



Pathways to Grid-Interactive Efficient Buildings

PRESENTED BY: CLARK BROCKMAN AIA, LEED Fellow
KARINA HERSHBERG PE, LEED AP

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pae-engineers.com



seradesign.com



Objectives

1

Explain why green buildings need to move beyond “Net Zero”

2

Explain why building decarbonization needs to align to grid decarbonization

3

Walk through practical ways to make buildings good grid citizens

Agenda

PATHWAYS TO GRID-INTERACTIVE EFFICIENT BUILDINGS



Intro and Terminology



How It Works



Case Studies



Summary



Questions

WHAT IS A NET ZERO ENERGY BUILDING?

NREL DEFINITION:

**Zero energy buildings
produce at least as much
energy as they consume
on an annual basis.**

It's so easy to say and understand...

...who wouldn't want one?

Net Zero Energy: A Brief History

1998



The USGBC releases the first version of LEED, introducing the concept of "green building" to the world

2006



ILFI releases the first version of the Living Building Challenge, boldly requiring "Net Zero" everything for buildings

2007



Ferreira Construction builds the first net zero electric building in the US (42,000 sf)

2013



The Bullitt Center, the first commercial scale Living Building opens in Seattle

2019



United Therapeutics opens the "Unisphere" and at 135,000sf, it's one of the world's largest net zero buildings

2022



PAE opens their new Living Building in Portland, and at 58,000 s.f., it's the world's largest Living Building

Net Zero Energy: What has it gotten us?



Net Zero Energy: What has it gotten us?

—
Green building bragging rights,
smaller energy bills, and...



**...architects (and everyone else)
learning what EUI means!**



THE KENEDA BUILDING FOR INNOVATIVE SUSTAINABLE DESIGN | ATLANTA, GA

Credit: Lord Aeck Sargent and The Miller Hull Partnership

Net Zero Energy: What's actually happening?

 Planetizen



Renewable Energy Powers Entire State of California— for a Few Minutes

Last Saturday afternoon, thanks to a combination of high production and reduced consumption, California's power needs were met almost entirely by renewable energy sources.

Read Time: 1 minute

May 5, 2022, 9:00 AM PDT

By [Diana Ionescu](#)  [@aworkoffiction](#)

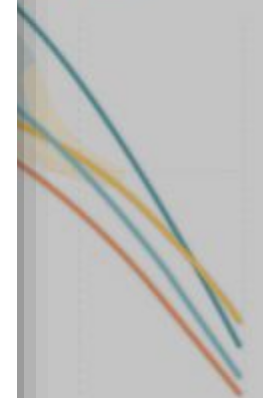
For a few minutes on the afternoon of April 3, California met almost 100 percent of its electricity needs using renewable energy.



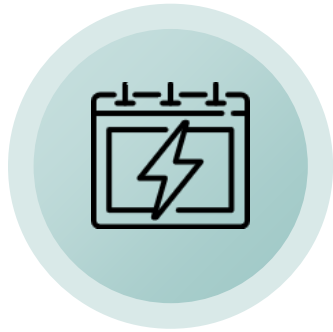
As more solar p
operators are d
can be visualiz

[The Solar Pow](#)
© Visual Capit

Solar production wanes as
the sun sets, just as demand
for energy peaks. Utility
companies have to ramp up
production to compensate
for this gap, often over-
stressing the grid.

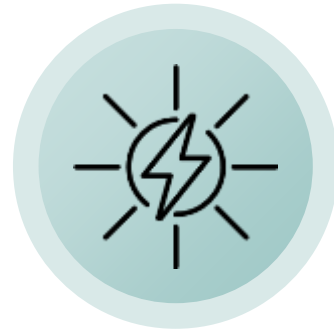


“Net Zero Energy” means...



Annualized

(i.e. compounded across the year)



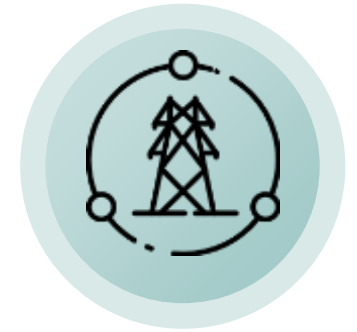
Energy is made when the sun is shining

(for solar)



“Hey Utility! Take all the clean energy I make and find a good use for it.”

(if you can)



When my building is not producing surplus renewable energy, it's buying energy from the grid...

whatever energy is flowing on the grid at that time.



“Net Zero Energy” is not...



**Addressing
operational carbon
emissions**



“Zero Carbon”



**The end game in
Green Building...**

But it is an important step
along the way.



**In fact, it’s likely that
due to the varying
carbon emissions
intensity of the grid,
most Net Zero Energy
buildings, in most
locations, are not Zero
Carbon Emissions.**



Unpacking Grid- Interactive Efficient Buildings

—

Why Do We Need Grid-Interactive Buildings?

Decarbonization



Resiliency



Cost Savings



Regulations

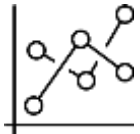


How to Talk Grid-Interactivity



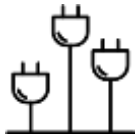
GRID-INTERACTIVE EFFICIENT BUILDING

(GEB) A GEB is efficient, able to shape it's load, and is highly interconnected



GRID PEAK CONTRIBUTION (GPC)

How much does your building contribute to rush hour on the grid?



DEMAND FLEXIBILITY (DF)

What can your building do about it?



GRIDOPTIMAL

A robust program by our own local resource NBI (New Buildings Institute)

**Note: This program is the framework for the relatively new [LEED pilot credit](#)*



LOVEJOY OFFICE BUILDING | PORTLAND, OR

Credit: Opsis Architecture



GRIDOPTIMALTM
BUILDINGS INITIATIVE

<https://newbuildings.org/gridoptimal/>

GRIDOPTIMAL™

BUILDINGS INITIATIVE

Launched mid-2018 and ongoing today

- *New building-grid interaction metrics*
- Metrics published ([blog](#), [white paper](#))
- Design and Operations [Guidance Materials](#)
- LEED Credit: GridOptimal Buildings [Alternative Compliance Path \(pilot credit\)](#)
- Utility Program guidance ([memo](#), [web dashboard](#))
- Code, standards, and policy development
- Pilot projects leading the market

A JOINT INITIATIVE OF:

nbi new buildings
institute



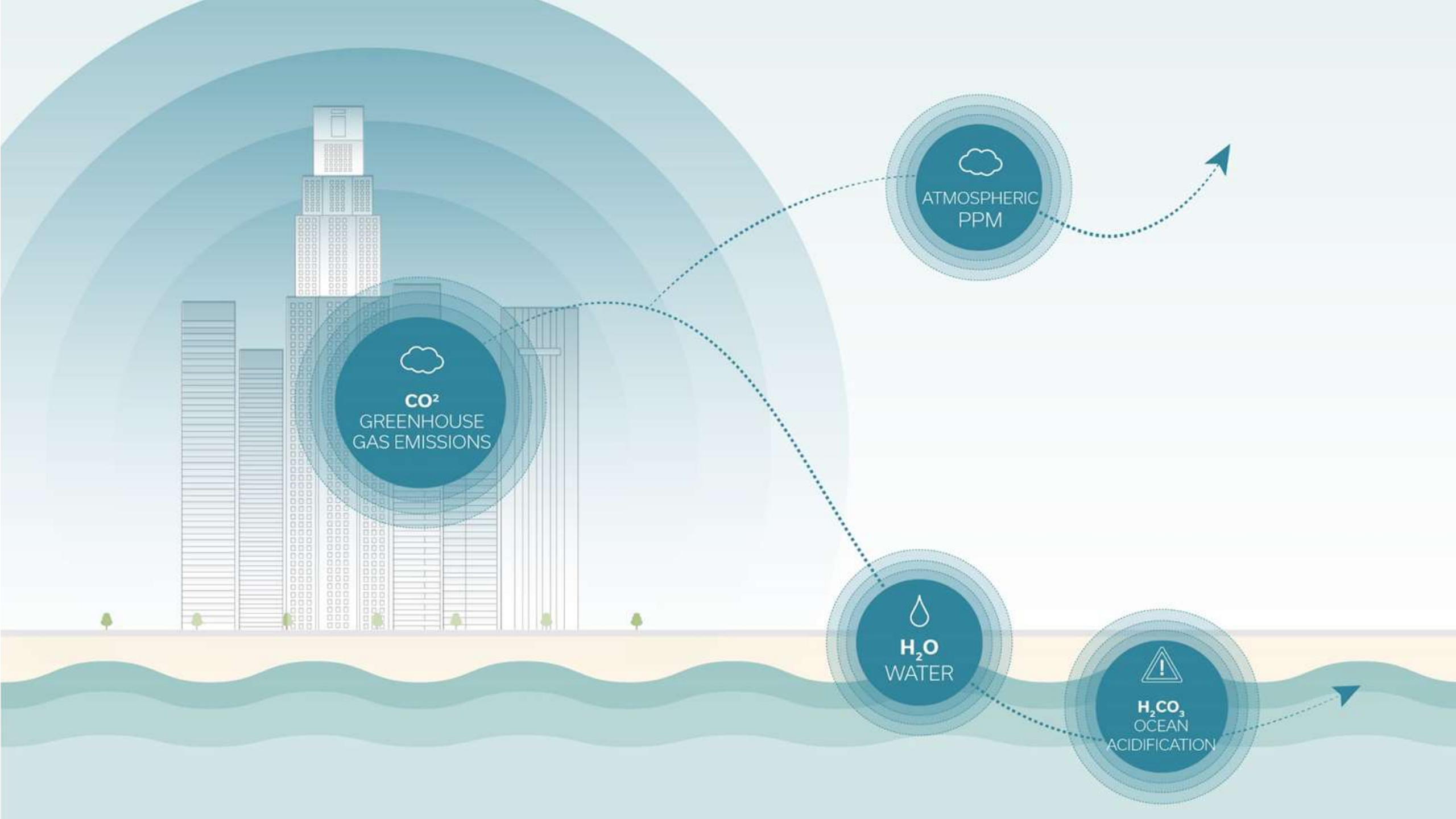
SUPPORTING MEMBERS:





Big Picture Context



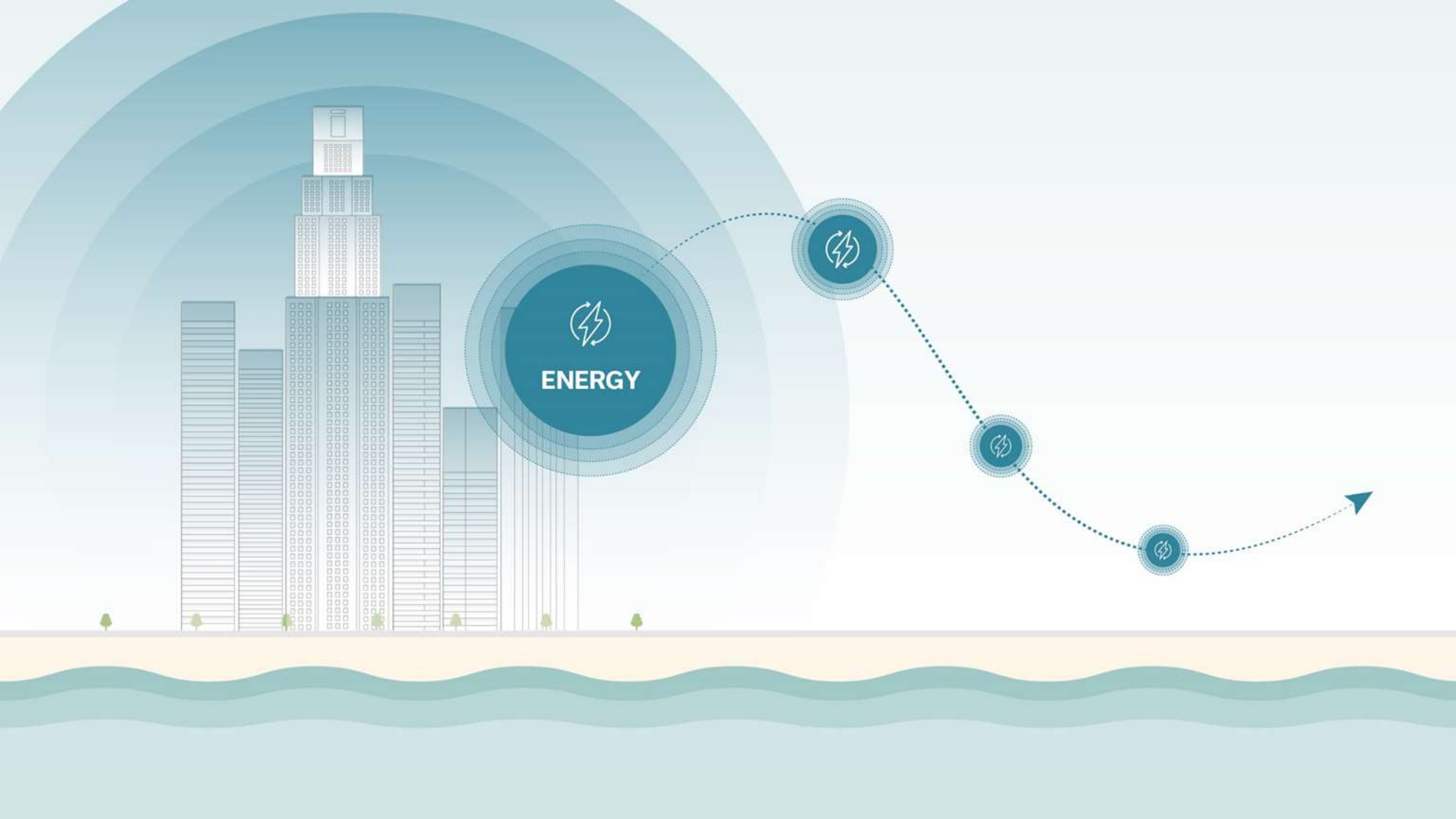


CO²
GREENHOUSE
GAS EMISSIONS

ATMOSPHERIC
PPM

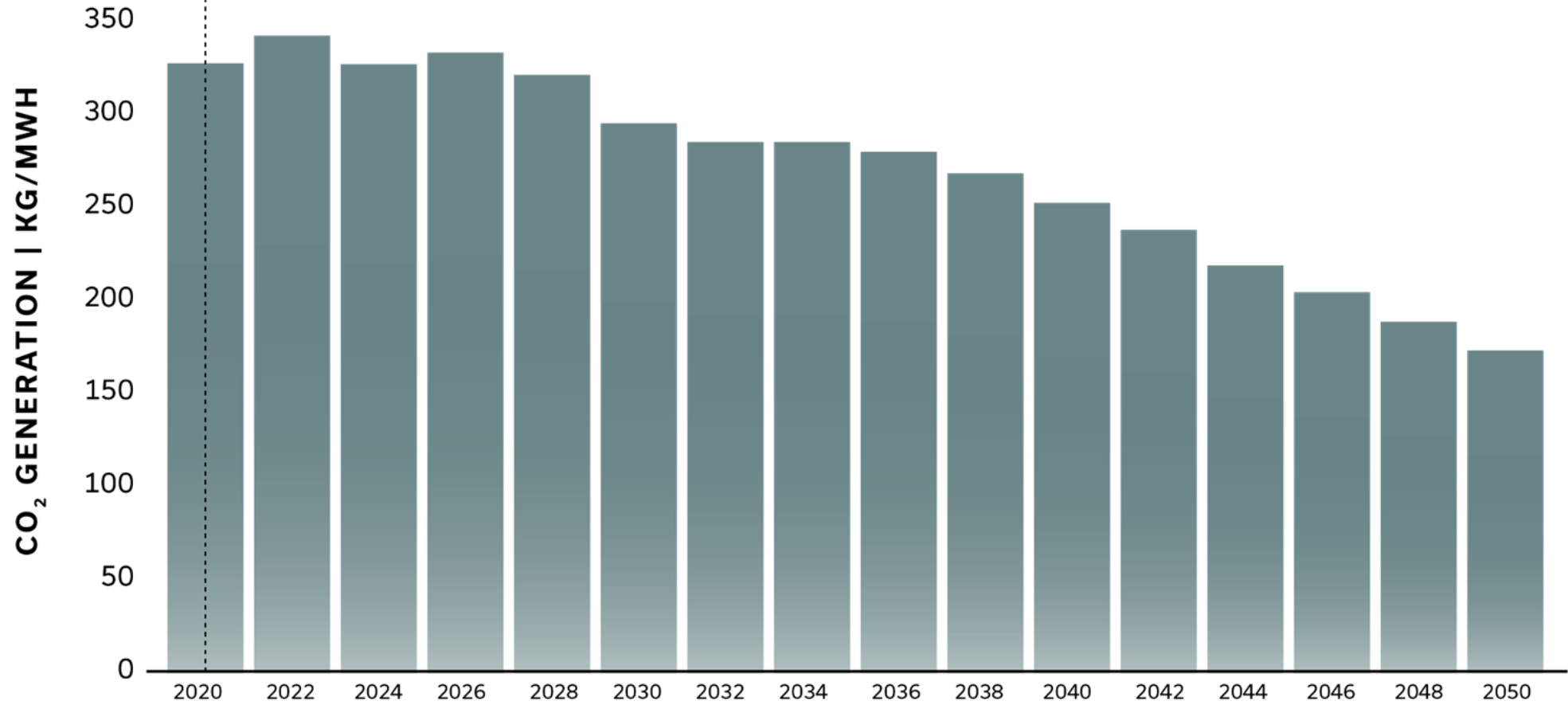
H₂O
WATER

H₂CO₃
OCEAN
ACIDIFICATION

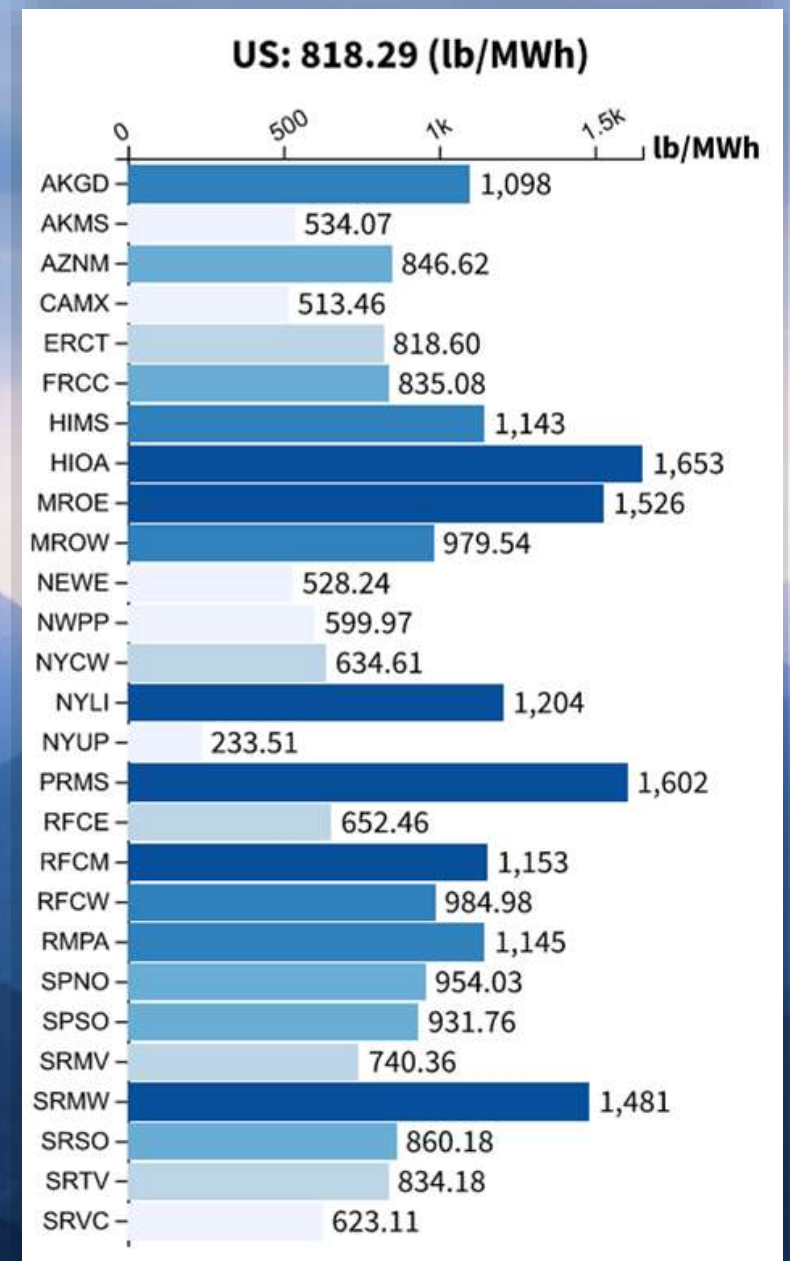
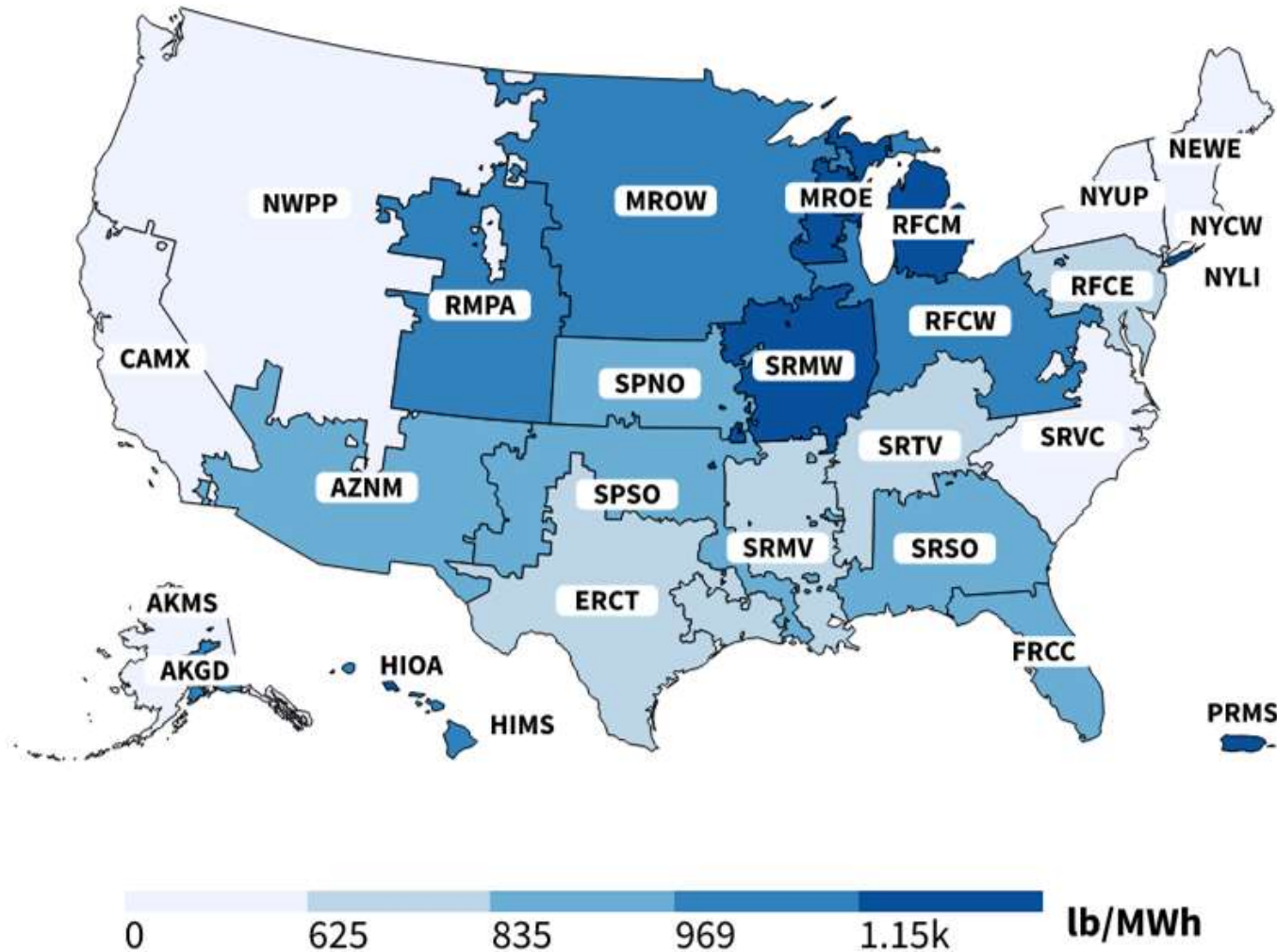


ENERGY

US Average Annual Electric Grid Emissions

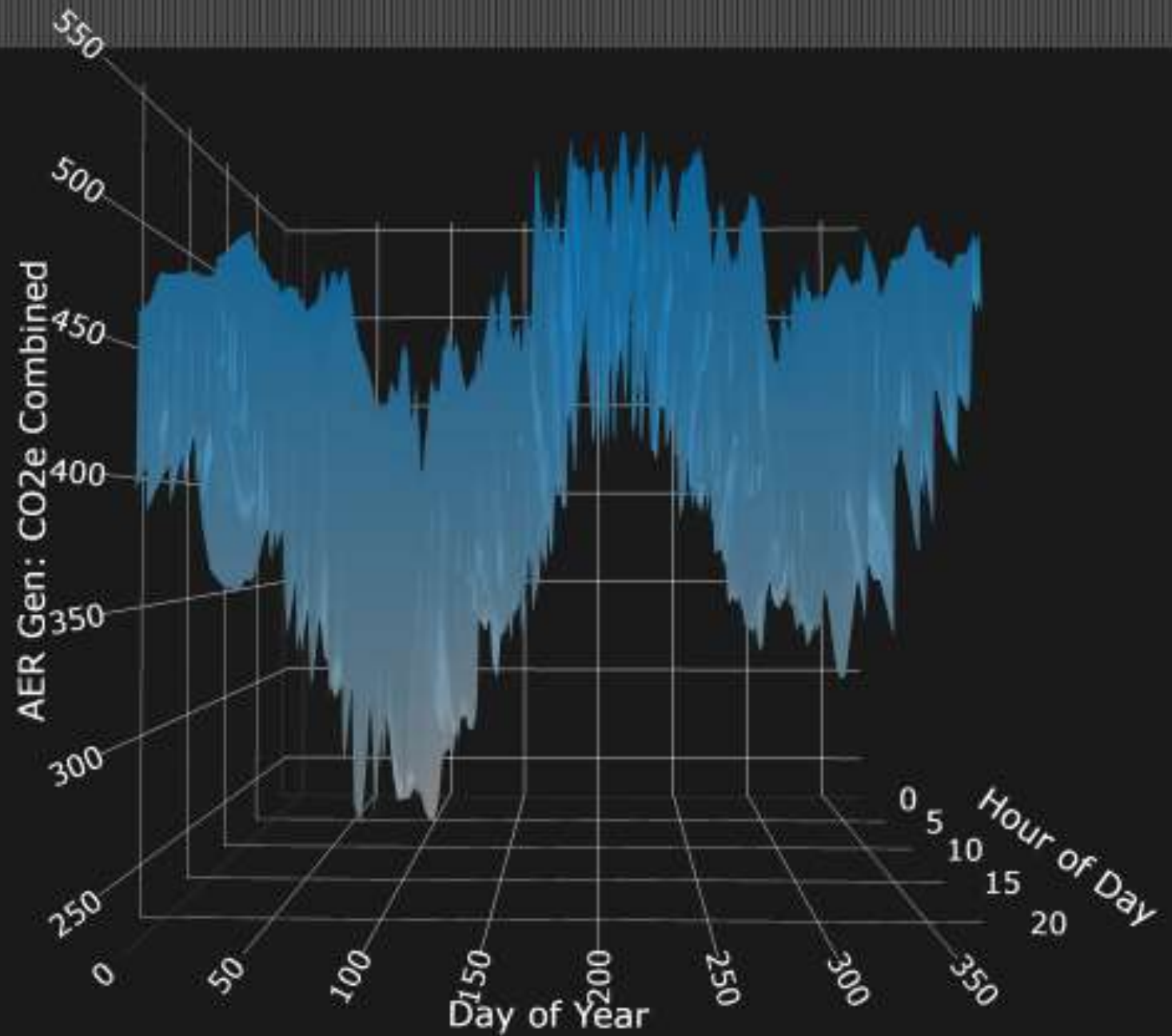


CO₂ Total Output Emission Rate (lb/MWh) by eGRID Subregion | 2020



Grid Emissions

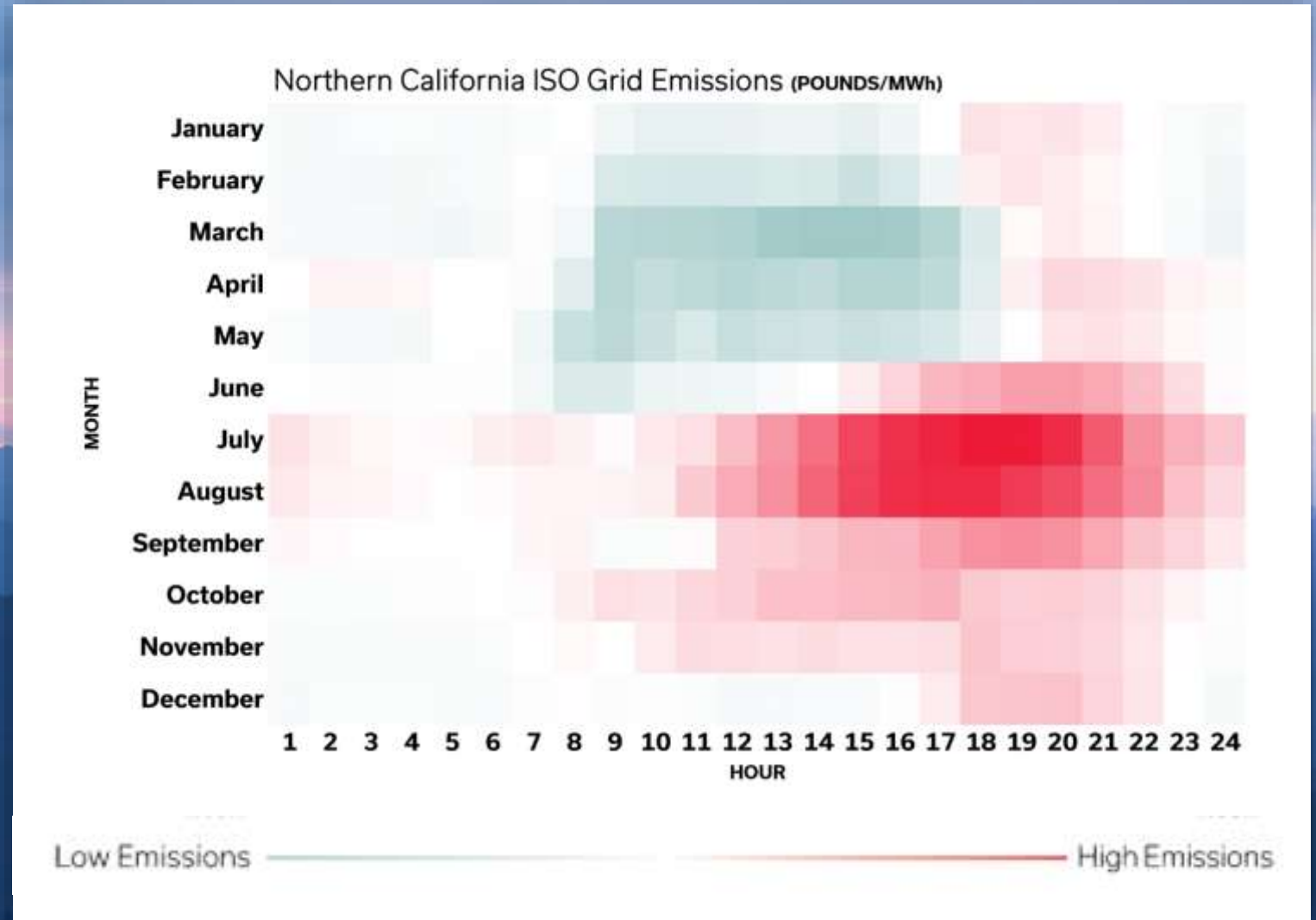
DYNAMIC + EVOLVING



Source: NREL Cambium Modeling

Time of Use Grid Emissions

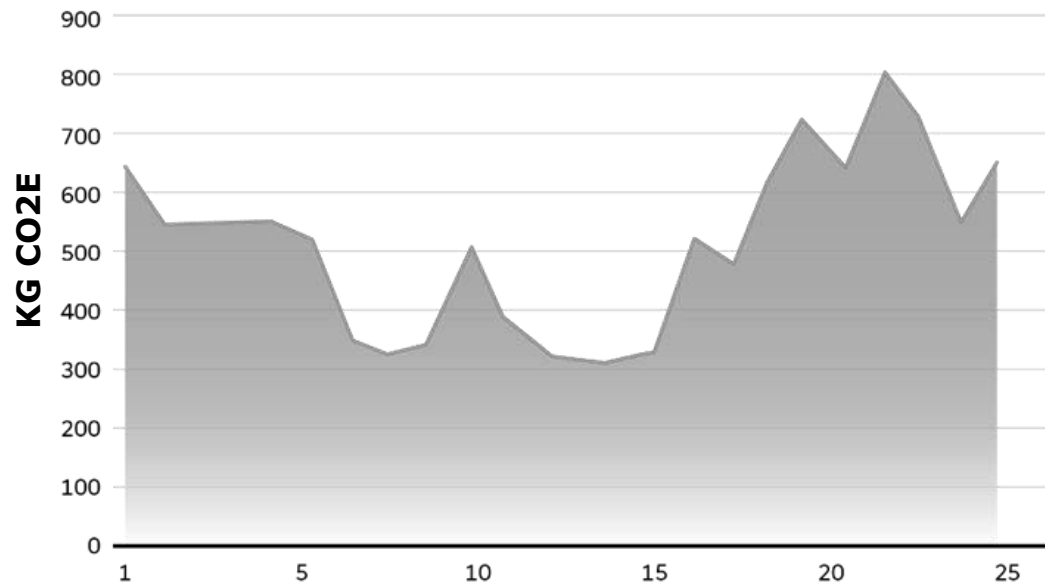
Annual utility emissions in time-of-use impacts



