BUILDINGENERGY BOSTON

How Passive Buildings Support Resiliency & Grid Flexibility

Lisa White (PHIUS)

Curated by Heather Iworsky (ReVision Energy) and Mark Schow (Elevated Design)

Northeast Sustainable Energy Association (NESEA)
March 1, 2022

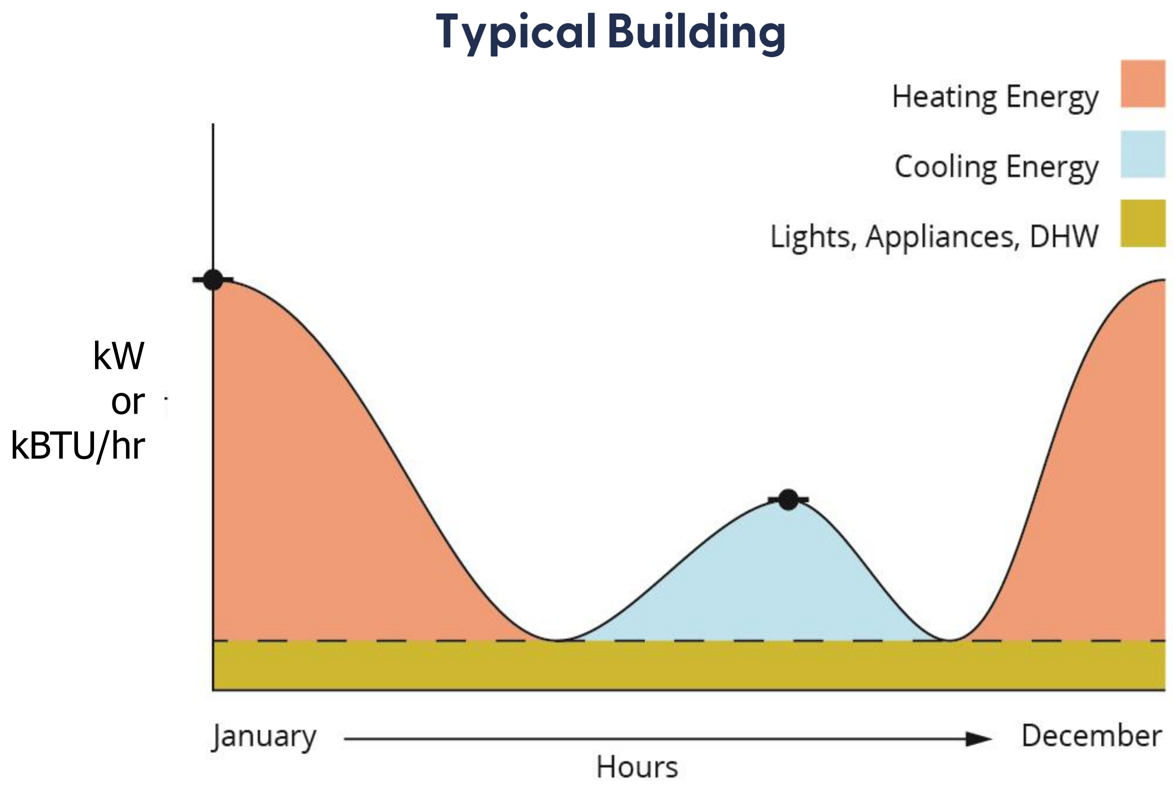
How Passive Buildings Support Grid Flexibility & Resiliency

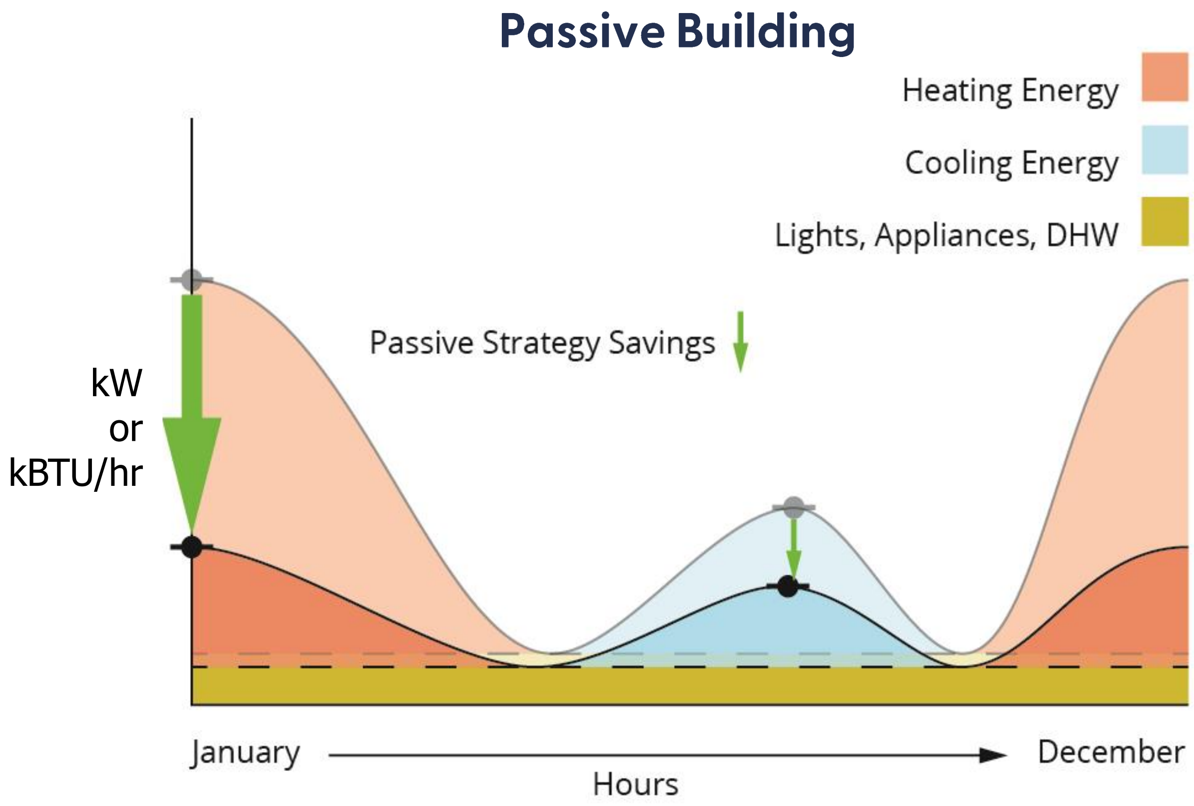
Lisa White | Phius

March 1, 2022

Buildings can be part of the solution.

What is Passive Building?



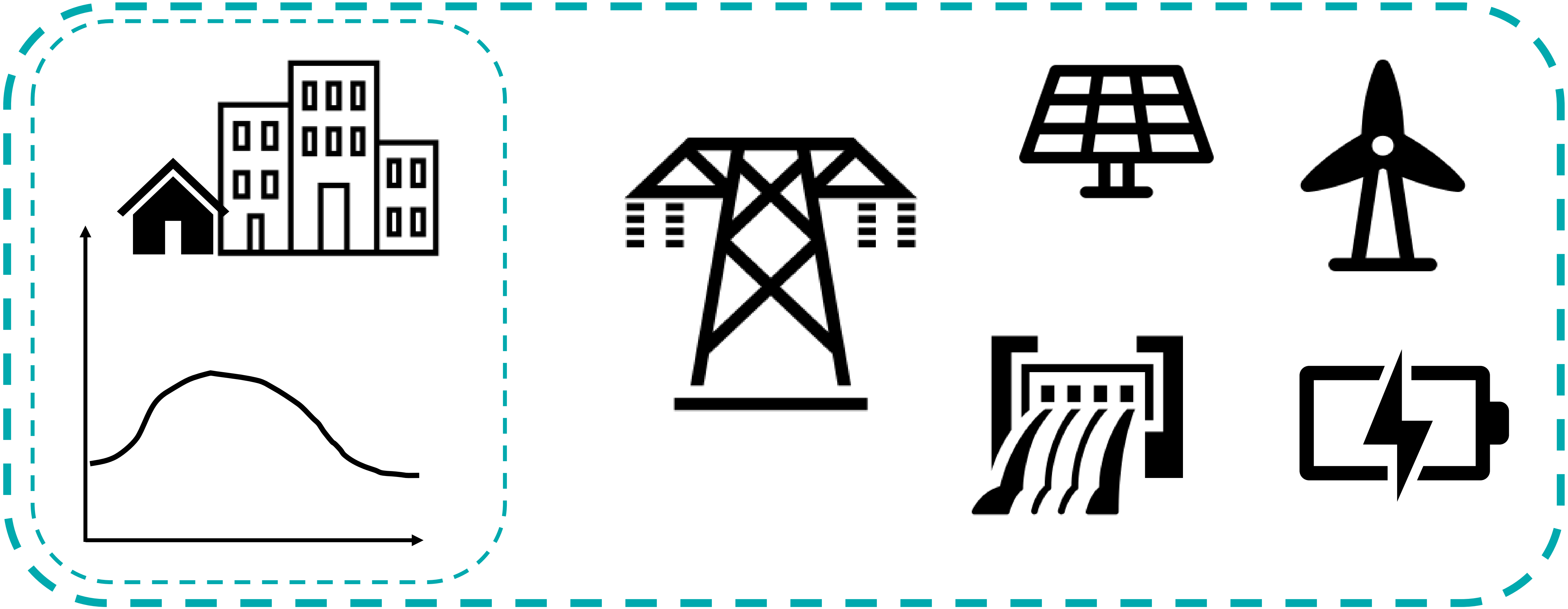


Annual Energy = kWh/yr (or kBTU/yr) → area under the curve

Peak Power = kW (or kBTU/hr) → point at top of curve

The Transition to a Renewable Future

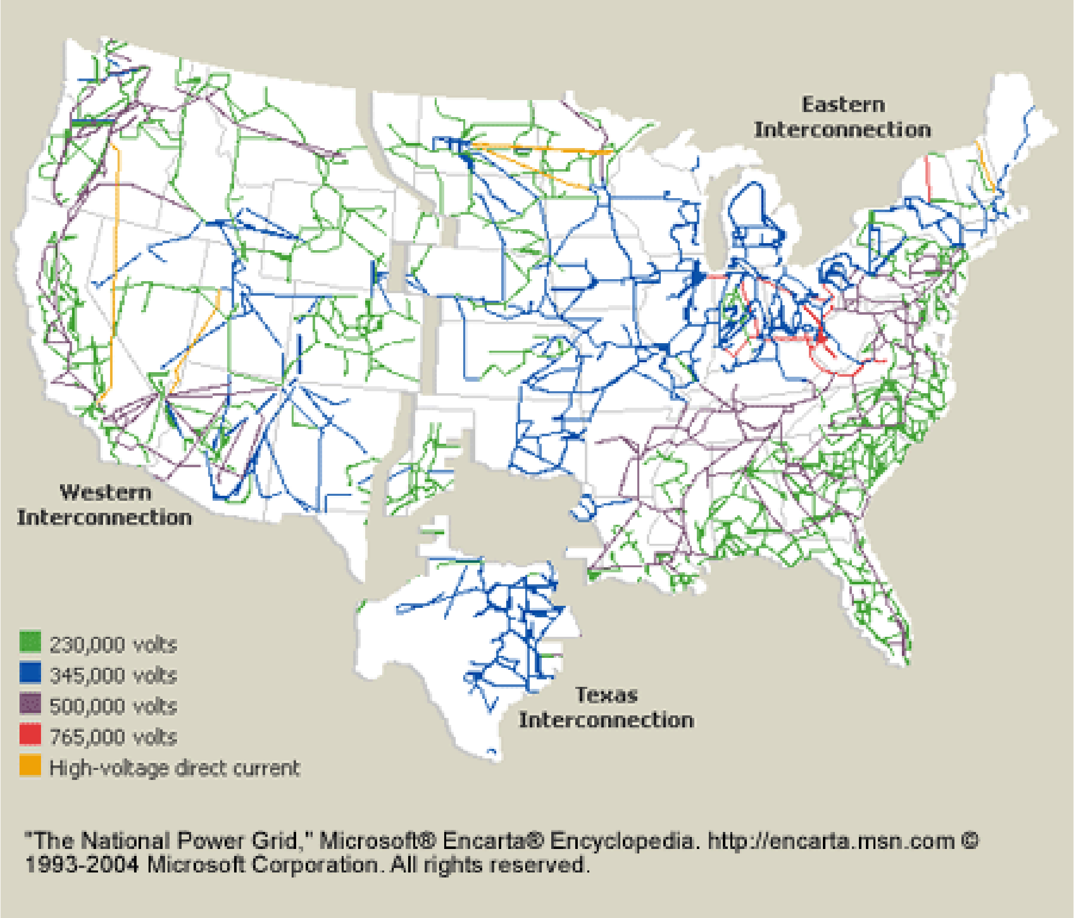
Requires Systems Level Thinking



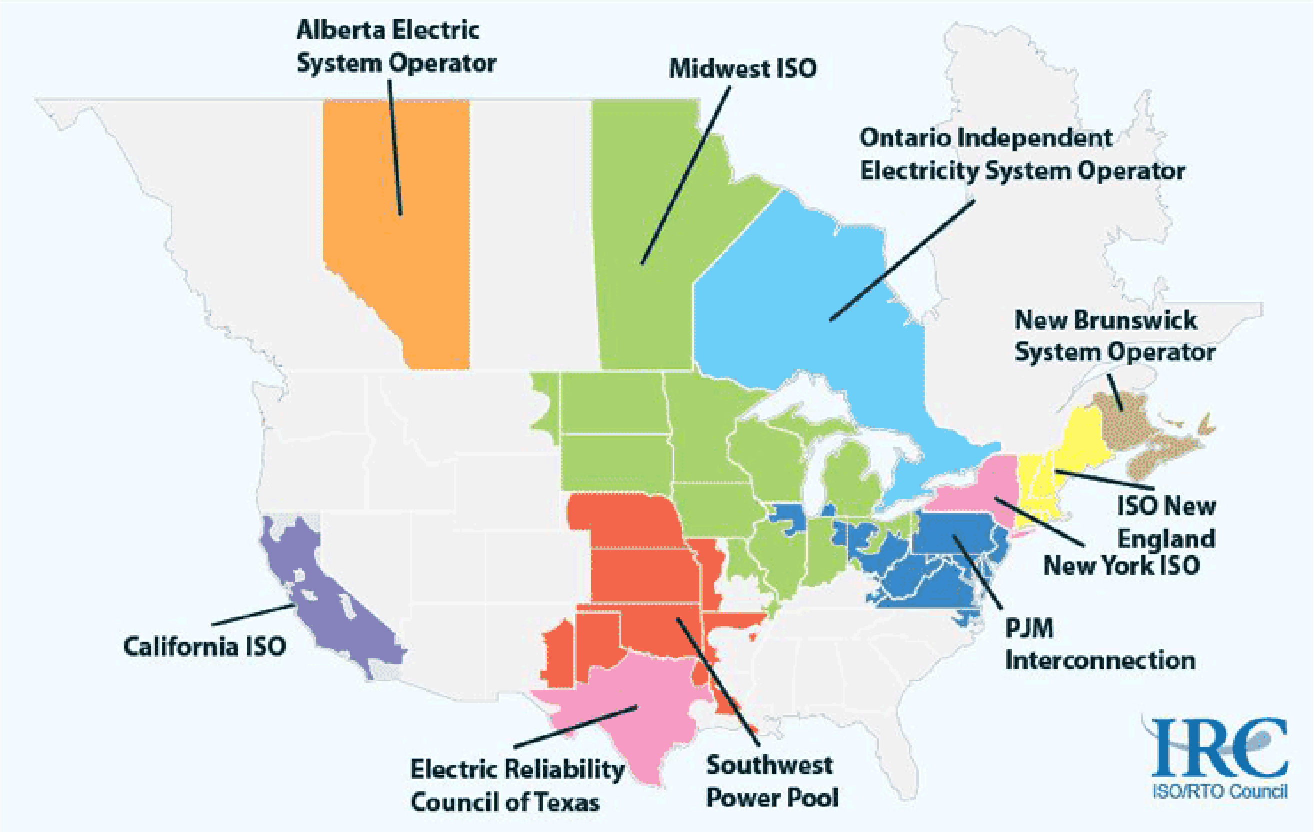
How do the decisions at this scale... Impact the decisions at this scale?

A bit of Background on Grid-Electricity

"The biggest machine on earth"



3 Interconnections

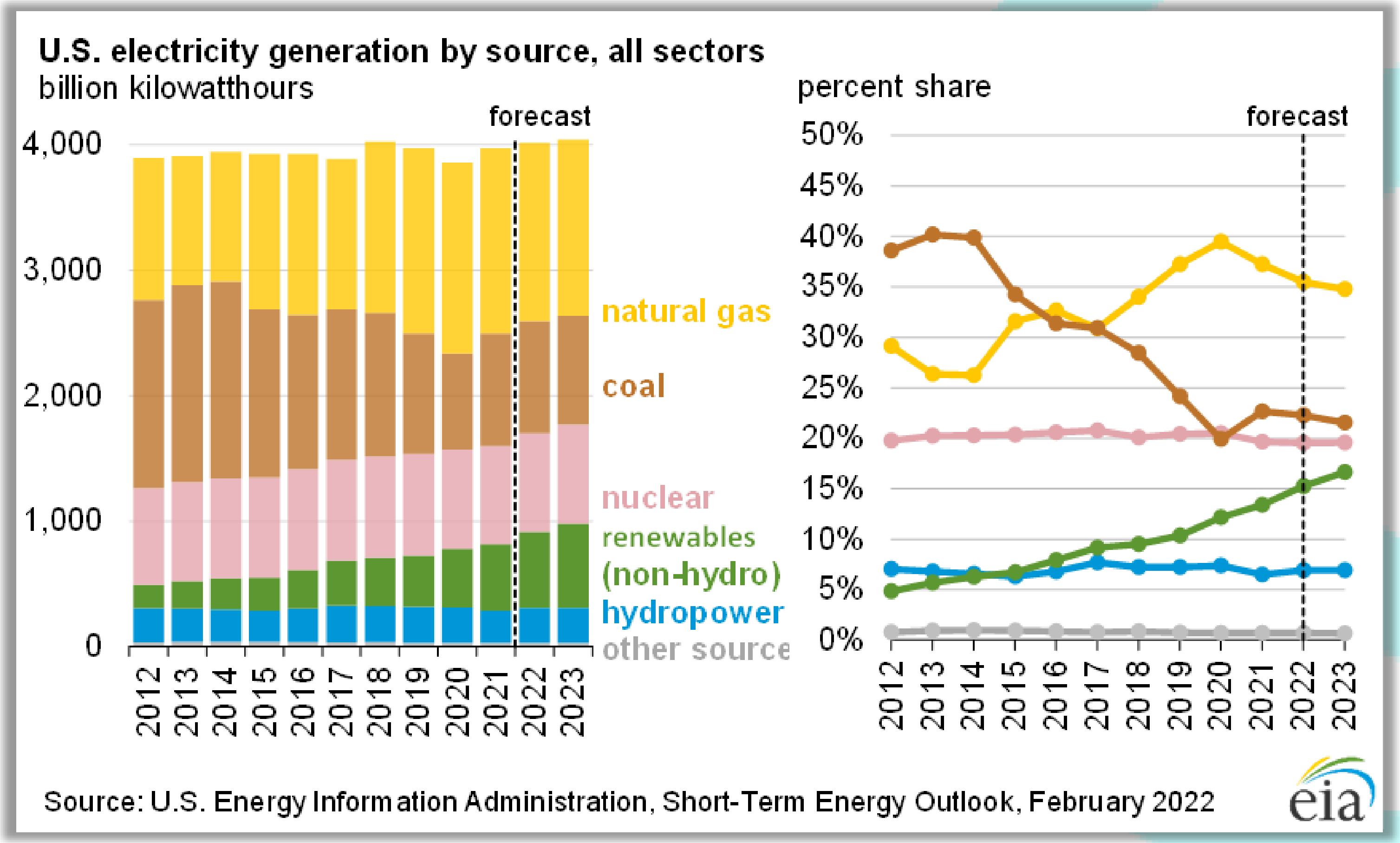


ISO's (Independent Service Operators)

CURRENT ELECTRIC GRID INFRASTRUCTURE

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

GENERATION RESOURCES



35%

22%

20%

14%

7%

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

SEASONAL LOAD PROFILES ON GRID

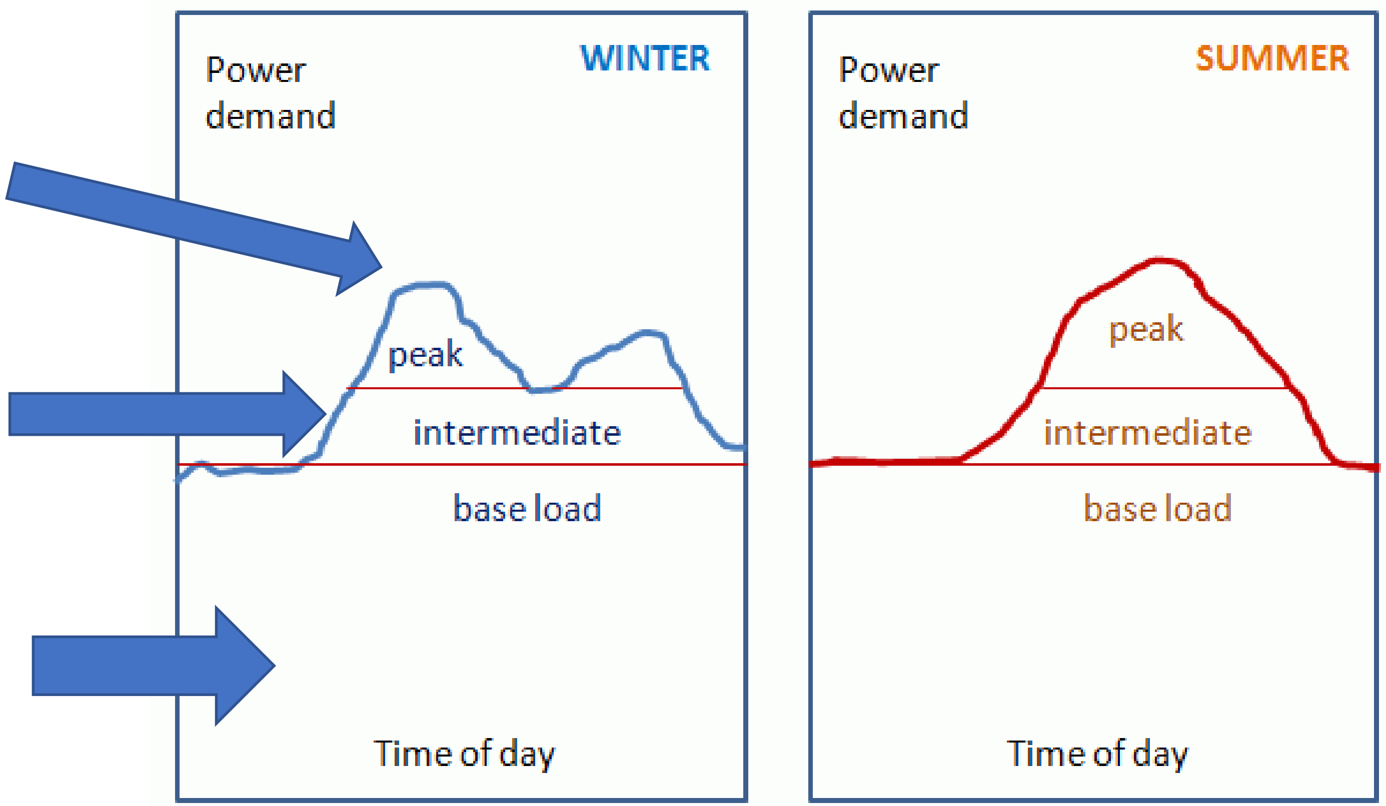
General daily patterns / grid loads are predictable, variability is mostly based on space conditioning loads.

