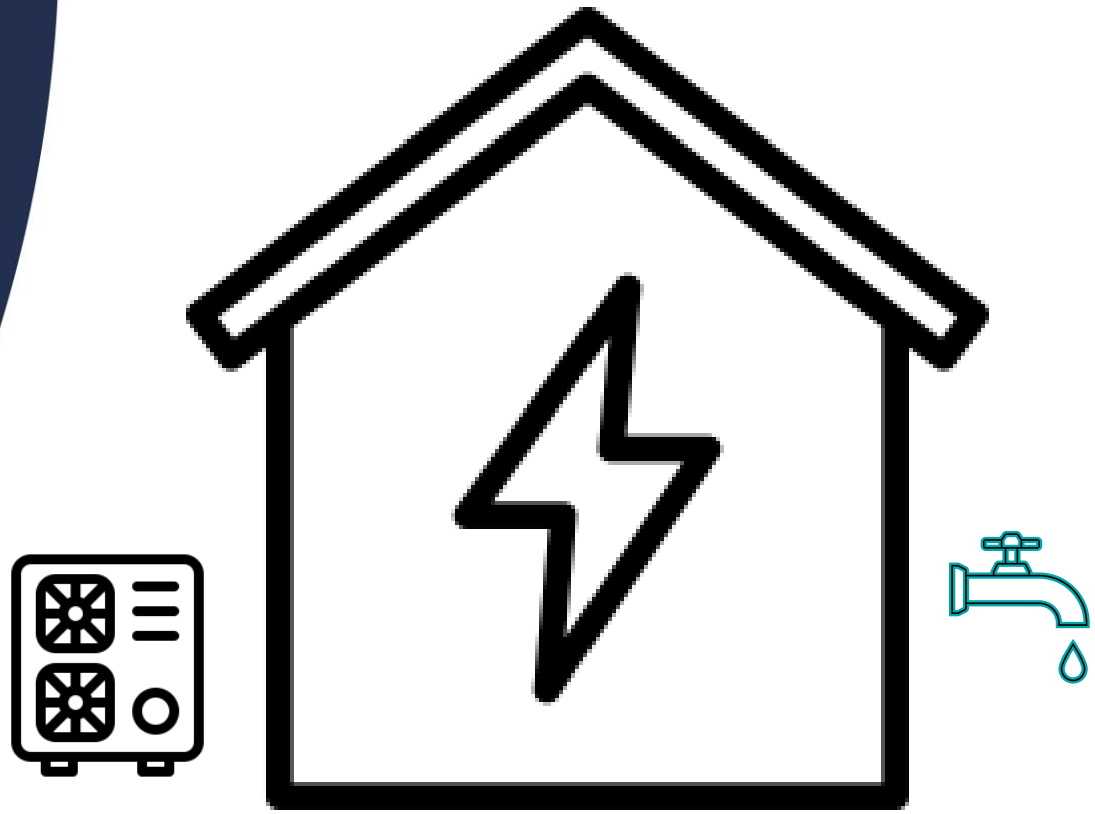
GEB + Passive Building Synergy

Passive building enclosures makes load shedding and shifting more accessible – adding inherent thermal storage capabilities to the GEB toolkit.





Building Electrification



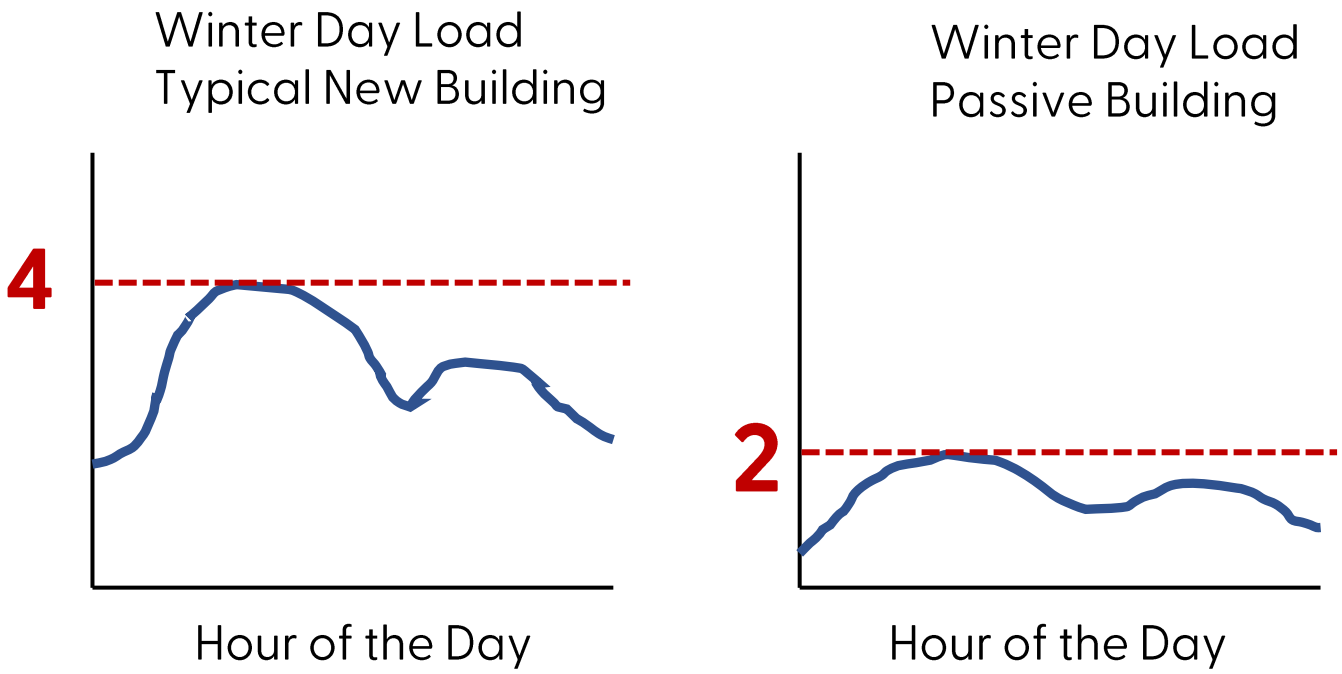
Electrified Water Heating

If water heater + storage tank, there is significant potential to act as an asset for the grid and facilitating renewables.

- Align demand with supply
- Store excess thermal energy during times with clean energy
- “Ride out” times with less supply

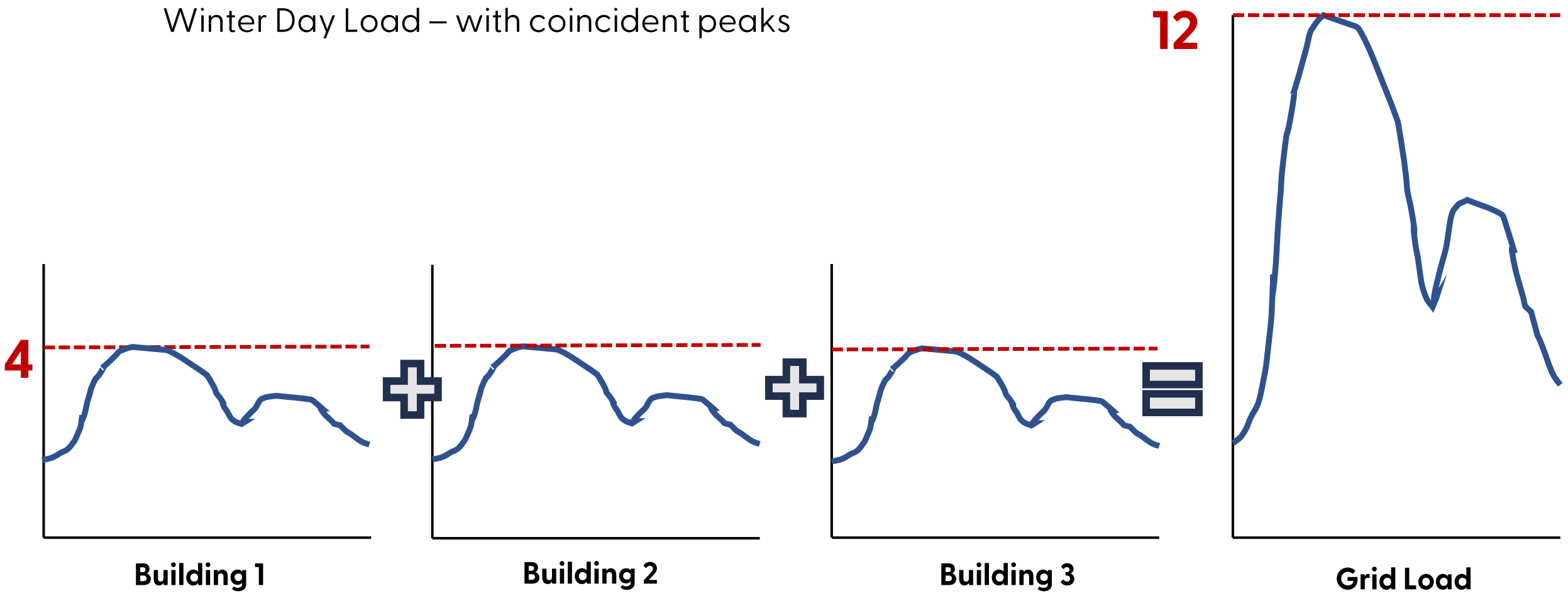
The peak is changing: WINTER IS COMING

Electrifying heating systems in buildings will shift the grid peak to the winter.



