Center for Sustainable Landscapes | Pittsburgh, PA *Photo: Paul G. Wiegman*

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# Grid-Interactive Efficient Building (GEB) Strategies

Tools, resources, and expertise for every member of your project team

# What is New Buildings Institute?

- 501(c)(3) nonprofit
- 25+ year history
- **Mission**: We advance best practices, codes, and policies through market leadership, research, guidance, and technical advocacy toward a built environment that equitably delivers community benefits and climate solutions.

www.newbuildings.org


*NBI headquarters office at PAE Living Building, Portland, OR Photo by Portland Drone*

# GRIDOPTIMAL®
## BUILDINGS INITIATIVE

- Launched mid-2018, ongoing
  - *New building-grid interaction metrics*
  - Metrics published (blog, white paper)
  - Design and Operations Guidance Fact Sheets
  - LEED Credit: GridOptimal Building ACP (& soon, v5)
  - Utility program guidance (memo, dashboard)
  - ASHRAE Grid Integrated Buildings Resource Guide
  - Codes, standards, and policy deployments

newbuildings.org/gridoptimal

A Joint Initiative Of:

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U.S. Green Building Council USGBC

Supporting Members:

Southern California Edison

PG&E Pacific Gas and Electric Company

SMUD

Austin Energy

Efficiency Vermont

Energy Trust of Oregon

# Poll #1

- How familiar are you with GEB concepts and behind-the-meter grid integration strategies? (1-5)

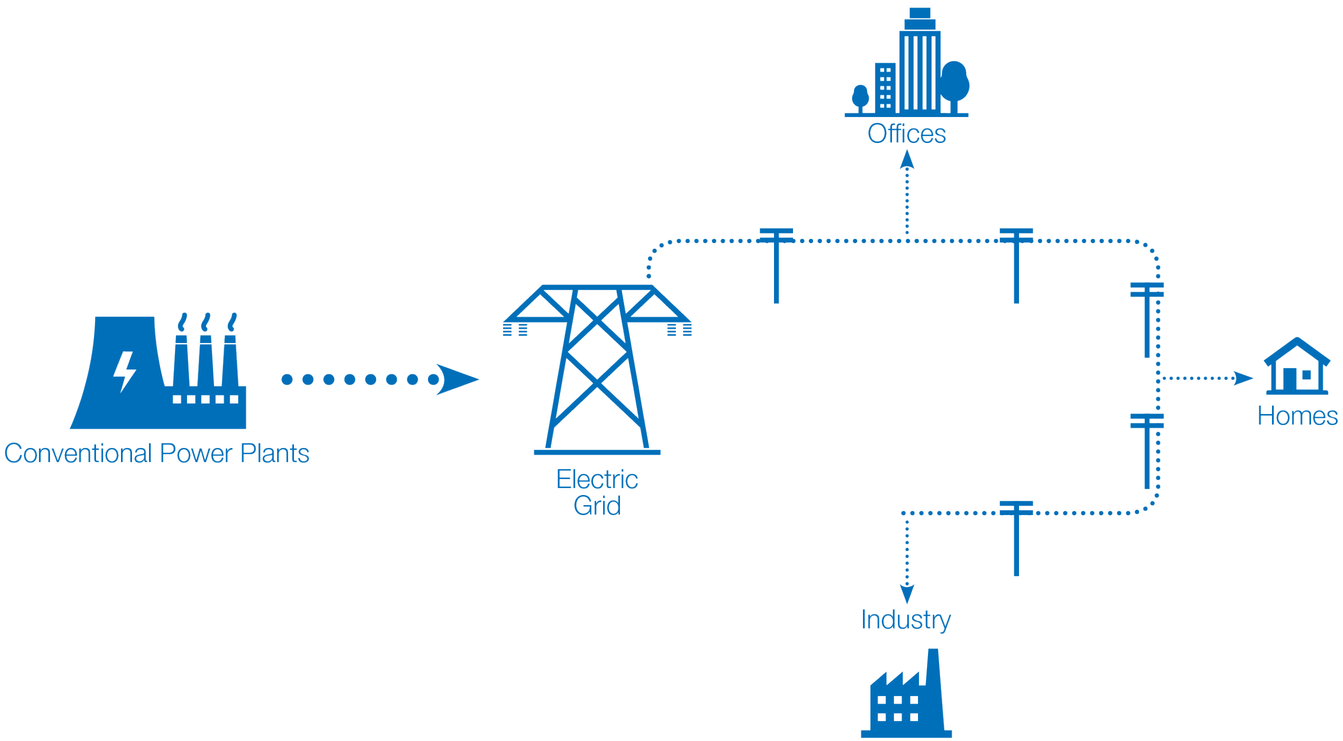
Credit: Michael Mathers

# Agenda

- Why we need grid-interactive buildings (GEBs)
- GEB basics: value streams and characteristics
- Systems and technologies for GEBs
- Communicating the value of GEBs