"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

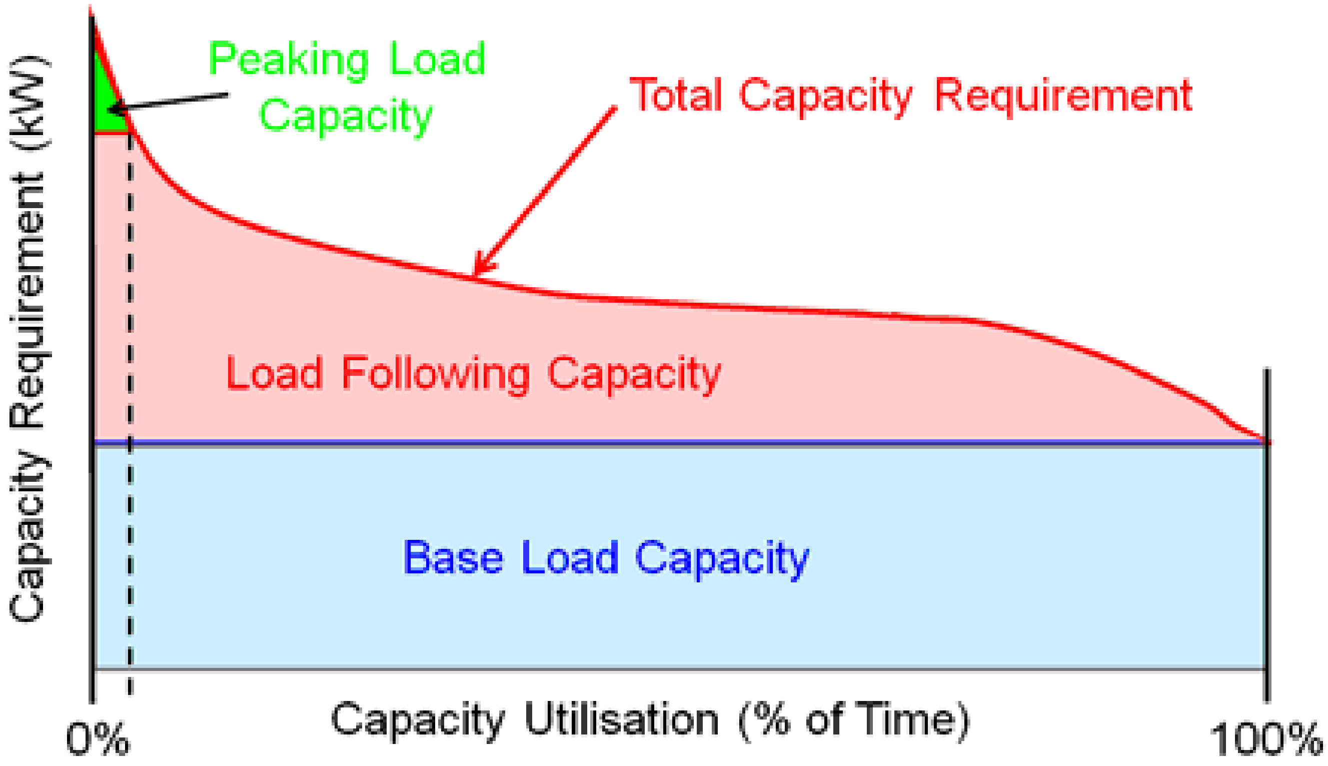
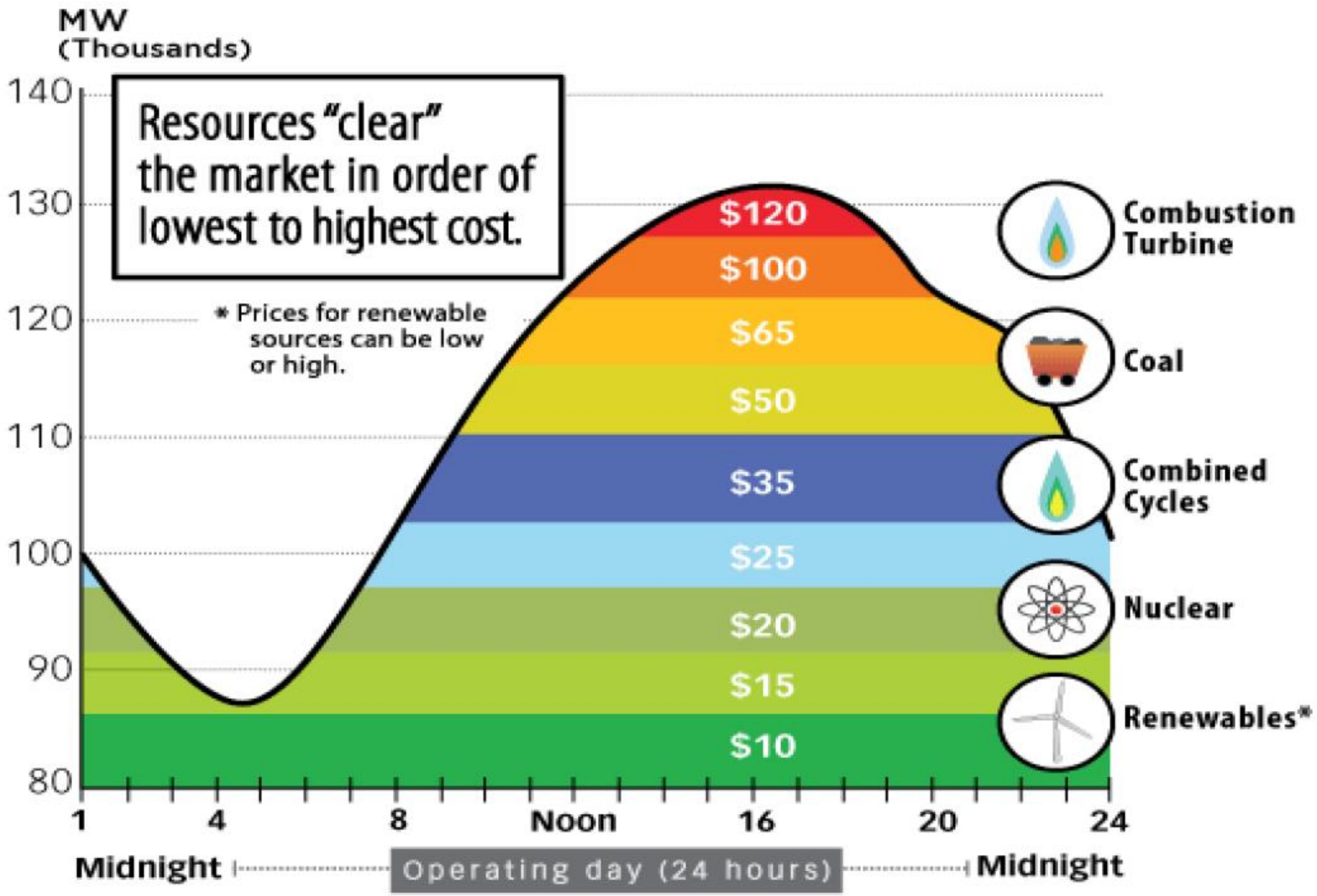


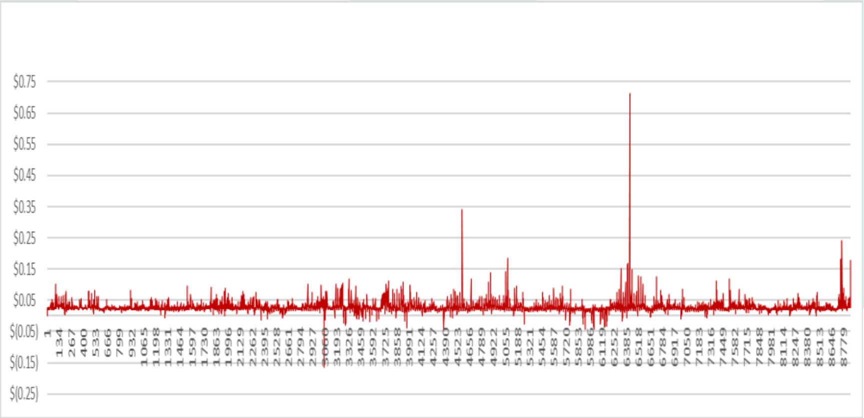
Image Source: Mark Pruitt

- The U.S. currently has about 2.5x more capacity than what's used annually.
- **Vehicles + building heating conversion to electricity may <u>double</u> consumption**

Meeting the Electric Load



Electricity Generation Sector - Scheduling



REAL TIME PRICING (RTP) – Chicago, IL

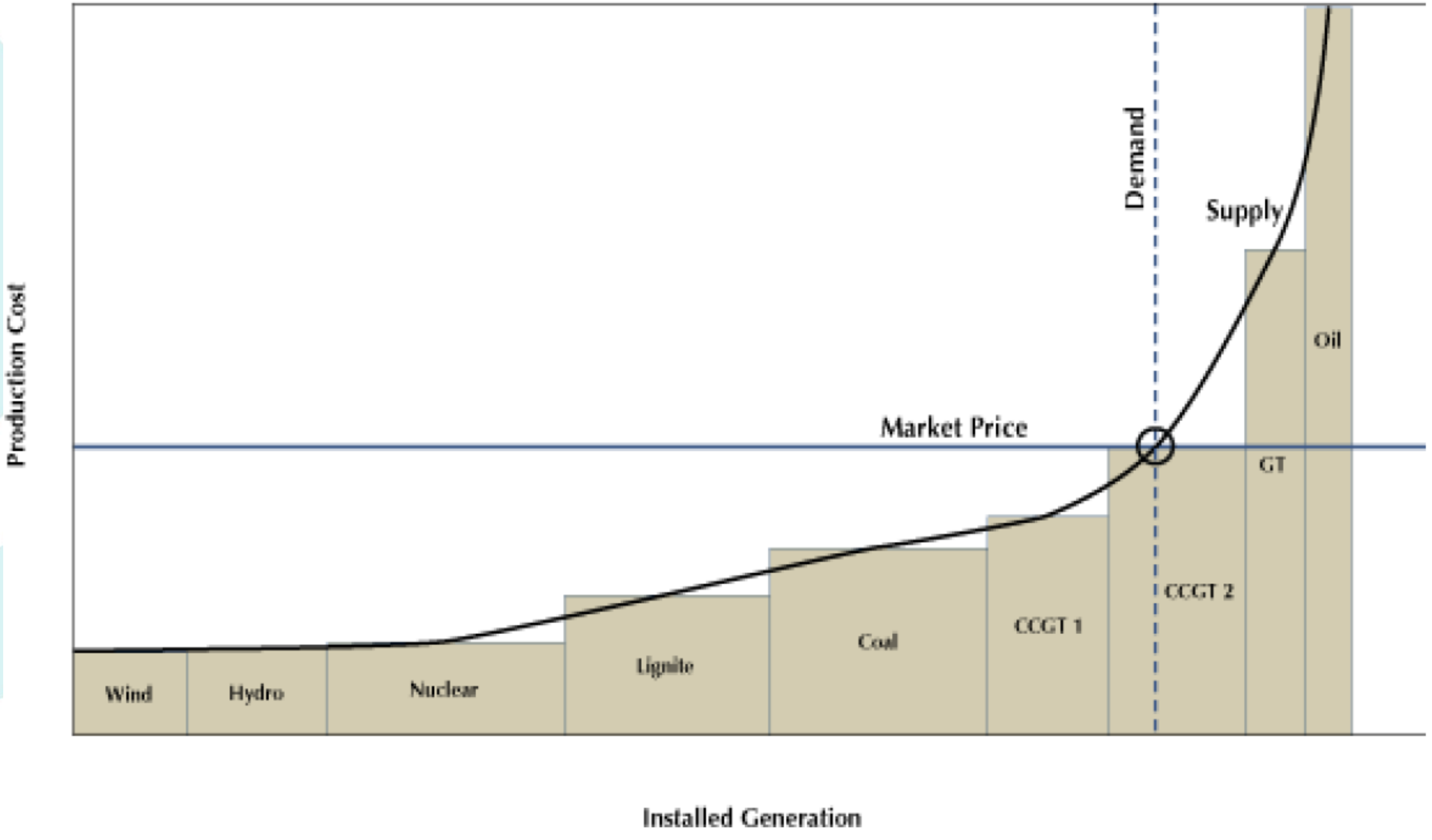
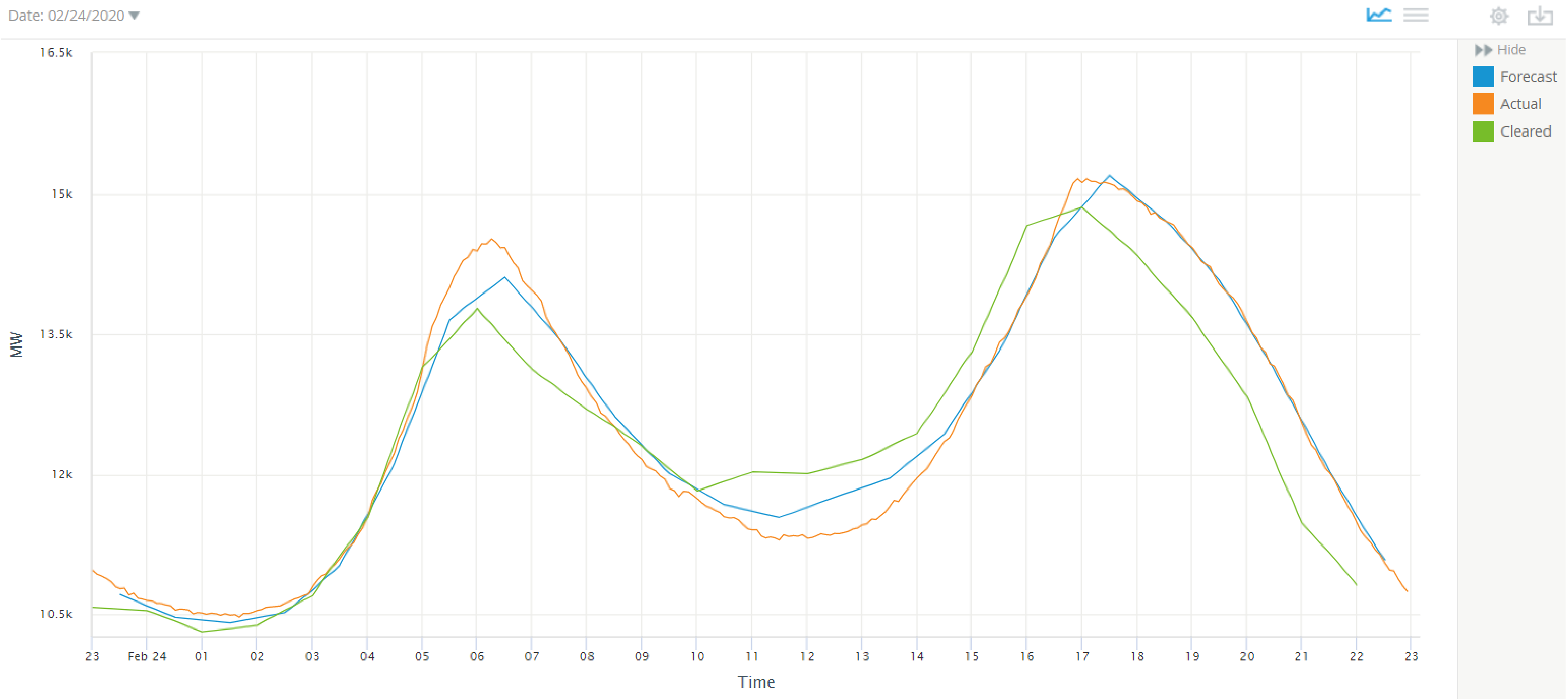


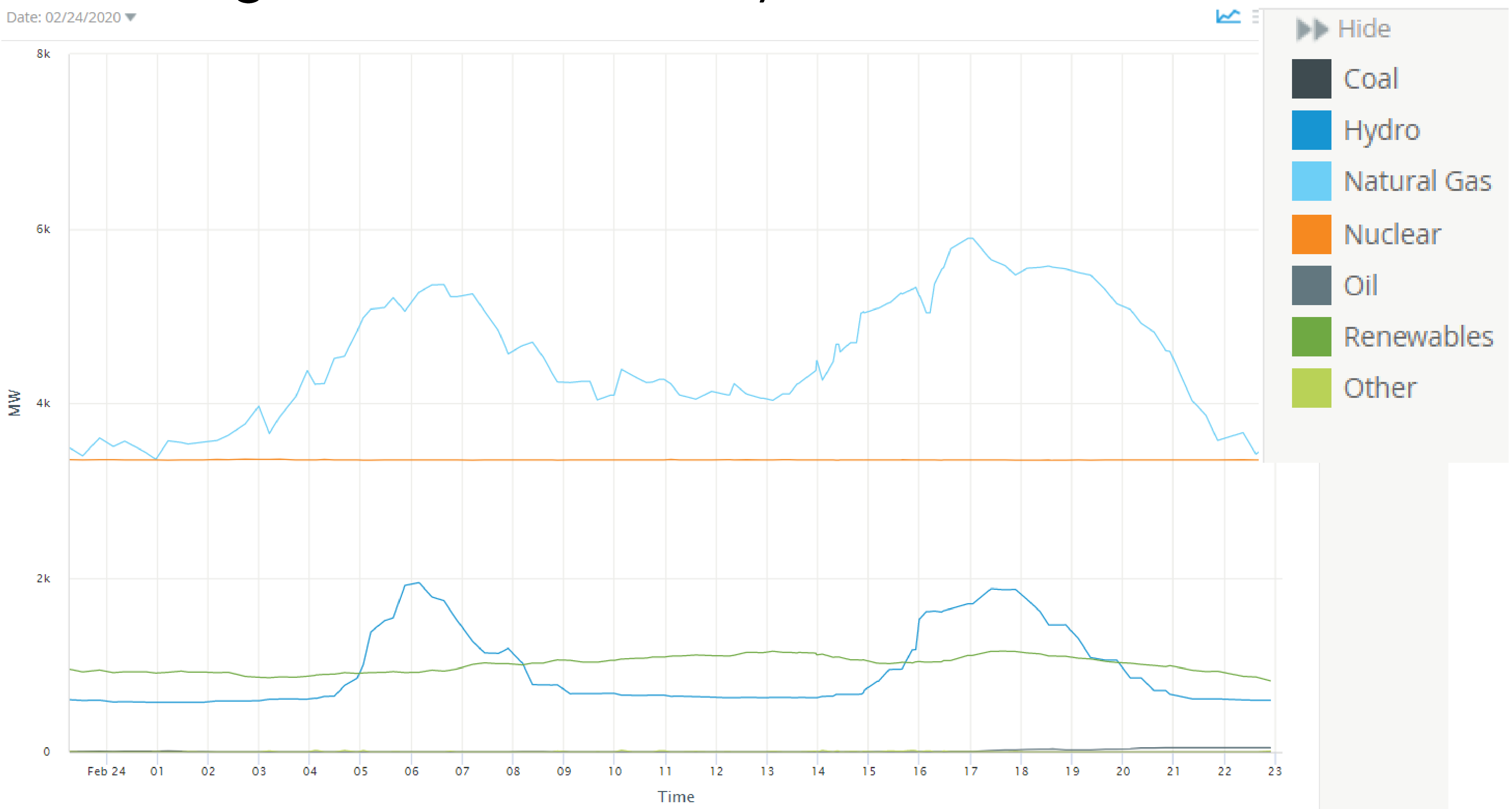
Image Source: Mark Pruitt

New England ISO - February 24, 2020



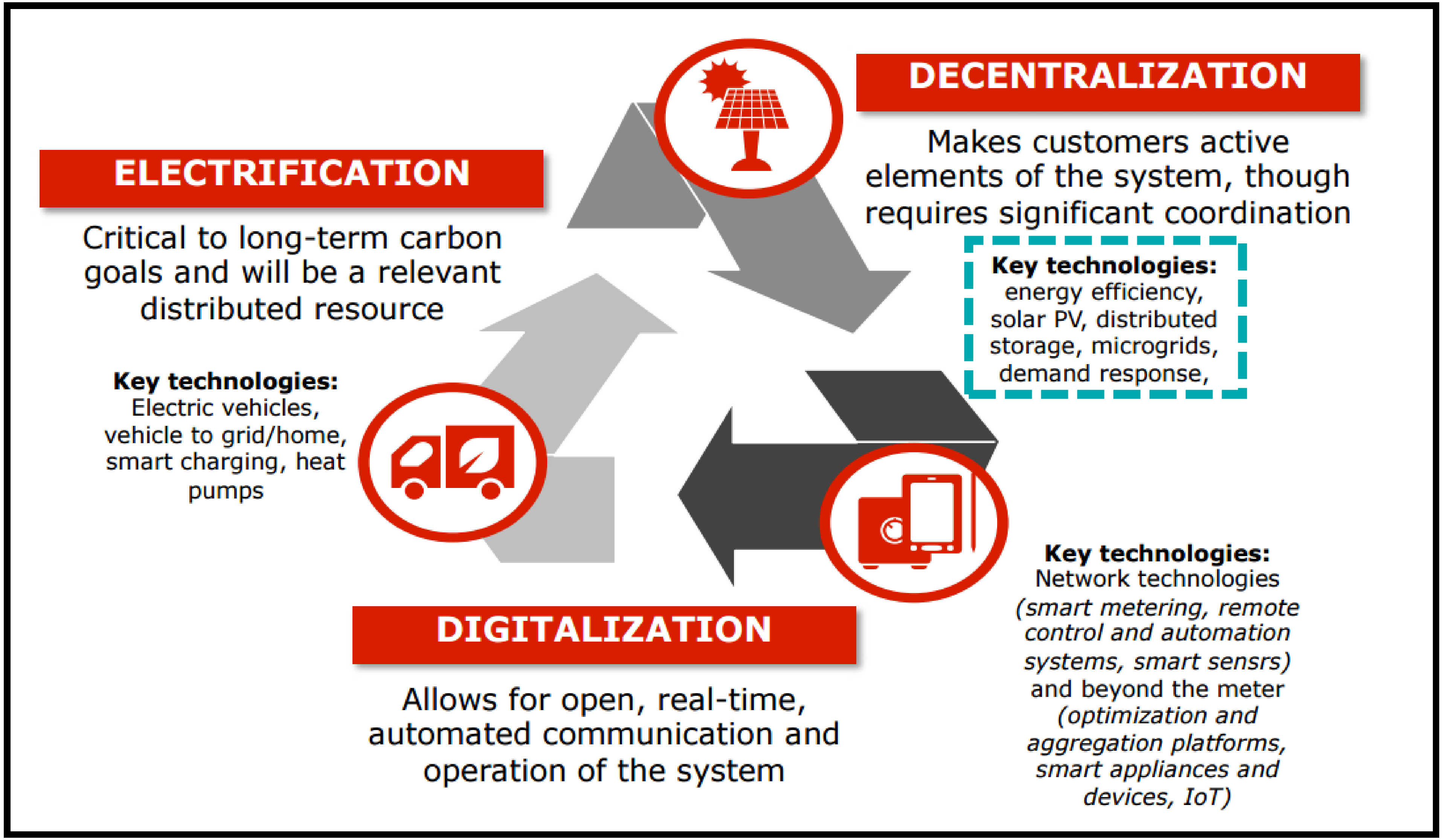
Source: https://www.iso-ne.com/isoexpress/