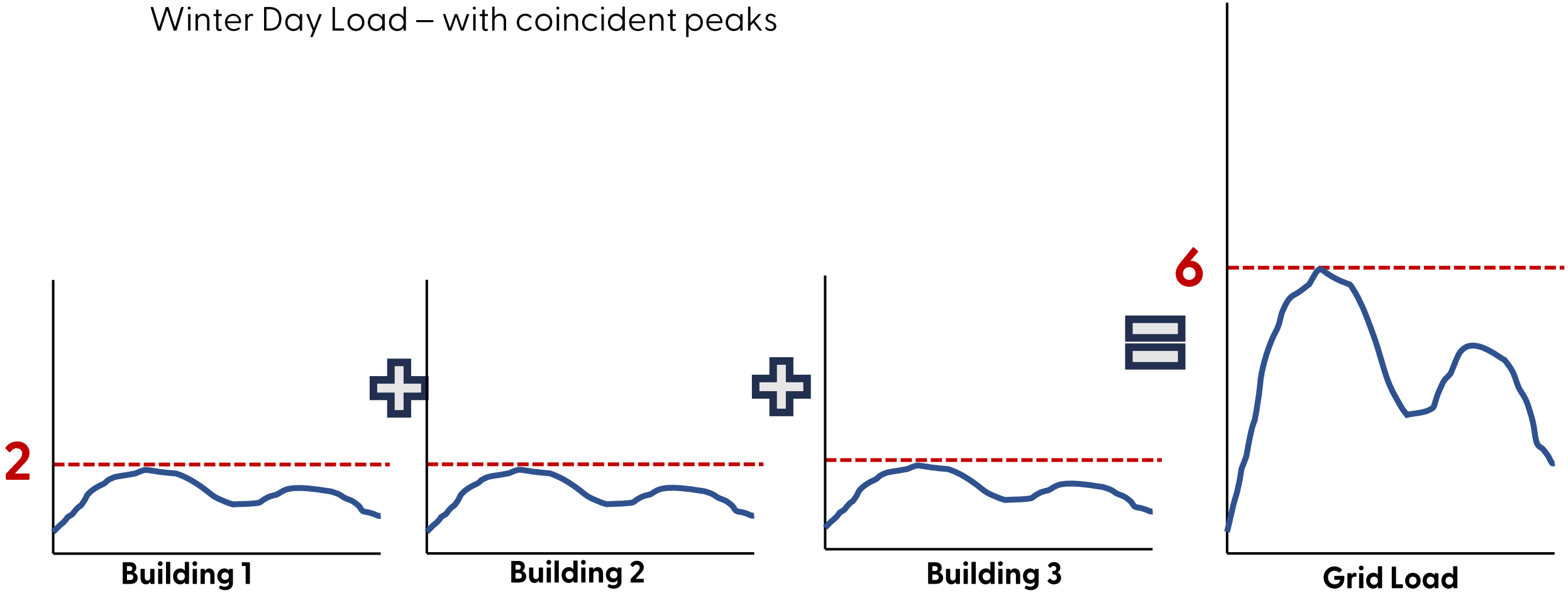
3 *Typical* Building Winter Peaks

Winter Day Load – with coincident peaks



3 *Passive* Building Winter Peaks

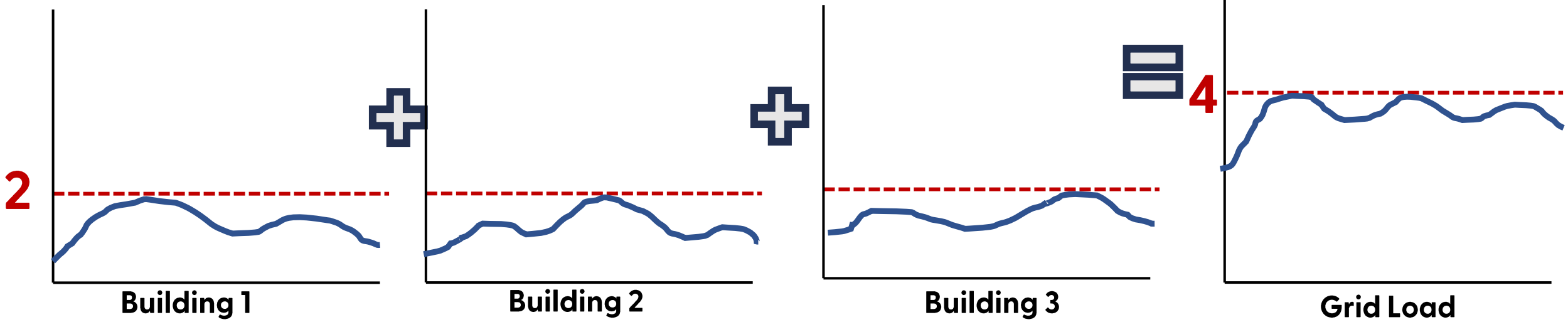
Winter Day Load – with coincident peaks



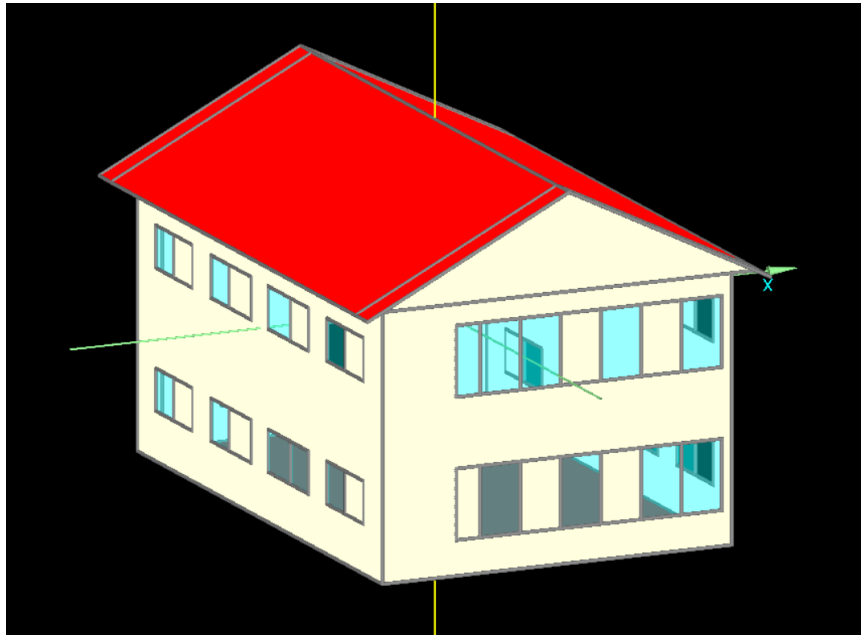
3 *Passive + GEB* Building Winter Peaks

Winter Day Load – with **GEB load shifting & smart technology**

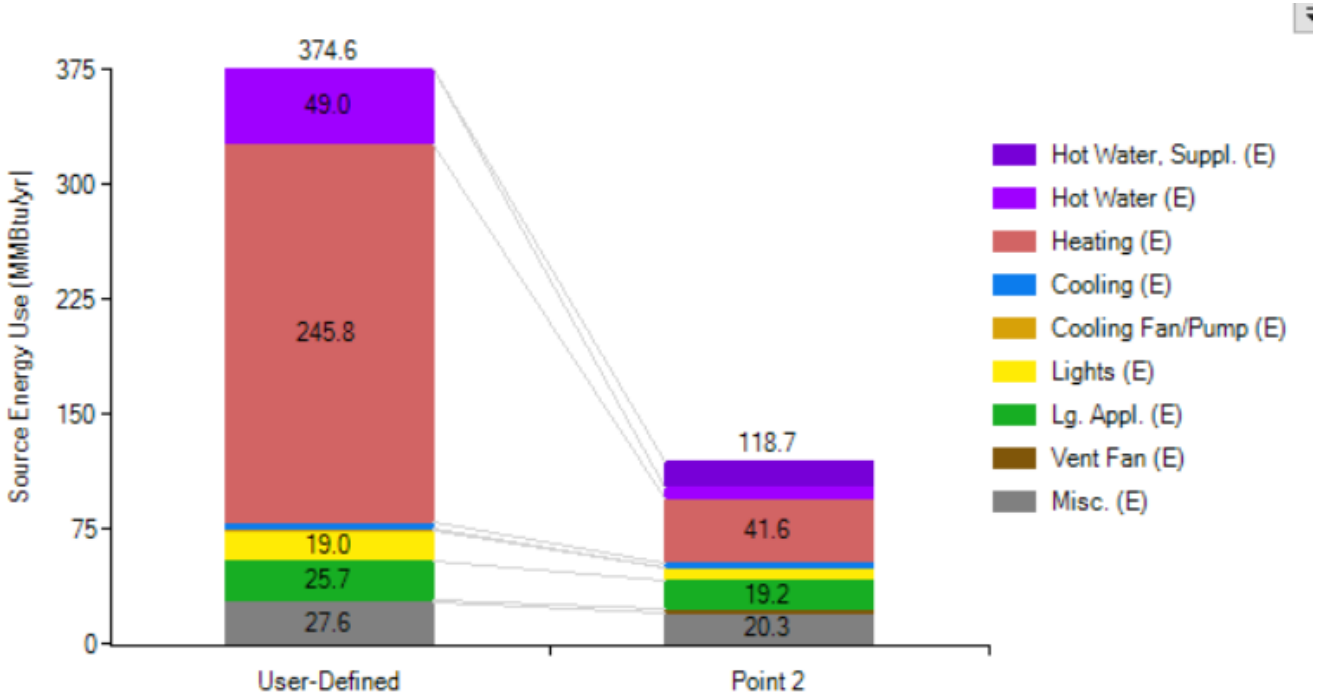
Passive building enclosure acting as thermal storage.