# Why do we need grid-interactive buildings?

# The one-way electricity grid of the past

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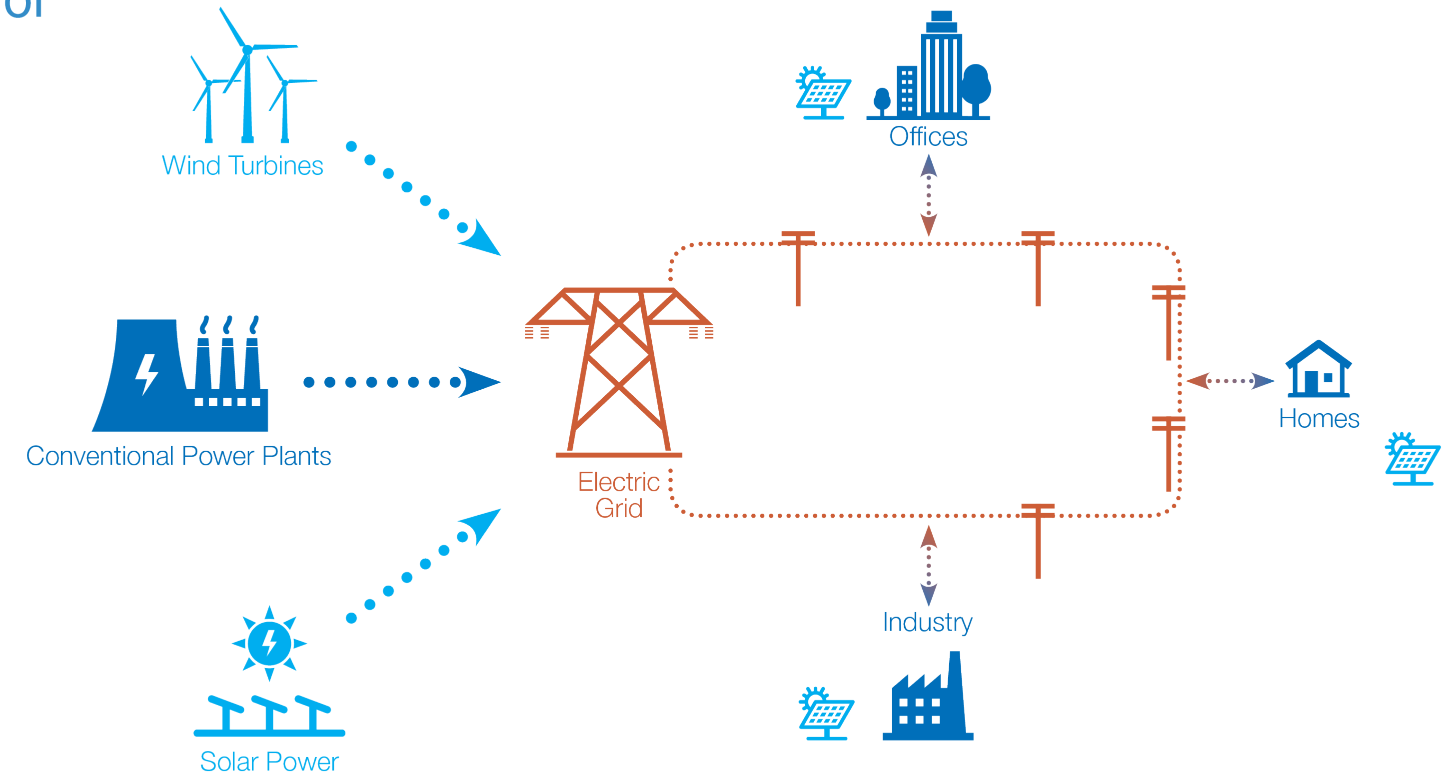
# The proliferation of distributed generation creates a need for more active grid management