New England ISO - February 24, 2020



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

THE GRID IS CHANGING



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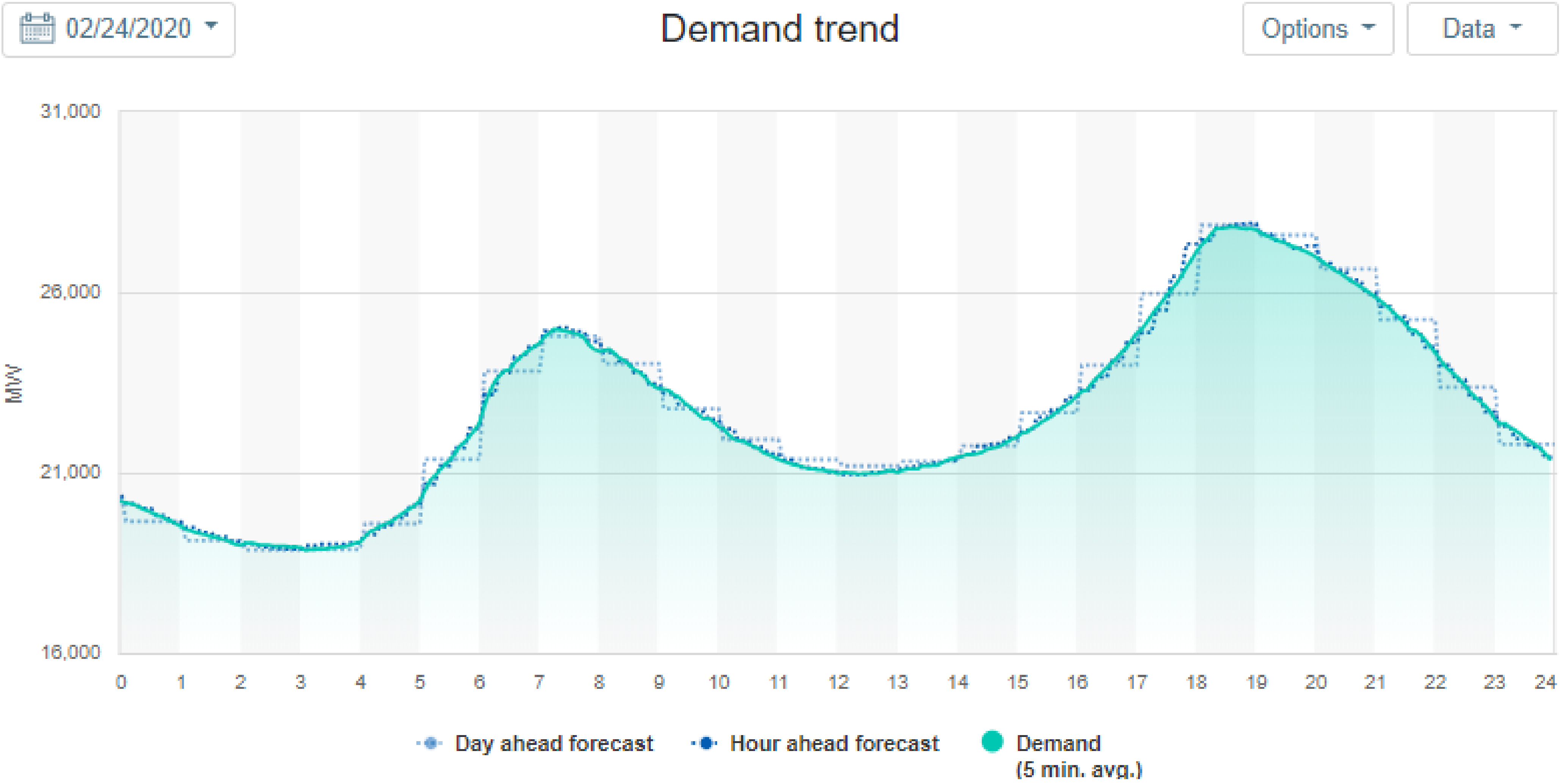
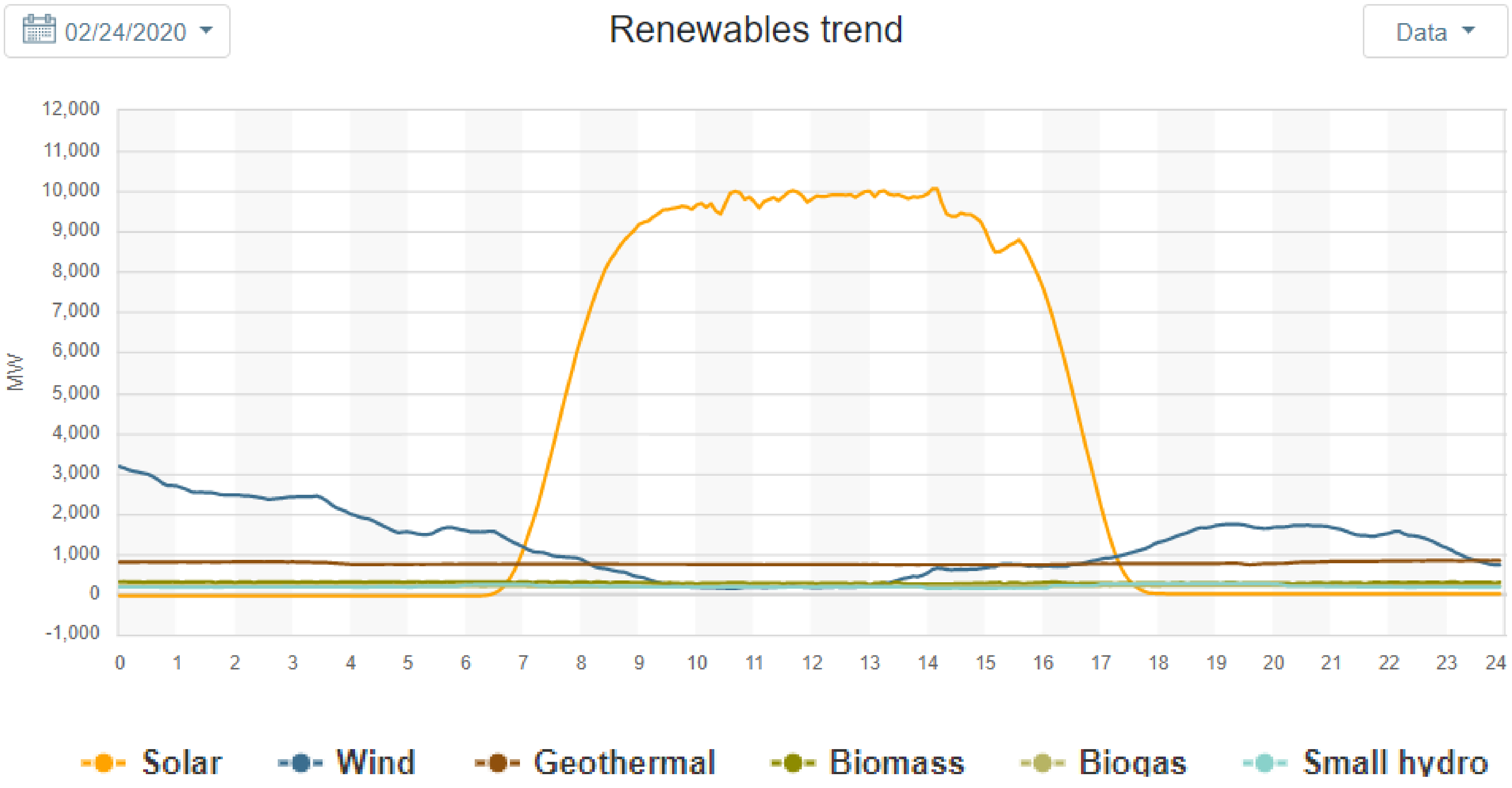
California ISO (CAISO) – February 24, 2020



http://www.caiso.com

California ISO (CAISO) – February 24, 2020



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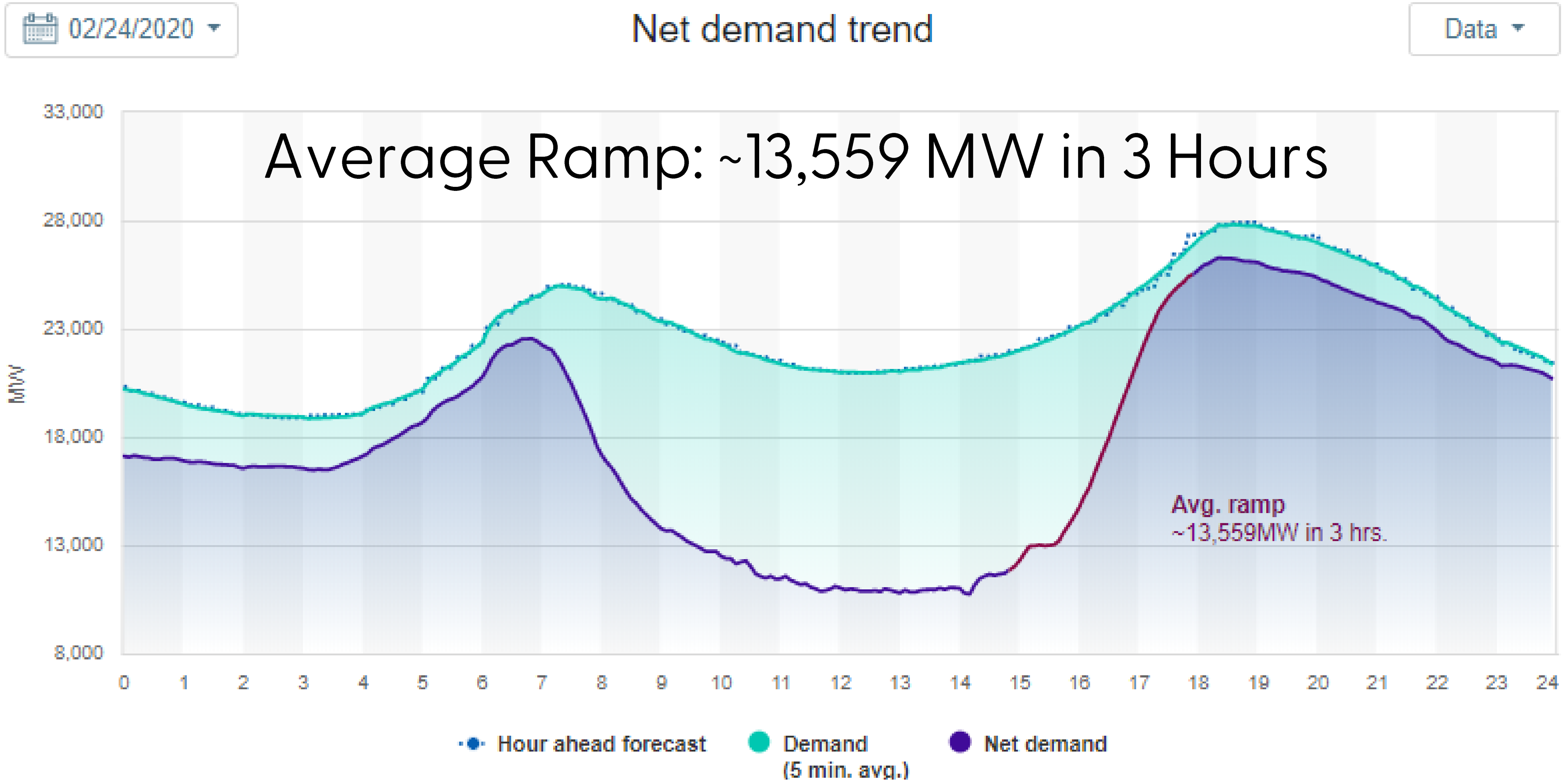

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THE GRID IS CHANGING

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

Dispatchable fossil fueled generation resources are being replaced with variable renewable energy resources.

The grid is digitalizing, allowing buildings to respond to grid signals and support more variable resources.

The total load is increasing from electrification of buildings and cars.

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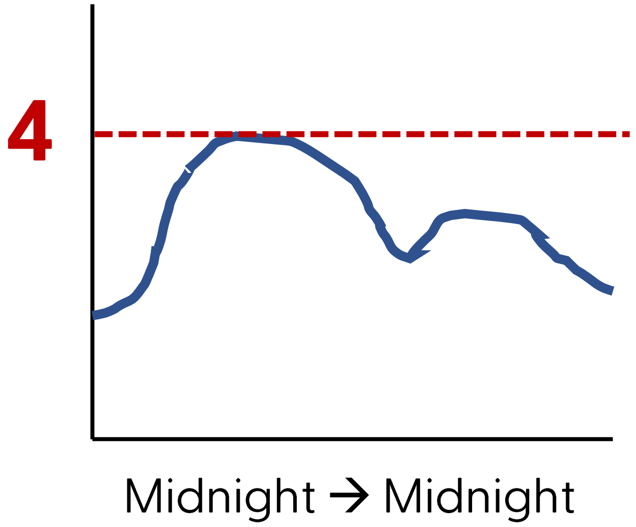
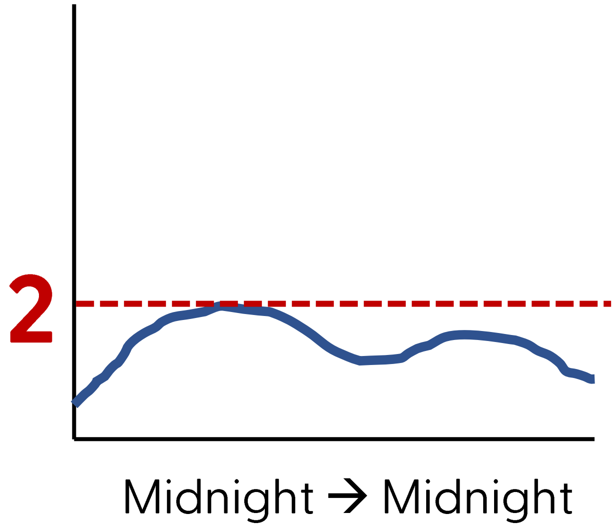
THE PEAK IS CHANGING: WINTER IS COMING

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

Winter Day Load
Typical New Building

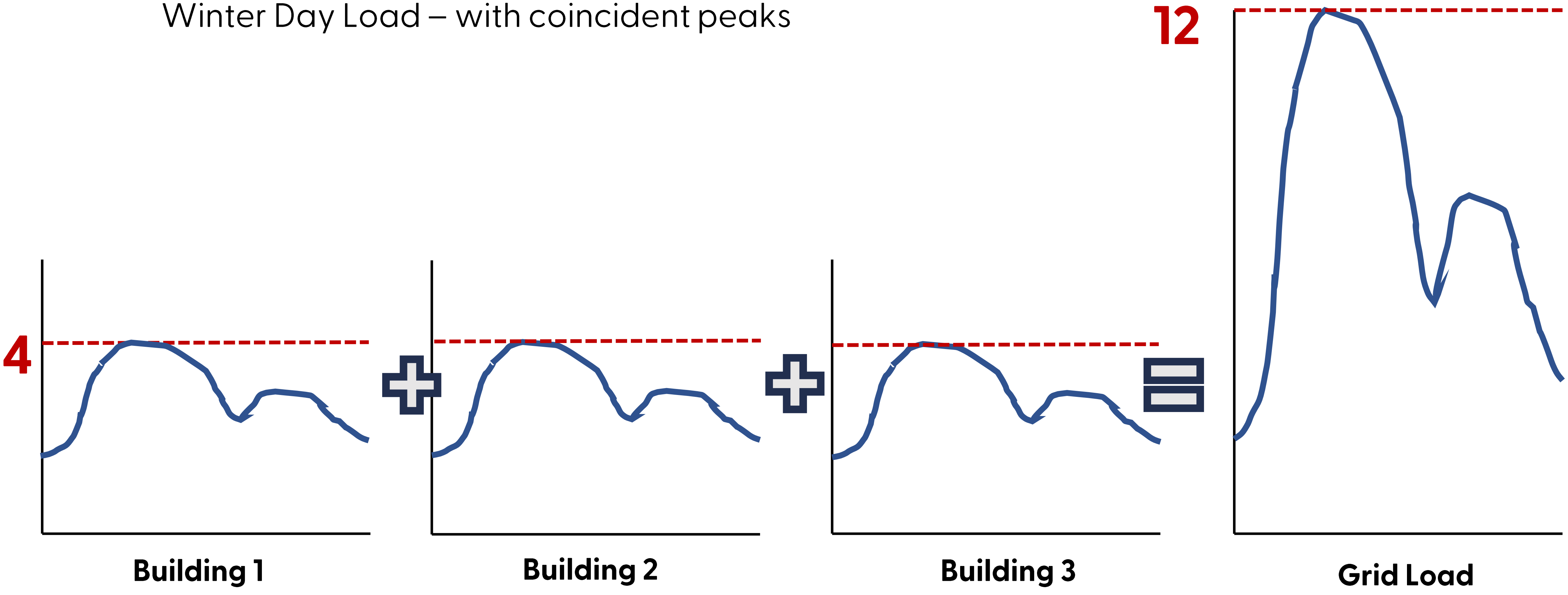


Winter Day Load
Passive Building



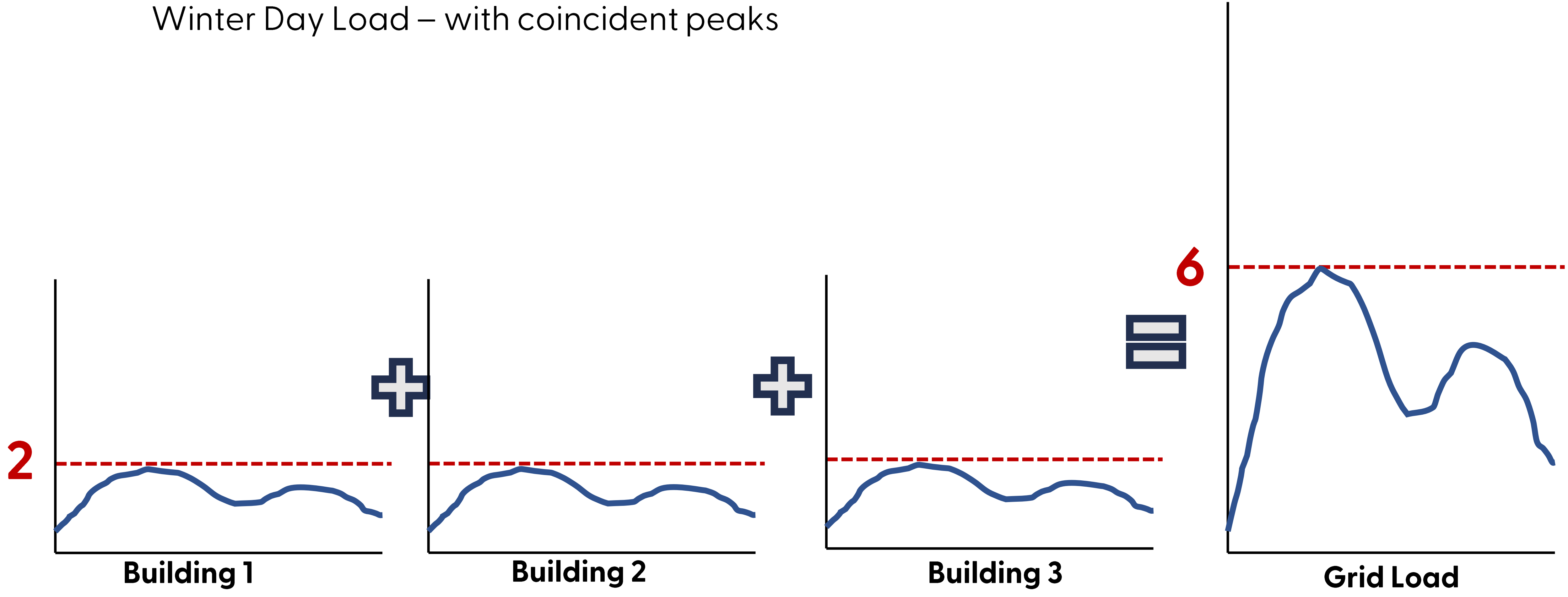
3 *Typical* Building Winter Peaks

Winter Day Load – with coincident peaks



3 *Passive* Building Winter Peaks

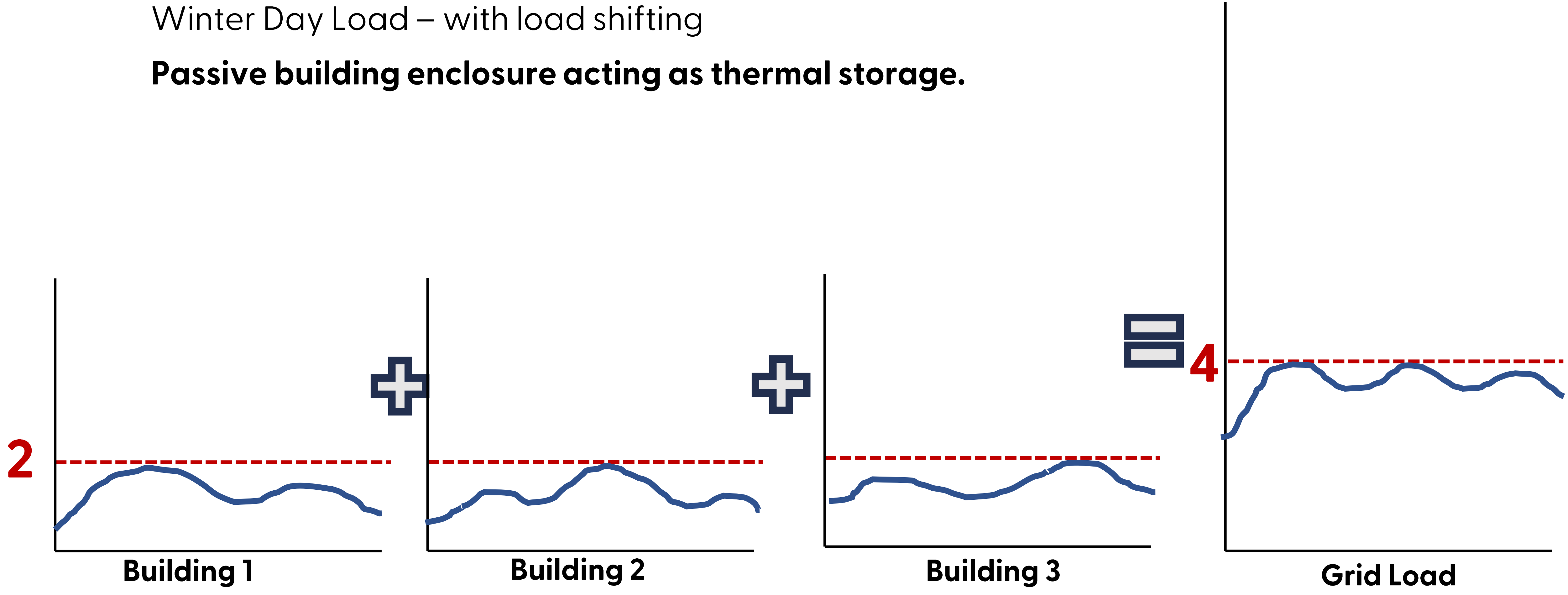
Winter Day Load – with coincident peaks



3 *Passive* Building Winter Peaks

Winter Day Load – with load shifting

Passive building enclosure acting as thermal storage.