Single Family Heat Load Case Study

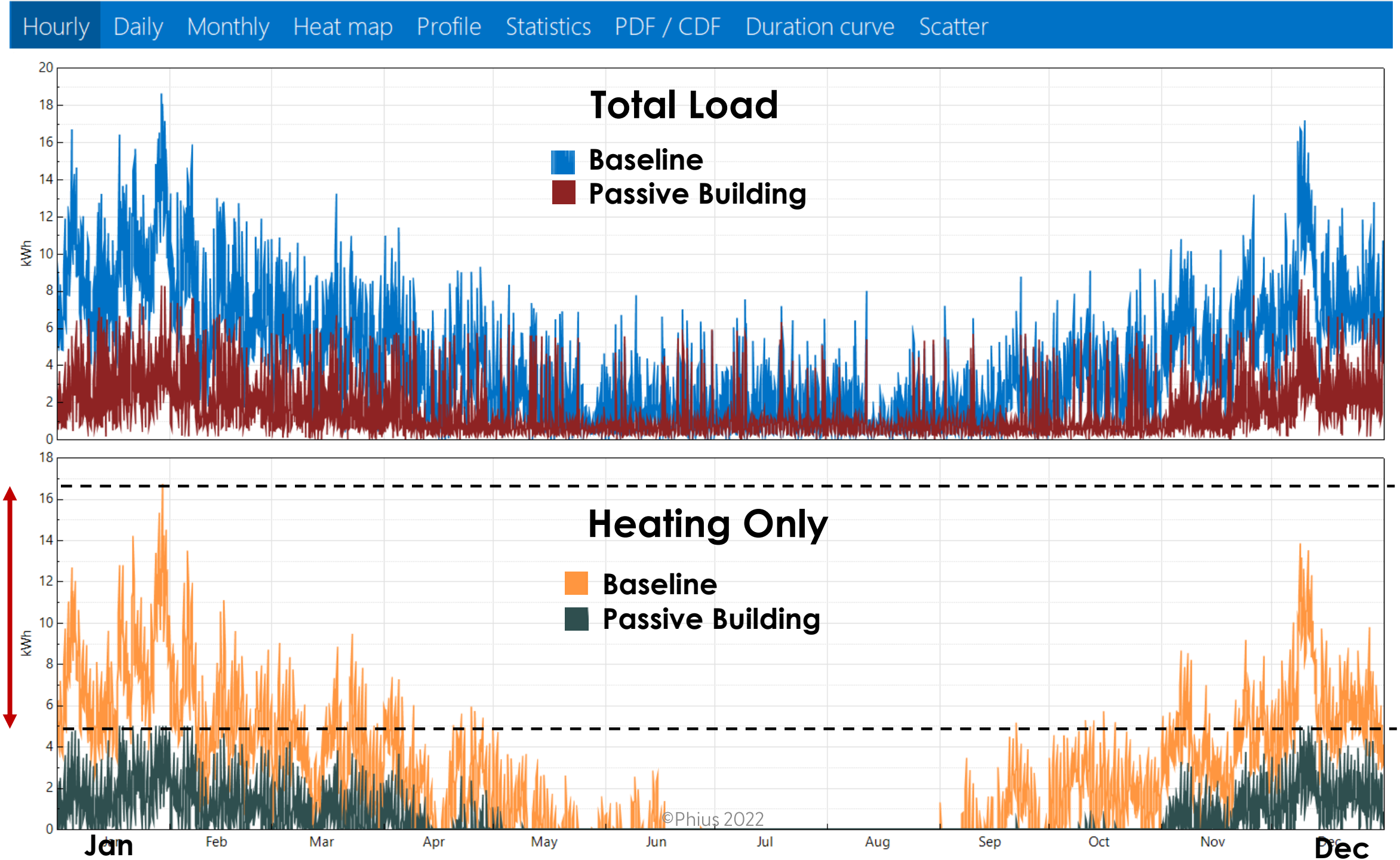


Single Family building
Location: Minneapolis, MN
5 occupants, ~1,800 sf
All Electric – Elec resistance heating only



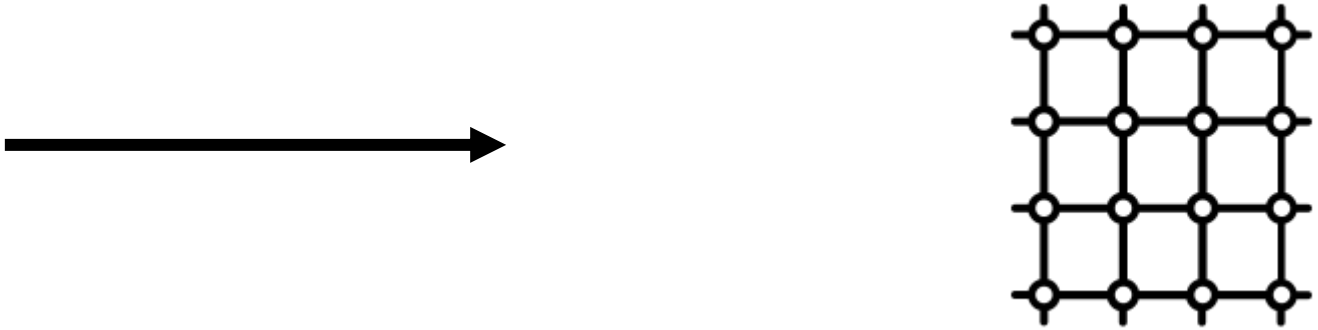
Two buildings studied:

1. Building America 2009 Benchmark
2. Passive building (Phius-compliant)


Hourly
Daily
Monthly
Heat map
Profile
Statistics
PDF / CDF
Duration curve
Scatter
Total Load
Baseline
Passive Building
kWh
Heating Only
Baseline
Passive Building
kWh
©Phius 2022
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

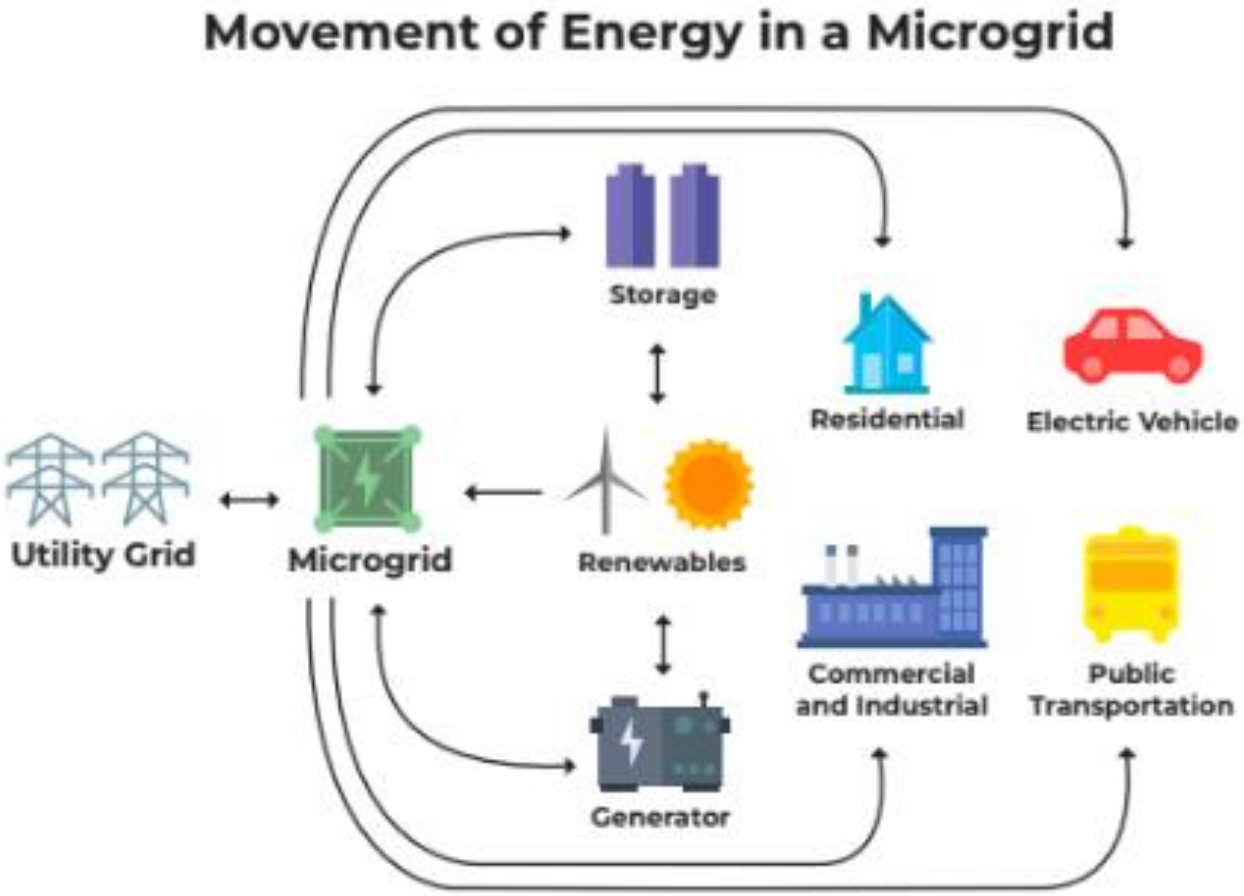
Microgrids

From a unidirectional power grid to more of a “mesh” network



Key Components:

Energy demand from buildings with grid-enabled loads
Energy generation
Energy storage
Microgrid Energy Manager/Optimization System
(Optional: Electric Vehicles)



Microgrid Manager:

When 1 kWh is produced, where should it go? Many options.