**GridOptimal Technologies and Strategies:**

renewable energy

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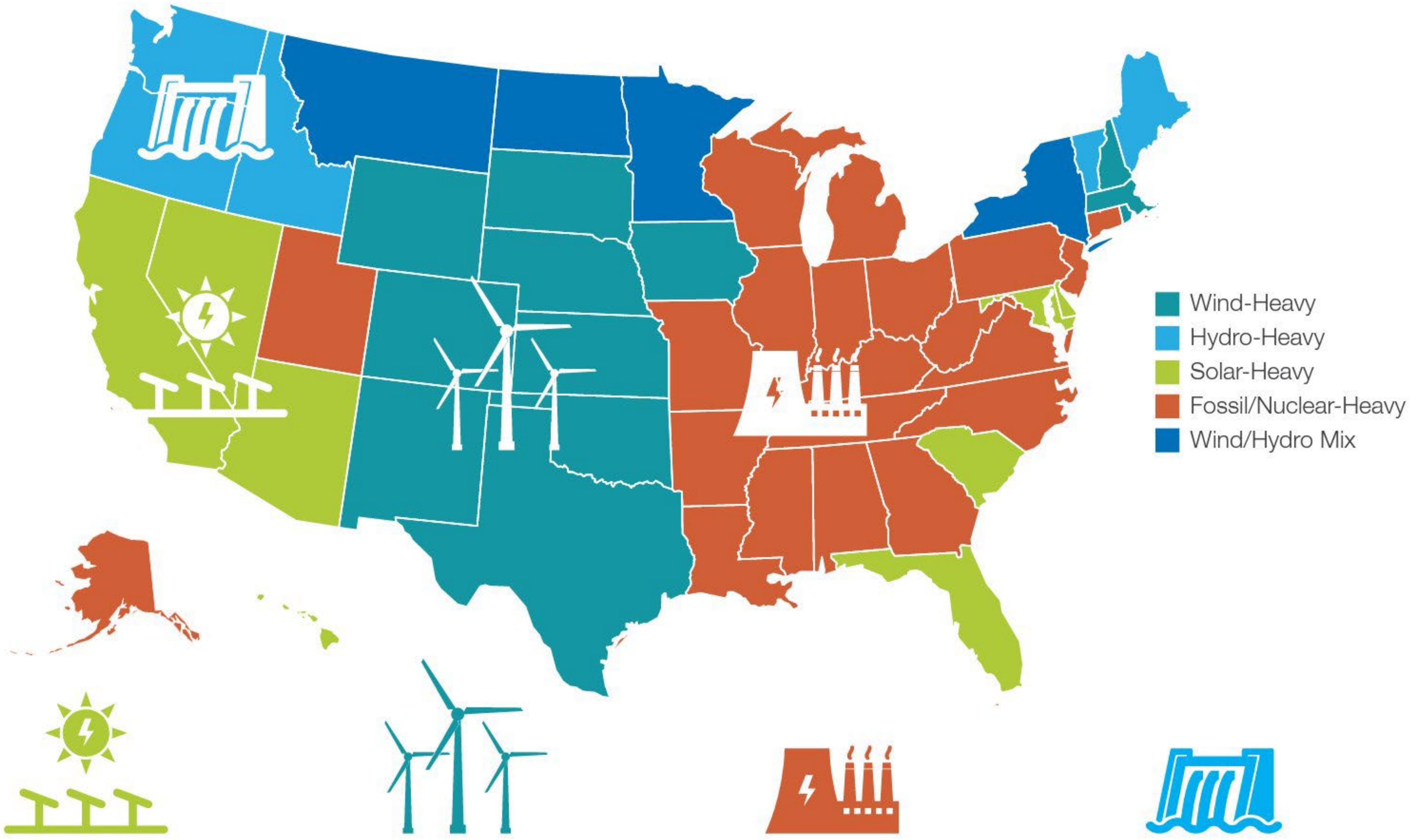
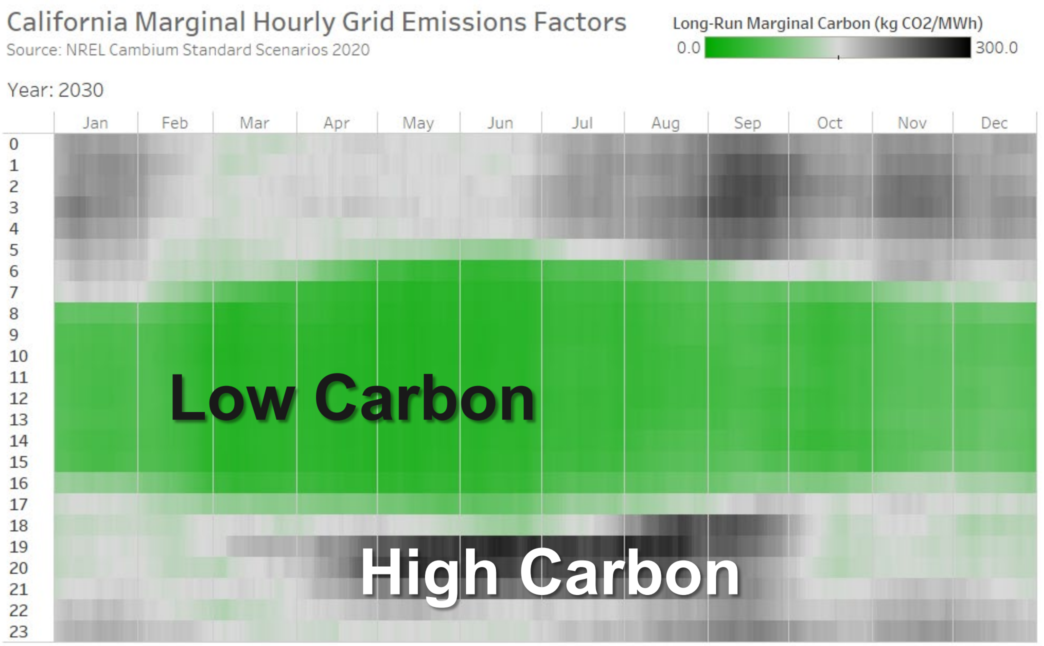
# There is no one “electricity grid”