Why this matters

Passive building **reduced winter peak load by a factor of 3.**

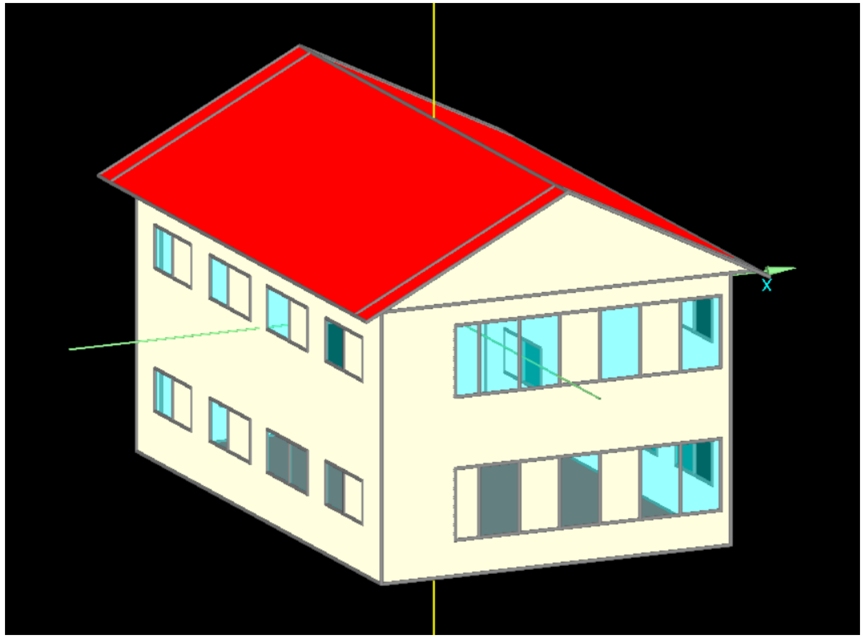
This *peak* determines the grid capacity needed.

- If you consider planned redundancy, 3x reduction in peak is more like a factor of 6 to 7.
- Grid capacity needed is directly correlated with the cost of transition to renewable energy grid.

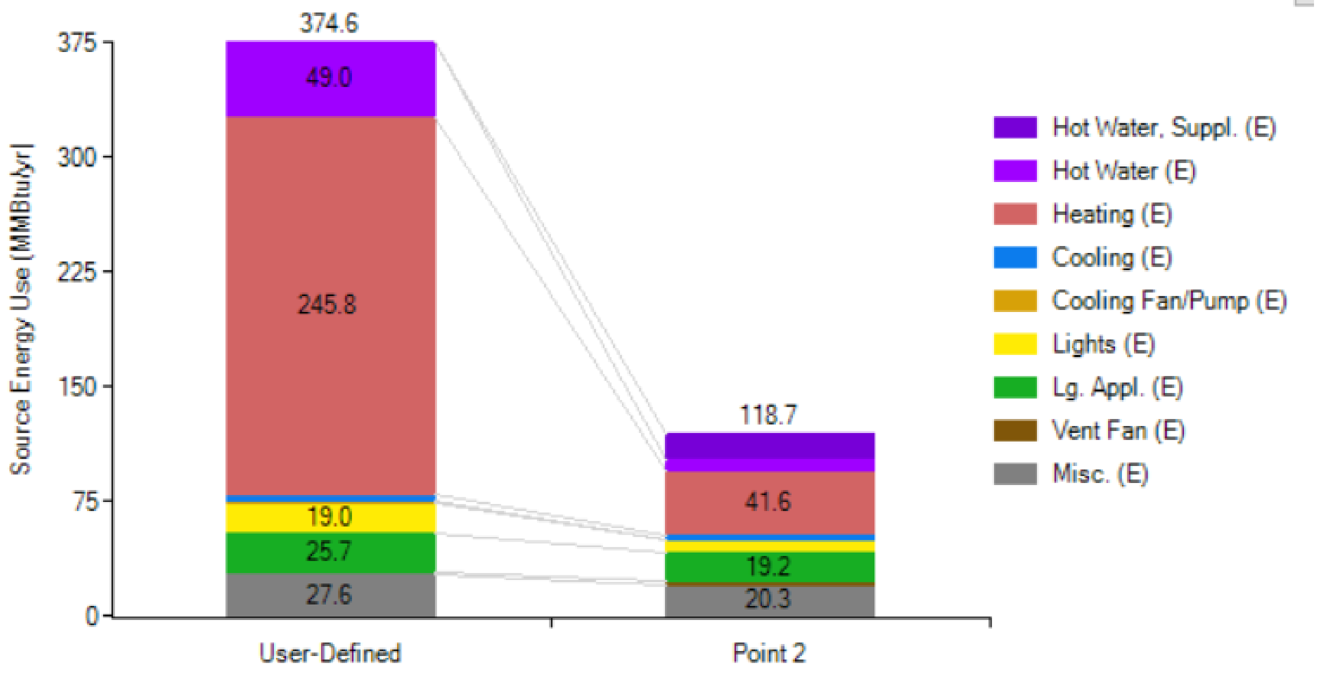
Peaks are often met with the most expensive and high carbon-emission generation resources.

- And likely will continue to during the transition to a renewable energy grid, due to their responsiveness and compatibility with intermittent generation sources.

CASE STUDY PROTOTYPE – PEAK SHAVING



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



Two buildings studied:

1. Building America 2009 Benchmark
2. Passive building


Hourly
Daily
Monthly
Heat map
Profile
Statistics
PDF / CDF
Duration curve
Scatter
Baseline Building - Total
Total (E) (kWh)
0
2
4
6
8
10
12
14
16
18
20
Baseline Building - Heating
Heating (E) (kWh)
0
2
4
6
8
10
12
14
16
18
Jan
Feb
Mar
Apr
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Jul
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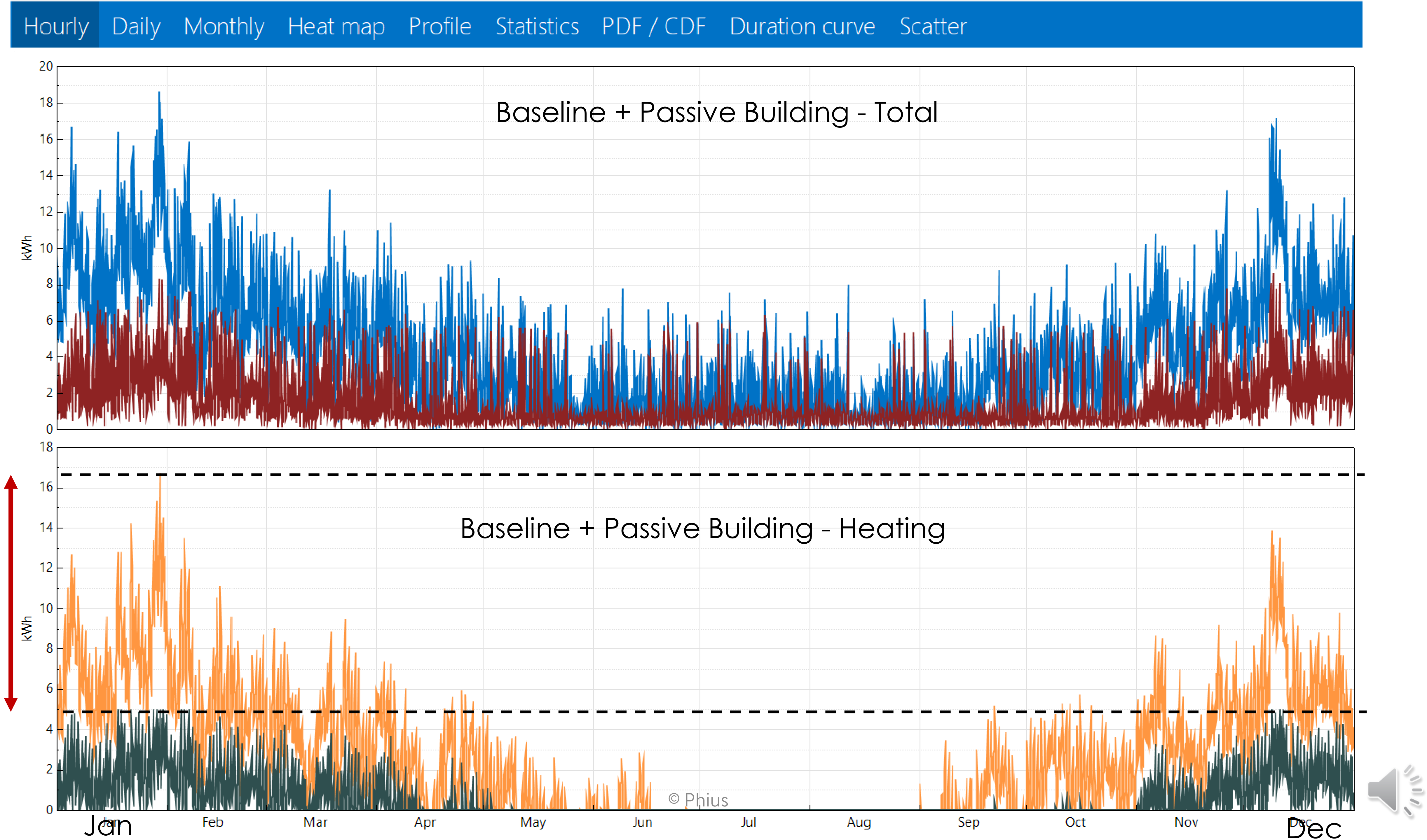
Sep
Oct
Nov
Dec
© Phius



Hourly
Daily
Monthly
Heat map
Profile
Statistics
PDF / CDF
Duration curve
Scatter
Baseline + Passive Building - Total
kWh
20
18
16
14
12
10
8
6
4
2
0
Baseline + Passive Building - Heating
kWh
18
16
14
12
10
8
6
4
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0
Jan
Feb
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© Phius

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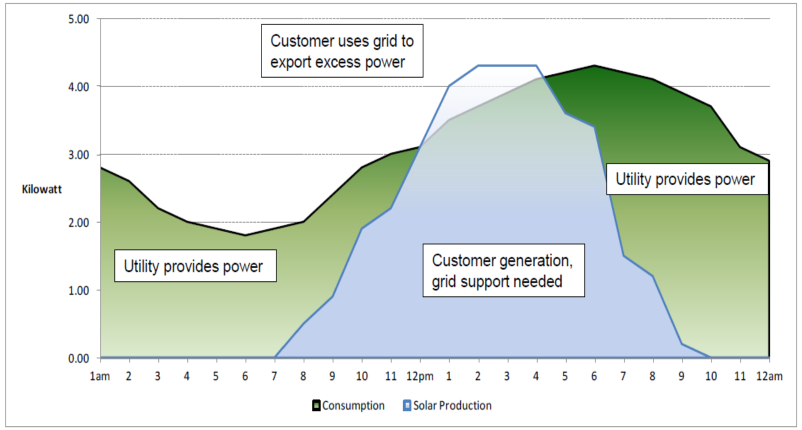
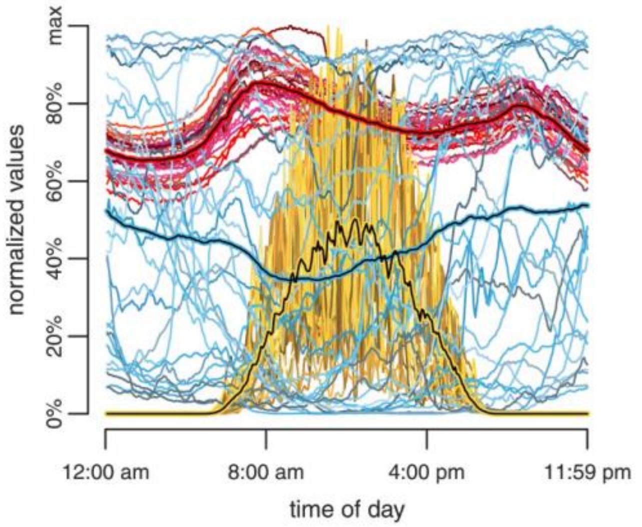
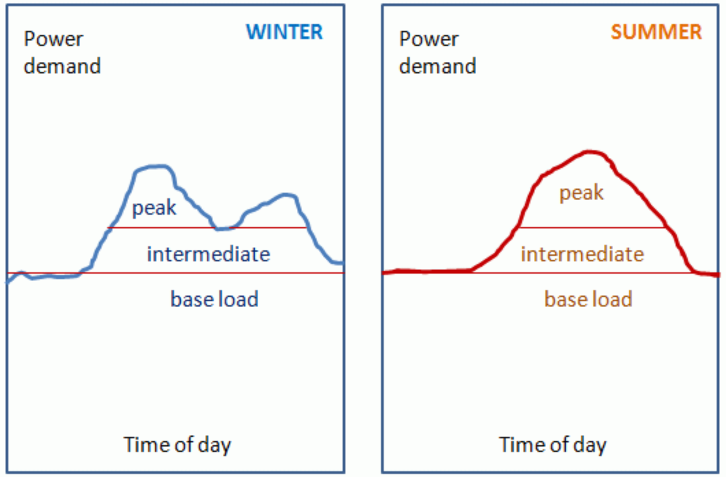
CHALLENGES OF RENEWABLE ENERGY INTEGRATION



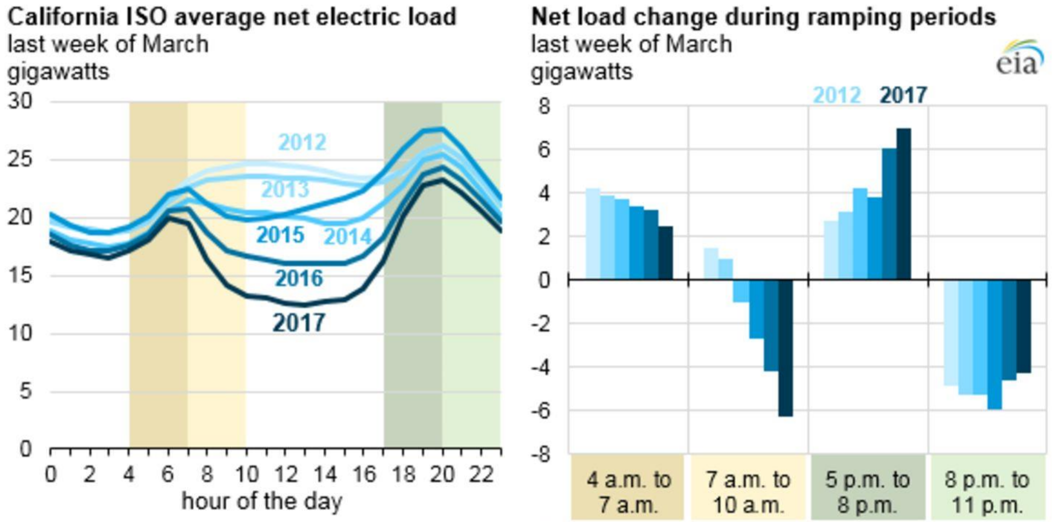
MISMATCH



INTERMITTENCY

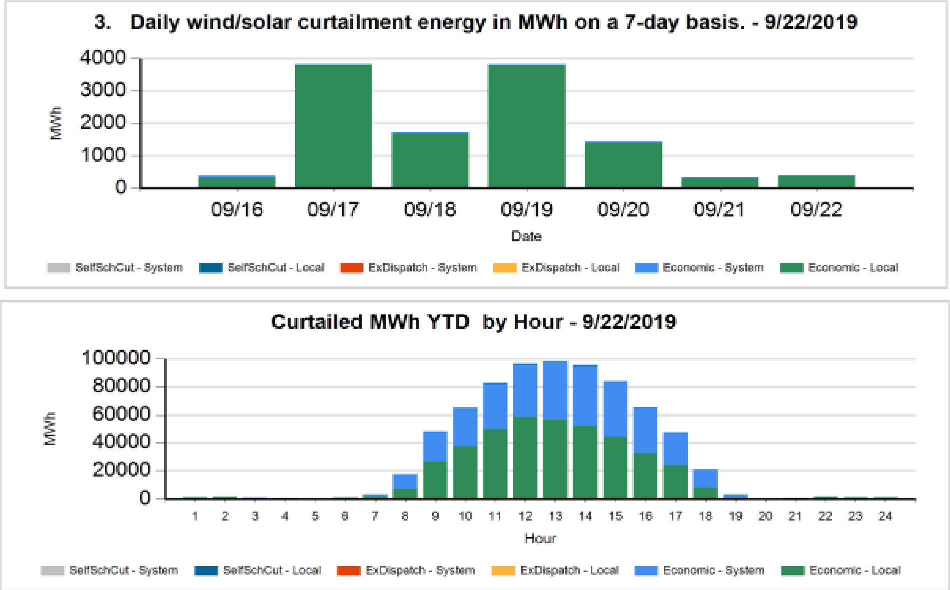


BASELOAD CHALLENGES



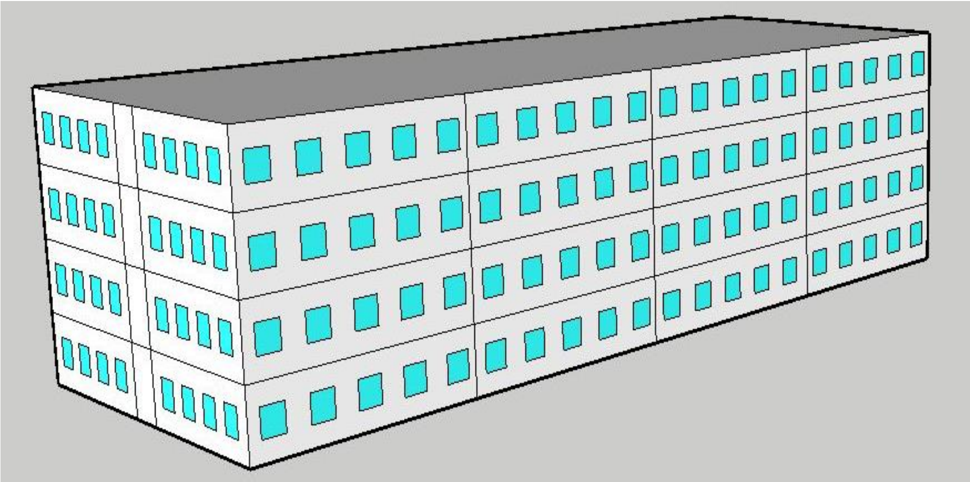
Source: U.S. Energy Information Administration, based on ABB Energy Velocity

NET LOAD/RAMPING



CURTAILMENT

GRID IMPACT – 'NET ZERO' CASE STUDY PROTOTYPE



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

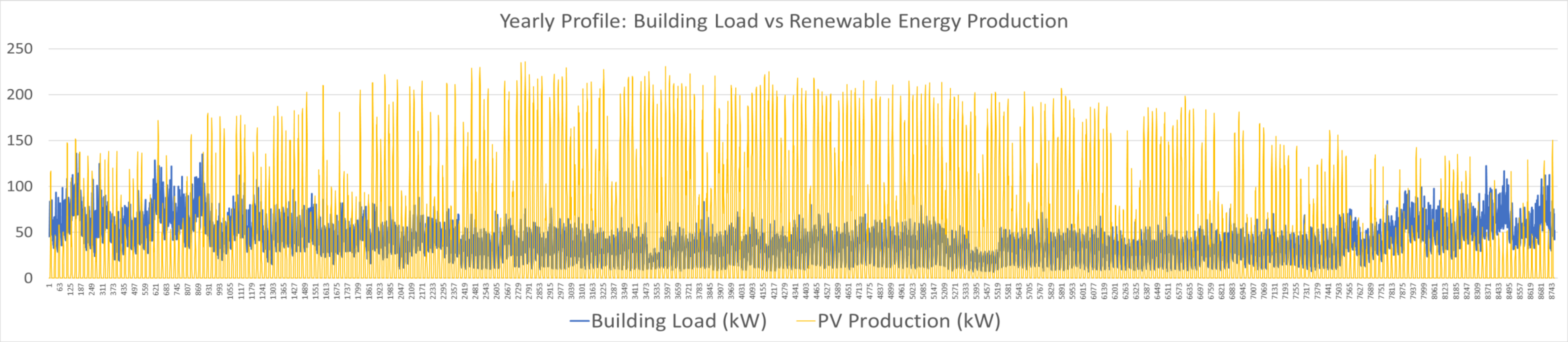
Two 'Net Zero' buildings studied:

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

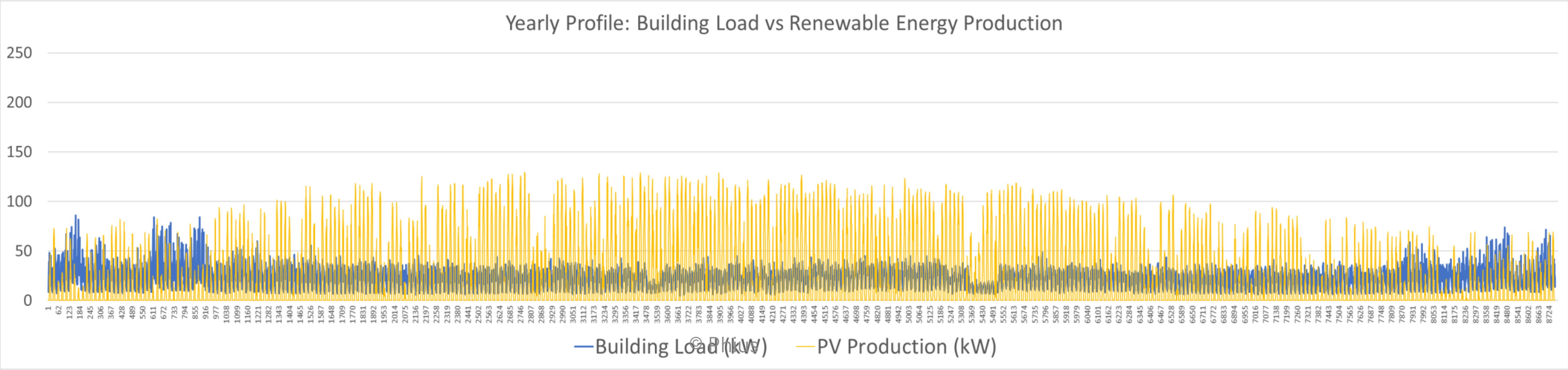
2. Passive building (Phius certifiable):
159 kW PV Array
All south facing, 10 degree tilt