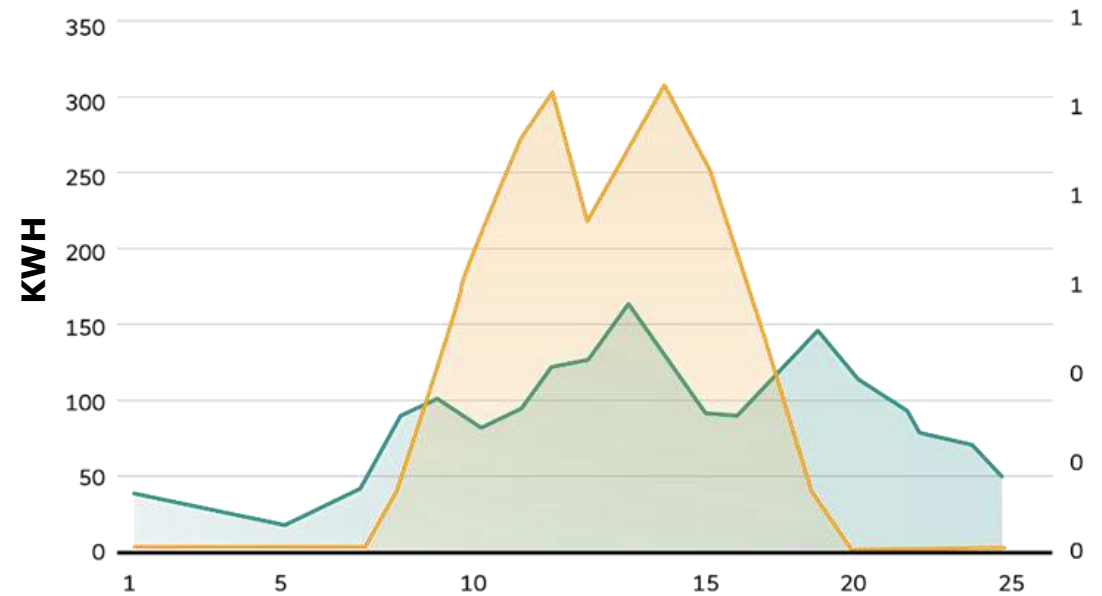
Source: WattTime Grid Emissions Intensity

What about NZE?

Hourly Grid Emissions Summer Day Example



Building Load vs. PV Generation

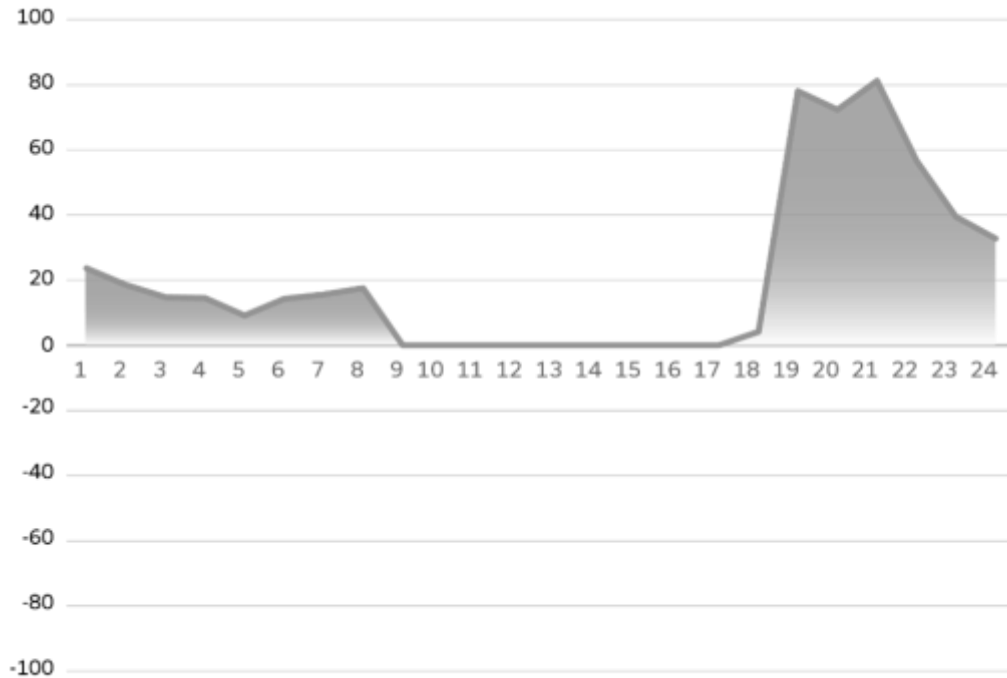


PV Generation

Building Load

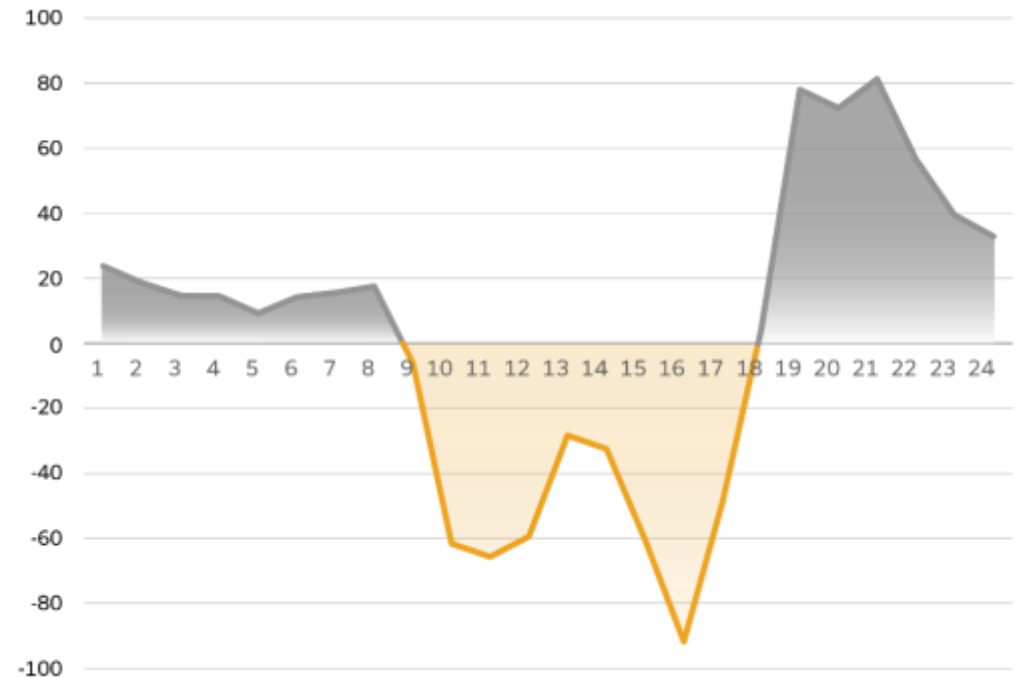
What about NZE?

Hourly Emissions (kg CO₂e)
TYPICAL SUMMER DAY



Without taking credit for the backfeed of the PV, the **daily emissions impact** of this net positive system is **490 kg CO₂e**.

Hourly Emissions (kg CO₂e)
TYPICAL SUMMER DAY



But even *with* taking credit for the backfeed of the PV, the daily emissions impact of this net positive system is **still 40 kg CO₂e!**

Decarbonization in the West

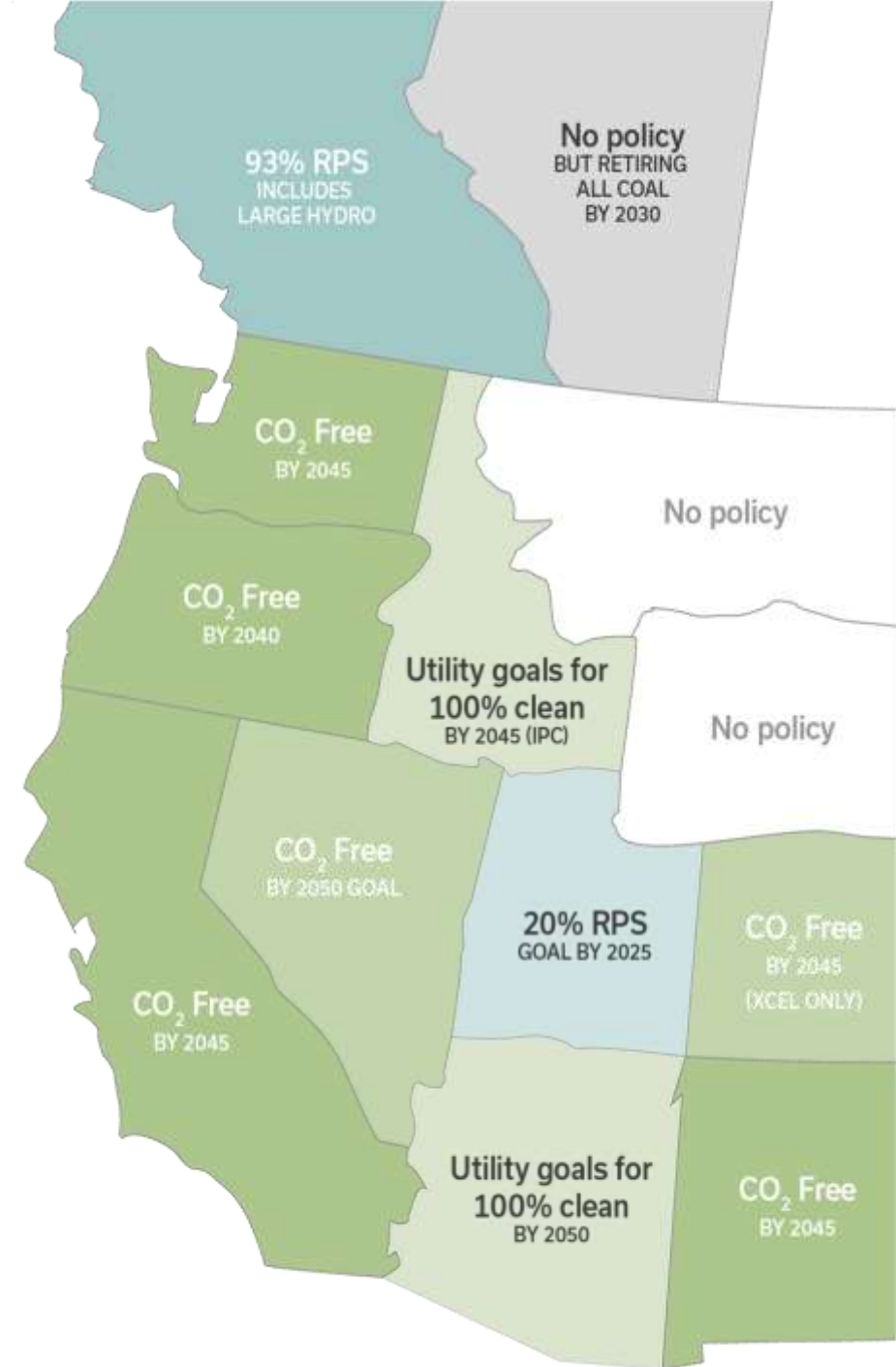
Decarbonization efforts throughout the west will lead to unprecedented generation and transmission development.

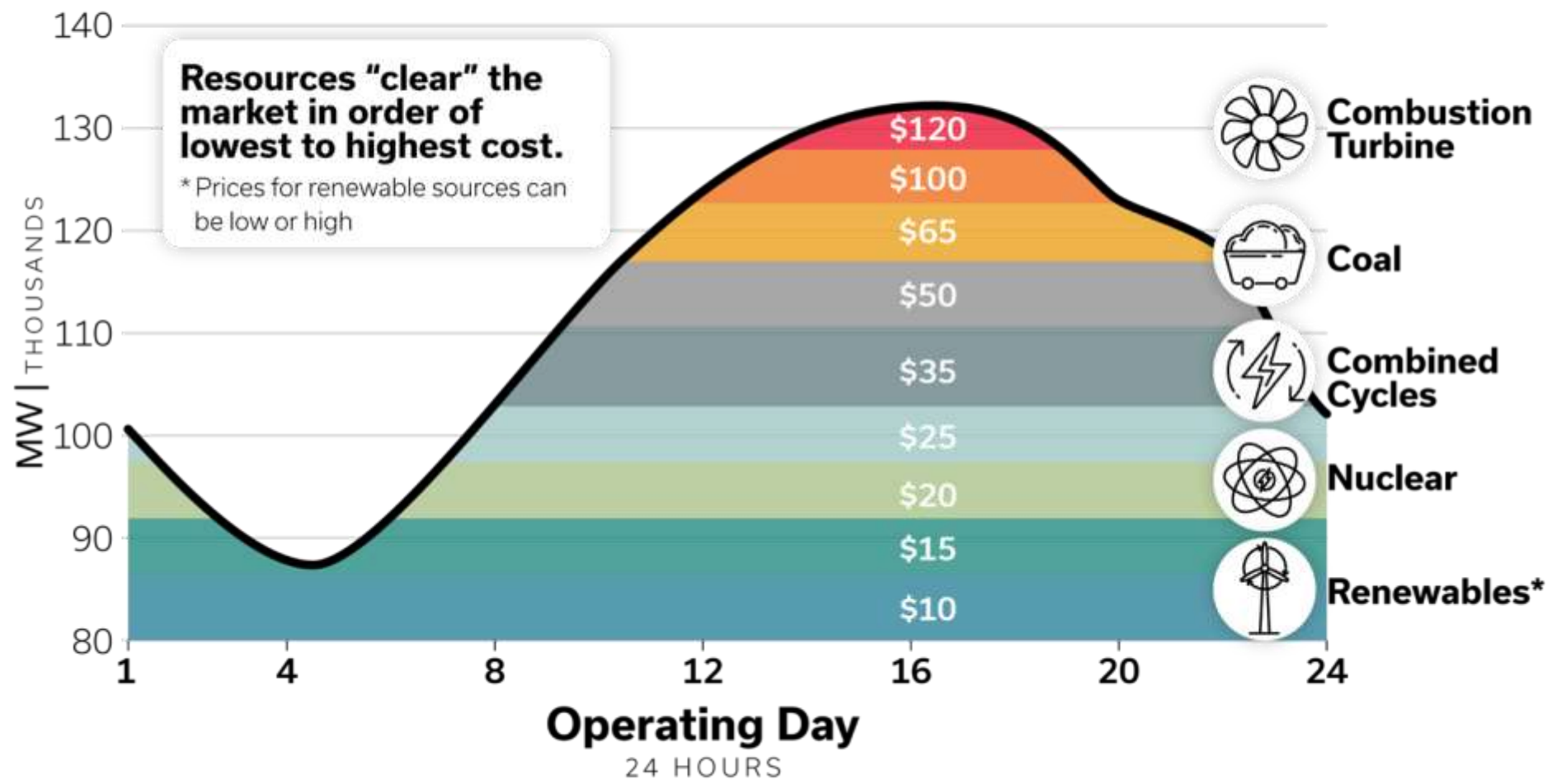


States across the West have a **commitment** to decarbonize electricity supply.



Some states with no policy are served by utilities that have publicly communicated their **intent** to decarbonize.