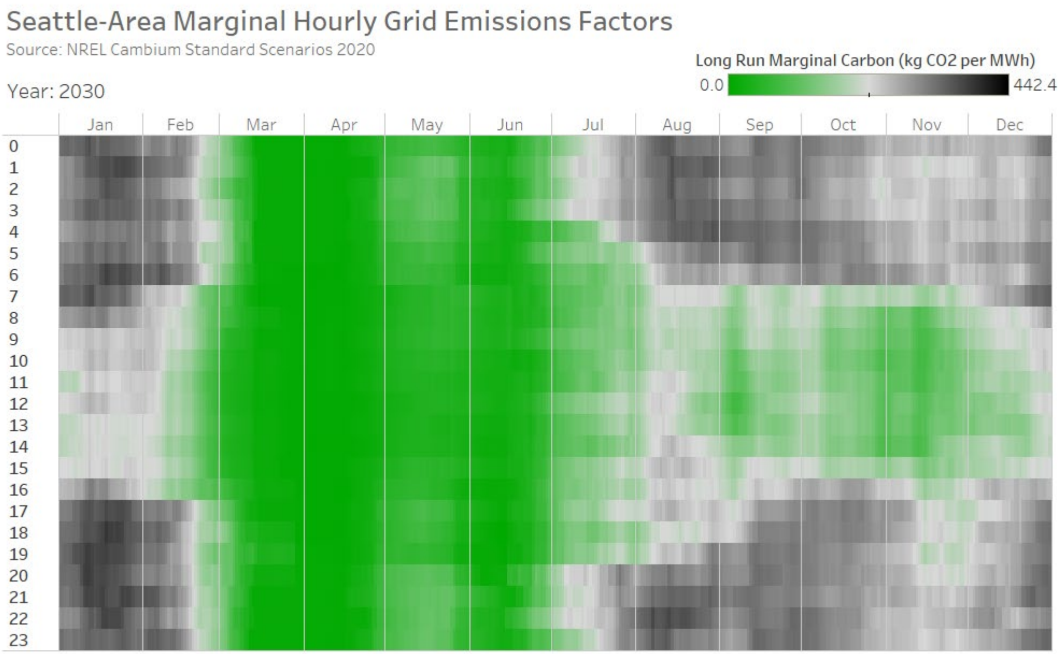


# GHG Intensity Varies Temporally and Regionally

- GHG intensity (CO2e/MWh) varies widely from hour to hour, day to day, season to season, and regionally
- This variability will grow as more wind and solar come online