If it's in a time of low supply:
- Serve "most critical load"

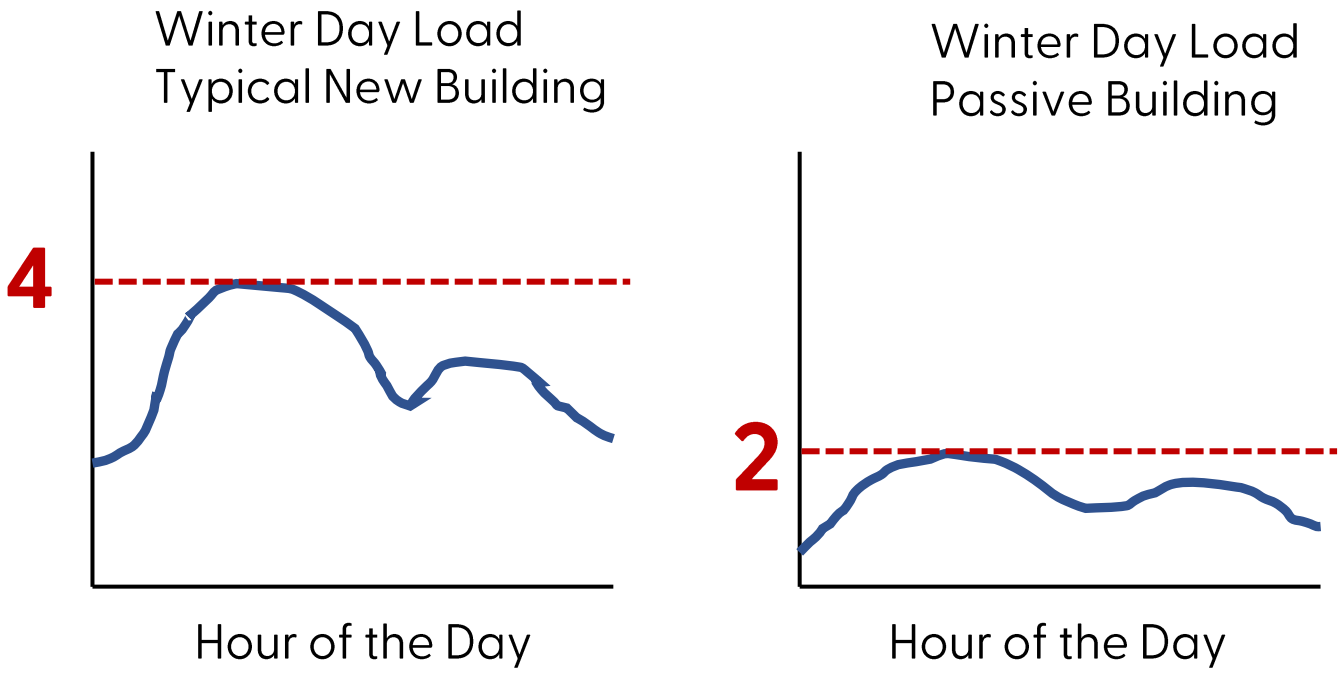
If in a time of excess supply:
- Electrical Energy storage (stationary or EVs)
- Shift non-critical load to use it
- Thermal energy storage (condition a space past its setpoint so that load is lower later in the day)

When a building adds a new load, how should it be met?
- Renewable energy
- Storage
- Is it critical, can the building shed the load?
- Main utility grid?

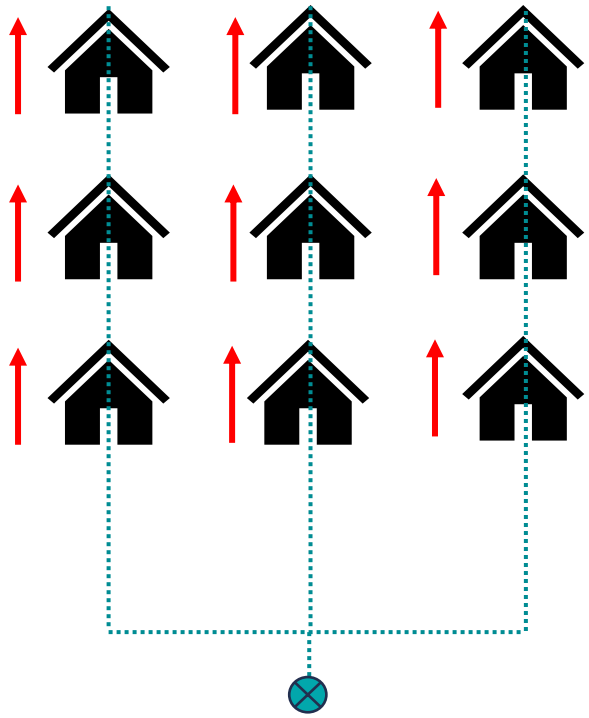
What about the winter peaks?

The peak is changing

Electrifying heating systems in buildings will shift the grid peak to the winter.



Baseline Building + Typical Centralized Grid

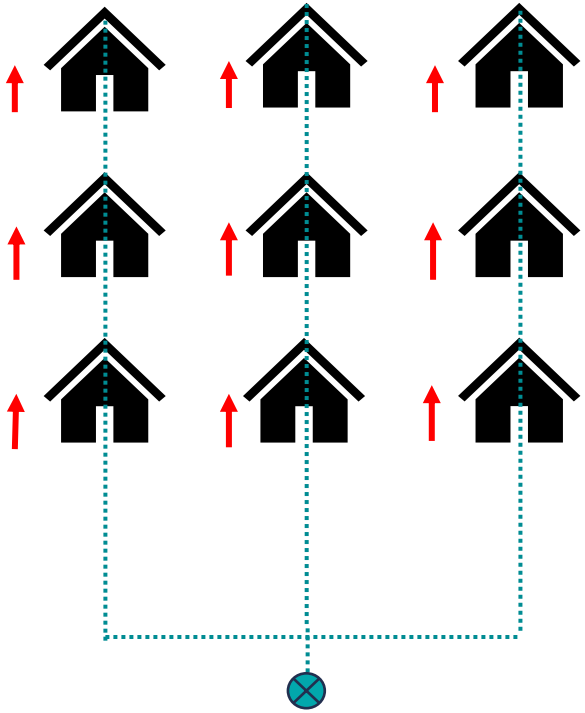


Sum of coincident peaks

Peak per building = 4

Grid peak = 9🏠 x 4 = 36

Baseline Building + Typical Centralized Grid + GEB Load Shifting or Shedding



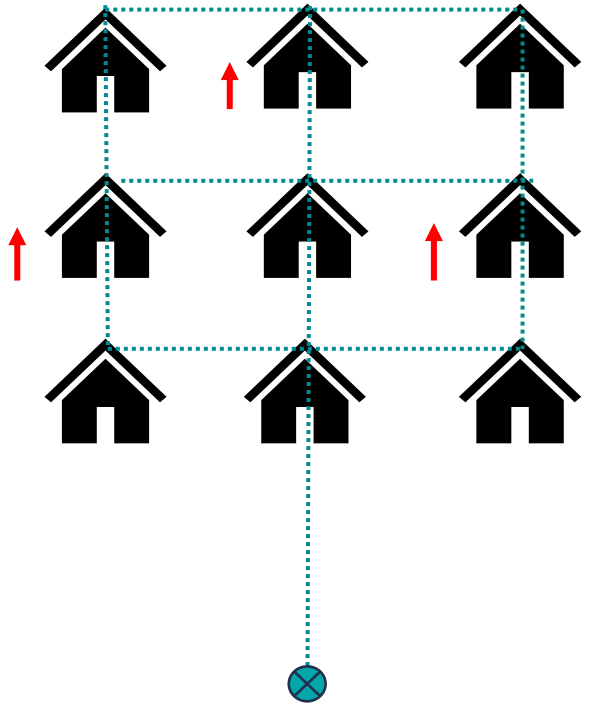
Sum of coincident peaks

Peak per building = 2

Grid peak = 9🏠 x 2 = 18

(Central Grid Signal)