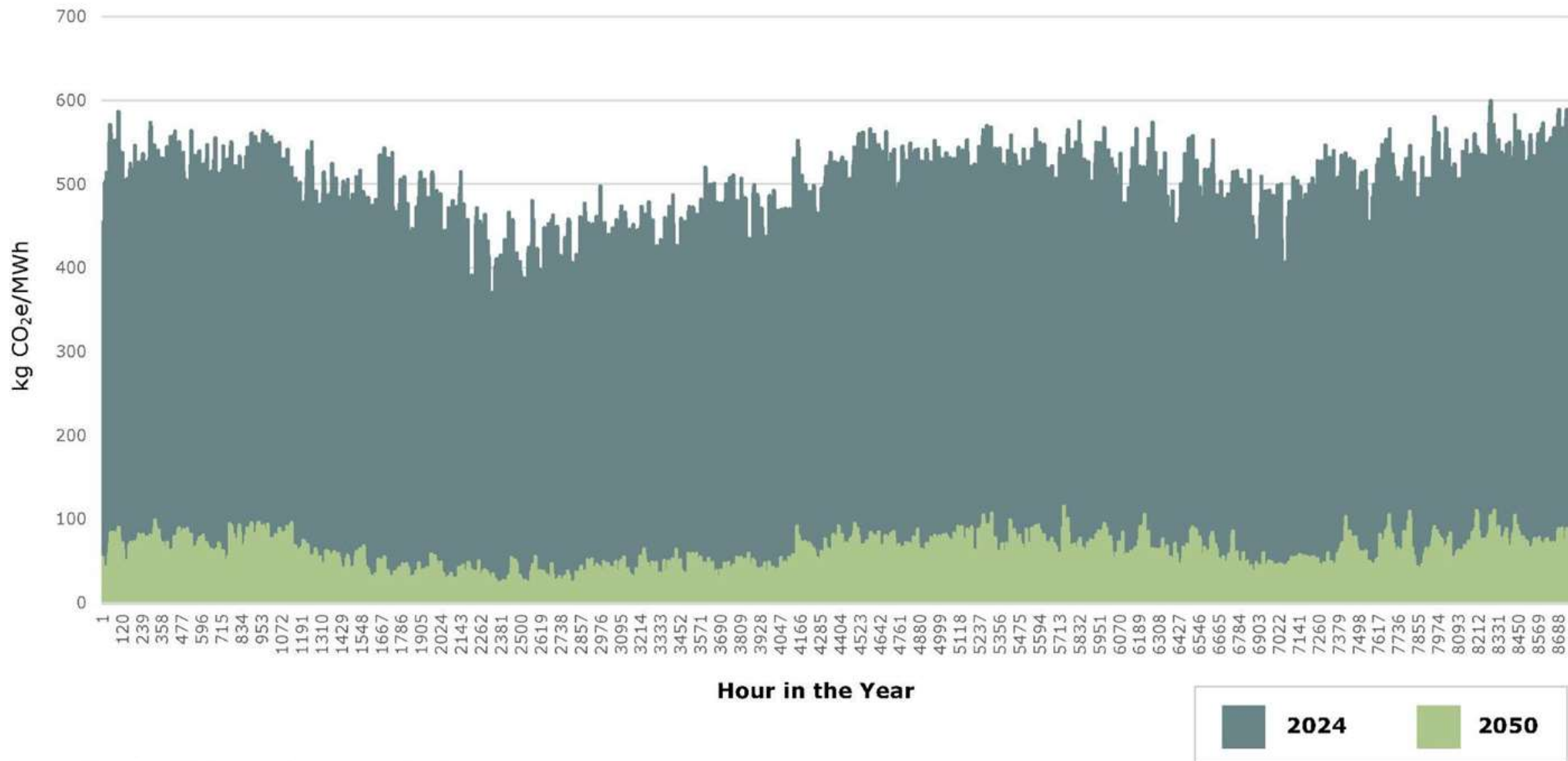




Emissions Trends



The grids can't solve this alone



Source: Cambium 2022, Low-Cost Renewables Scenario



**Buildings + Grid
Collaboration**



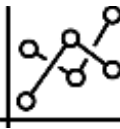
**Grid Stands
Alone**

Rethink Loads



"...over **\$10 billion worth of capital invested** [by BPA] in transmission and distribution **sits idle for over 8100 hours per year**"

- CRITFC ENERGY VISION



"...a massive investment in commercial and residential building investments could cut annual power system costs involved with achieving nationwide carbon-free electricity by 2050 by as much as **\$107 billion per year**.

Those savings would require both significant investments in energy efficiency, as well as outfitting buildings with the technology required to shift electricity use based on the ups and downs of solar and wind power, a capability known as "demand flexibility."

- BUILDING SECTOR DECARBONIZATION SCENARIOS TO 2050, LBNL AND BRATTLE GROUP



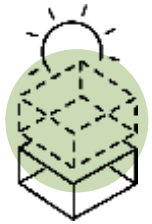
PAE LIVING BUILDING | PORTLAND, OR
Credit: ZGF

Little Actions = Big Impact

Customer Actions - Aug 14, 2023

PGE customers are making a big difference by shifting or reducing their energy use





What does this mean for building design?

In the past, grids shaped supply to match demand.

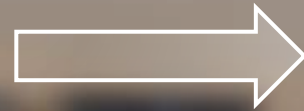
In the future, grids will shape demand to match supply.

What is a Virtual Power Plant?

Traditional Generation



Electricity
Generation



Transmission
Power



Power
Distribution

Virtual Power Plant + Smart Grid



Forecast

PRICE | PRODUCTION | DEMAND



FLEXIBLE
DEMANDS



SOLAR PV



Smart Grid



ENERGY
STORAGE



WIND
GENERATION

BUILDING-GRID INTEGRATION

Building-grid integration allows buildings and the electrical grid to coordinate energy supply and demand to

- optimize energy consumption
- reduce peak demand
- offer more clean energy
- provide a reliable electricity supply.

Source: NBI

CRITICAL CONSIDERATIONS



Energy Efficiency



Shift Peak Energy Loads



Design for Flexible Loads



Allow for Dispatchable Energy Storage



Grid-Interactive Buildings

—

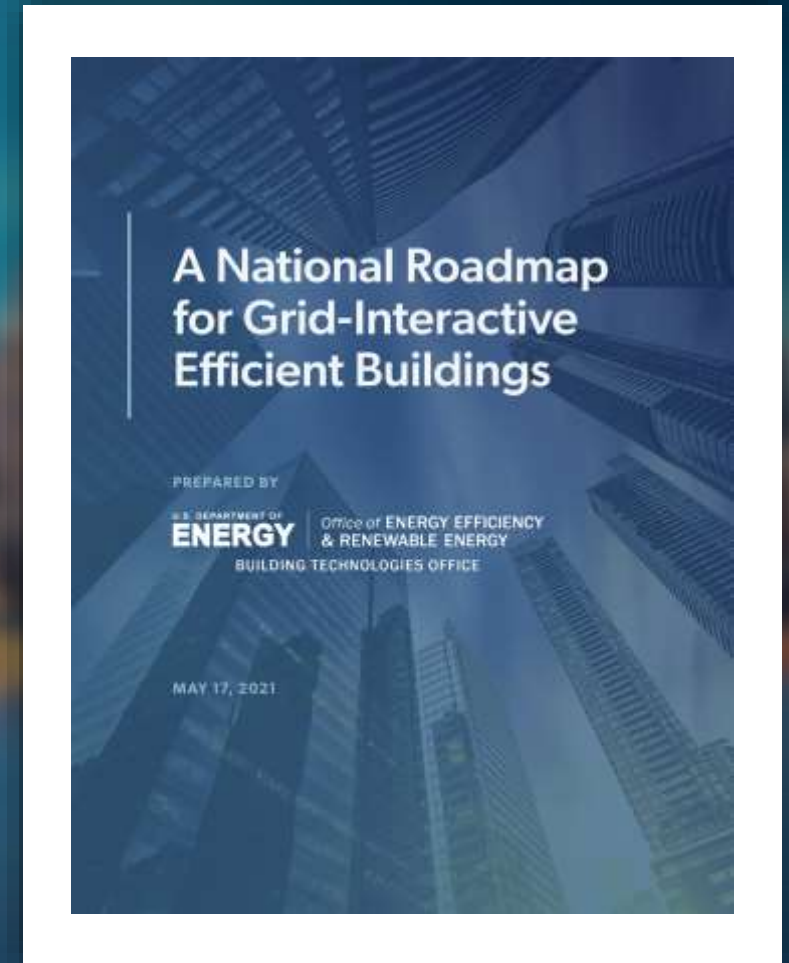
What is a Grid-Interactive Building?

DEFINITION

Grid-interactive efficient buildings (GEBs) are **energy efficient** buildings with **smart technologies** characterized by the **active use of distributed energy resources** (DERs) to optimize energy use for grid services, occupant needs and preferences, and cost reductions in a continuous and integrated way.

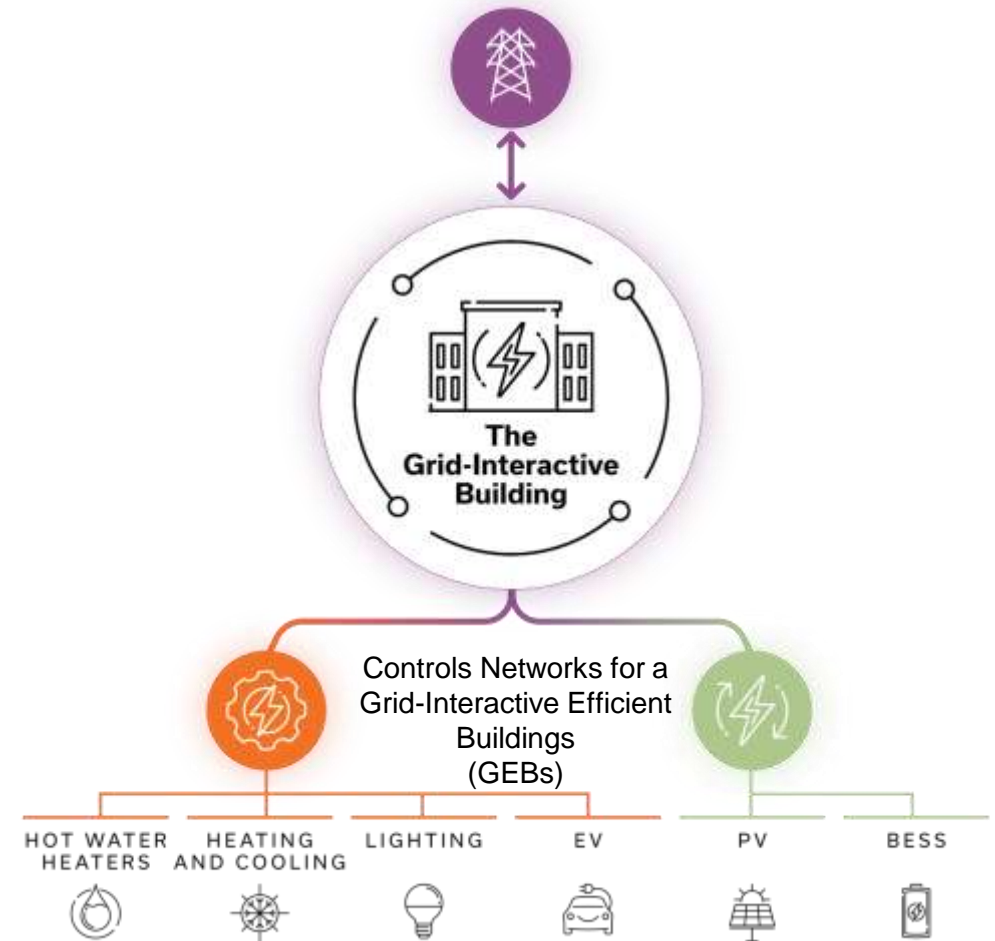
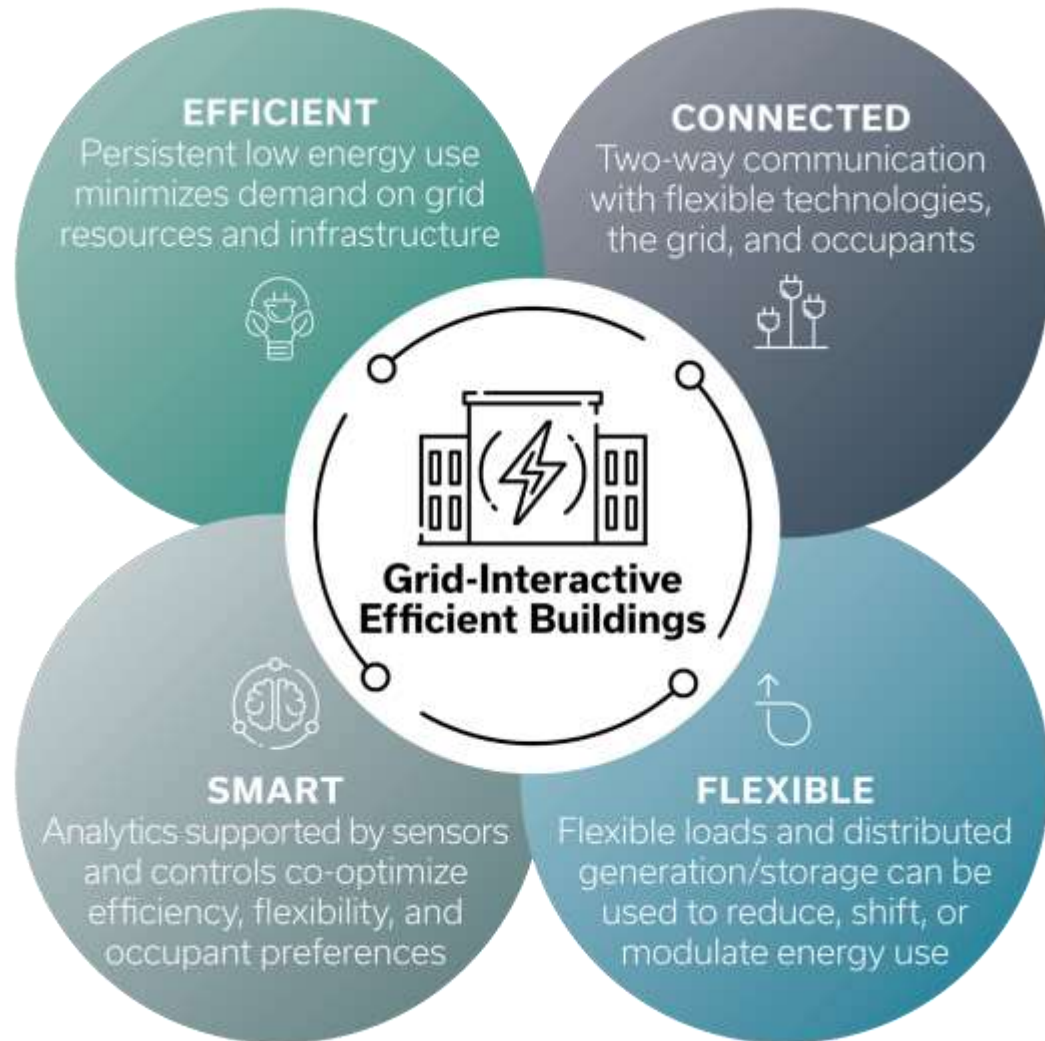


A Grid-Interactive building is **efficient, able to shape its loads** and **highly interconnected**