Solar-Heavy Grid




Hydropower-Heavy Grid

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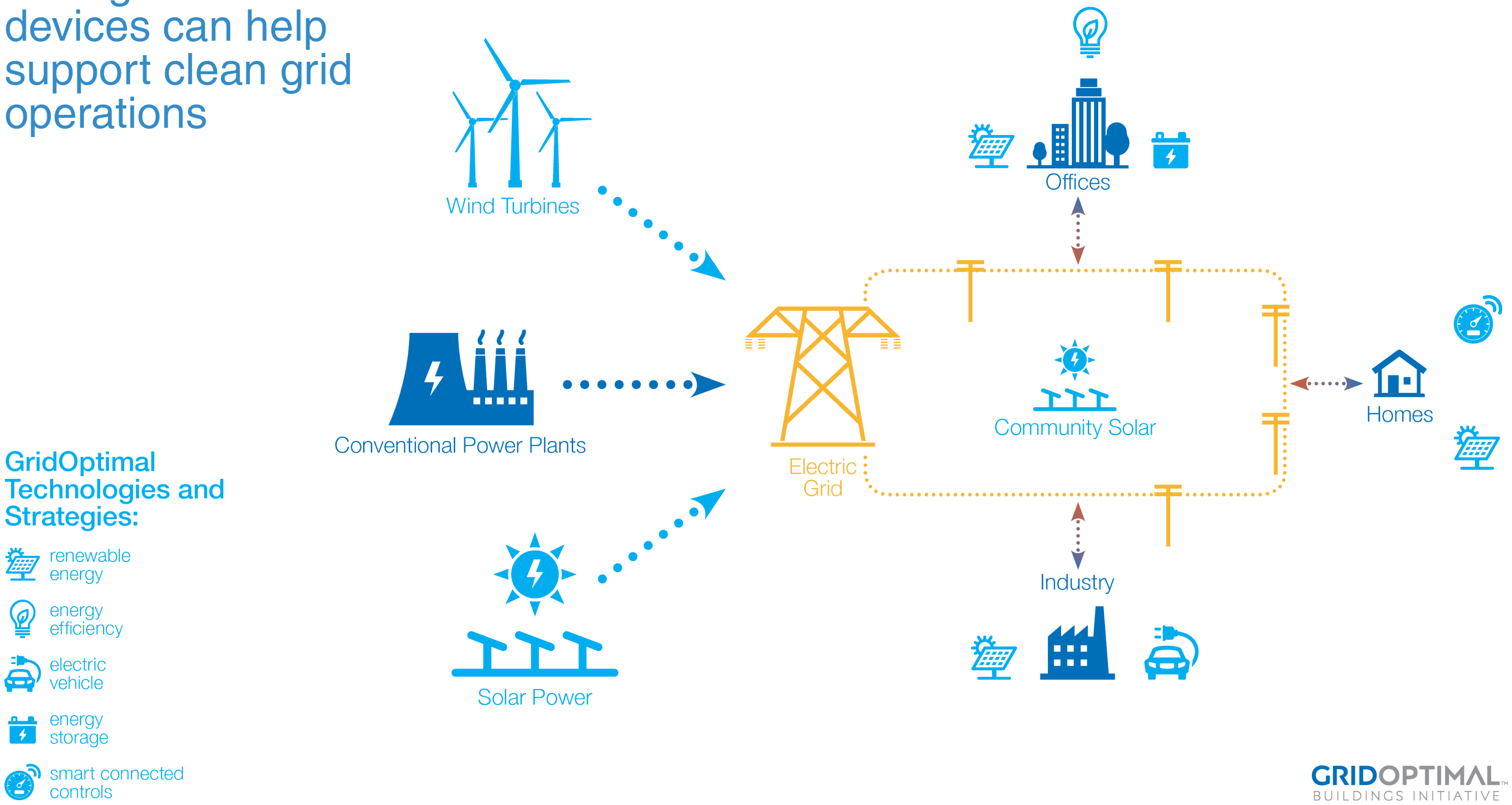