CASE STUDY

Baseline building



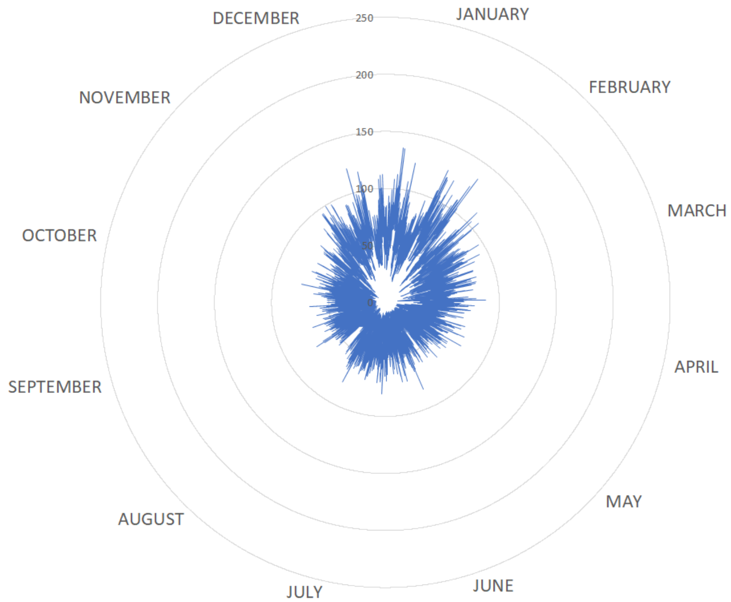
Passive (Phius Certified) building

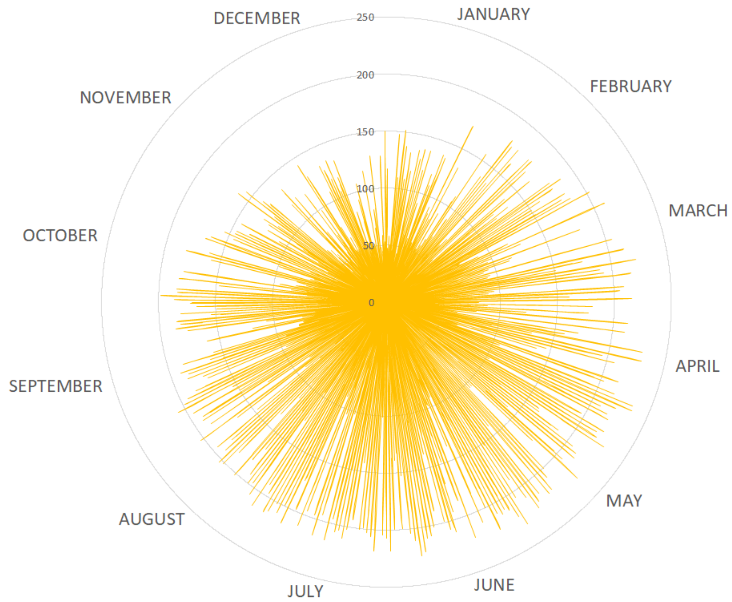


CASE STUDY

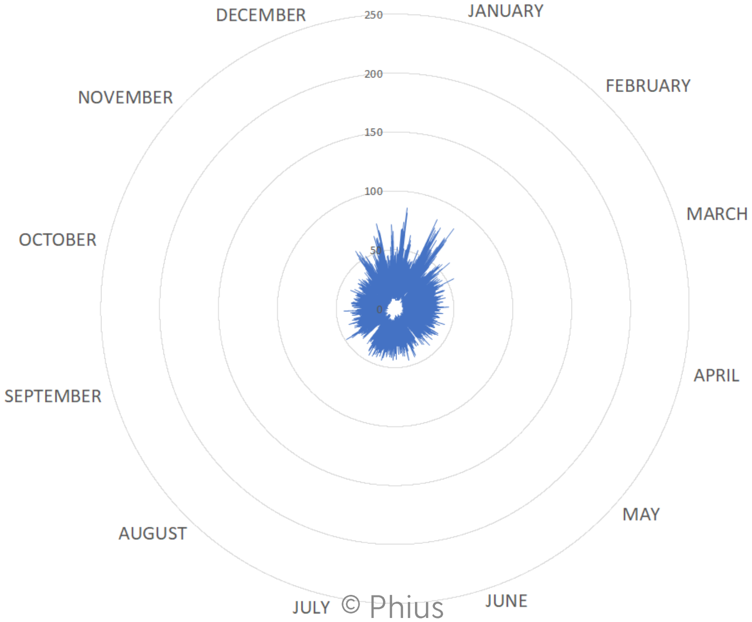
Hourly Building Load (kW) | Hourly PV Production

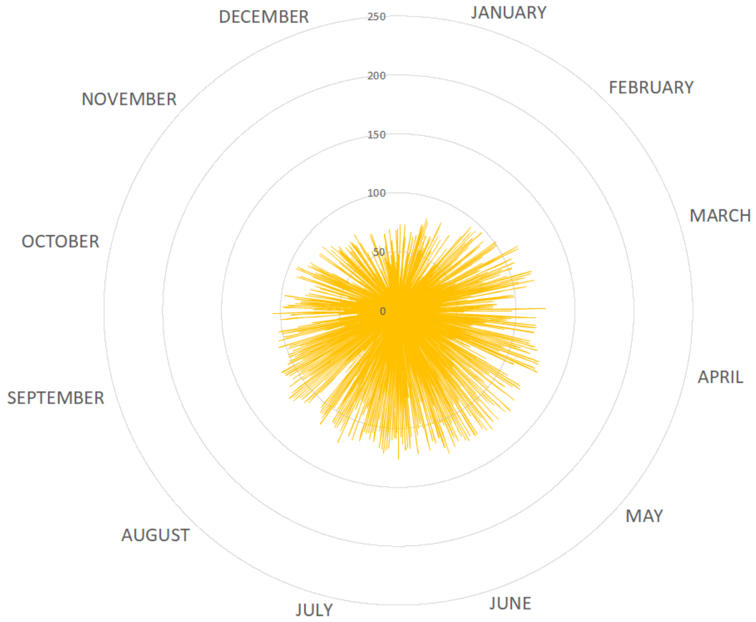
Baseline building





Passive building

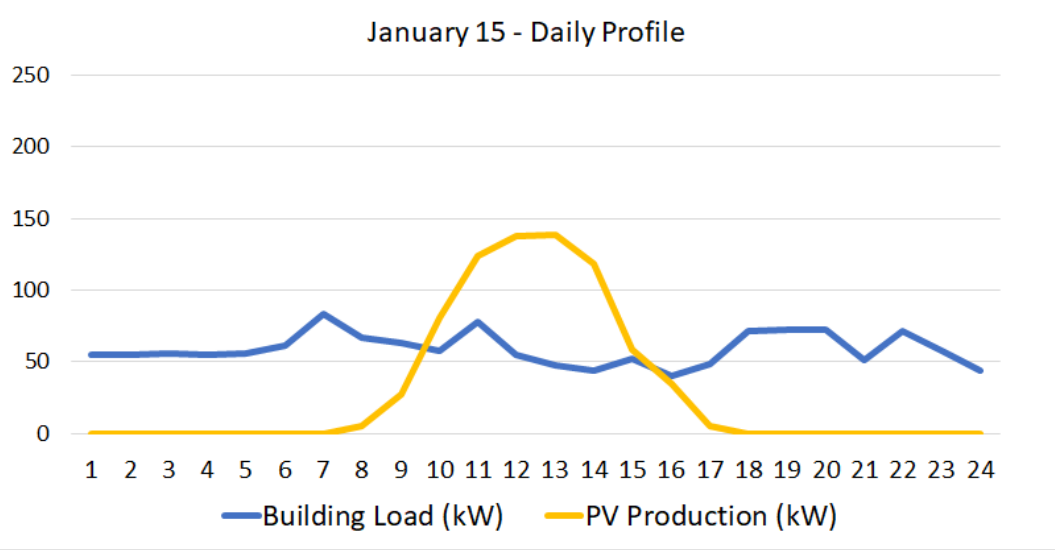


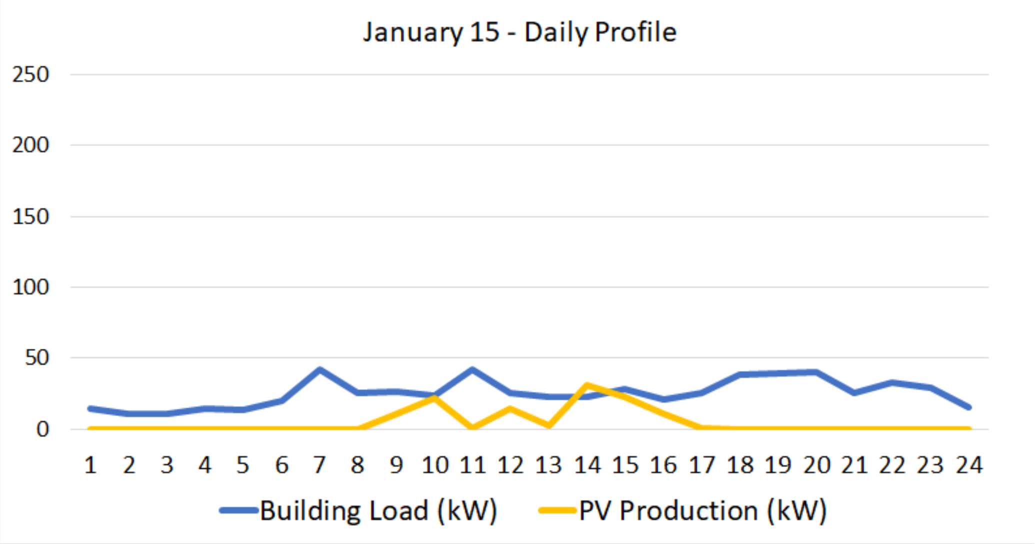


Daily Loads & PV Production

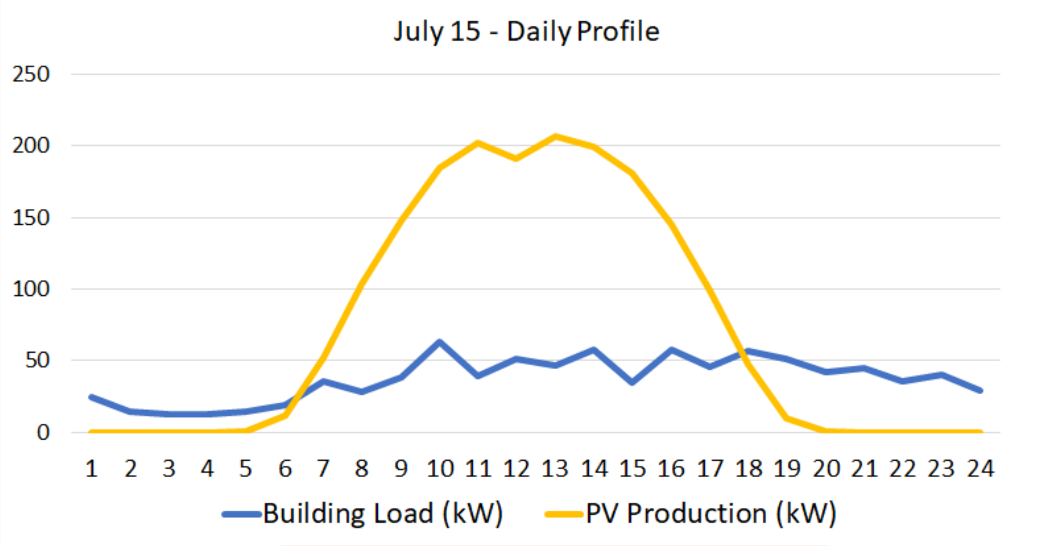
Winter & Summer

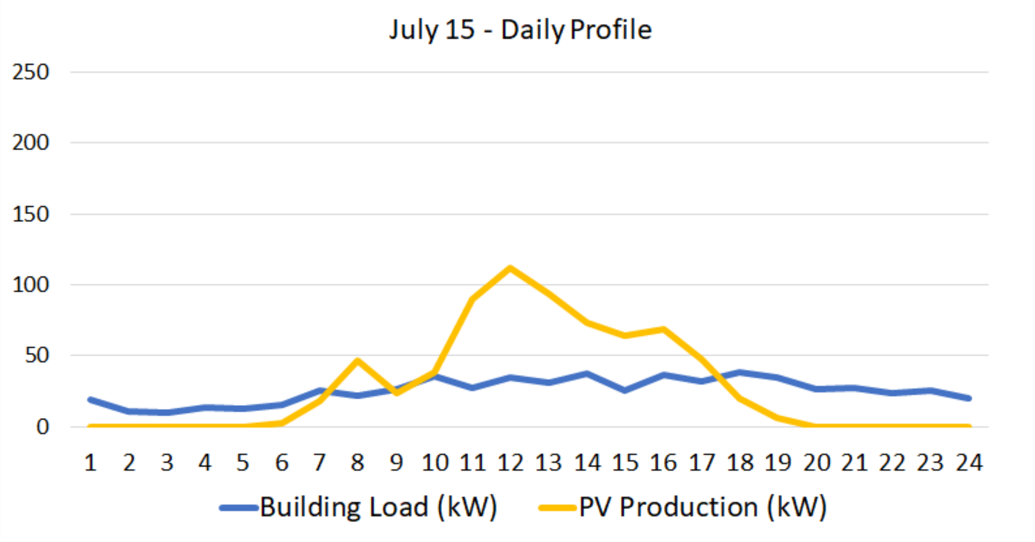
January 15





July 15





Baseline building

Passive building

In Reality…

“Net Zero” ≠ “Zero Impact”

Only about ~**35% coincident production-and-use of on-site PV.**

The grid must cover the rest.

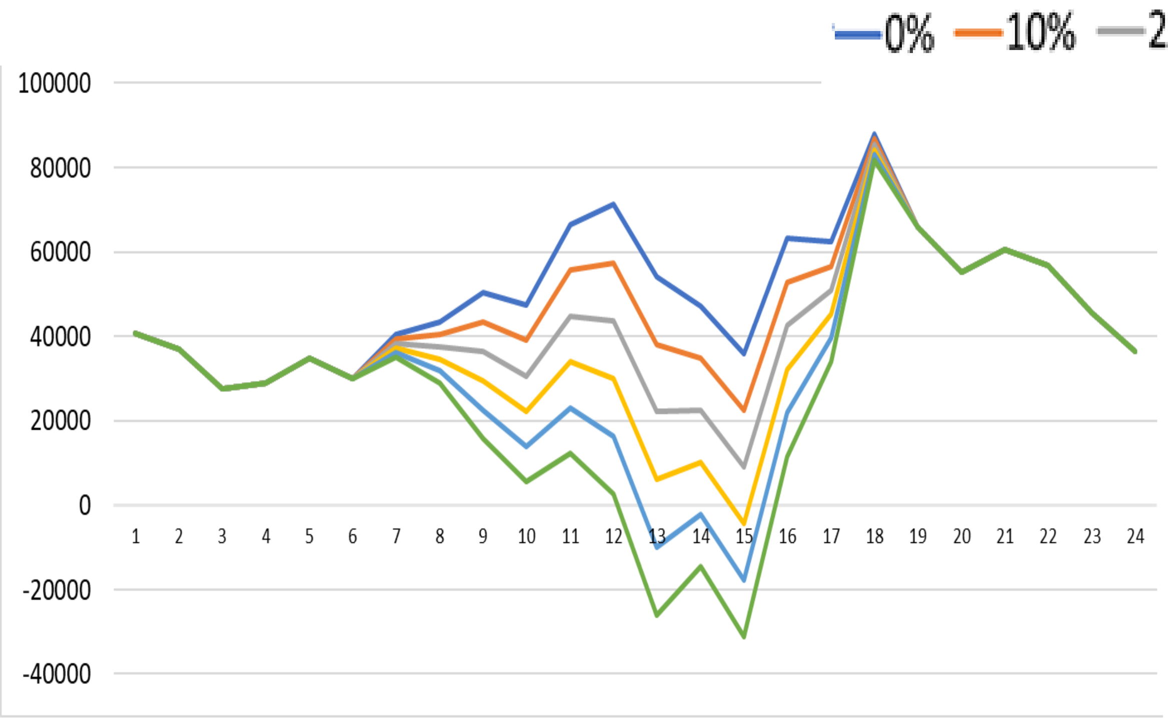
Reducing the annual load reduces dependency on the grid to cover the remaining load.

The marginal emissions at the time of renewable energy production may be different than when the building is using grid energy.

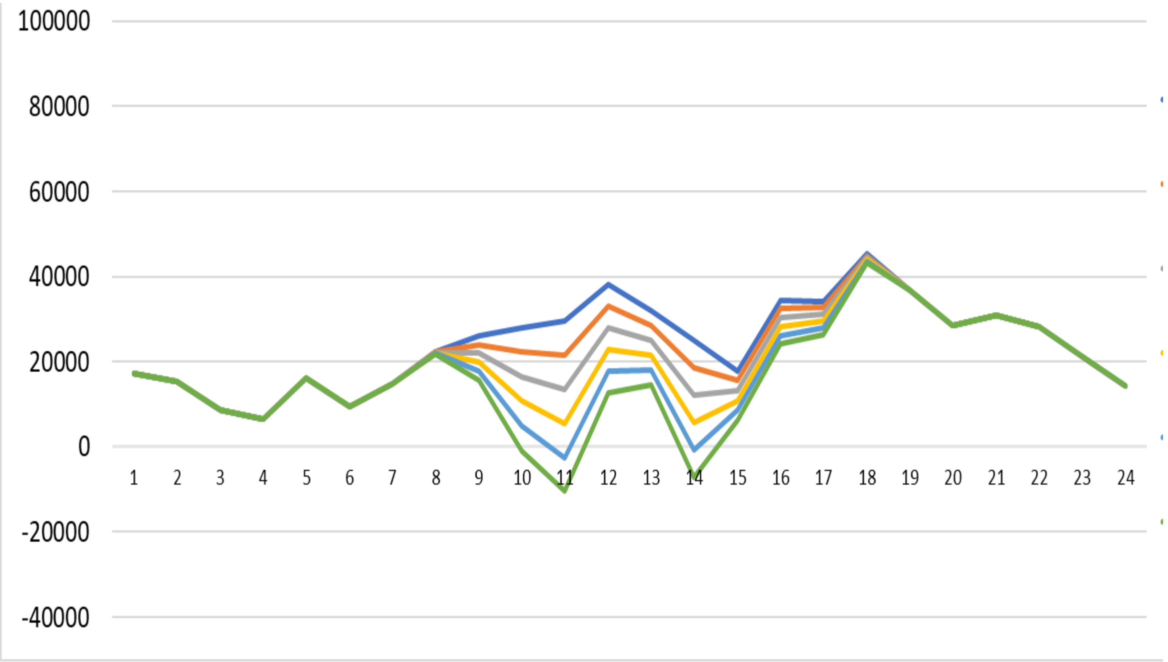
Net Load on Grid/Ramping Analysis

*Community Scale – **1000 Multifamily Buildings***

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)

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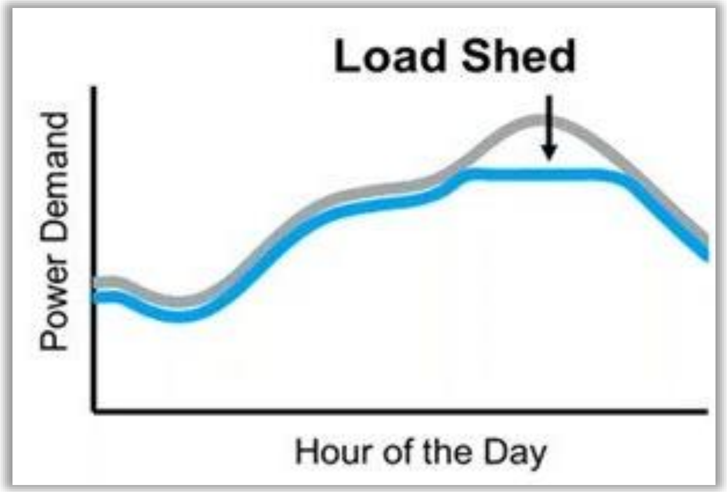
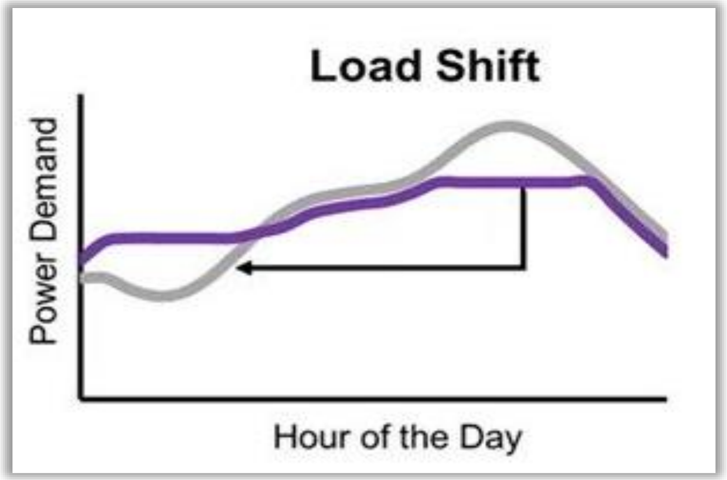
Load Shedding & Shifting

Utilizing the thermal storage capabilities of passive buildings.