Baseline Building + Microgrid Control + GEB Load Shifting or Shedding



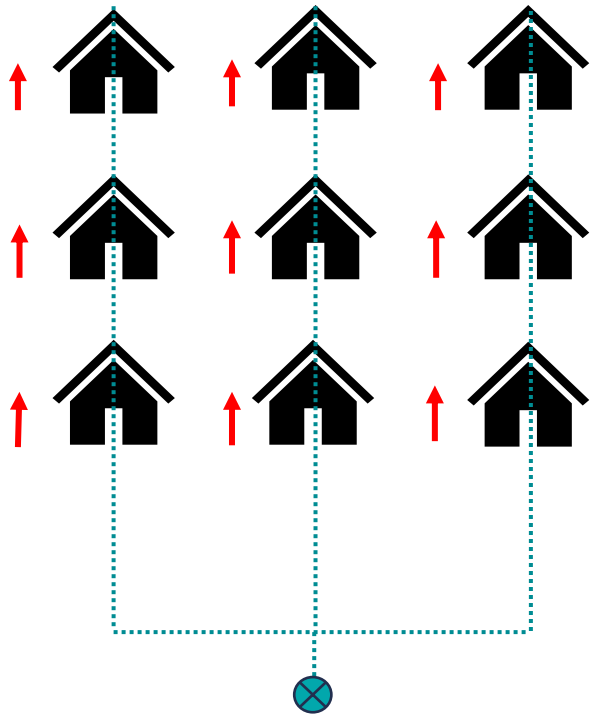
Sum of coincident peaks

Peak per building = 2

Grid peak = 3🏠 x 2 = 6

(Grid Signal + Manager between Buildings)

Passive Building + Typical Centralized Grid

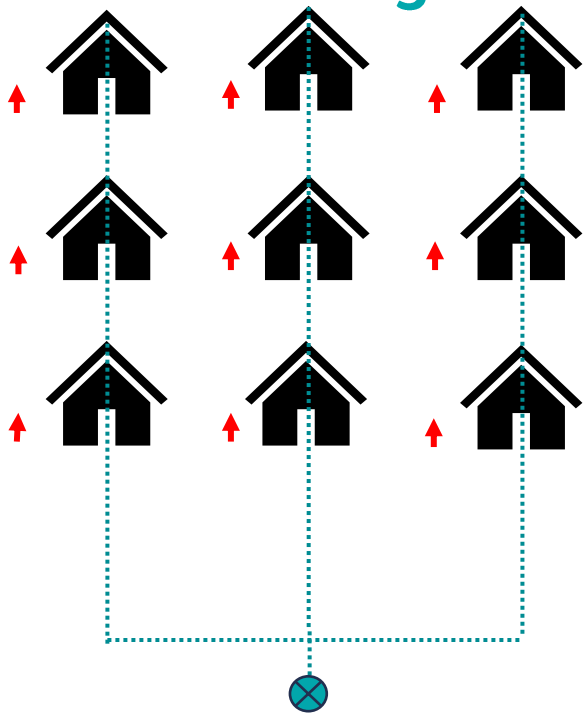


Sum of coincident peaks

Peak per building = 2

Grid peak = 9 x 2 = 18

Passive Building + Typical Centralized Grid + GEB Load Shifting or Shedding

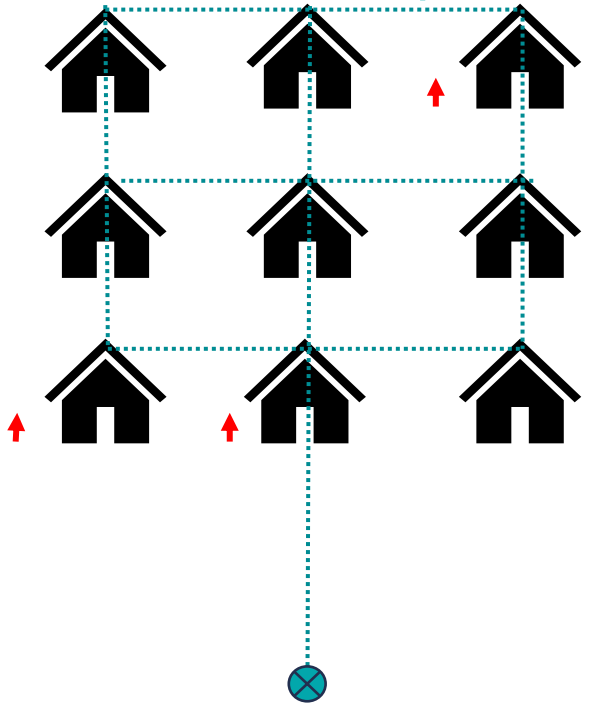


Sum of coincident peaks

Peak per building = 1

Grid peak = 9 x 1 = 9

Passive Building + Microgrid Control + GEB Load Shifting or Shedding

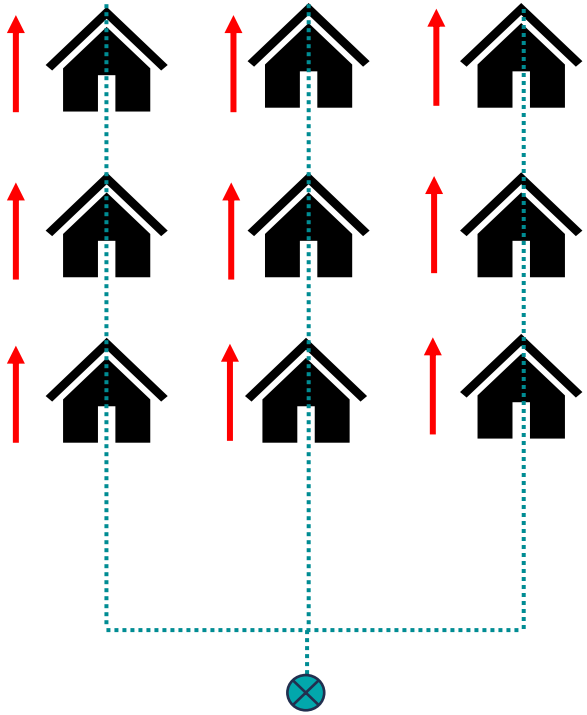


Sum of coincident peaks

Peak per building = 1

Grid peak = 3 x 1 = 3

Baseline Building +
Typical Centralized Grid

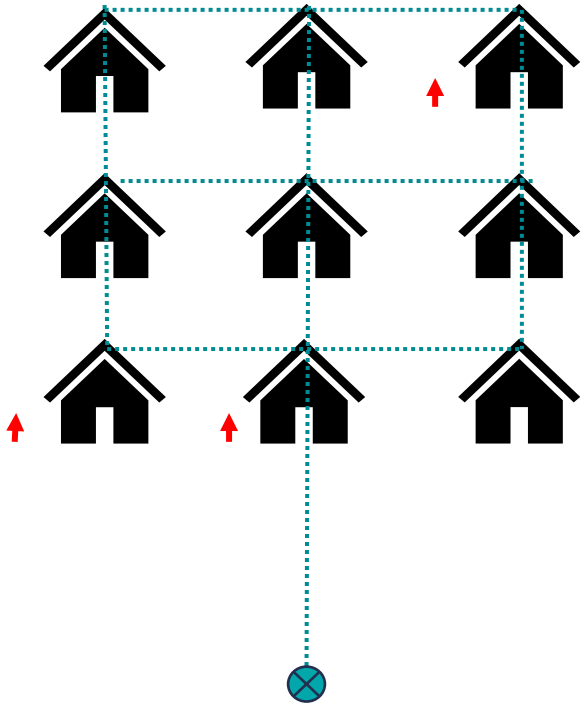


Sum of coincident peaks

Peak per building = 4

Grid peak = 9 x 4 = 36

Passive Building +
Microgrid Control +
GEB Load Shifting or Shedding



Sum of coincident peaks

Peak per building = 1

Grid peak = 3 x 3 = 3

Other Microgrid Benefits

- Bring generation closer to the load, less reliability on vulnerable transmission & distribution lines
- Resilience when lines down/intentional island
- Improved renewable resource utilization → matching supply to demand
- Optimize smaller areas of the grid to help alleviate stress on the central grid
- Energy independence & potentially lower costs and less vulnerable to utility energy pricing