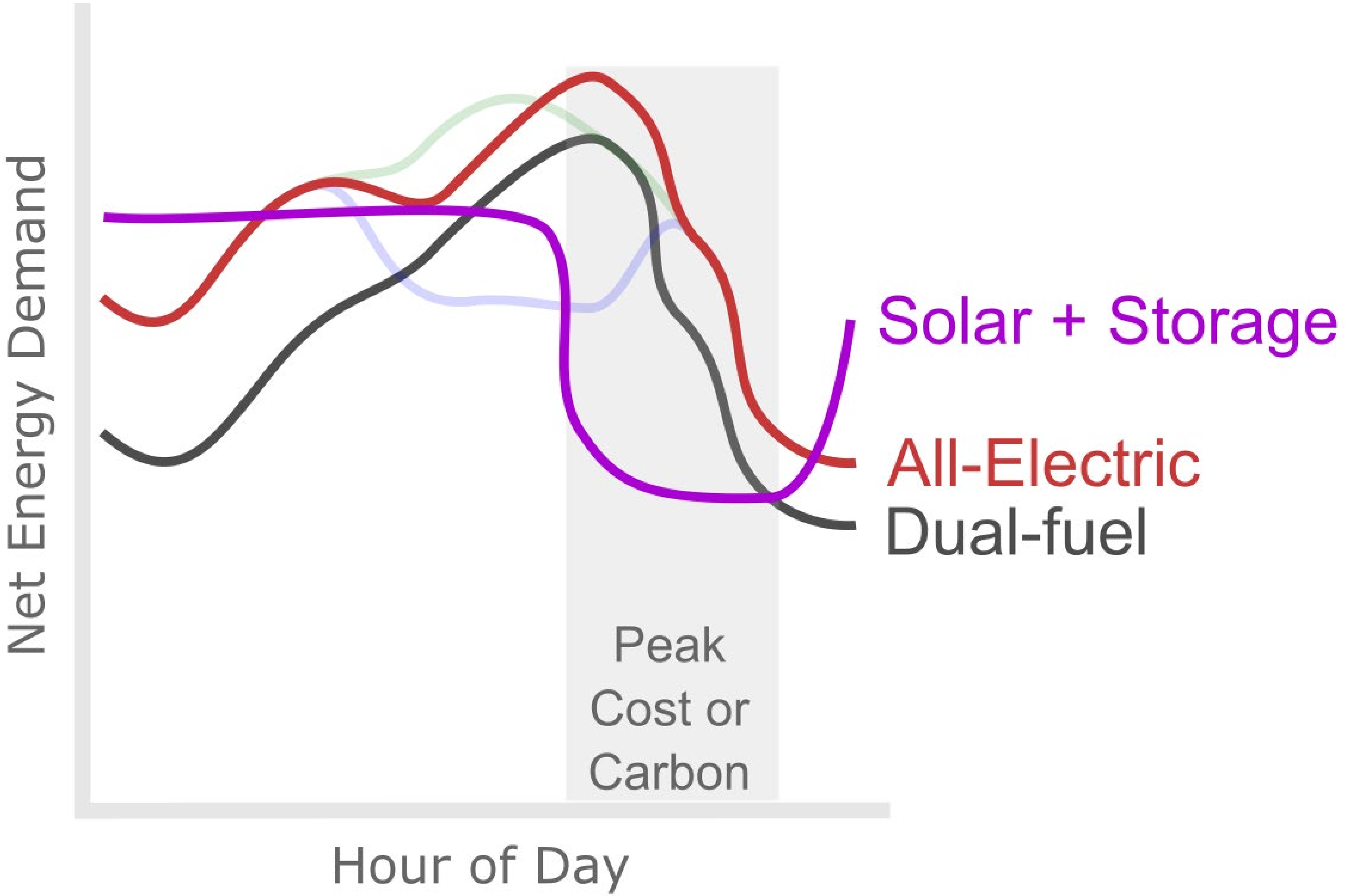
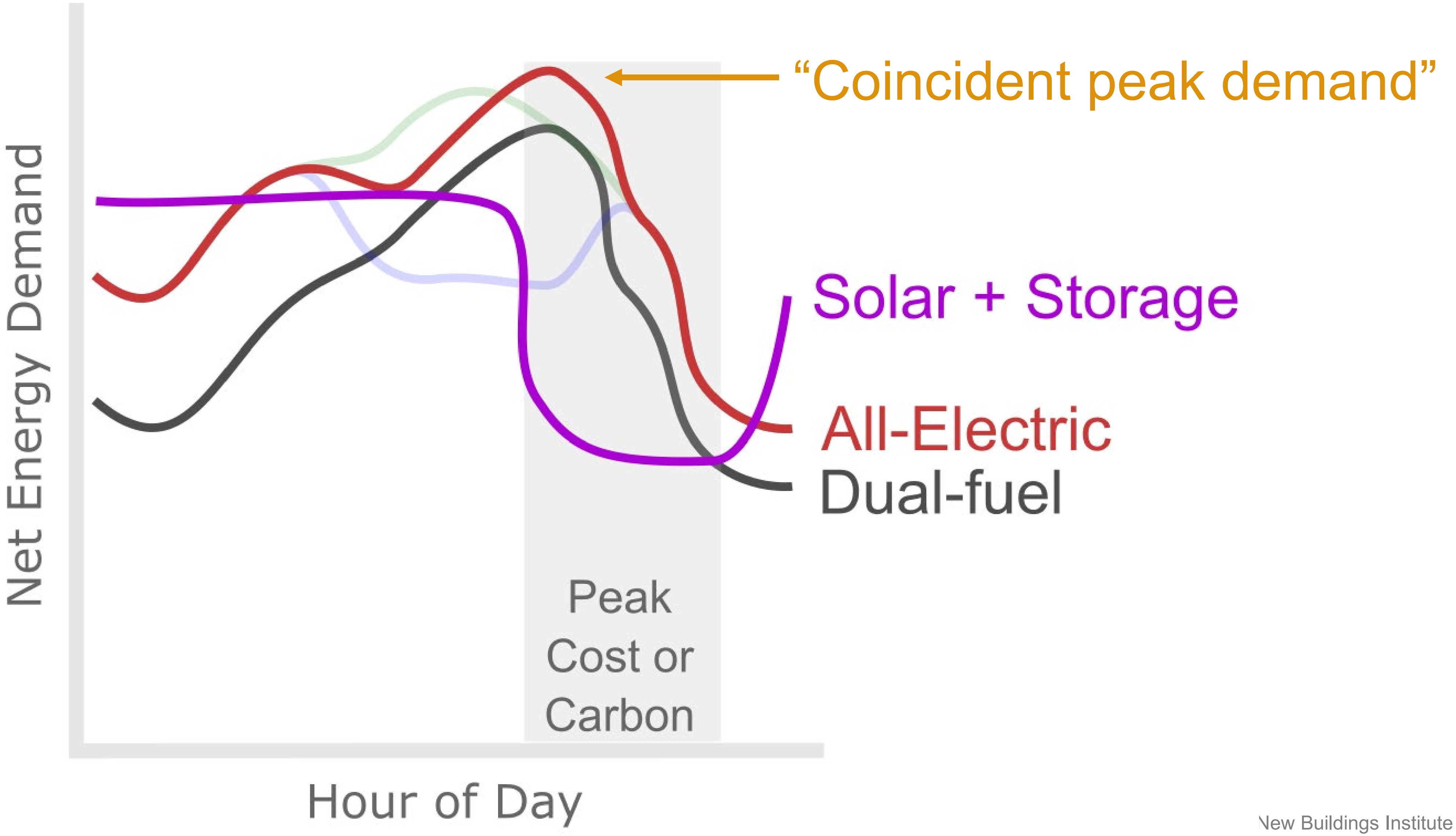
# Storage and smart devices can help support clean grid operations