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



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

DEMAND RESPONSE LOAD SHED SIMULATION

Summer & Winter | Chicago, IL

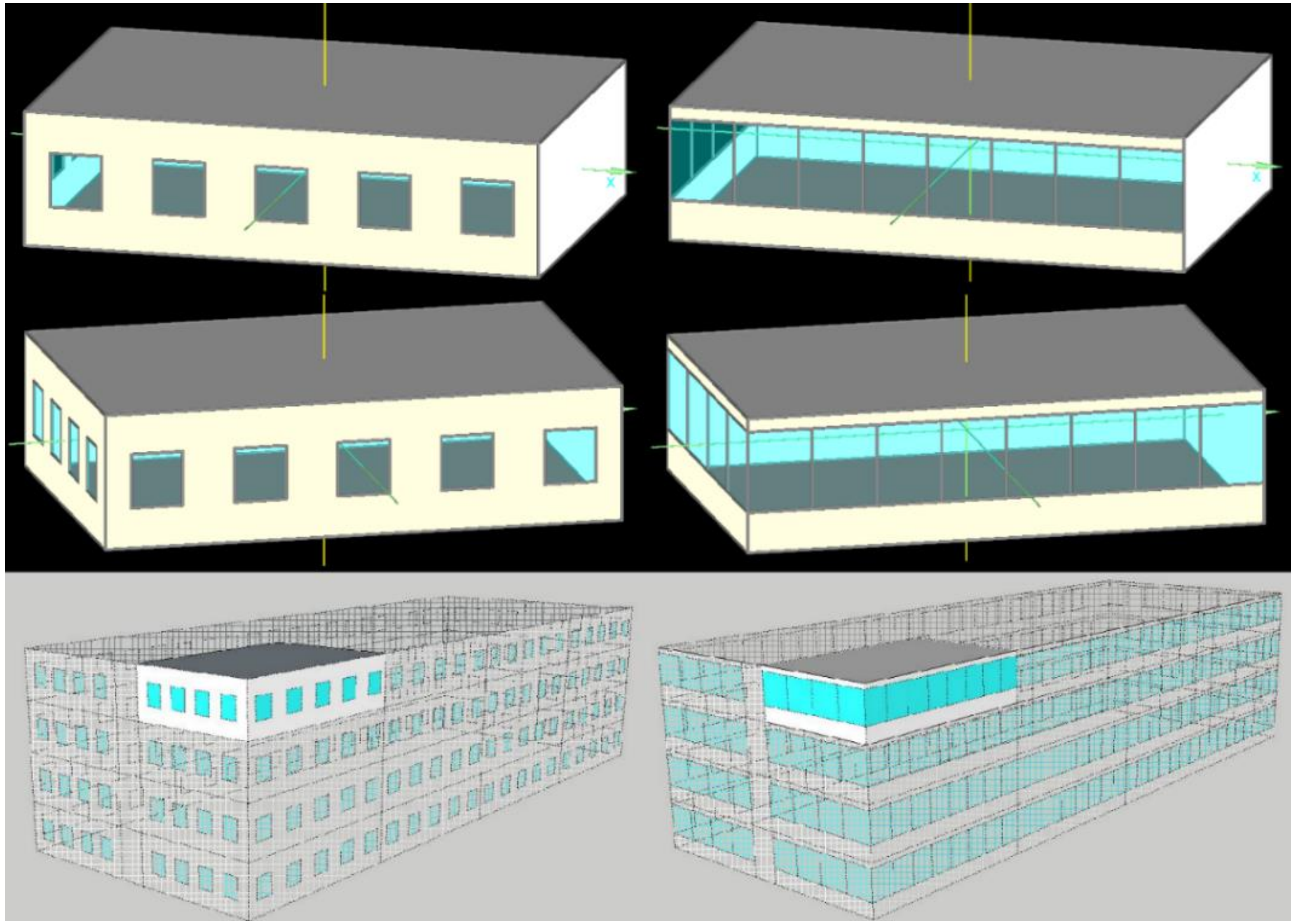
Single SW corner unit of study building, complies with PHIUS+ 2018 standard.

<u>Four Scenarios Evaluated:</u>

- 20% WWR – Low Mass
- 60% WWR – Low Mass
- 20% WWR – High Mass
- 60% WWR – High Mass

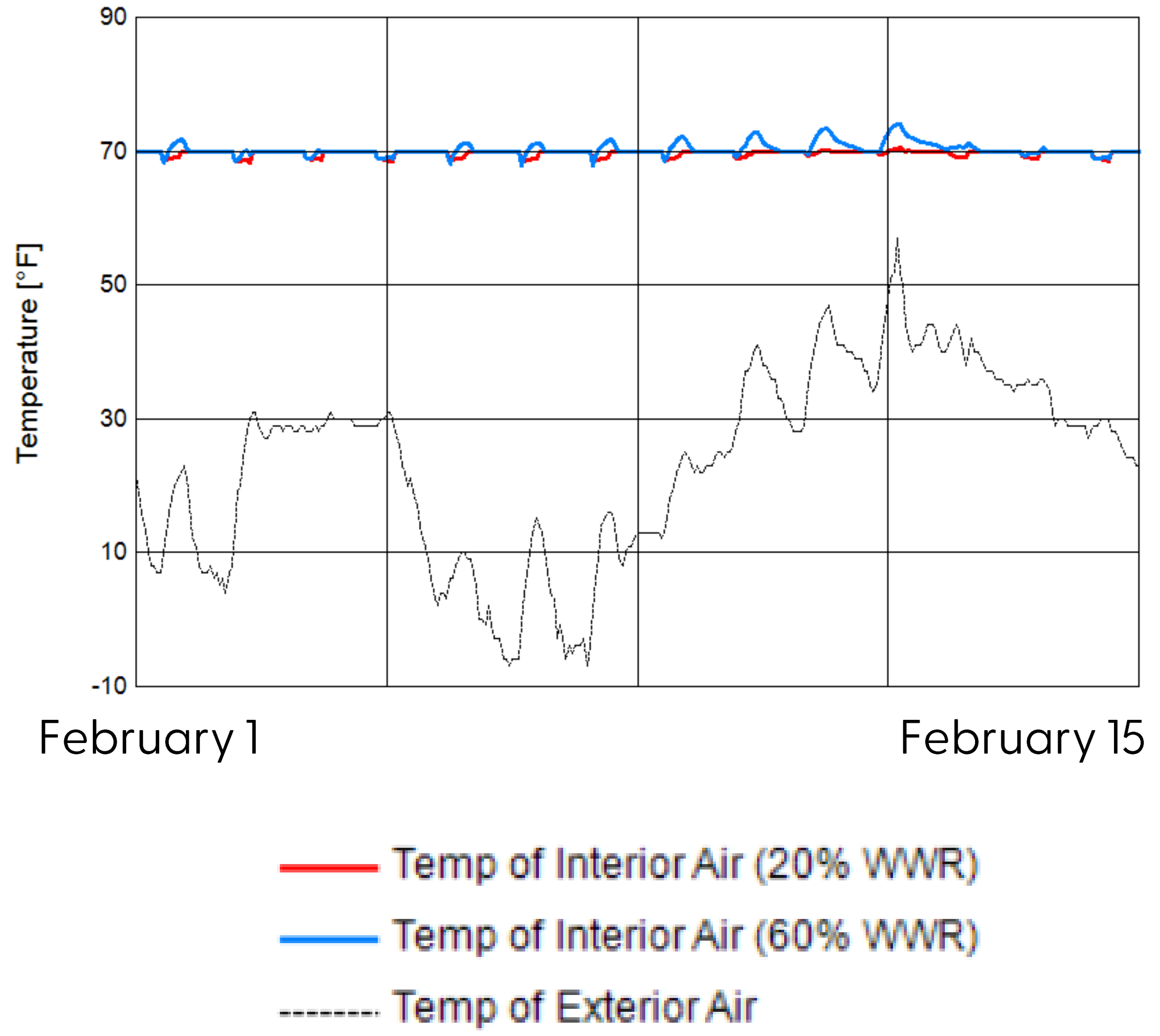
Removed all space heating capacity February 1 –15, 8am-2pm

Removed all cooling & dehumidification July 14-21, 3pm – 8pm

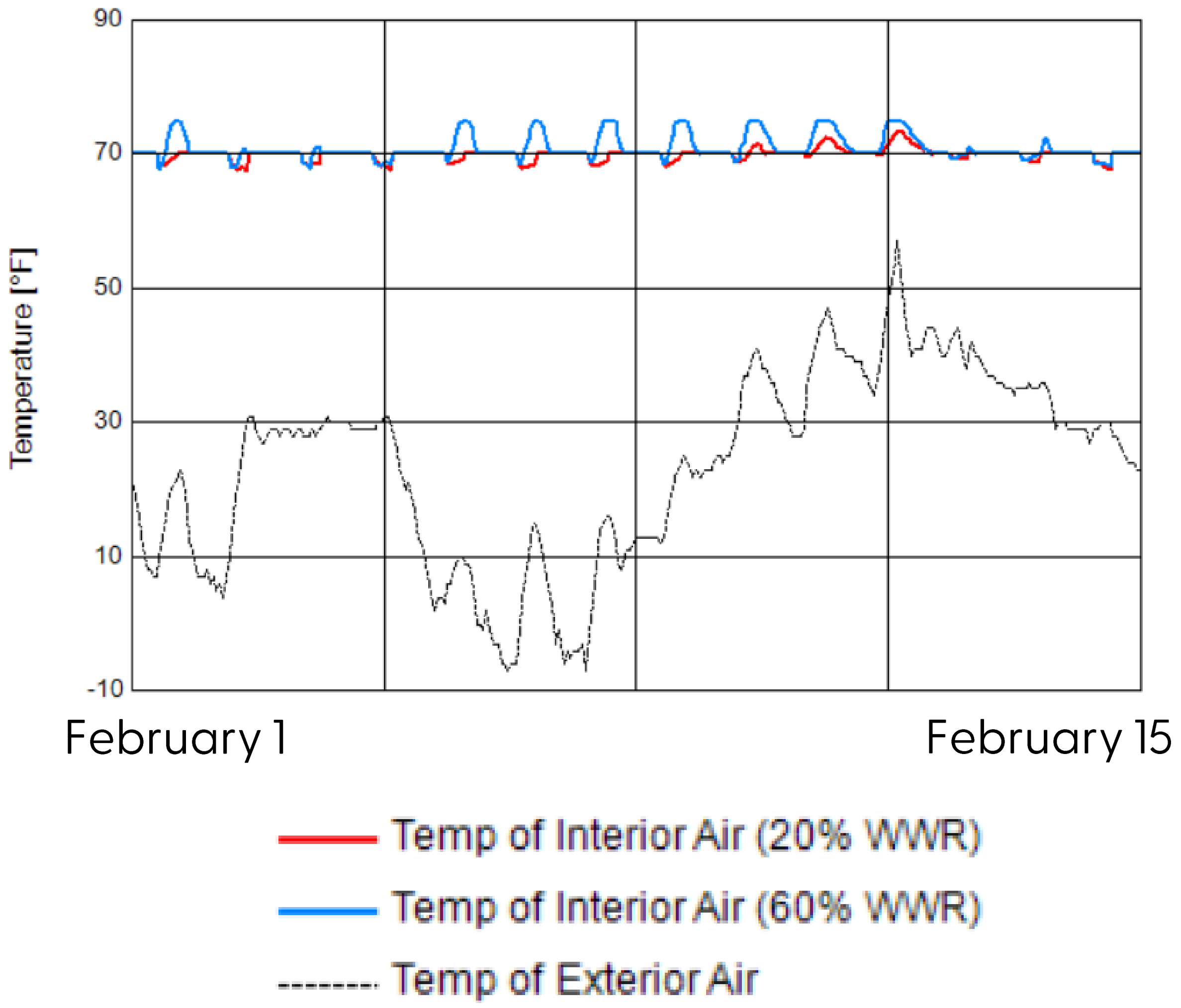


DEMAND RESPONSE LOAD SHED
NO HEATING FROM 8 AM - 2 PM FOR 2 WEEKS IN FEBRUARY

HIGH MASS



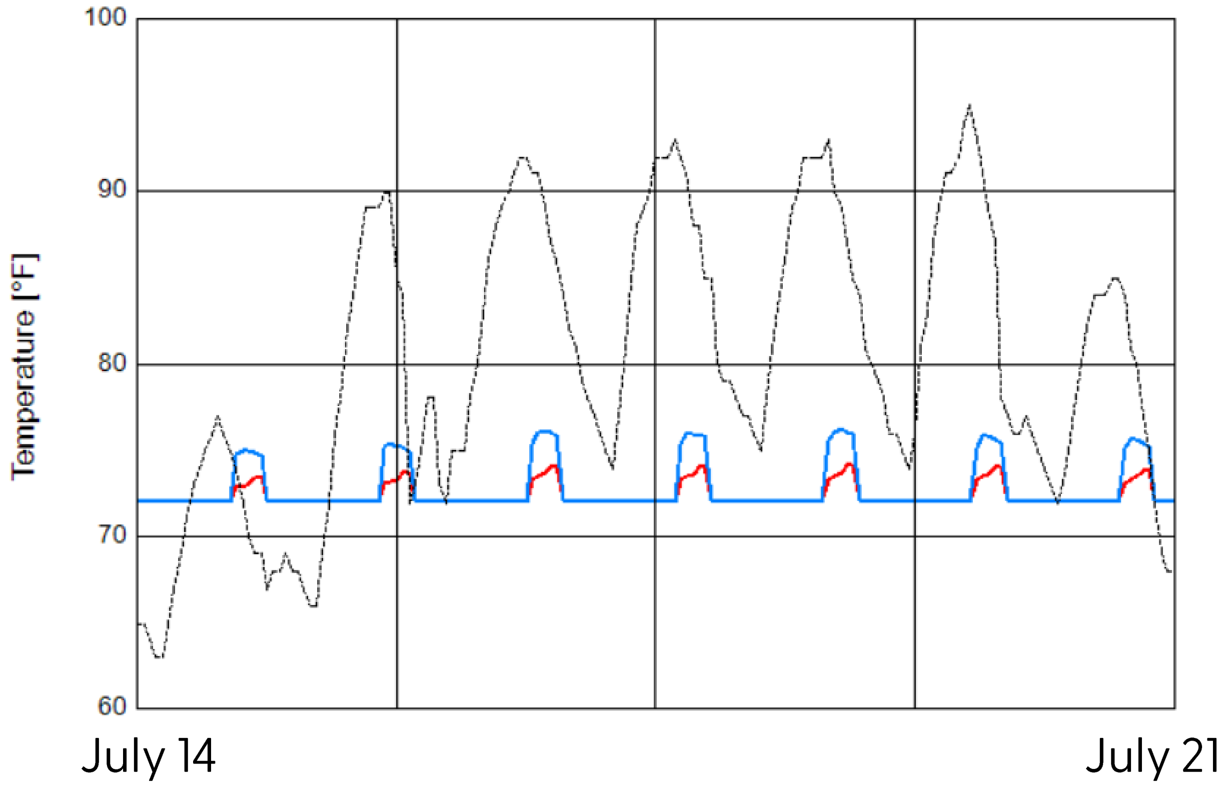
LOW MASS



DEMAND RESPONSE LOAD SHED

NO COOLING/DEHUM FROM 3-8 PM FOR A WEEK IN JULY

HIGH MASS

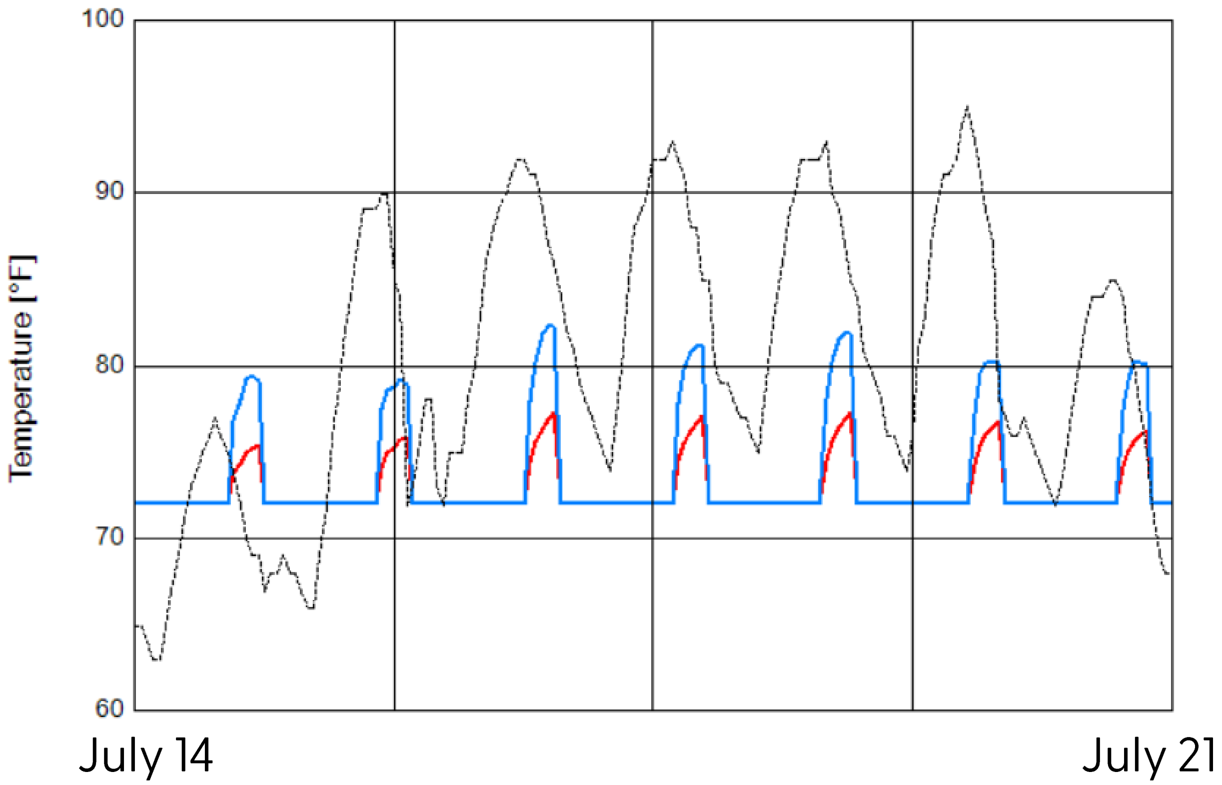


Temp of Interior Air (20% WWR)

Temp of Interior Air (60% WWR)

Temperature of exterior air

LOW MASS



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Temp of Interior Air (60% WWR)

Temperature of exterior air

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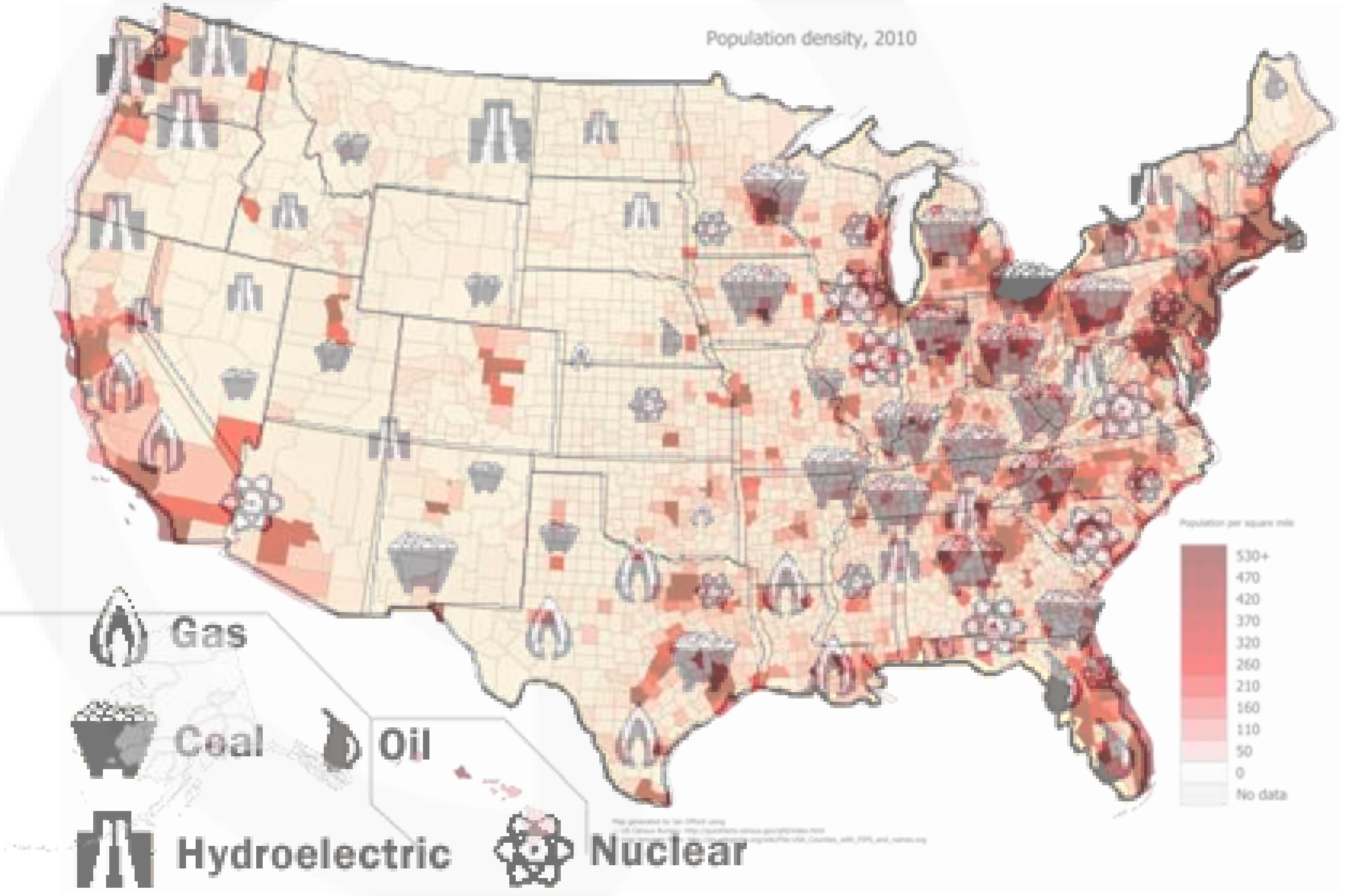
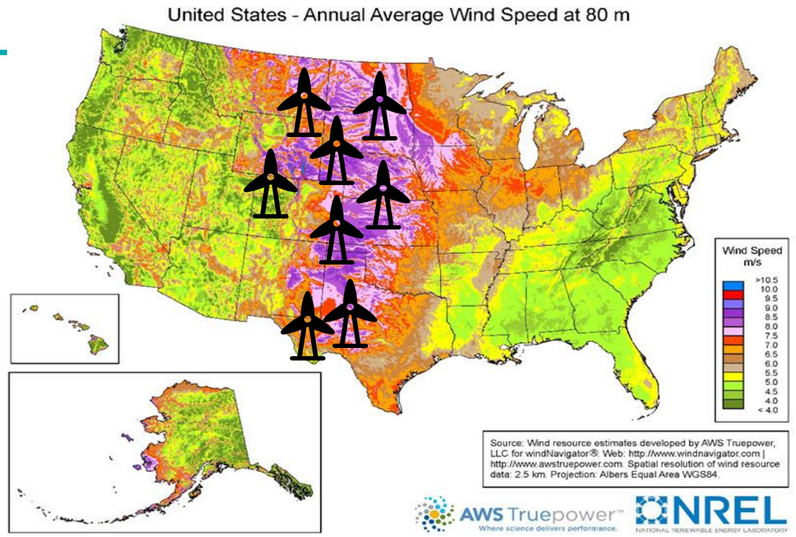
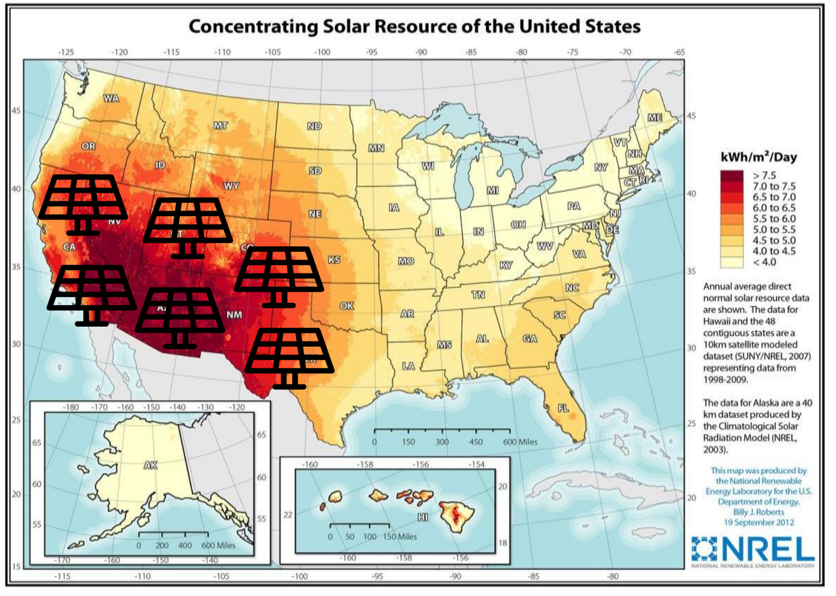
…So the electric load is increasing *while* we are trying to clean it up.