Solutions

Optimization at Each Level

Passive Building =
Optimizing deign to significantly reduce Building Loads

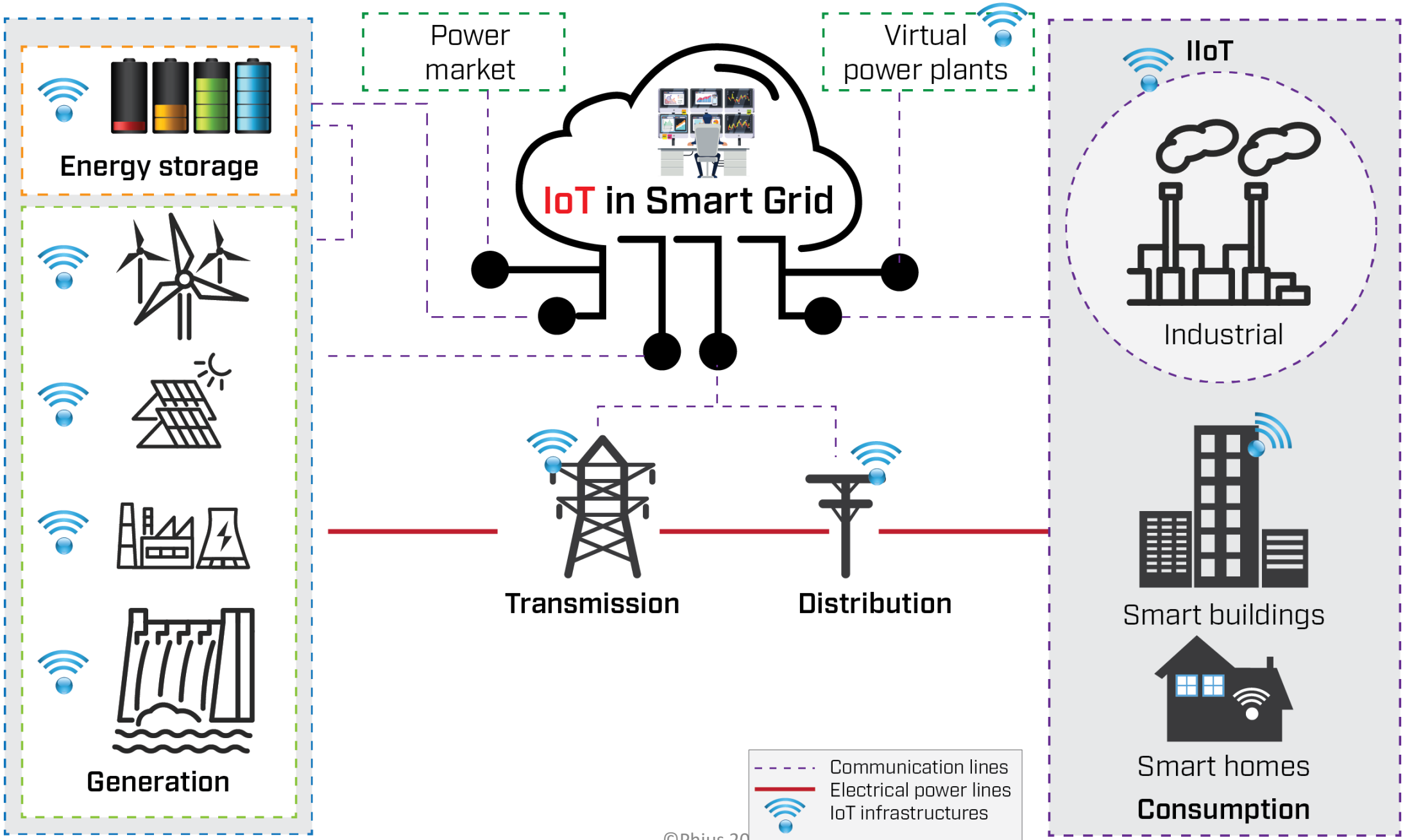
Reducing demand (and renewable supply required to meet it)

Grid-Interactive Efficient Building (GEB) =
Optimizing operation of remaining building loads, + maybe generation and supply

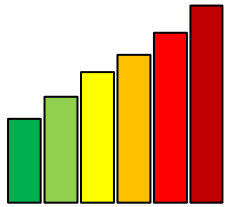
Enabling demand to align with supply

Microgrid =
Optimizing generation, storage, and a group of operational building loads

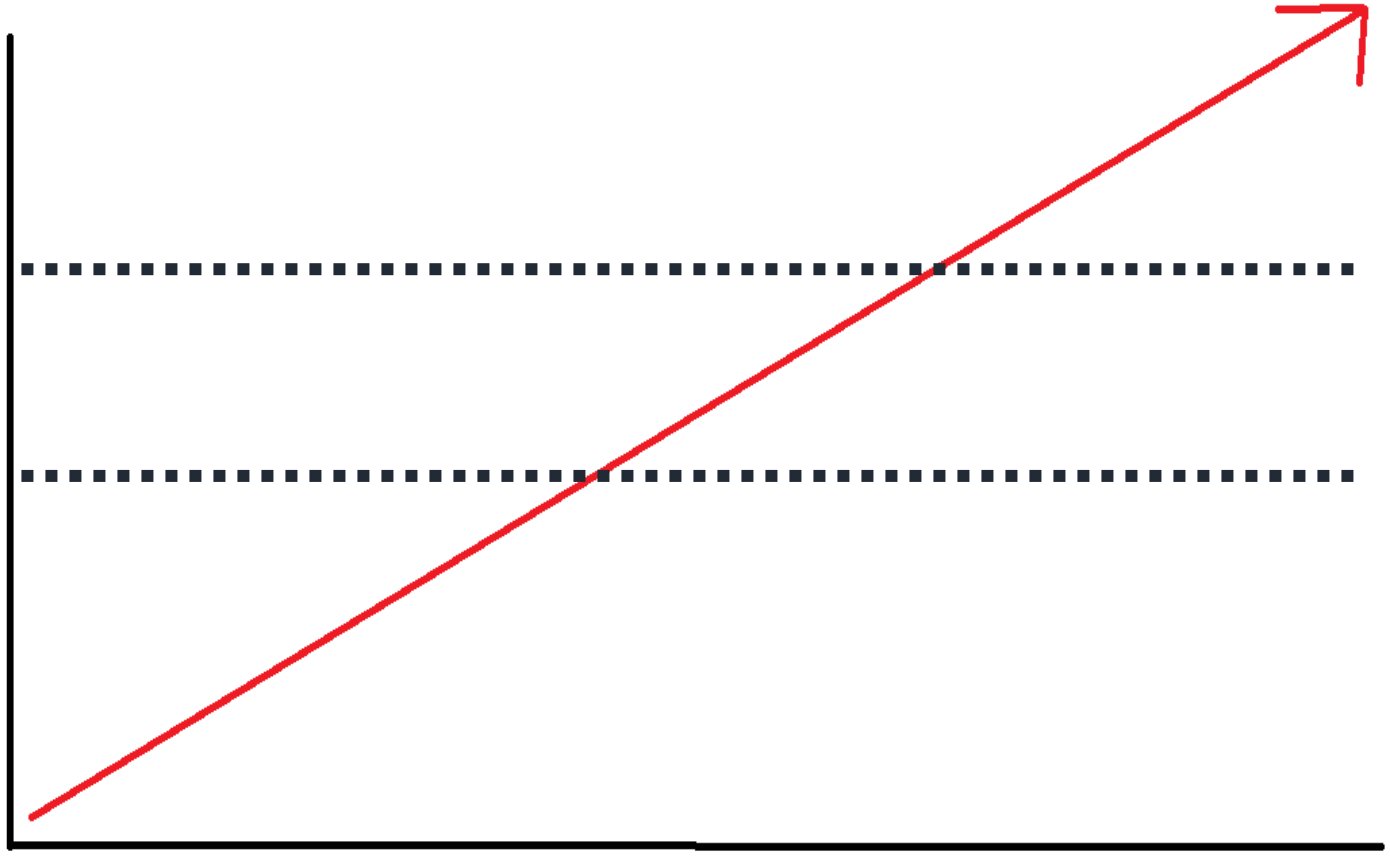
Optimizing supply and demand to maximize use of infrastructure & minimize emissions.

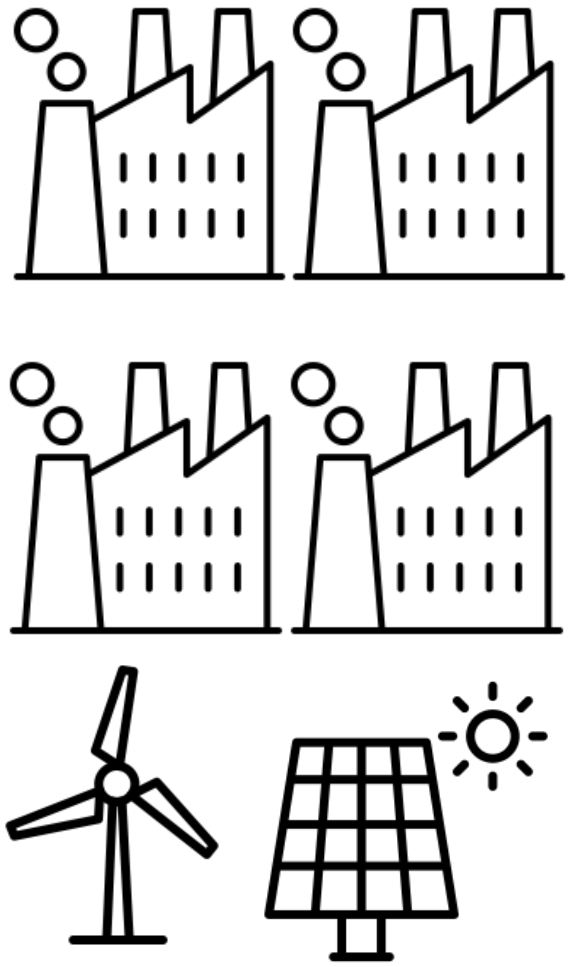

Power market
Virtual power plants
IIoT
Energy storage
IoT in Smart Grid
Industrial
Transmission
Distribution
Smart buildings
Smart homes
Generation
Consumption
Communication lines
Electrical power lines
IoT infrastructures

Business as Usual

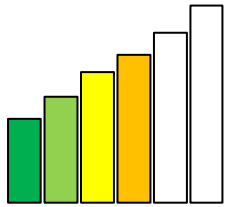


Electricity Demand (Grid Load)