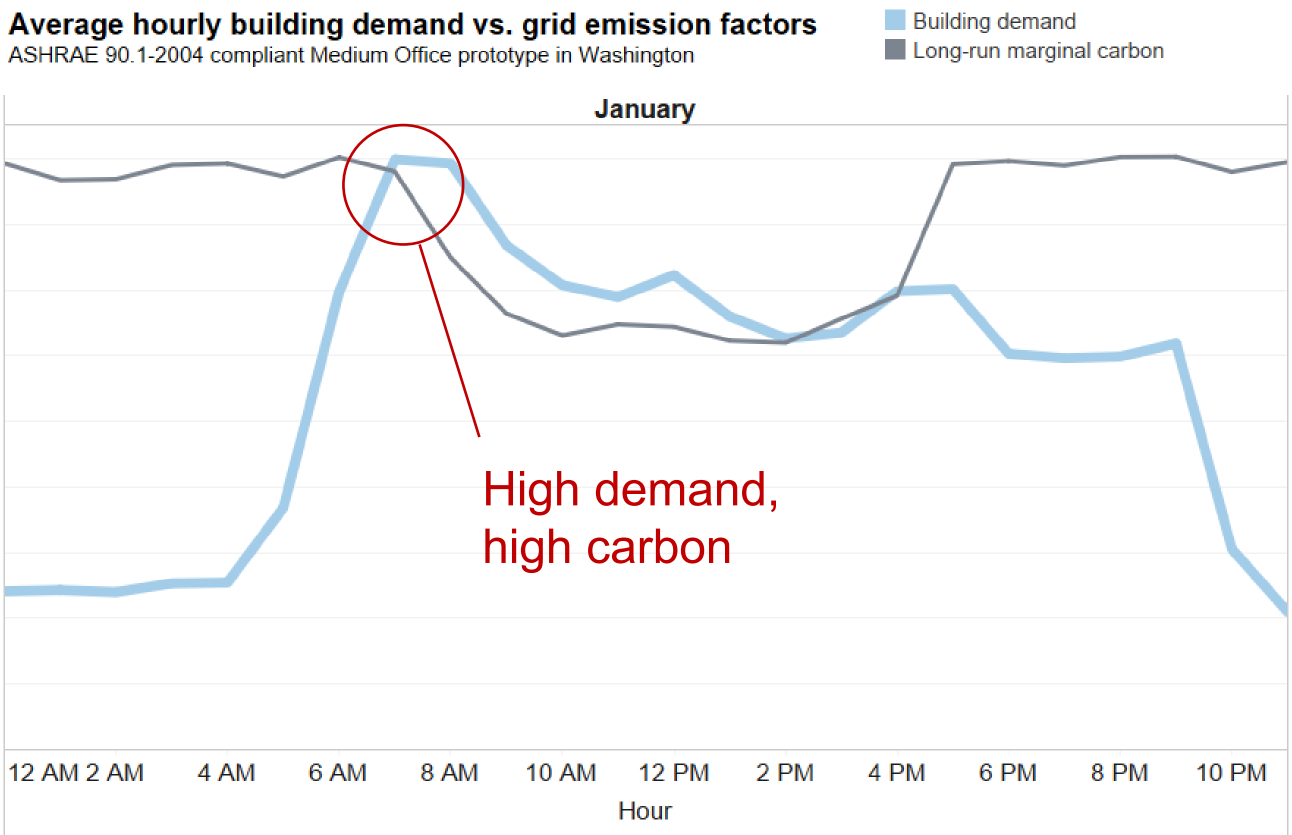
# Grid-Interactive Building Demand Management