A breakdown of the major power plants in the United States, by type

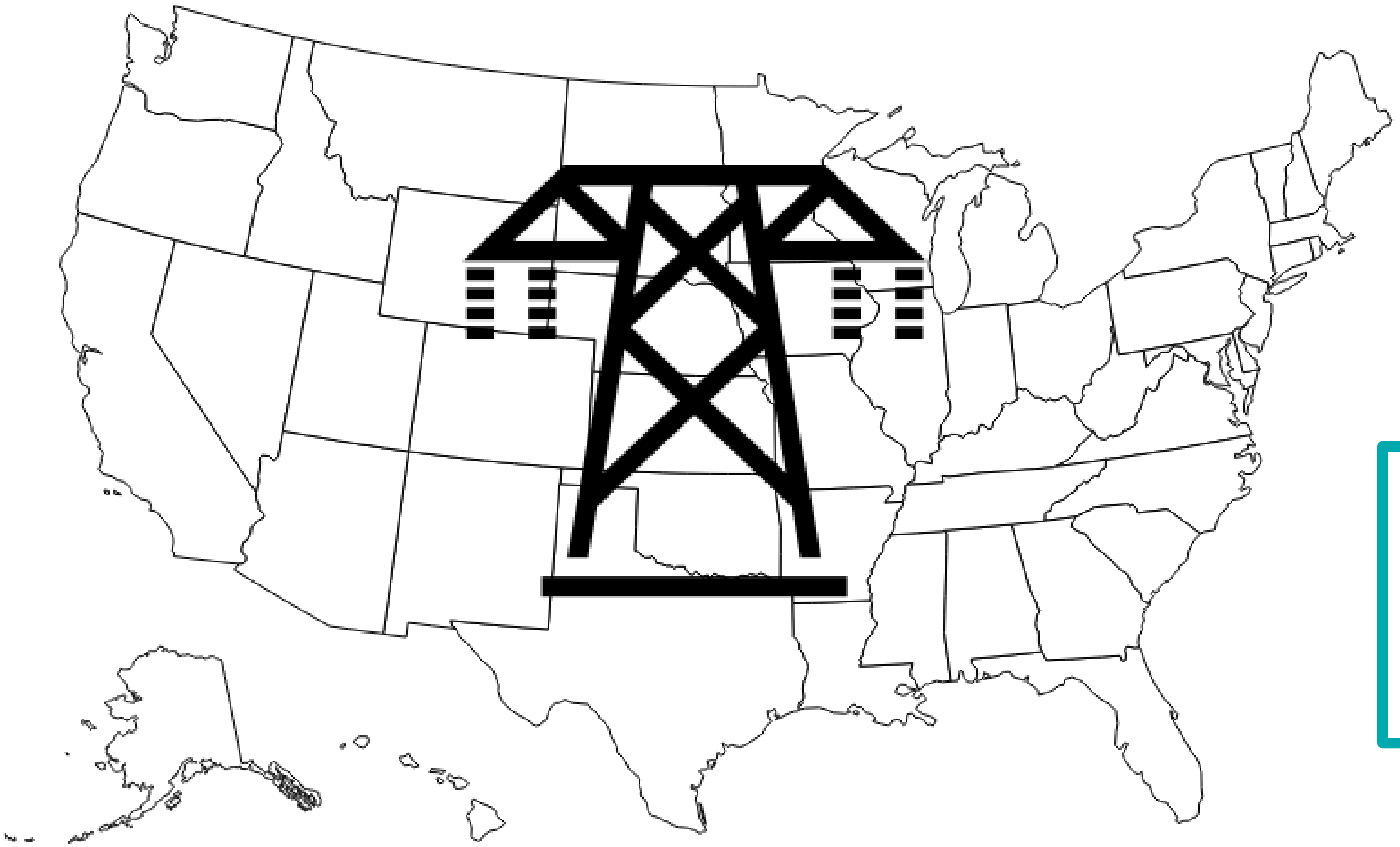






Lots of Future Investment in Transmission & Distribution

To get the resource to the load



And the "more" the lines need to carry, the more investment is needed.

__Lower peaks__, and **__lower annual energy use__** reduces the required investment in updating T&D.

The Opportunity – PhiusGEB

Phius ZERO + GEB

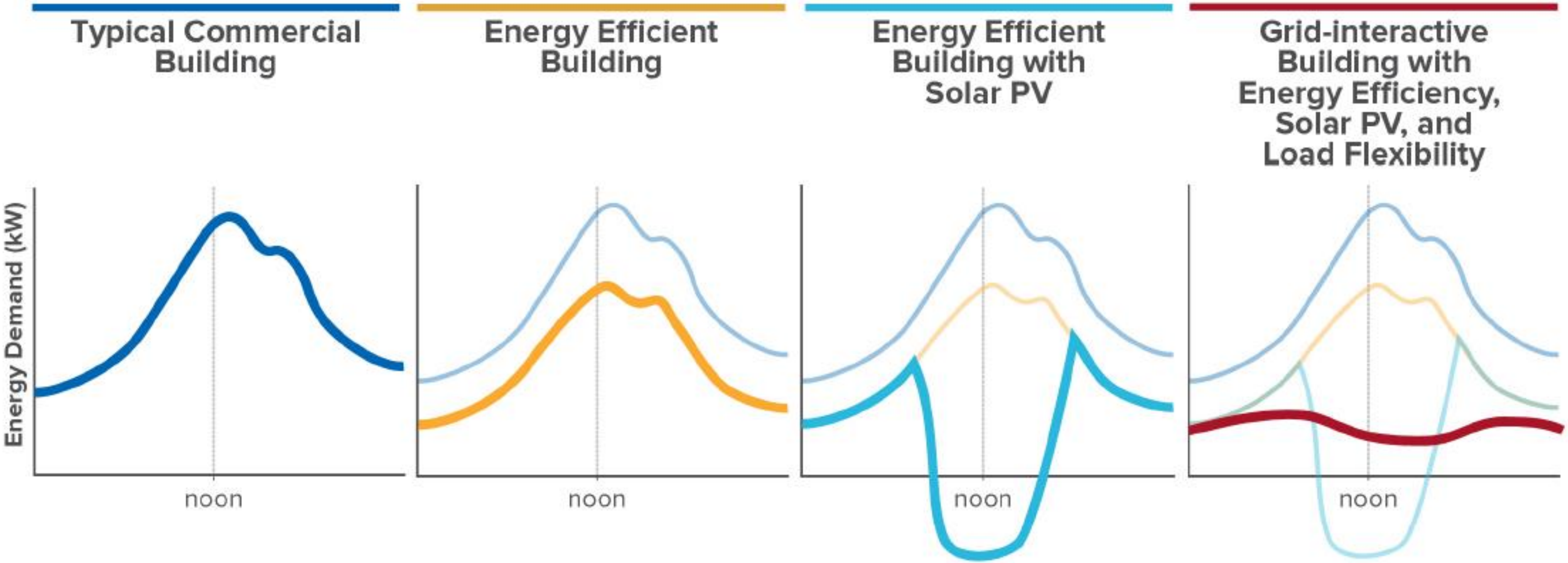
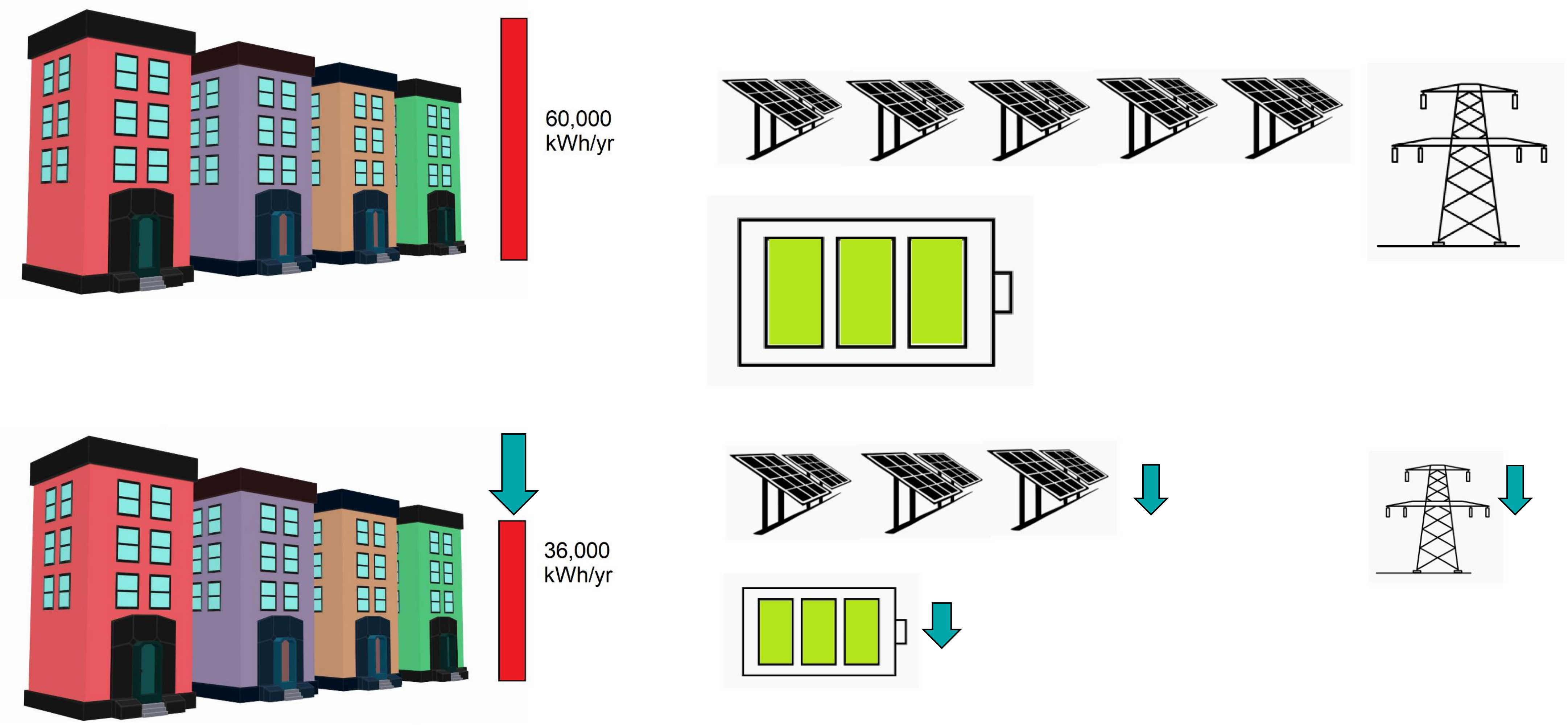


Image Source: RMI/GSA

The *Ripple Effect* of Conservation

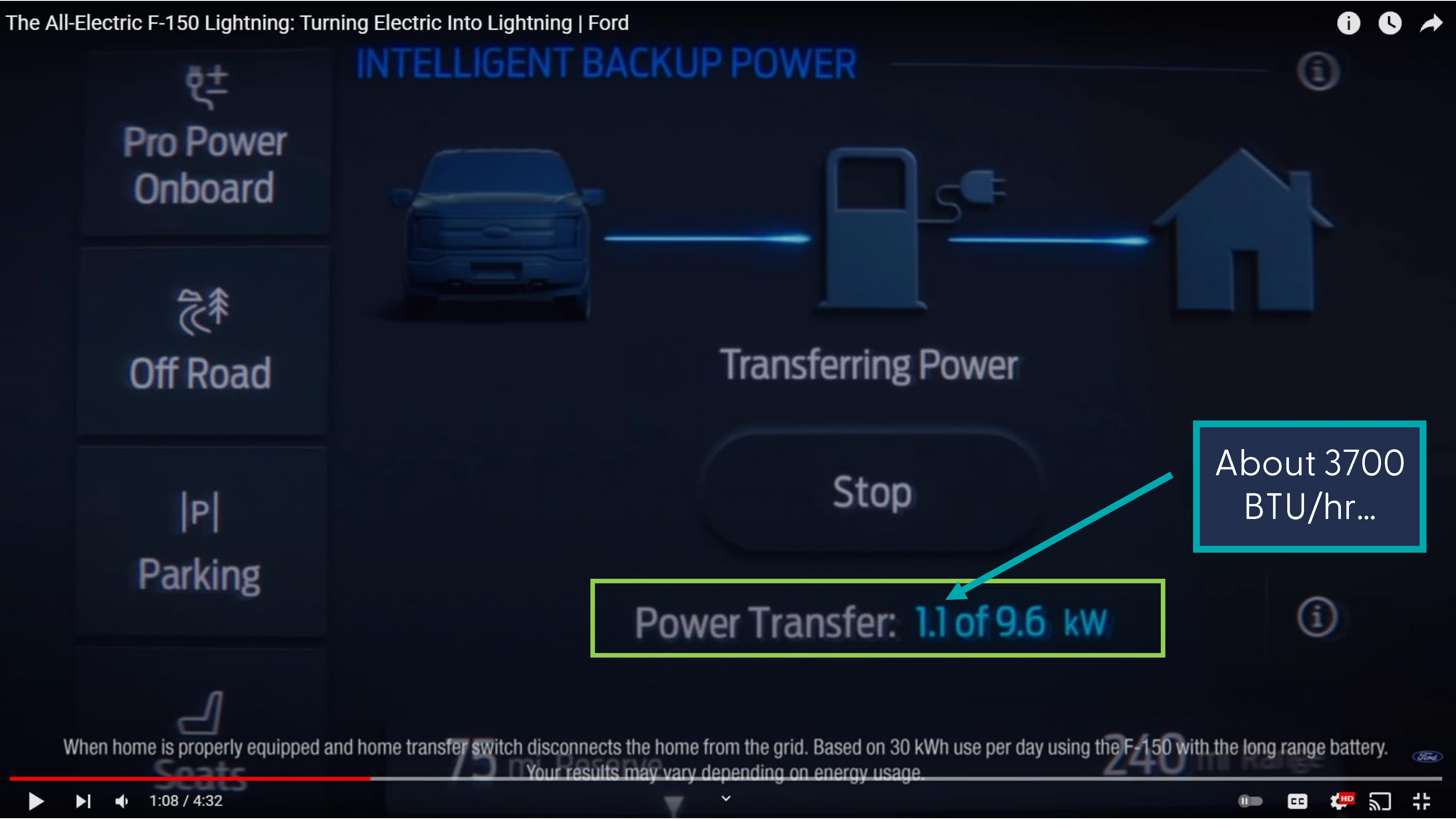
Conservation means less generation, less storage, and less transmission capacity needed



Resilience & Passive Survivability


The All-Electric F-150 Lightning: Turning Electric Into Lightning | Ford
1:03 / 4:32
© Phlus


The All-Electric F-150 Lightning: Turning Electric Into Lightning | Ford
1:06 / 4:32



The All-Electric F-150 Lightning: Turning Electric Into Lightning | Ford
INTELLIGENT BACKUP POWER
Pro Power Onboard
Off Road
|P|
Parking
Transferring Power
Stop
Power Transfer: 1.1 of 9.6 kW
About 3700 BTU/hr...
When home is properly equipped and home transfer switch disconnects the home from the grid. Based on 30 kWh use per day using the F-150 with the long range battery.
Your results may vary depending on energy usage.
1:08 / 4:32


The All-Electric F-150 Lightning: Turning Electric Into Lightning | Ford
9.6 kW
AVAILABLE INTELLIGENT BACKUP POWER
Based on 30 kWh use per day using the F-150 with the long range battery.
When home is properly equipped and home transfer switch disconnects the home from the grid. Based on 30 kWh use per day using the F-150 with the long range battery.
Your results may vary depending on energy usage.
1:12 / 4:32

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How A Texas Passive House Survived the 2021 Deep Freeze

Stacey Freed, Rise Writer
Mar 15, 2021 · 9 min read

US

Phius Certified Project

Austin, TX | ~1400 sf

3 Day Outage

60°F after one day

53°F after after the 2nd

-10°F outside

While not "comfortable", no risk of pipes freezing.

"The **house next to ours was identical to what ours was** before our Passive House remodel," says Trey Farmer, architect and principal of Forge Craft Architecture + Design in Austin, Texas. **"After 12 hours without power, it was below freezing inside in the home next door."**

NYC Manhattan Outages post Hurricane Sandy 2012

Many places left without power for > 5 days

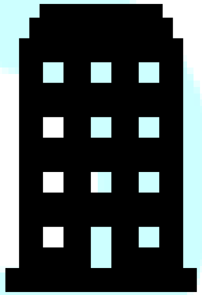
Passive Survivability

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

- *Alex Wilson, 2005*
  President, Resilient Design Institute

Metrics for Passive Survivability

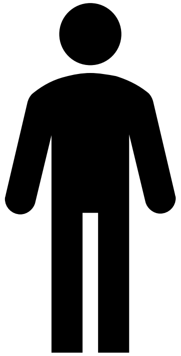
ASHRAE's *Thermal Environmental Conditions for Human Occupancy Standard* 55-2004



Indoor Summer Comfort Range: 74°F – 83°F

Indoor Winter Comfort Range: 67°F – 79°F

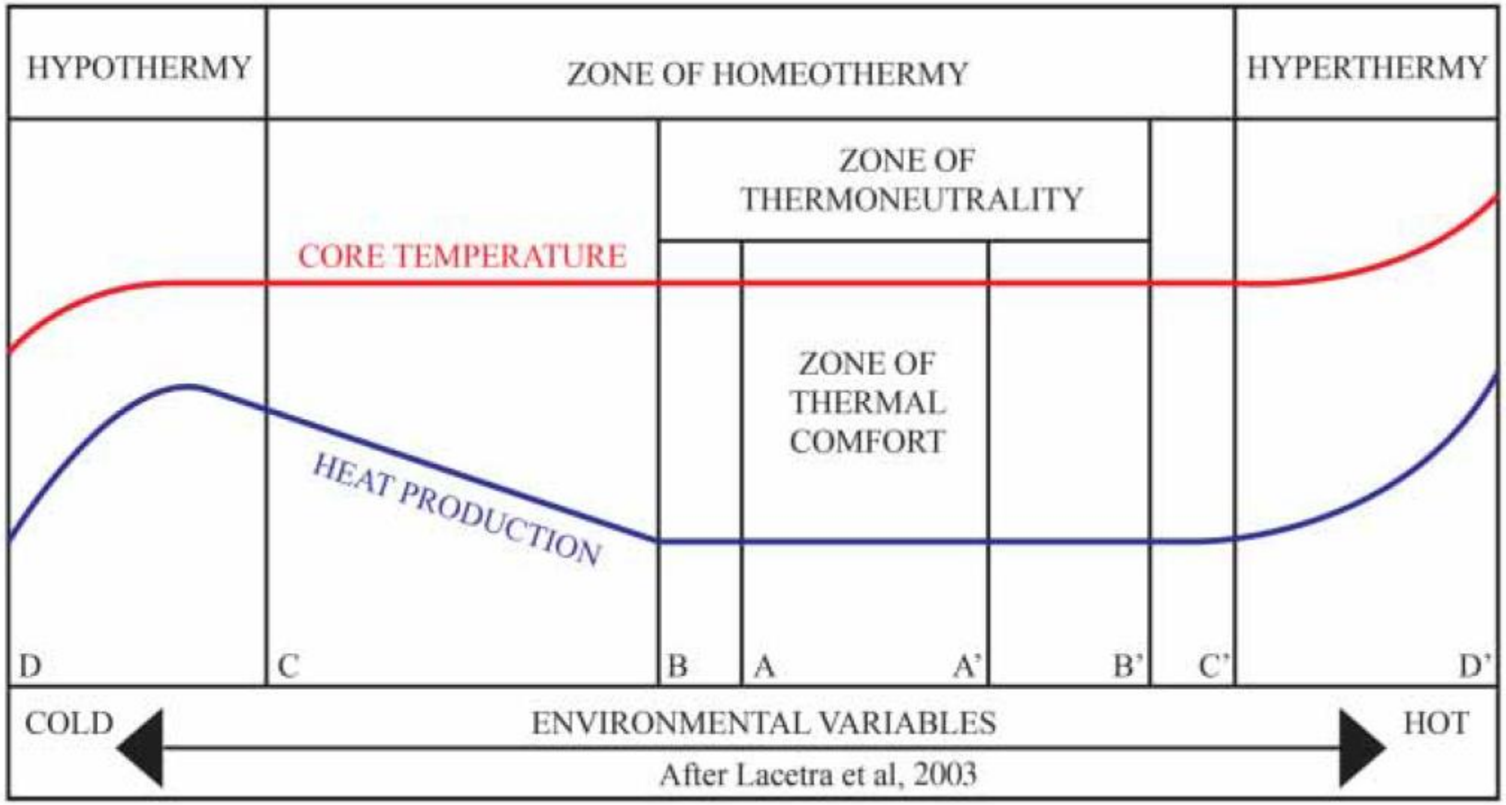
Acceptable for naturally ventilated spaces: 50°F – 93°F



Homeothermy: Form of temperature regulation used by humans, where the body maintains the same internal core temperature (98.6°F), regardless of external influences.

Metrics for Passive Survivability

Core body temperature estimates shown below.
This can vary significantly from person to person.



Person	~80^{o}F	~95^{o}F	~98^{o}F	~100^{o}F	~108^{o}F
Building	~???	50^{o}F	67-83^{o}F	93^{o}F	~???

Picture Courtesy of Holmes, S, et al. Overheating and passive habitability: indoor health and heat indices.