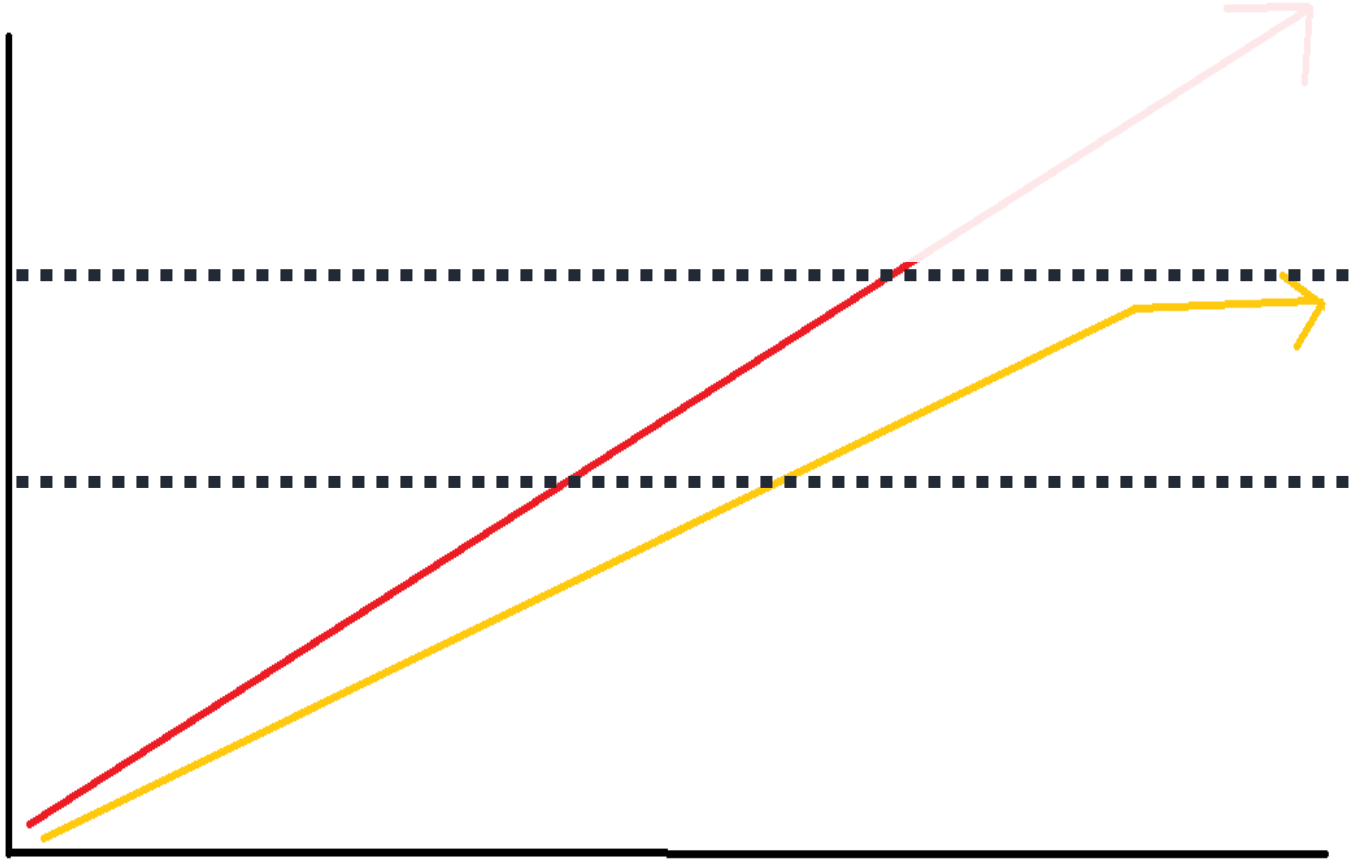


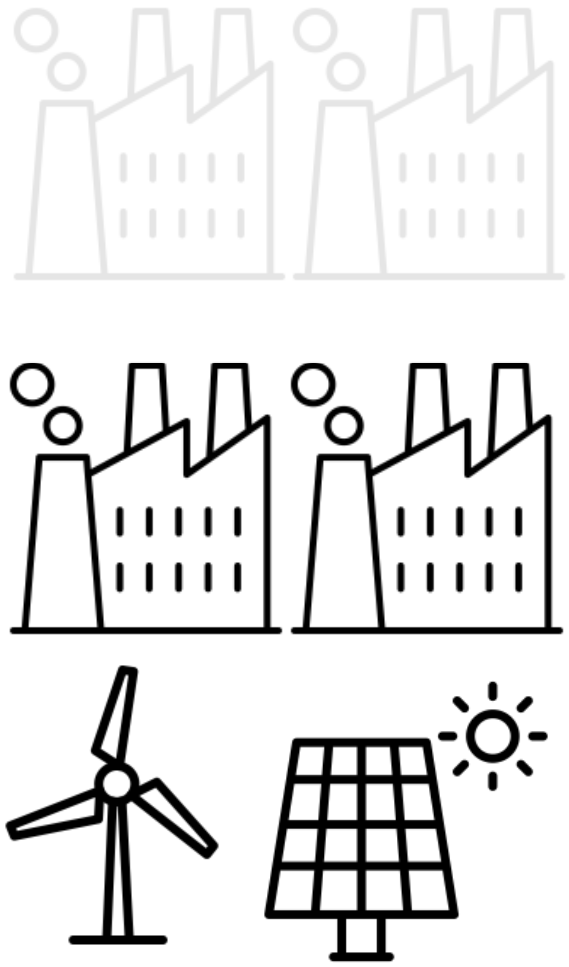


Passive Building

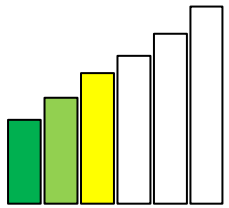


Electricity Demand (Grid Load)