Source: US Department of Energy Office of Energy Efficiency & Renewable Energy

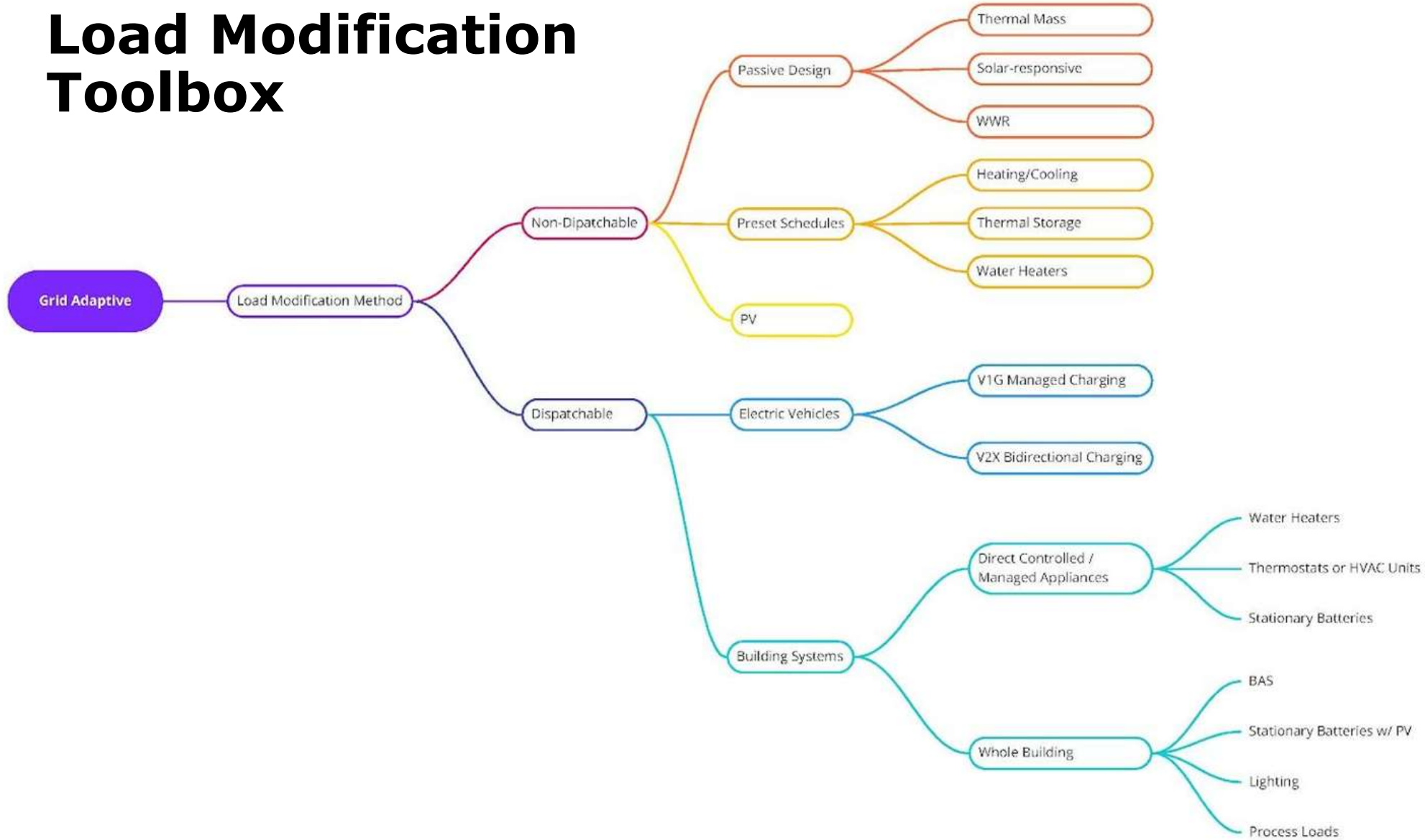
The Future is Grid Interactive



“...devices in GEB buildings – loads, storage, and generation – need to coordinate with each other both to manage flows of power, and to provide effective building and grid services”

- A National Roadmap for Grid-Interactive Efficient Buildings, 2021

Load Modification Toolbox



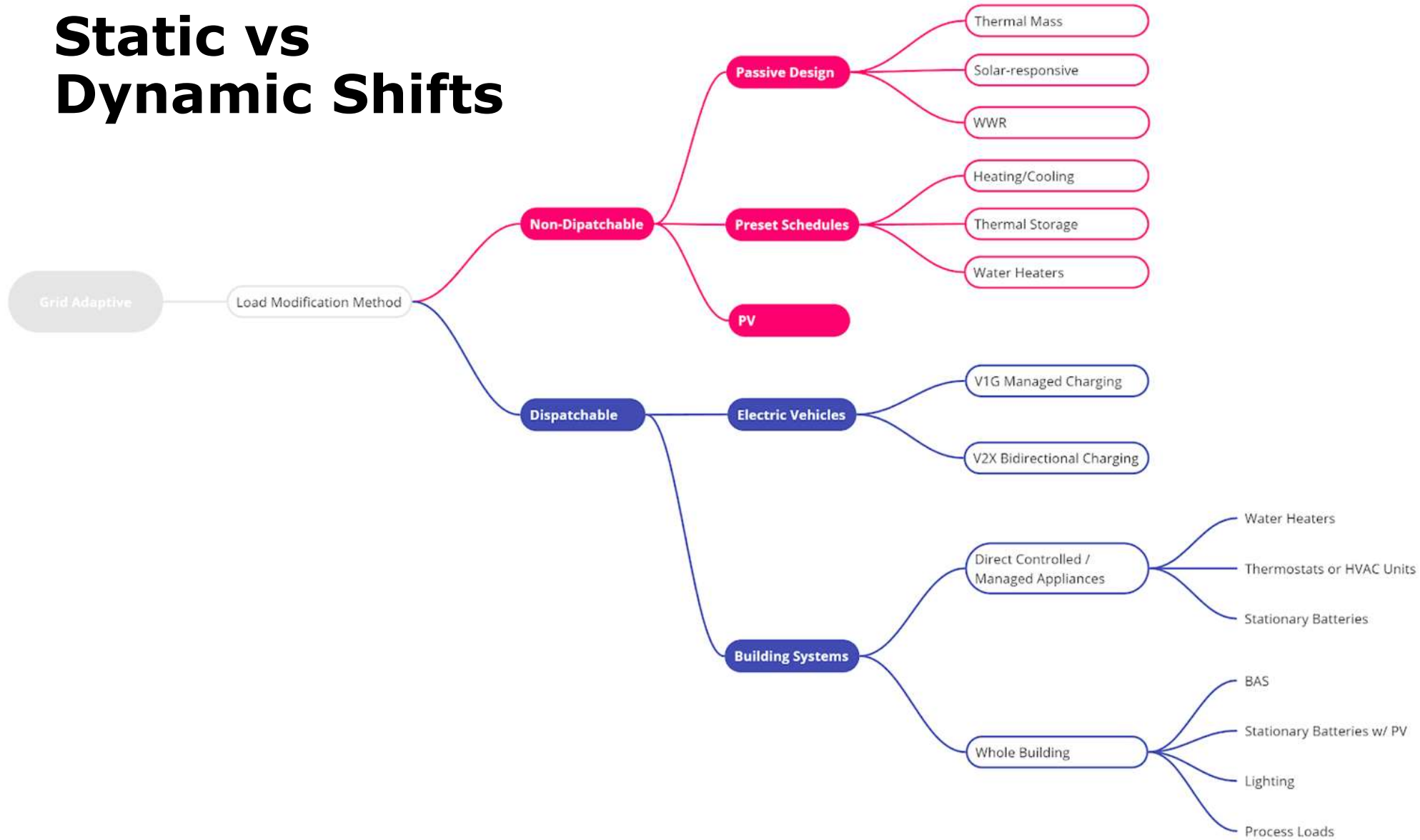
Non-Dispatchable




Dispatchable



Static vs Dynamic Shifts

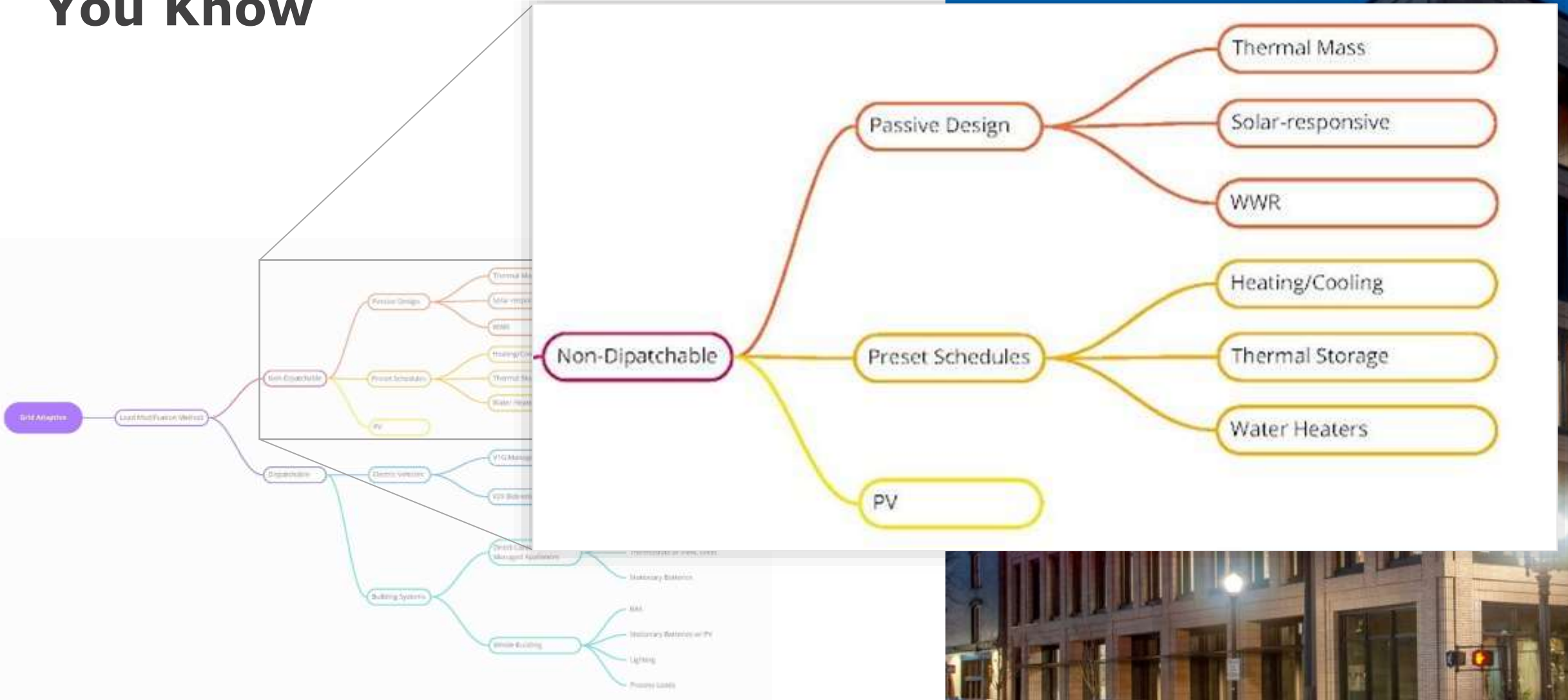


KEY

-  Locked In or Prescheduled
-  Real Time Dynamic

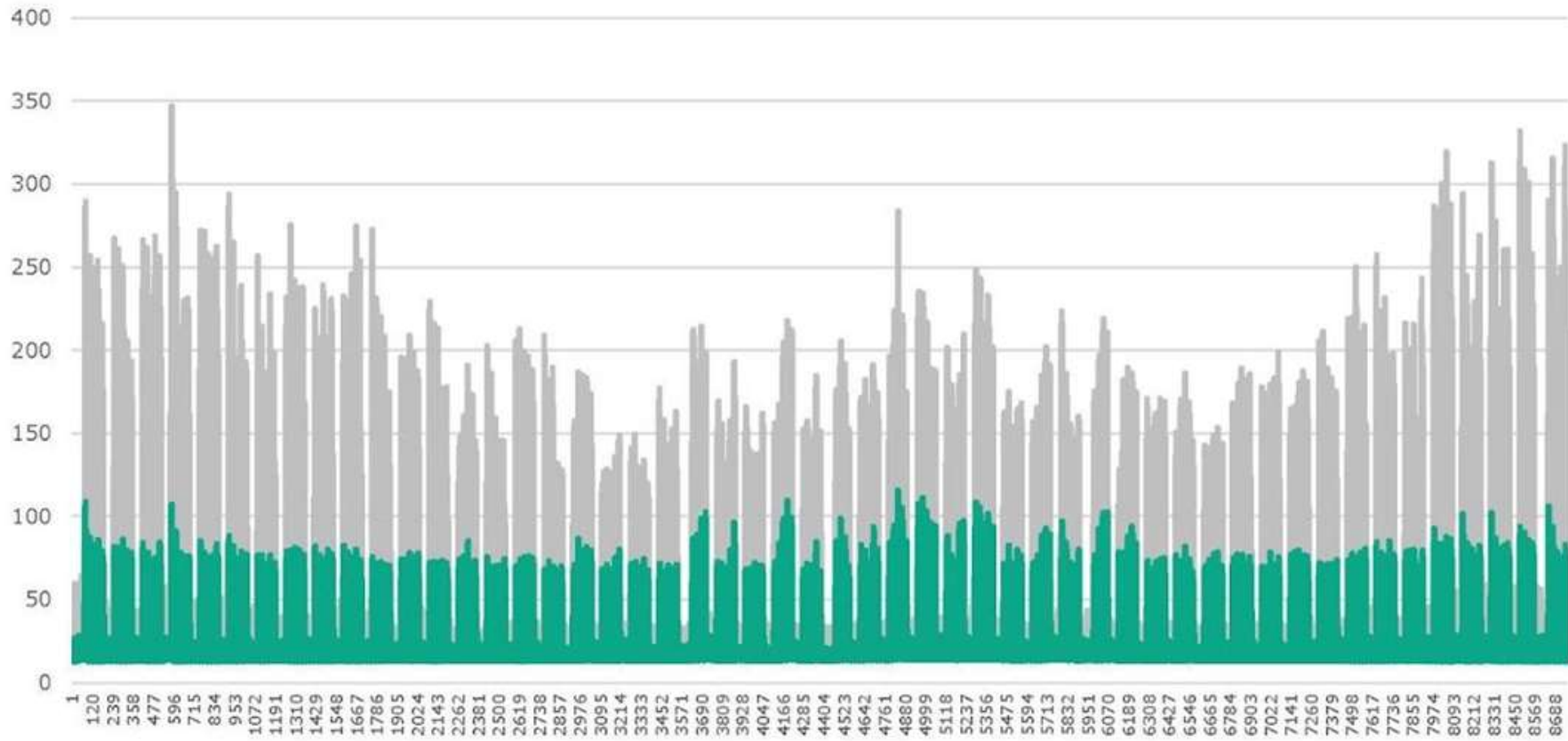


Begin with What You Know



Stop Peaks Before They Start

Peak Reduction with Good Design



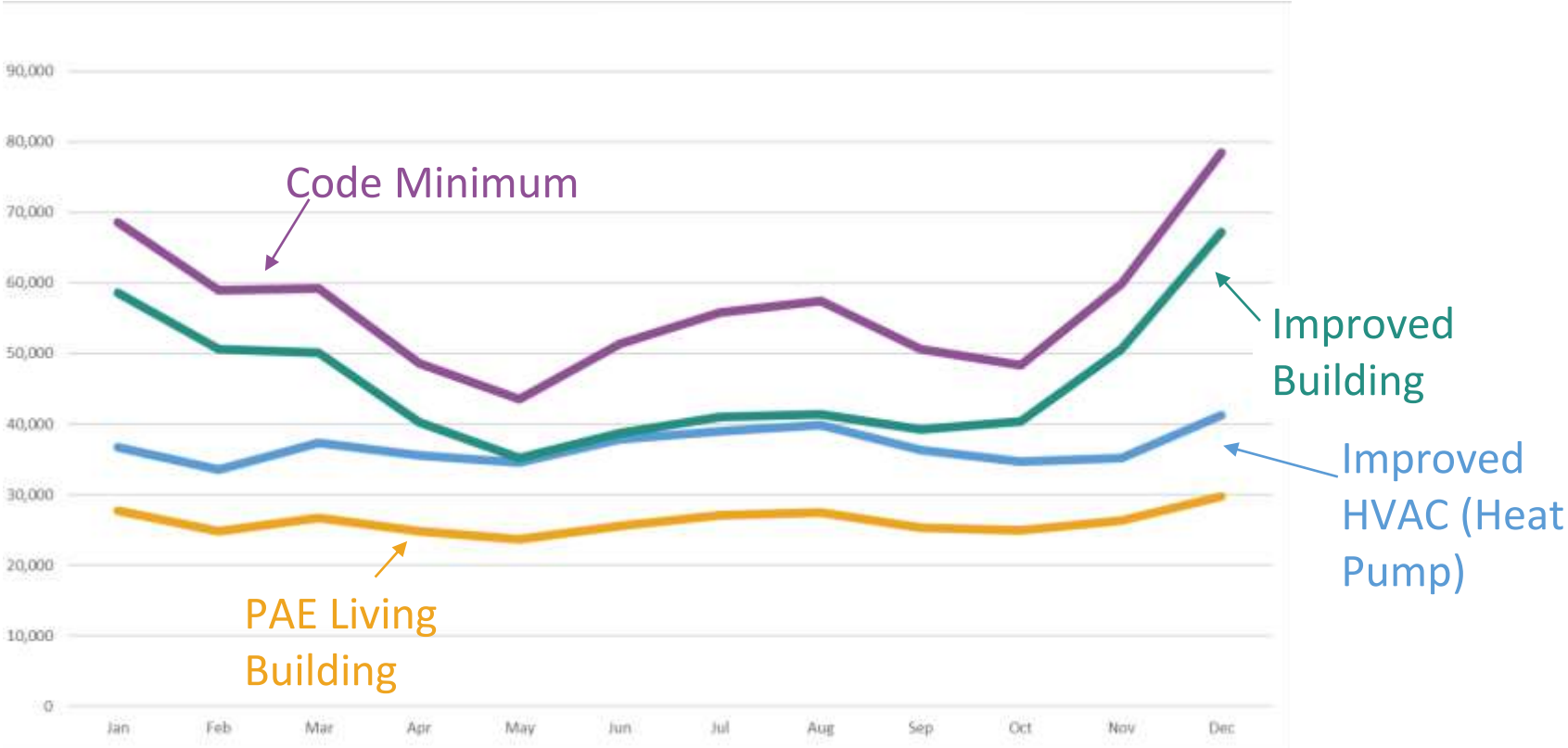
KEY

- Baseline Bldg Energy (kWh)
- Design Bldg Energy (kWh)