Assessment Overview & Variables

1) **Window to wall ratio**

    20%
    60%

2) **Building Performance Standards**

    ASHRAE 90.1-2013
    PHIUS+ 2015

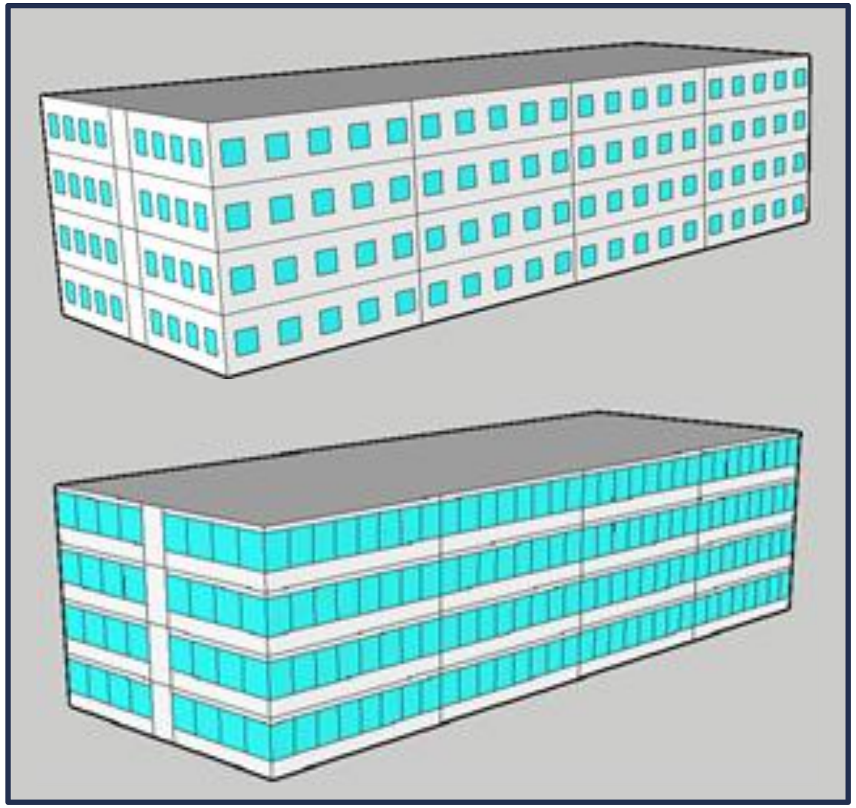
3) **Construction Types / Thermal Mass**

    Low Mass (Wood-framed)
    High Mass (concrete/insulated concrete forms)

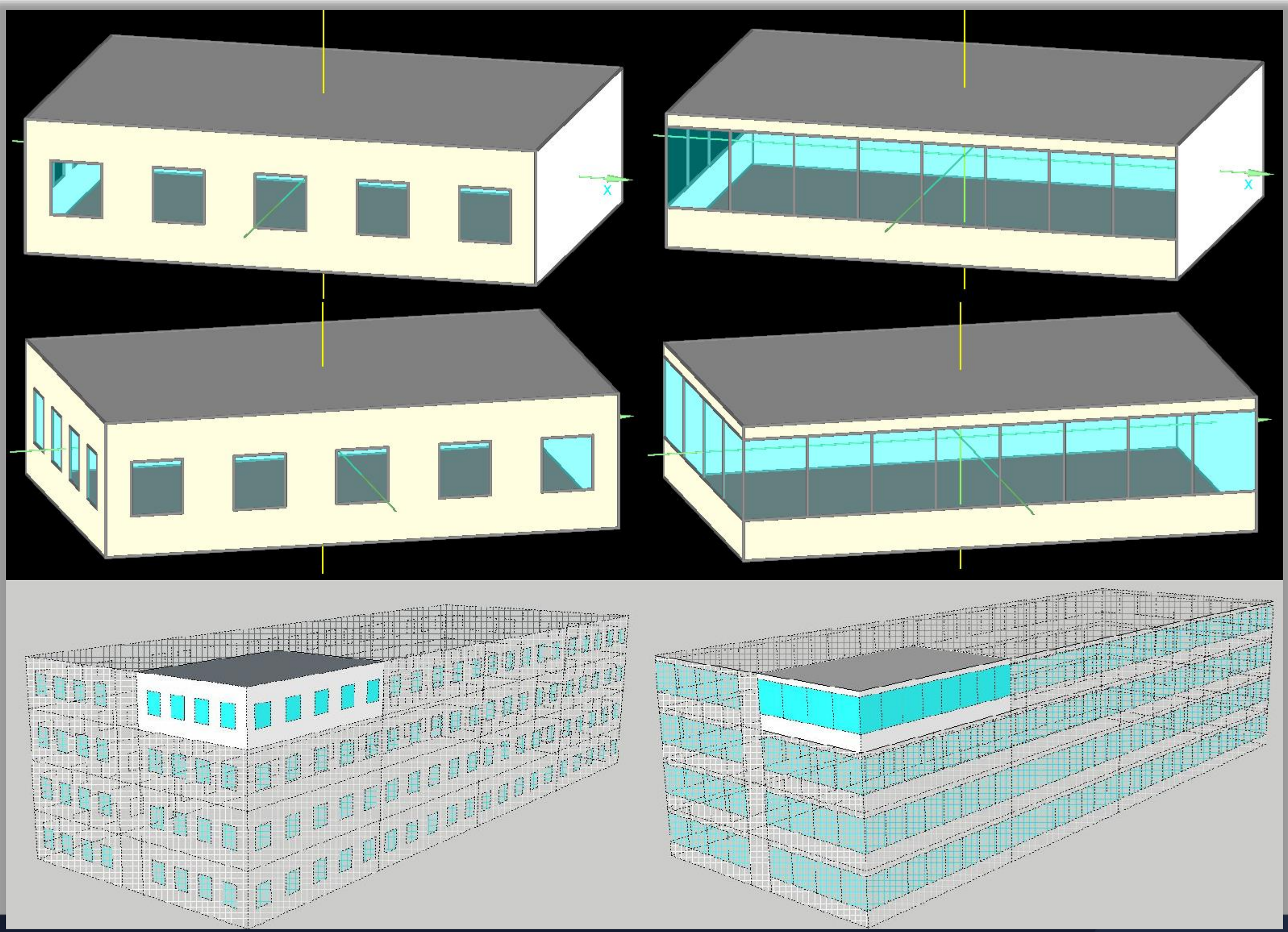
4) **Orientation of units**

    Southwest

    Northeast



OUTAGE SIMULATION SETUP



- 32 dynamic simulations
- Simulate power outage during **5-day resilience design week in Chicago, IL**

<u>Cover all combinations of:</u>

- 8 buildings (mass & performance)
- 2 dwelling unit orientations
- 2 seasons

WINTER RESILIENCE RESULTS

								% of Hours in Simulation Above Threshold Temperature											
Case	Season	Const. Type	Orientation	Standard	WWR %	Avg. Temp.	Min. Temp.	>65°F	>60°F	>55°F	>50°F	>45°F	< 40°F	< 35°F	< 30°F	>25°F	>20°F	>15°F	>10°F
1	Winter	Wood framed	SW	PHIUS	20	43.8	29.2	3%	14%	21%	32%	42%	53%	68%	97%	100%	100%	100%	100%
2					60	50.9	33.5	13%	27%	41%	47%	61%	78%	97%	100%	100%	100%	100%	100%
3				ASHRAE	20	32.0	18.1	0%	3%	7%	15%	19%	23%	36%	42%	54%	91%	100%	100%
4					60	28.5	14.4	0%	1%	6%	12%	17%	20%	27%	38%	41%	61%	98%	100%
5			NE	PHIUS	20	40.4	27.1	3%	8%	16%	22%	33%	42%	55%	81%	100%	100%	100%	100%
6					60	35.5	22.9	3%	5%	13%	18%	22%	33%	39%	47%	83%	100%	100%	100%
7				ASHRAE	20	30.3	17.7	2%	5%	8%	13%	18%	22%	28%	38%	45%	79%	100%	100%
8					60	21.8	10.3	2%	3%	4%	6%	8%	13%	16%	18%	22%	36%	60%	100%
9		Concrete/ICF	SW	PHIUS	20	57.6	49.2	12%	37%	62%	95%	100%	100%	100%	100%	100%	100%	100%	100%
10					60	57.3	46.8	11%	39%	59%	83%	100%	100%	100%	100%	100%	100%	100%	100%
11				ASHRAE	20	49.2	36.8	3%	16%	27%	42%	61%	84%	100%	100%	100%	100%	100%	100%
12					60	42.9	27.5	2%	10%	18%	29%	39%	48%	68%	93%	100%	100%	100%	100%
13			NE	PHIUS	20	56.3	47.9	7%	28%	53%	85%	100%	100%	100%	100%	100%	100%	100%	100%
14					60	53.2	43.1	3%	19%	38%	60%	93%	100%	100%	100%	100%	100%	100%	100%
15				ASHRAE	20	48.1	35.7	3%	13%	23%	38%	55%	79%	100%	100%	100%	100%	100%	100%
16					60	39.7	25.4	2%	6%	14%	20%	33%	40%	56%	78%	100%	100%	100%	100%

Percentage of hours ***above*** threshold temperature shown across the top

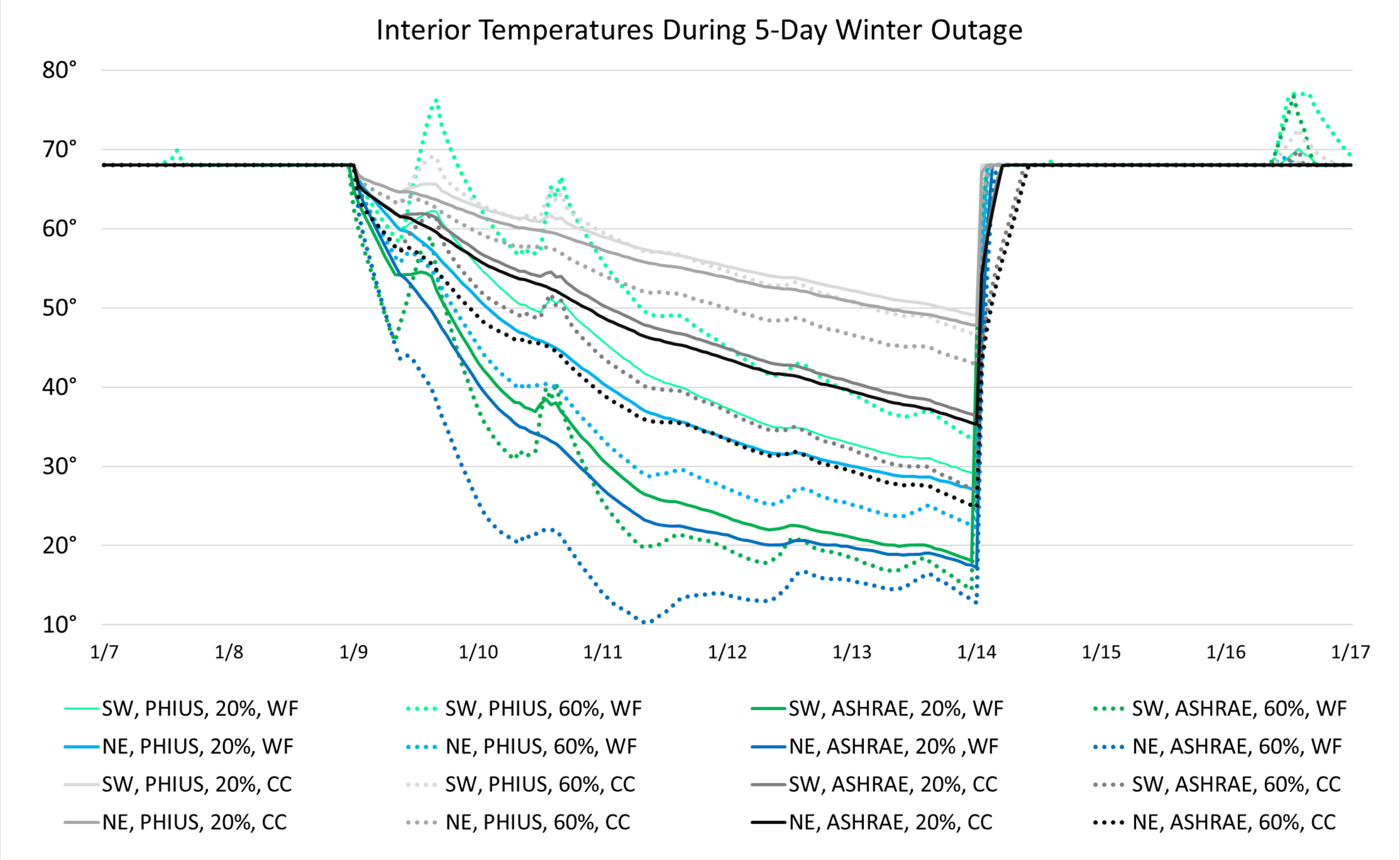
<50% = **red**
50-90% = **yellow**
>90% = **green**

WINTER RESILIENCE RESULTS

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

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

WINTER RESILIENCE RESULTS



Dotted Lines = More Windows

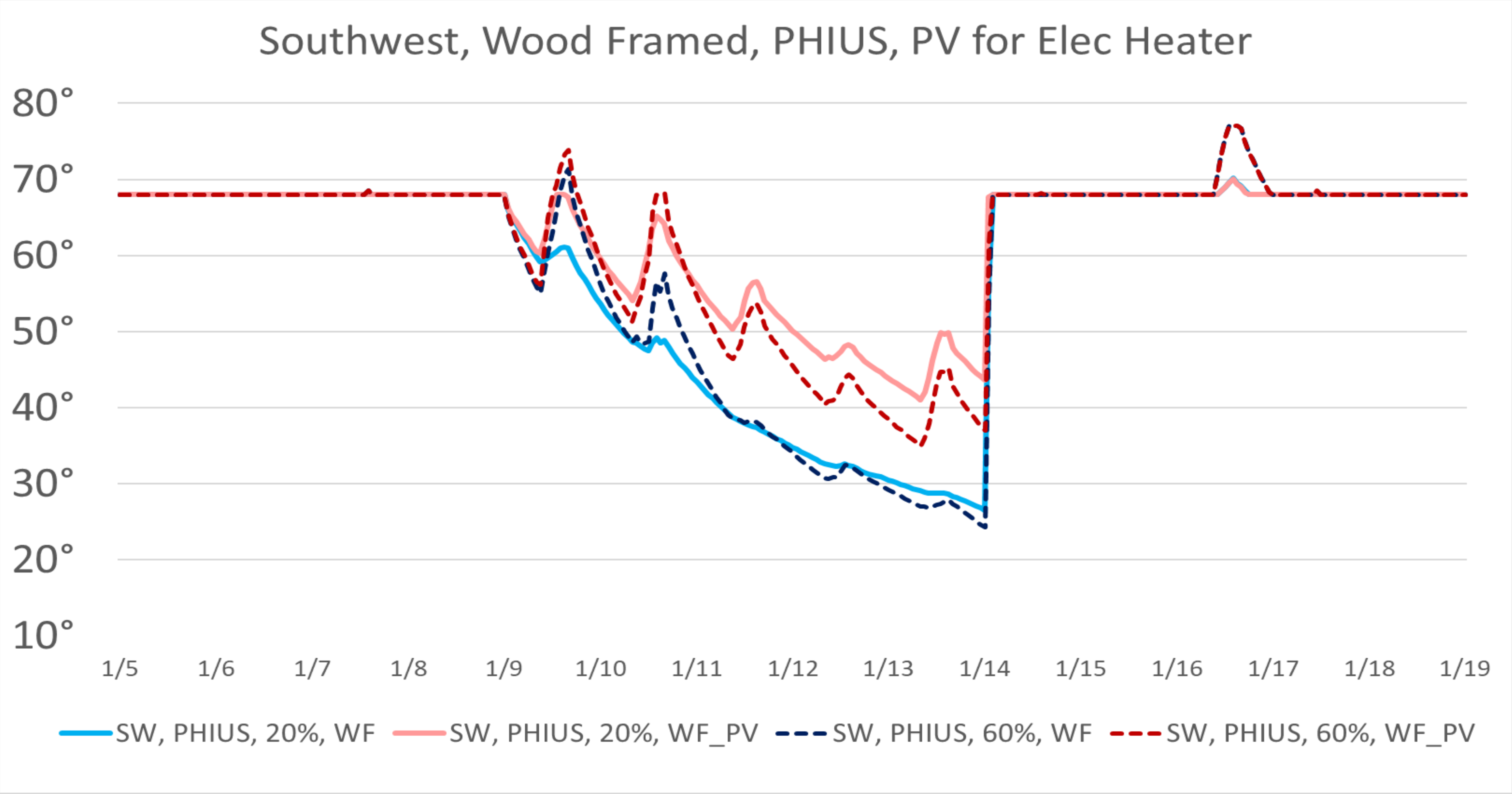
Gray/Black Lines = High Mass

Teal/Blue Lines = Low Mass

phius

WINTER RESILIENCE RESULTS

195 kW array, instantaneous PV output used for ventilation & electric resistance space heating during outage



Picture Courtesy of Lisa White

SUMMER RESILIENCE RESULTS

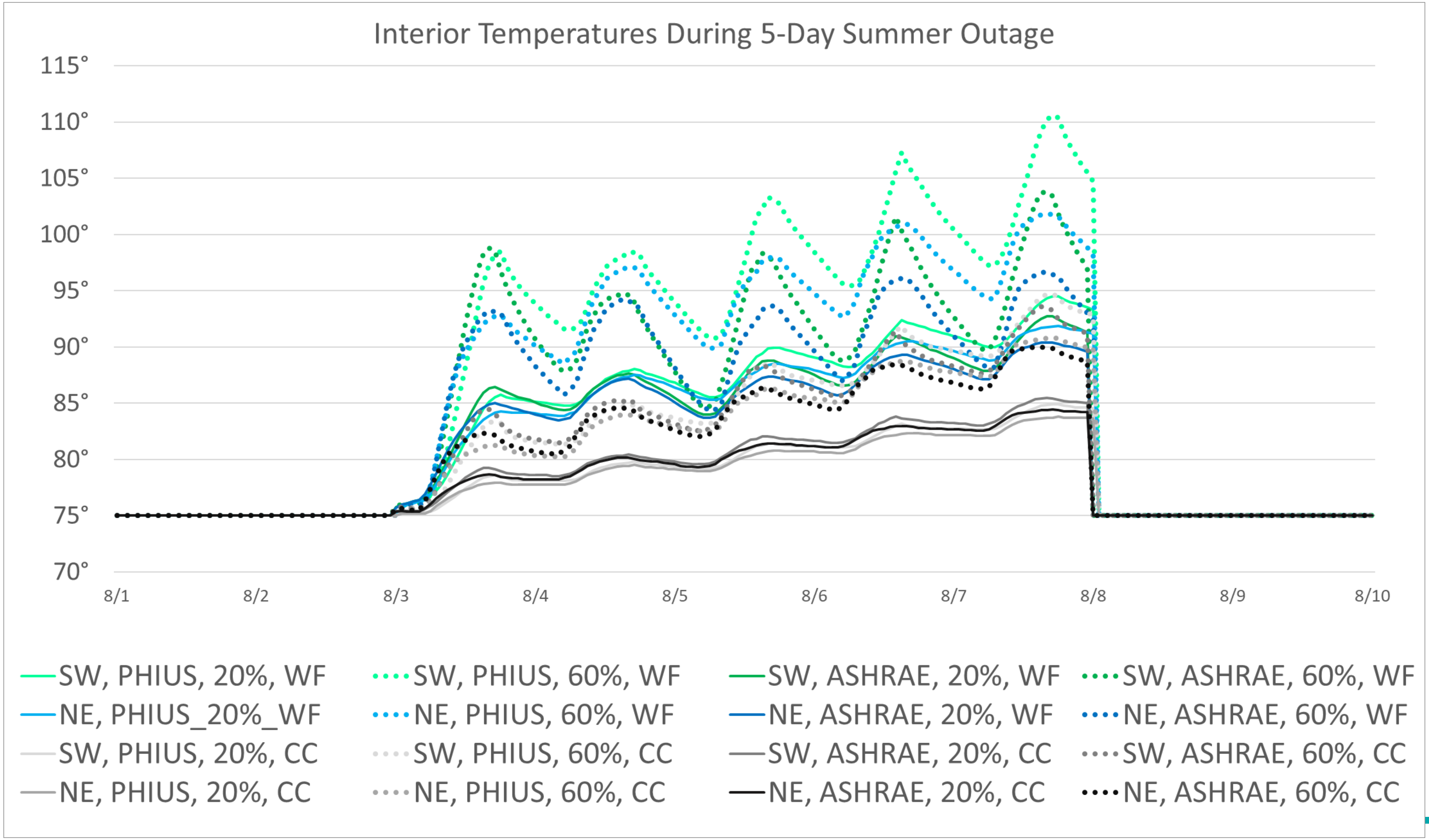
								% of Hours in Simulation Below Threshold Temperature							
Case	Season	Const. Type	Orientation	Standard	WWR %	Avg. Temp.	Max. Temp.	< 80°F	< 85°F	< 90°F	< 95°F	< 100°F	< 105°F	< 110°F	< 115°F
17	Summer	Wood framed	SW	PHIUS	20	81.6	94.5	59%	59%	70%	100%	100%	100%	100%	100%
18					60	86.0	110.6	59%	59%	59%	59%	76%	88%	98%	100%
19				ASHRAE	20	80.8	92.7	60%	60%	83%	100%	100%	100%	100%	100%
20					60	83.2	103.8	60%	60%	66%	80%	92%	100%	100%	100%
21			NE	PHIUS	20	81.1	91.9	59%	59%	81%	100%	100%	100%	100%	100%
22					60	84.3	101.9	59%	59%	59%	69%	87%	100%	100%	100%
23				ASHRAE	20	80.5	90.4	59%	59%	93%	100%	100%	100%	100%	100%
24					60	82.1	96.7	59%	59%	72%	88%	100%	100%	100%	100%
25		Concrete/ICF	SW	PHIUS	20	78.3	84.9	59%	100%	100%	100%	100%	100%	100%	100%
26					60	81.3	94.7	59%	59%	80%	100%	100%	100%	100%	100%
27				ASHRAE	20	78.5	85.5	59%	92%	100%	100%	100%	100%	100%	100%
28					60	80.9	93.6	59%	59%	83%	100%	100%	100%	100%	100%
29			NE	PHIUS	20	78.0	83.8	59%	100%	100%	100%	100%	100%	100%	100%
30					60	80.4	90.8	59%	60%	90%	100%	100%	100%	100%	100%
31				ASHRAE	20	78.2	84.4	59%	100%	100%	100%	100%	100%	100%	100%
32					60	80.1	90.0	59%	65%	100%	100%	100%	100%	100%	100%

Picture Courtesy of Lisa White

Percentage of hours ***below*** threshold temperature shown across the top

<50% = **red**
50-90% = **yellow**
>90% = **green**

SUMMER RESILIENCE RESULTS



Dotted Lines = More Windows

Gray/Black Lines = High Mass

Teal/Blue Lines = Low Mass

Picture Courtesy of Lisa White

Phius REVIVE *Pilot* Framework

REVIVE = Phius' existing retrofit program
REVIVE *Pilot* = Retrofit program in development

New Framework: Enclosure upgrades justified based on resilience (rather than cost optimization, how the existing program is framed)

→Winter = Limiting number of degree hours below 54°F to 216, in a 7-day simulation (somewhat aligned with LEED pilot credit)

→Limiting number of hours below 35F to 0 for equipment

→Summer = Using Heat Index (combo of temperature and Relative Humidity) and Mora et. Al "deadly days". Thresholds not determined.

Thanks!
Questions?

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