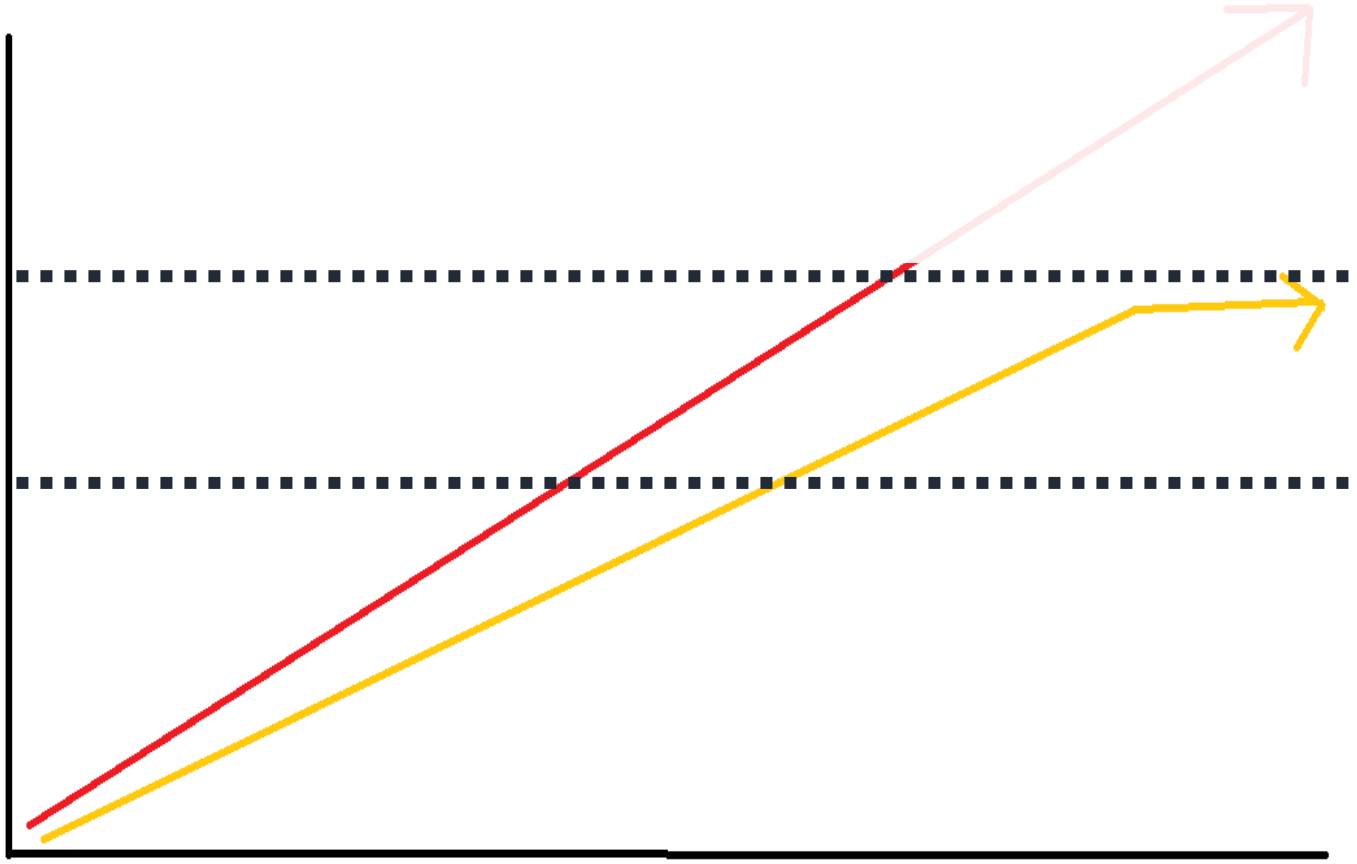


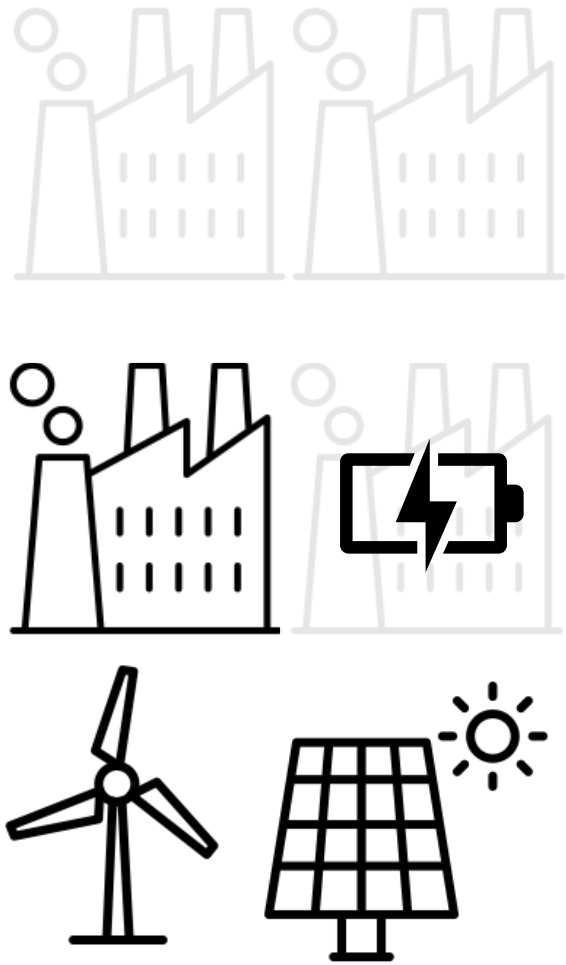


Passive Building + GEB

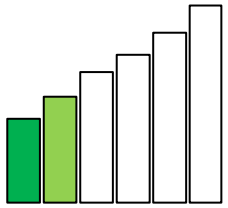


Electricity Demand (Grid Load)

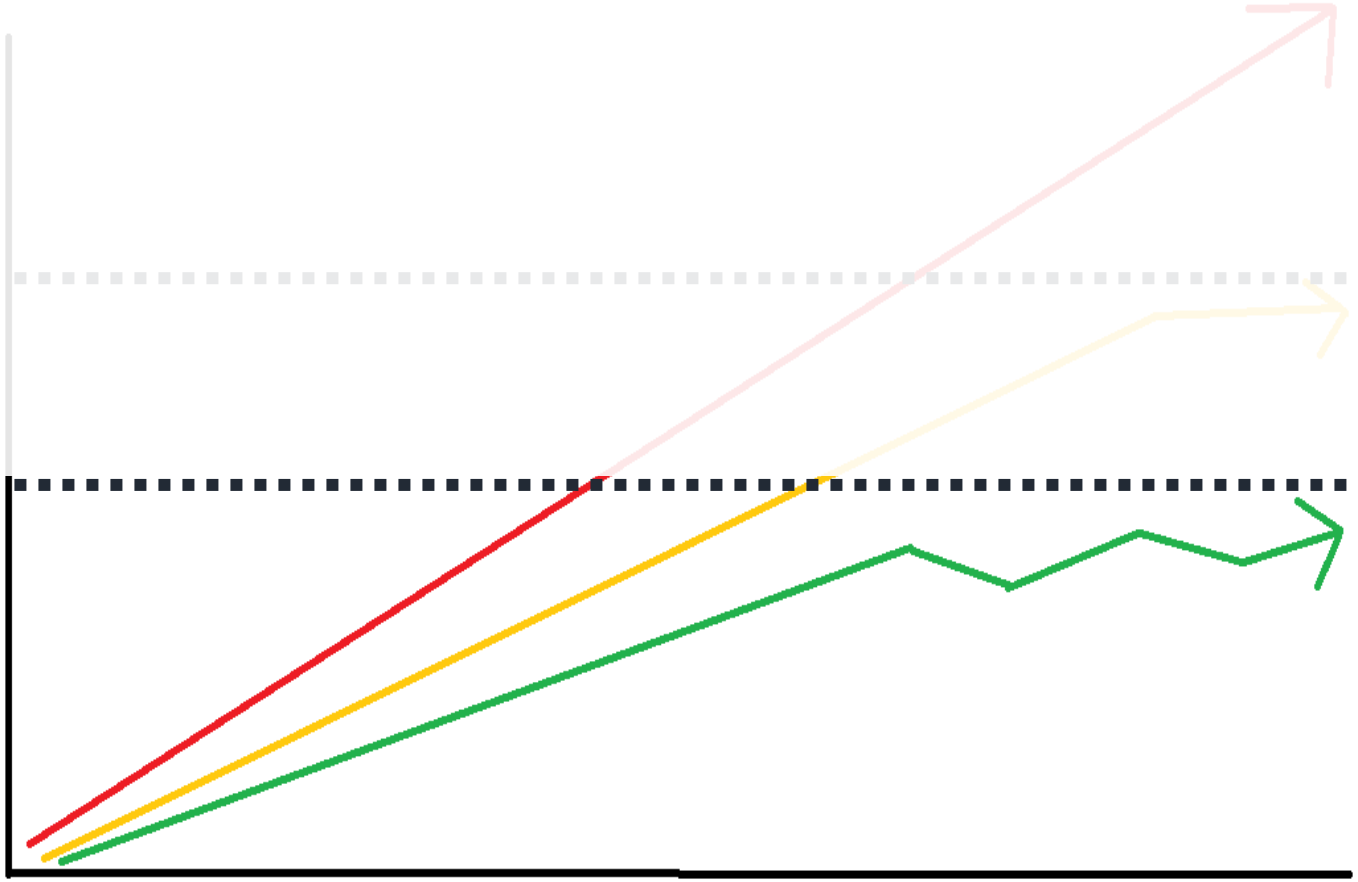


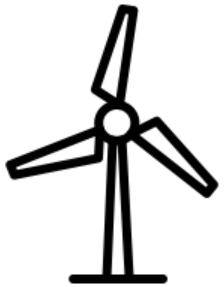


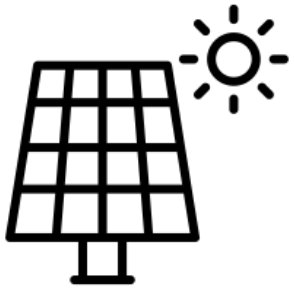
Passive Building + GEB + Microgrid Manager



Electricity Demand (Grid Load)



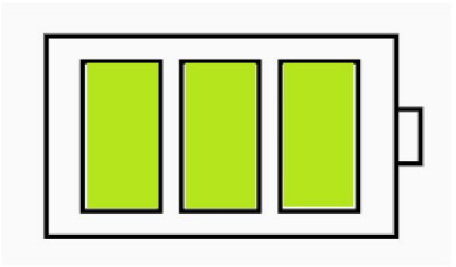


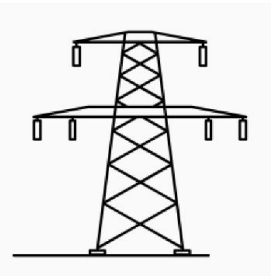


The *Ripple Effect* of Conservation

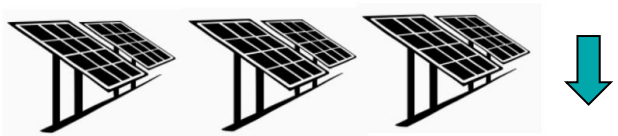
Conservation means less generation, less storage, and less transmission capacity needed

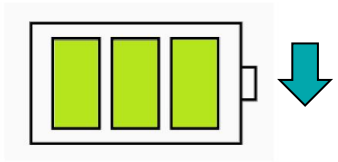
60,000
kWh/yr

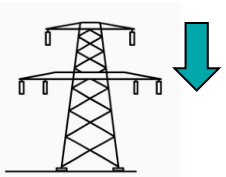




36,000
kWh/yr







Open Bar: 4pm-10pm

We have everything, drink as much as you want, and we'll be sure to keep it coming.	**Business as Usual on the Grid**
An attendee only consumes half of the average person, and does that slow and steady.	**Passive Building**
We get very busy from 5-7pm, so if you only drink canned drinks from the cooler during that time, we'll give you a discount on your entrance fee.	**Demand Response (DR)**
I'm going to bring my own empty cooler and drink out of there when it's not empty, people can add to it whenever they want, but if I can't drink it quickly enough, I expect you to pay me for what I don't drink.	**Net Zero with Solar**
If our taps run slow, we'll ask you to drink less periodically. If they run fast, we'll ask you to drink more (assuming this means you'll drink less later)	**Grid-Interactive Efficient Building (GEB)**
We're going to give you a keg, a tap, and cups and you can distribute evenly amongst yourselves. Don't come to the bar unless it's gone.	**Microgrid**

Thanks!
Questions?

Lisa White

Associate Director | Phius

Lwhite@phius.org