Reduce Peaks Through Design



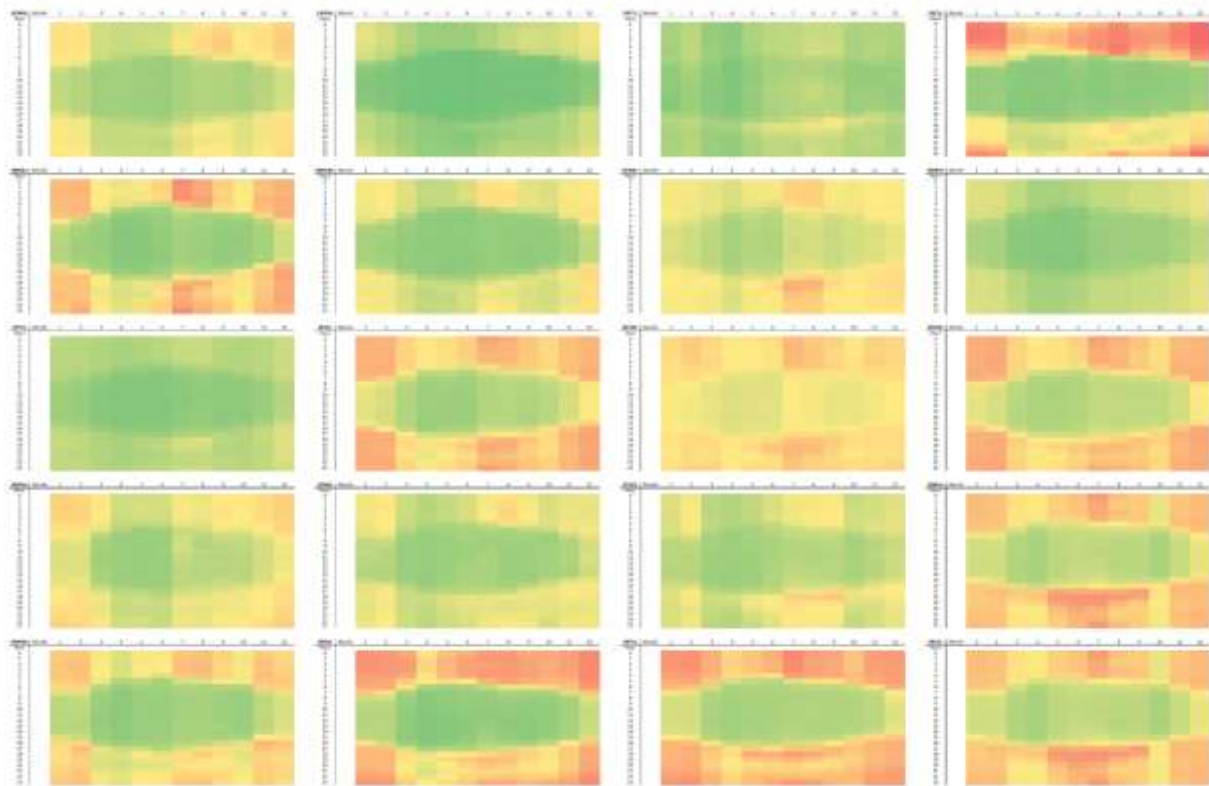
PEAK REDUCTION THROUGH DESIGN:

 Improved Building = Summer Peak Reductions

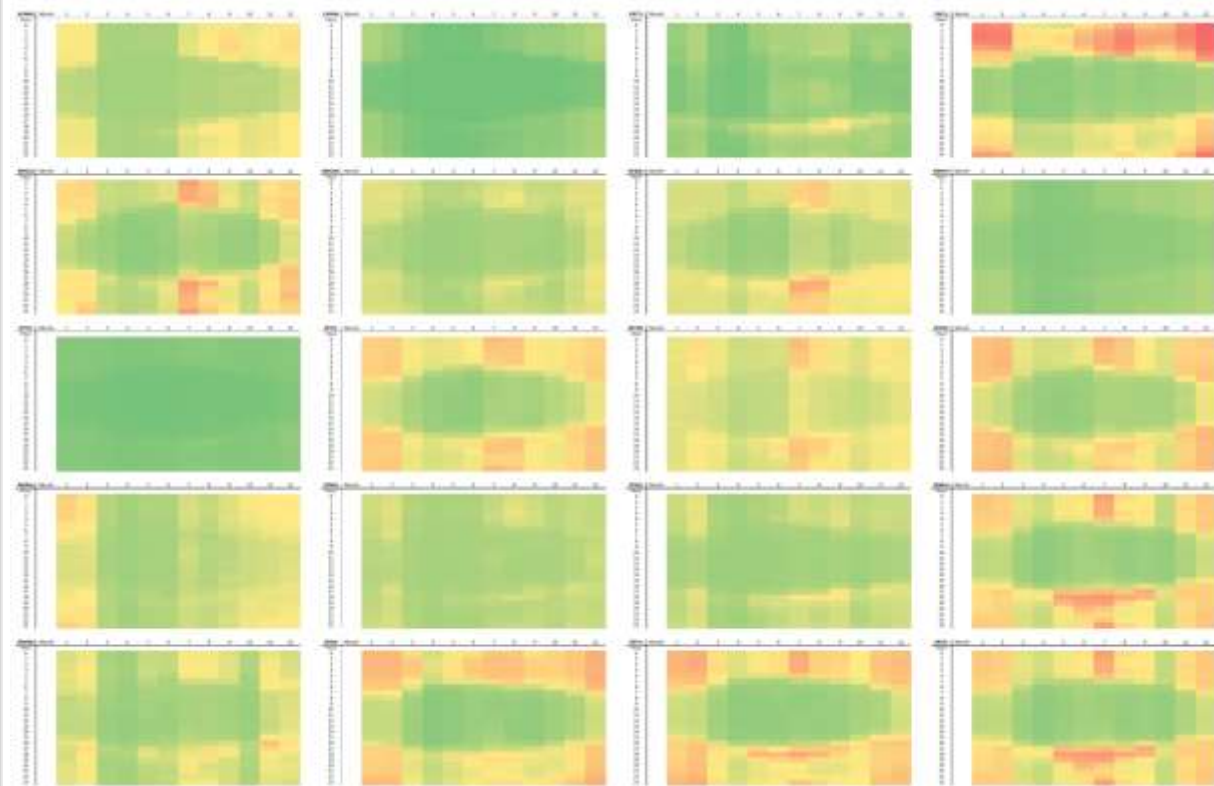
 Heat Pump = Winter Peak Reduction

Future Outlook for Time Varying Emissions

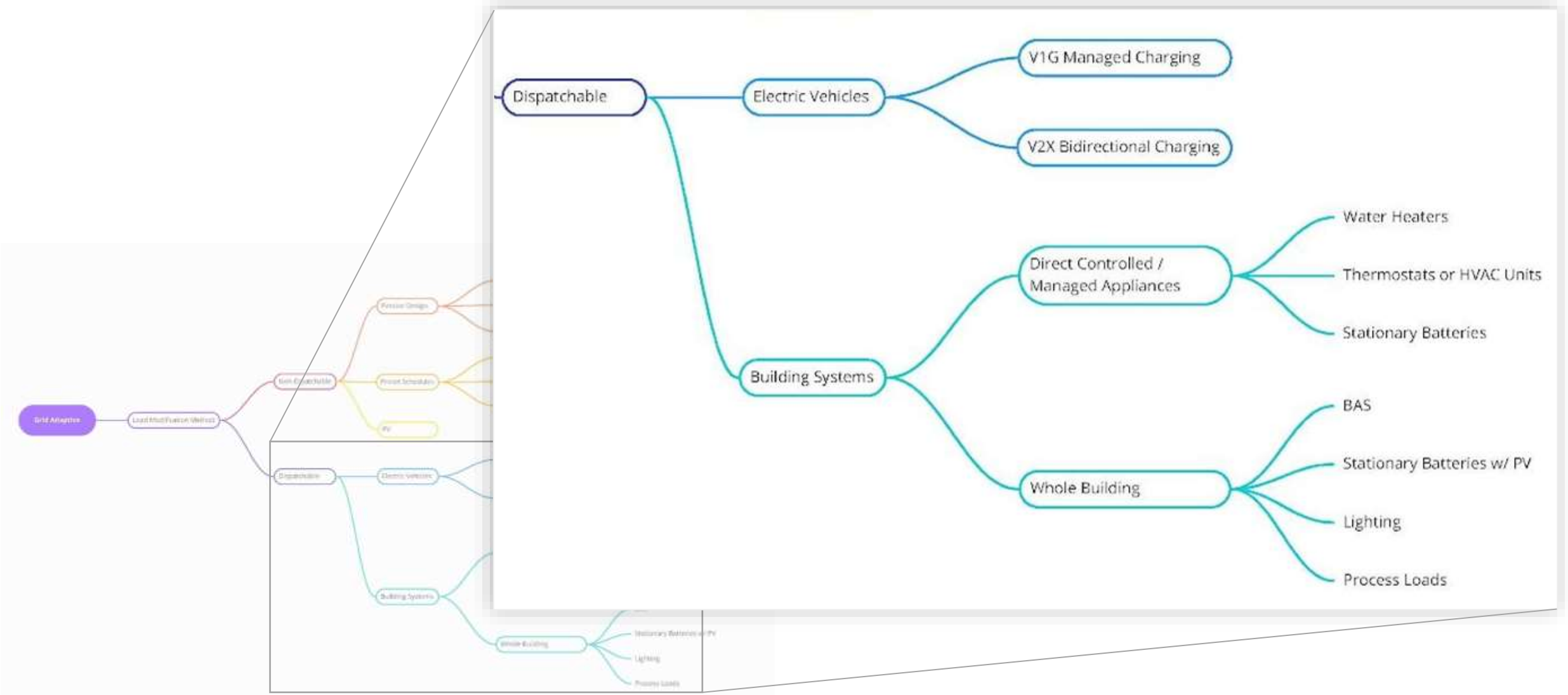
2023



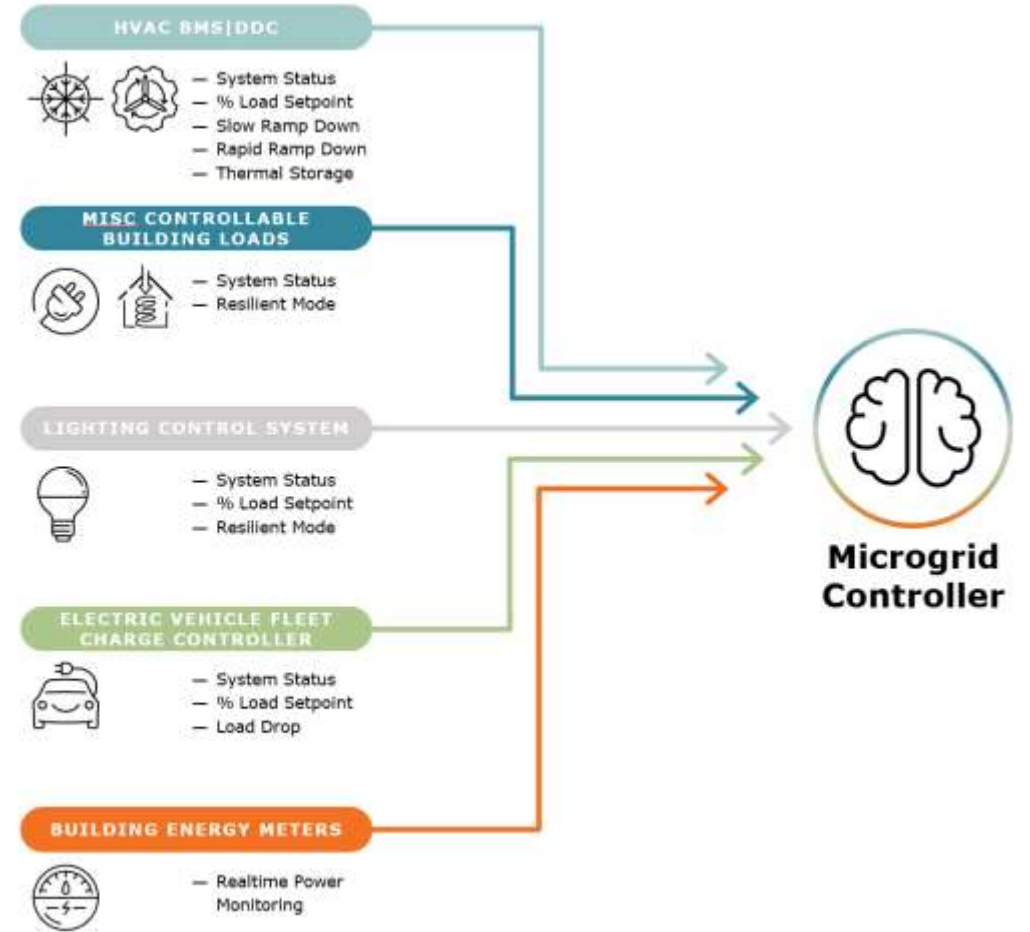
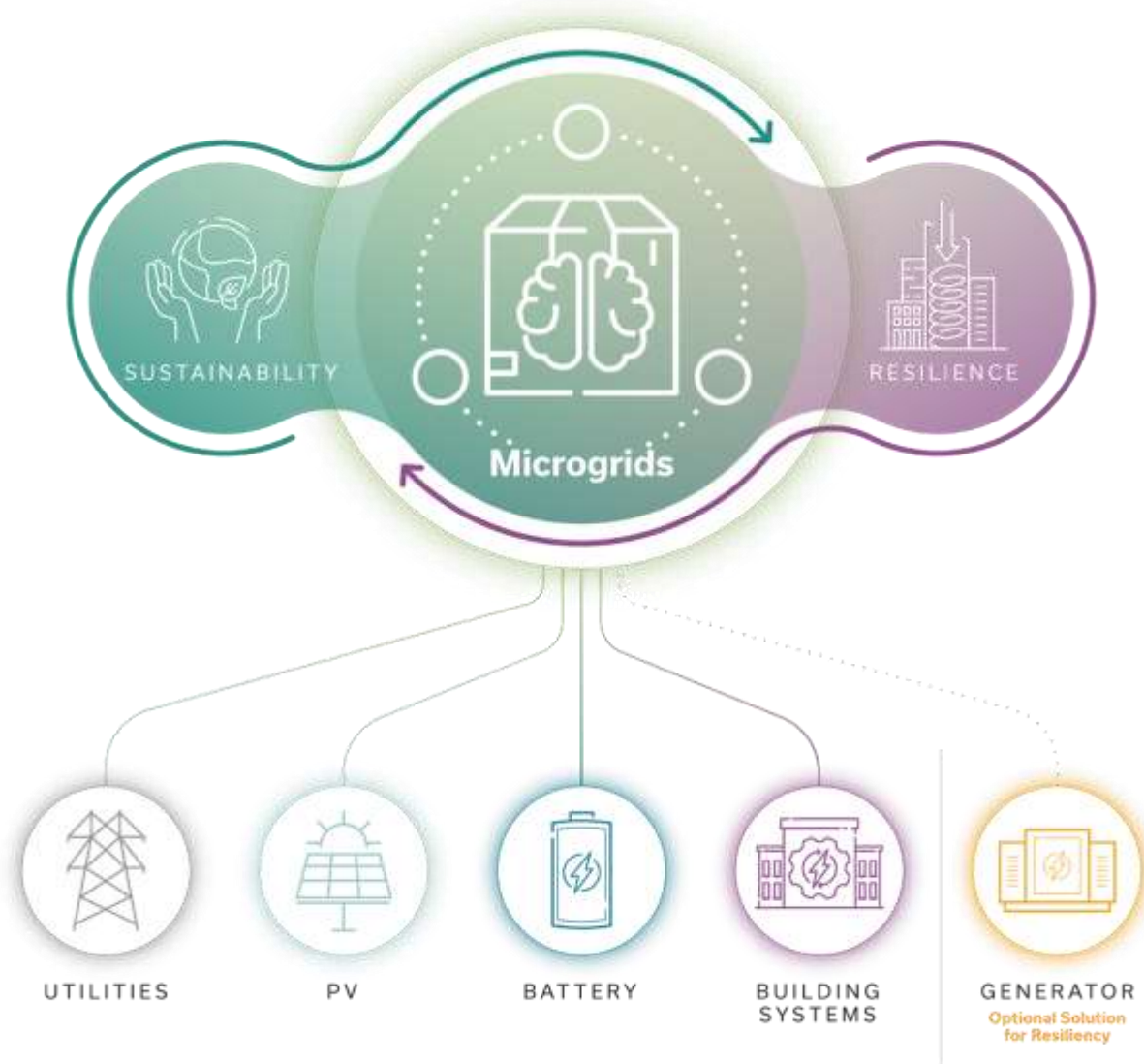
2030



Activate What You Can



Microgrids and DERs



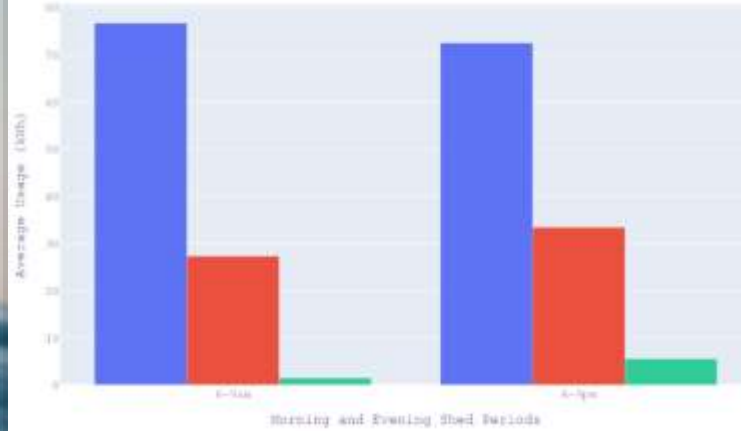
Water – The Other Storage



Photo credit: Ecotope

Bayview Towers demonstrates CHPWH technology, inclusion, environmental stewardship, and energy savings

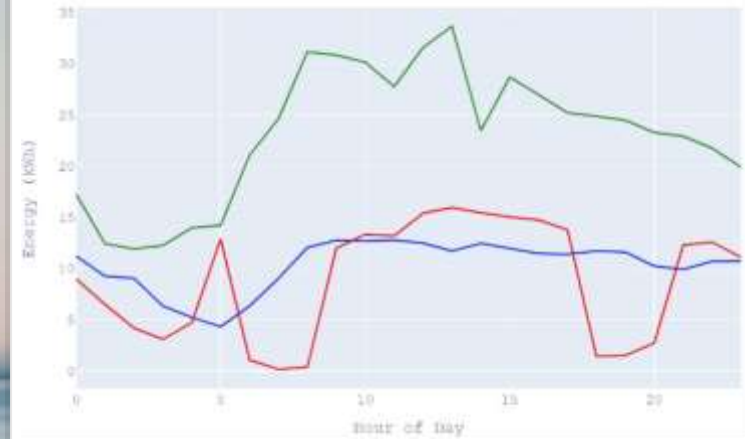
Energy Used During 3-hr Shed Periods



DHW System

- In Unit Electric
- QAHV No Load Shift
- QAHV Load Shift

Average Hourly Energy Usage



DHW System

- QAHV System
- QAHV System - Load Shift
- In-Unit Electric

How can I be flexible?

Distributed Energy Resources:

- Solar photovoltaics
- Thermal Storage
- Energy storage
- Electric Vehicles
- Combined heat and power plants

Grid-friendly Building Strategies:

Permanent Efficiency

- Efficient systems

Peak Shifting and Flexible Loads

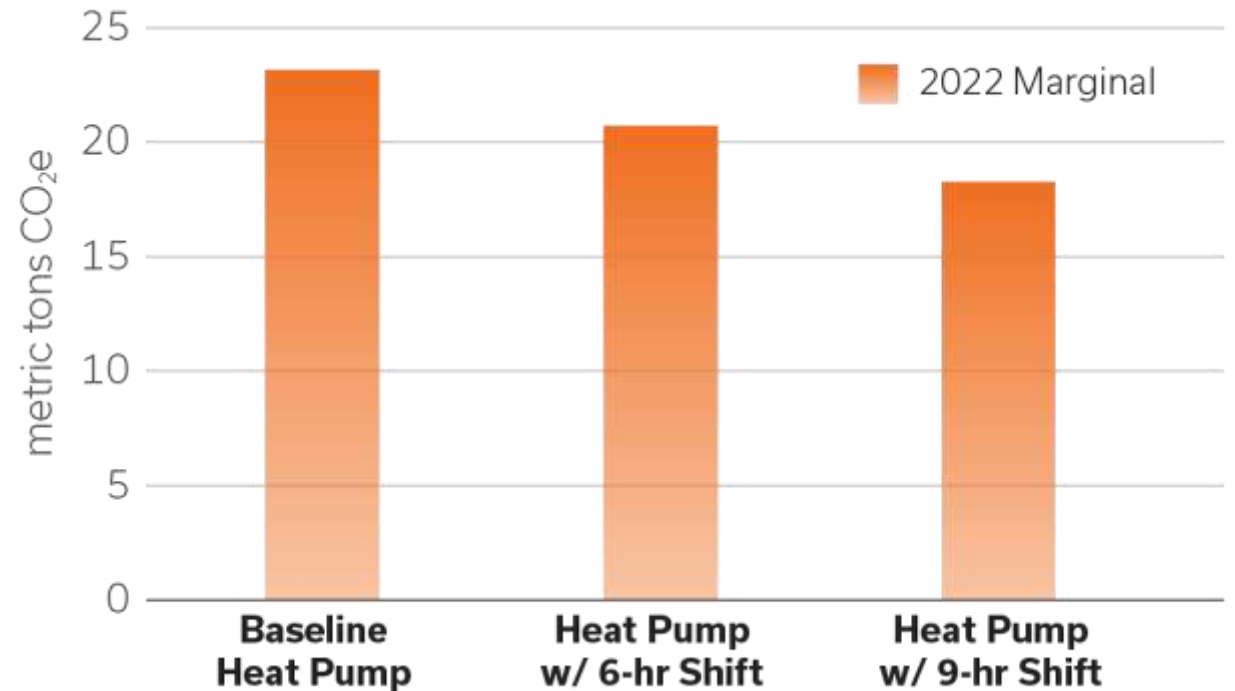
- Smart controls
- Thermal mass
- Energy storage / batteries

Dispatchable Energy Storage

- Intelligent, grid-integrated communication
- Smart systems and devices for HVAC, water heating, lighting, and electric vehicles, can align building energy

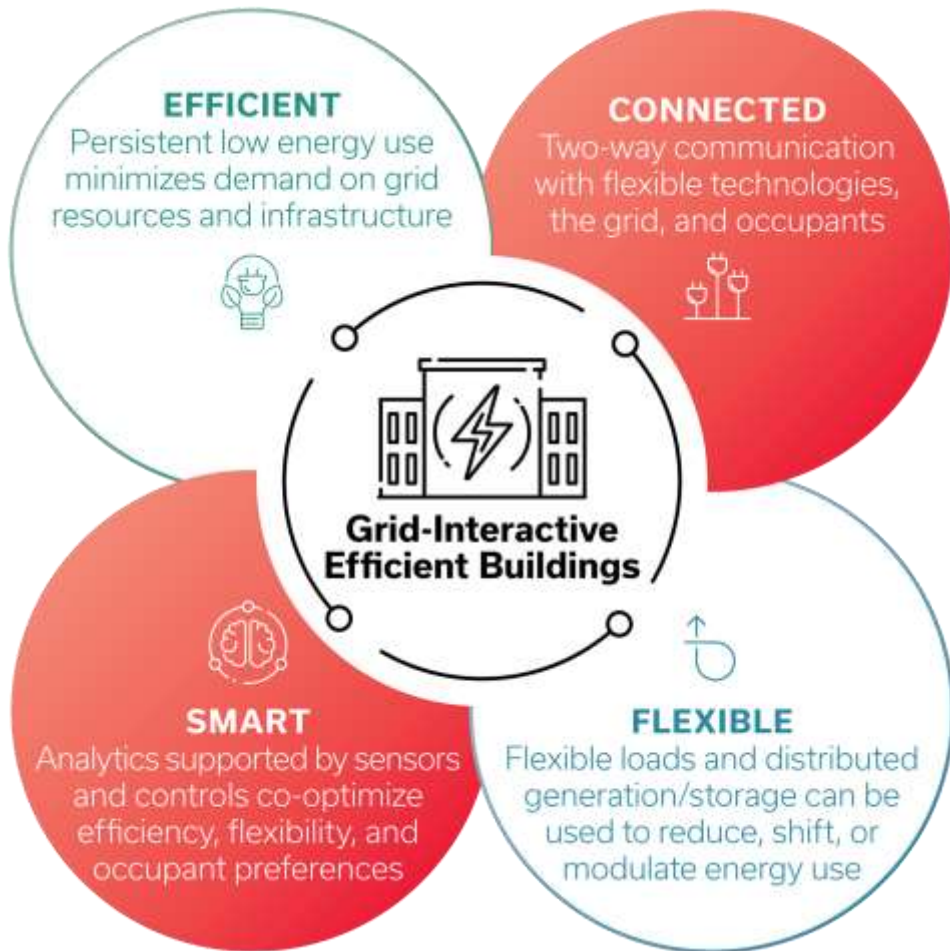
Source: NBI

EMISSIONS REDUCTIONS WITH LARGER DHW TANK



Source: PAE, PGE

The Long Arc to GEBs



- DOE Definition, graphic by RMI

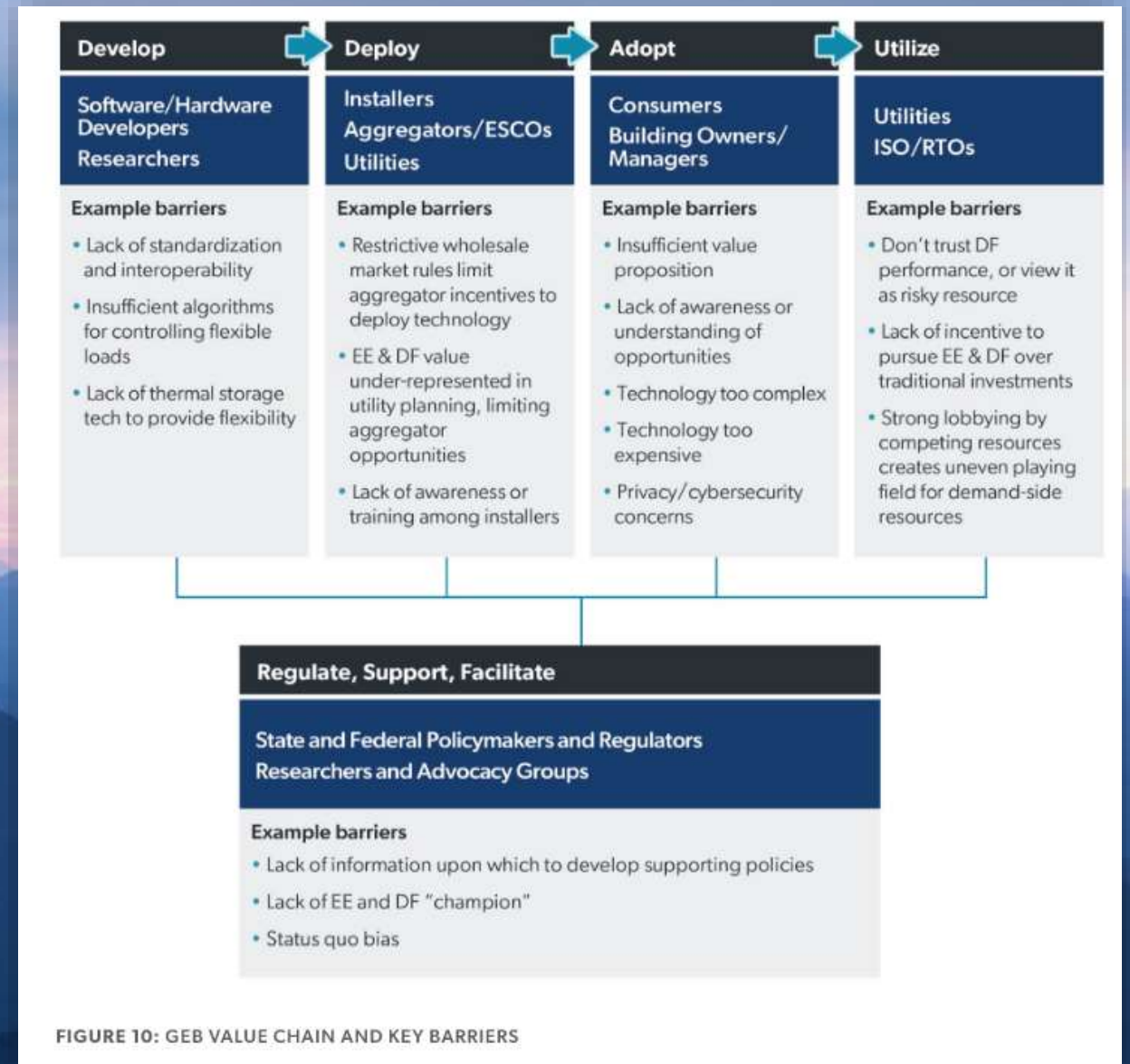


FIGURE 10: GEB VALUE CHAIN AND KEY BARRIERS

- A National Roadmap for Grid-Interactive Efficient Buildings, 2021

Designing the Future

Grid-Interactive Efficient Buildings



Demand Flexible



Grid Adaptive



Happy Occupant



PASSIVE
SYSTEM
SOLUTIONS



ACTIVE
SYSTEM
SOLUTIONS





Case Studies

—

PAE Living Building

PORTLAND, OR

QUICK STATS

OWNER	Multiple Owners
ARCHITECT	ZGF Architects
PROGRAM	Commercial + Corp. Office
PAE SCOPE	Mechanical, Electrical, Plumbing, Technology Design, Building Performance Analysis, Renewable Energy Systems, Greenhouse Gas Consulting, Commissioning, Architectural Lighting Design (via LUMA)
DELIVERY	CMGC
SIZE	58,000 sf



Pursuing Living Building

19

Energy Usage Intensity



Pursuing Net Zero Energy

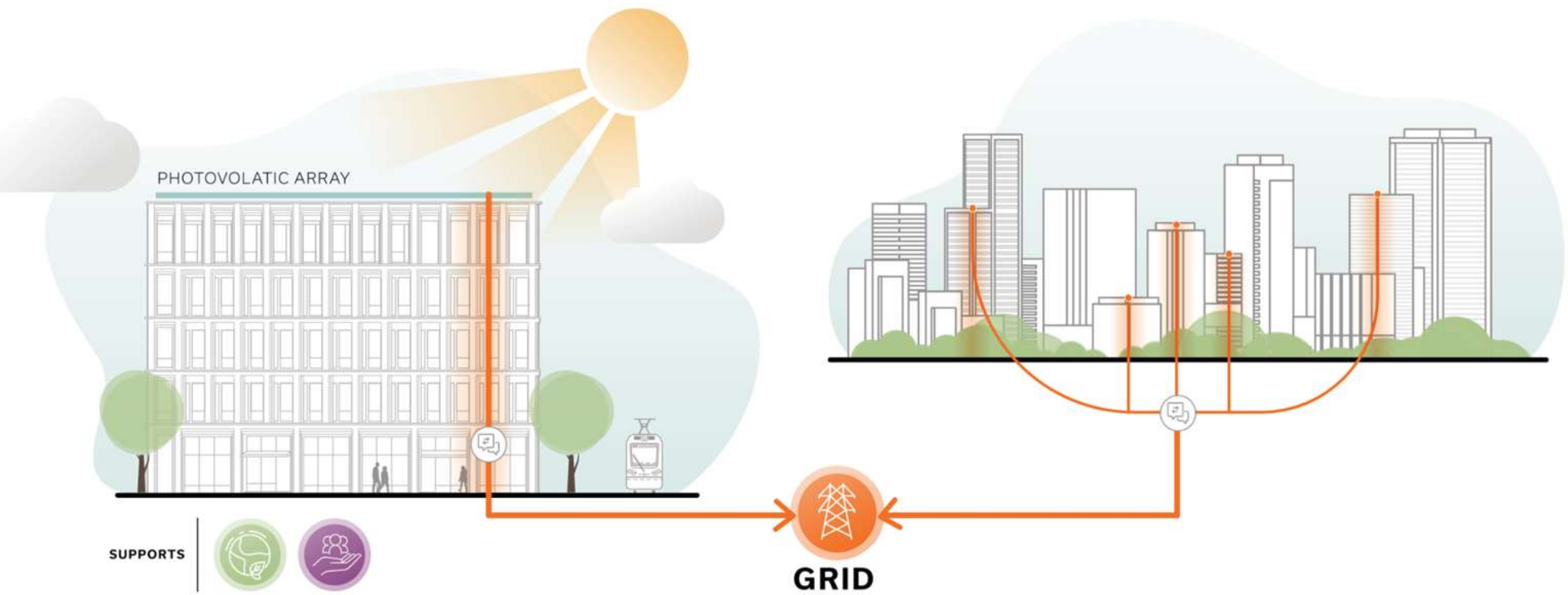
99/100

Walk Score



Pursuing Net Zero Water

PAE Living Building



SBP St. Peter Multifamily

NEW ORLEANS, LA



QUICK STATS

OWNER	SBP AmeriCorps Disaster Corps
ARCHITECT	Eskew+Dumez+Ripple
PROGRAM	Affordable Housing
SIZE	45,000 sf, 50 apartments



Targeting Net
Zero Energy

18

pEUI

\$164

Per Square
Foot



Battery
Storage



Enterprise Green
Communities



09-02-21

In New Orleans, a solar microgrid is keeping lights on in this affordable apartment building

While the rest of the neighborhood is dark, the residents at the St. Peter Apartments still have power. Can it be a model for more resilient architecture?



[Photo: courtesy Eskew Dumez + Ripple]

178 kW PV array



125kW / 371 kWh battery



 **HAPPY RESIDENTS:**
Energy bills < \$35/month



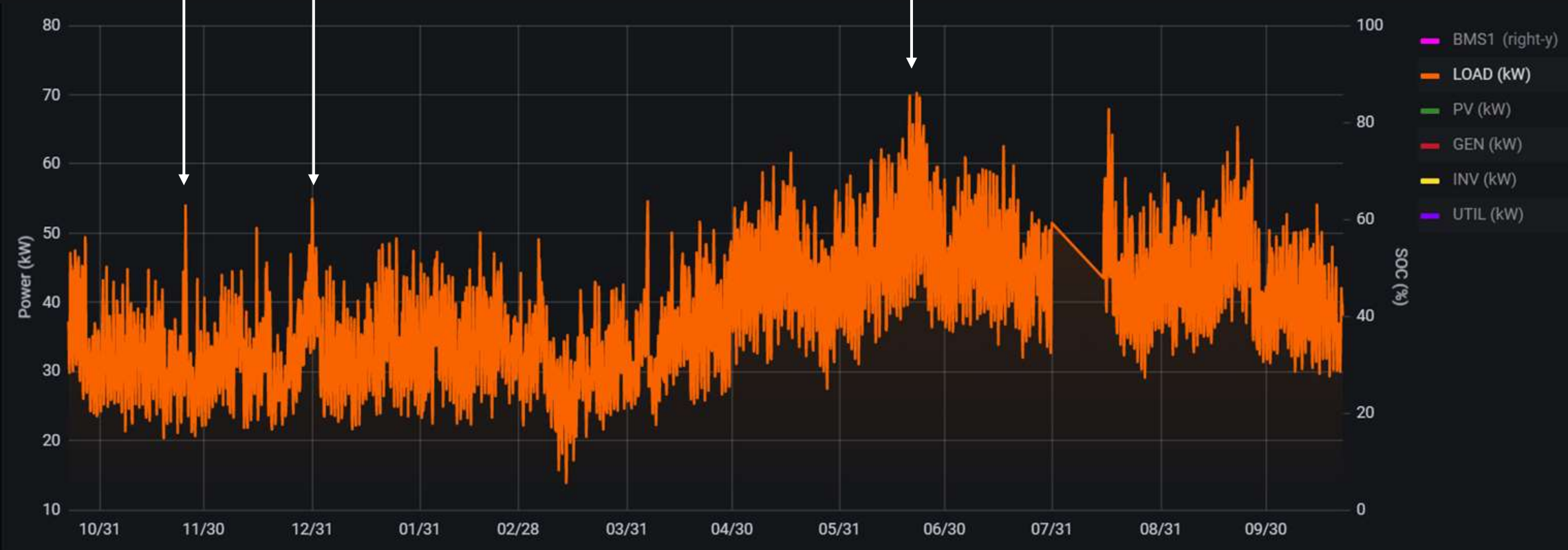
Heat pump water heaters help cool
and dehumidify apartments

Building Energy Consumption

Thanksgiving

New Year's Eve

Record heat wave



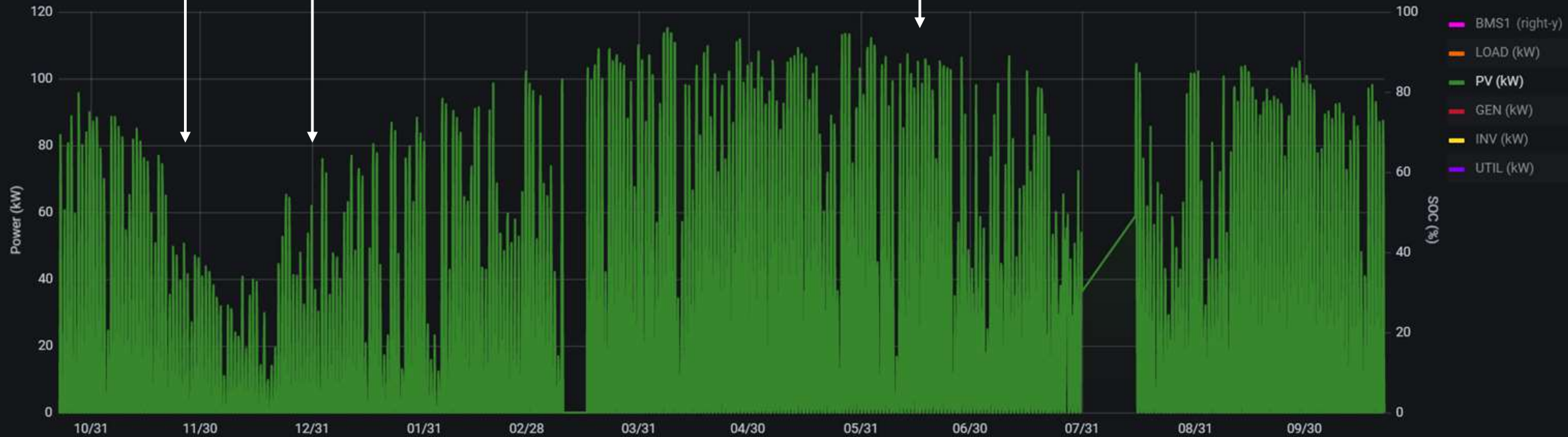
Solar Production



Thanksgiving

New Year's Eve

Record heat wave



How this building looks to the utility



Thanksgiving New Year's Eve Record heat wave

From Grid ↑

35 kW

0 kW

To Grid ↓



- BMS1 (right-y)
- LOAD (kW)
- PV (kW)
- GEN (kW)
- INV (kW)
- UTIL (kW)

Best Practices Principles + Latest Technologies (To De-Peak the Building)

- Cellulose cavity insulation + continuous insulation sheathing
- Field-verified airtight construction
- Moderate glazing (WWR 10%)
- Exposed thermal mass

- High-SEER/HSPF heat pumps
- Heat pump water heaters
- Solar PV – cover the available flat roof
- Battery capacity = 15 h average consumption
- Islanded off-grid after Hurricane Ida

- AFFORDABLE housing: \$164/sf



Simple metrics for grid adaptive buildings?

Make your building efficient, electric, and able to shape its load

	GOOD	BETTER	BEST
Efficient	75 th percentile EUI	90 th percentile EUI	95 th percentile EUI
Peak demand on utility	<3x annual average building consumption	<2x annual average building consumption	<1.5x annual average
Demand reduction on request	Able to shed 25% of load for 4h	Able to shed 50% of load for 4h	Go off-grid for 24h
Provide power to the grid		Able to push annual average demand for 1h	Able to push annual average demand onto grid for 4h
Carbon balance		Able to reduce demand in response to a marginal carbon intensity signal	'Net Zero Carbon': carbon emissions associated with power pushed onto the grid \geq carbon emissions associated with power drawn from the grid

GridOptimal

Design guidance available for 6 building types and for 7 regions of the US

BUILDING TYPES:

- Office
- Education
- Multifamily Housing
- Single Family Homes
- Retail
- Warehouses

USA GRID REGIONS:

- Southwest
- Northwest
- Texas + Southern Great Plains
- Northern Great Plains
- Midwest & Mid-Atlantic
- Northeast
- Southeast

<https://newbuildings.org/resource/gridoptimal-design-guidance/>



GRIDOPTIMAL DESIGN AND OPERATIONS GUIDANCE

Guideline / October 26, 2021 / Building Innovation



These easy-to-understand fact sheets are available for six building types and seven regions across the United States and provide key context and recommend selected high-impact building design and operations strategies.

The GridOptimal Buildings Initiative aims to improve building-grid interactions across the built environment by empowering building owners, designers, utilities, and other key players with dedicated metrics, tools, and guidance. [Learn more about GridOptimal.](#)

Optimizing Building Grid Integration in Building Types

Office Buildings
Education Buildings
Multifamily Buildings
Single Family Homes
Retail Buildings
Warehouses

Optimizing Building Grid Integration in U.S. Regions

Southwest United States
Northwest United States
Texas and the Southern Great Plains
Northern Great Plains
Midwest and Mid-Atlantic
Northeast United States
Southeast United States

GridOptimal Guidance Example: Northwest

Designing and Operating Buildings in a Hydro-Heavy Grid

In the Northwest U.S., hydropower is the most common electricity source. The share of wind and solar will grow, but low-carbon hydropower dams will remain central to the region's grid.

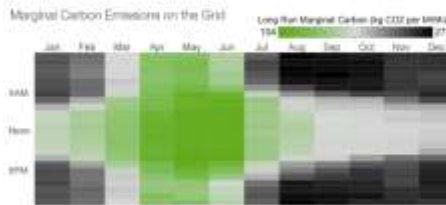
Hydropower is very flexible on a short-term basis and can compensate for variability in wind and solar generation and from the demand side. However, it is less flexible on a seasonal basis. Hydropower provides abundant, low-cost, clean electricity in spring and early summer when rivers are high, but less so from late summer through mid-winter. Solar and onshore wind deliver cleaner electricity during the day, but fossil generators help meet demand during nighttime and peak-demand hours.

To minimize carbon emissions from electricity consumption, identify hours in each season when high building demand coincides with high grid carbon factors. Search for energy-saving or demand flexibility opportunities in the end-use and equipment that are driving significant building demand during those hours. Strategies that are well-suited to the grid paradigm include passive load shaping (e.g., west-facing shading or electrochromic glass), demand flexibility strategies (e.g., pre-cooling temperature setbacks) as well as short- to medium-duration energy storage (e.g., batteries, cold-hot water tanks).

Electricity grids across the region are transforming toward zero carbon emissions. Buildings can enable this transition by focusing on time of use energy efficiency and demand flexibility.



Hours with high net system load (dashed lines) tend to be those expensive and higher carbon. Net system load equals total load minus renewable generation.



All graphs and charts on this page show an average of 2016-2020 hourly data from the 2020 review of NRE's Carbon Standard Database, available at <https://www.nre.com>

Top 5 GridOptimal Building Design and Operation Strategies:

Northwest U.S.

Efficiency and demand flexibility strategies have widely ranging impacts across building types, climates, and grid conditions. These high-impact strategies can help improve building grid integration outcomes on both sides of the meter in the region.



Building envelope. Buildings with well-insulated, airtight envelopes reduce winter heat loss and summer heat gain, decreasing HVAC energy needs while maintaining comfortable indoor temperatures. Additional passive measures such as west-facing shading, window treatments, and cool roofs can decrease peak cooling load (resulting in shorter airflows and peak winter heating demand), both of which typically occur during high-cost, high-carbon hours.



Smart HVAC controls

Temperature setback and schedule adjustments such as setbacks, precooling, and preheating can reduce peak demand summer and shift load toward low-cost, low-carbon hours. Communications standards such as OpenADR 2.0b enable current and future participation in demand response and service programs.



Energy storage. Both battery electric and thermal (e.g., ice or hot water) storage systems can reduce load shifting away from high-cost, high-carbon hours. Key benefits include energy cost savings, emissions reductions, and resiliency options. Systems designed only for resiliency may not deliver cost and carbon savings. An optimal system design and operation to achieve the right balance of resiliency, cost savings, and carbon reductions.



Managed EV charging

Electric vehicles (EVs) have the decarbonization potential but charging adds substantial demand. Charging during off-peak hours and reducing or staging charging during peak hours improves the impact. Softer rates and other incentives can often motivate for smart EV charging.



Efficient systems. Efficient mechanical systems (HVAC and water heating) meet occupant thermal needs with decreased energy use. Consider variable-capacity heat pump HVAC systems and grid-connected heat pump water heaters to lower energy savings and carbon emissions. Paired with air efficiency building envelopes, efficient systems improve resiliency by increasing building's ability to remain comfortable and habitable through a partial or complete power outage. Efficient systems are an enabler and often an impact multiplier for demand flexibility.

Key Enablers: Energy Efficiency and Distributed Energy Resources

Energy efficiency is critical: more-efficient buildings have lower operating costs, carbon impacts, and power demand. Efficient buildings with high-performance envelopes remain comfortable for longer without mechanical conditioning, widening the demand response potential and load shifting window.

Passive strategies can deliver targeted time-of-use energy savings. Insulation and air-sealing save energy all the time, but especially during peak conditions. West-facing shading and electrochromic windows reduce cooling demand during costly, high-carbon summer evenings.

Active strategies offer demand response by shifting load away from peak hours toward low-cost, low-carbon hours. Automated grid-integrated controls on HVAC,

water heating, lighting, and appliances facilitate reliable, consistent load shifting during occupied or unoccupied hours.

Distributed Energy Resources (DERs) including solar PV, batteries, managed EV charging, and the energy storage can deliver energy flexibility. Target energy storage systems that can charge during the day and reduce evening demand. Co-optimize storage systems for both cost and carbon through real-time rate and carbon signals or by adding a time-varying synthetic carbon cost. At a minimum, be solar-ready and storage-ready: reserve space and capacity in conduits and electrical panels for future DERs and related electric infrastructure.



Efficient systems. Efficient mechanical systems (HVAC and water heating) meet occupant thermal needs with decreased energy use. Consider variable-capacity heat pump HVAC systems and grid-connected heat pump water heaters to maximize energy savings and carbon emissions reductions. Paired with an efficient building envelope, efficient systems improve resiliency by prolonging the building's ability to remain comfortable and habitable through a partial or complete power outage. Efficient systems are an enabler and often an impact multiplier for demand flexibility.

What should building designers do?

- Start with NBI GridOptimal guides—then match to your project
- Apply old-school passive design principles first, then new tech to make your project less “peaky”, efficient, and able to shape its load
- Taking responsibility for your project’s consumption with onsite & offsite renewable power is the *starting* point. NZE is good, but grid-adaptive is better



**Buildings
should be efficient
and able to shape
their load.**

What do we need from utilities?

Partnership and Transparency

- Better real-time data
- Normalized two-way communications
- Clear direction on what utilities need from buildings

More and better examples of Time-Of-Use (TOU) pricing to incentivize decarbonizing behavior



Utilities and Buildings can work together to solve the problem.

Calls to Action

The **potential** is huge.
The **barriers** are real

Share knowledge between all stakeholders:

- Designers
- Owners/Operators
- Utilities
- Manufacturers
- Research institutions and labs
- Venture capitalists
- Policy and program developers

Every project can **implement a solution today.**



Clark Brockman AIA, LEED Fellow

Principal Emeritus | SERA

clarkb@seradesign.com



Karina Hershberg PE, LEED AP

SENIOR ASSOCIATE | PAE

karina.hershberg@pae-engineers.com