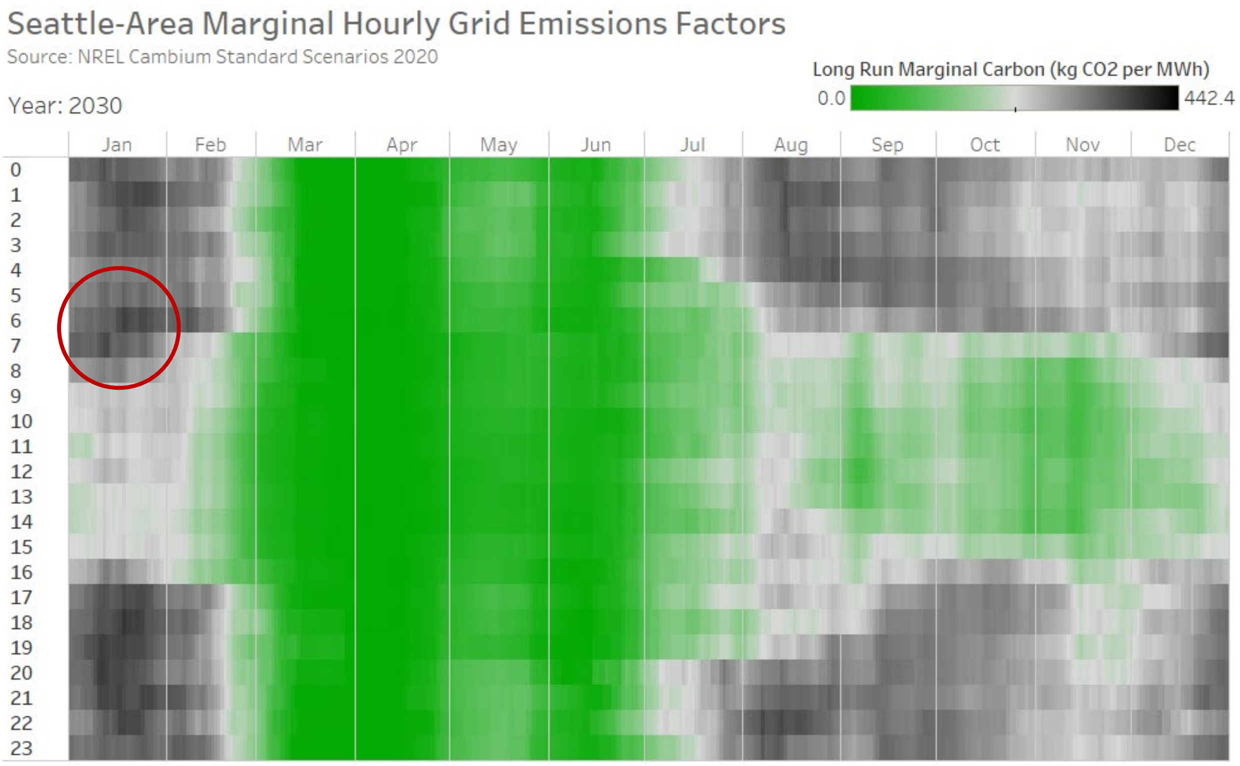


# Grid-Interactive Building Demand Management



# Building energy use vs. grid carbon

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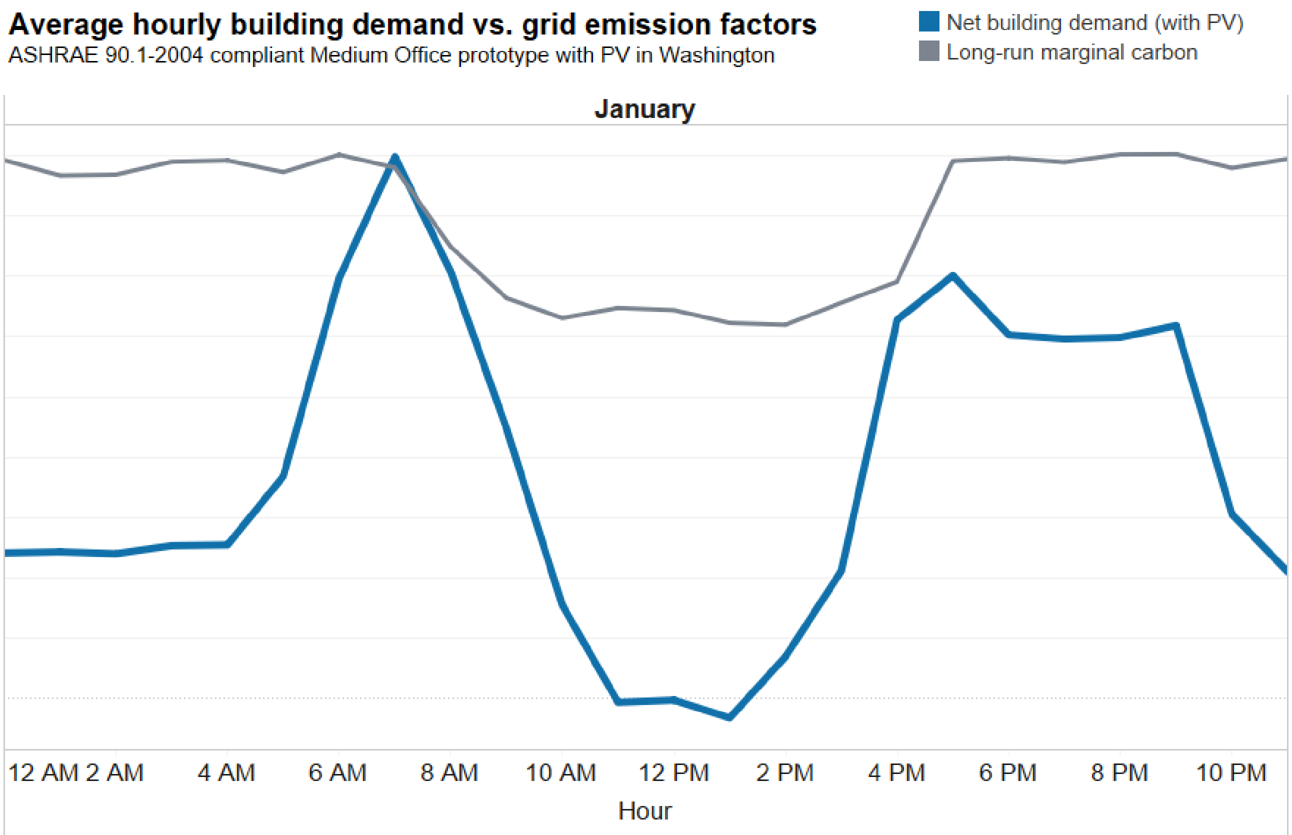
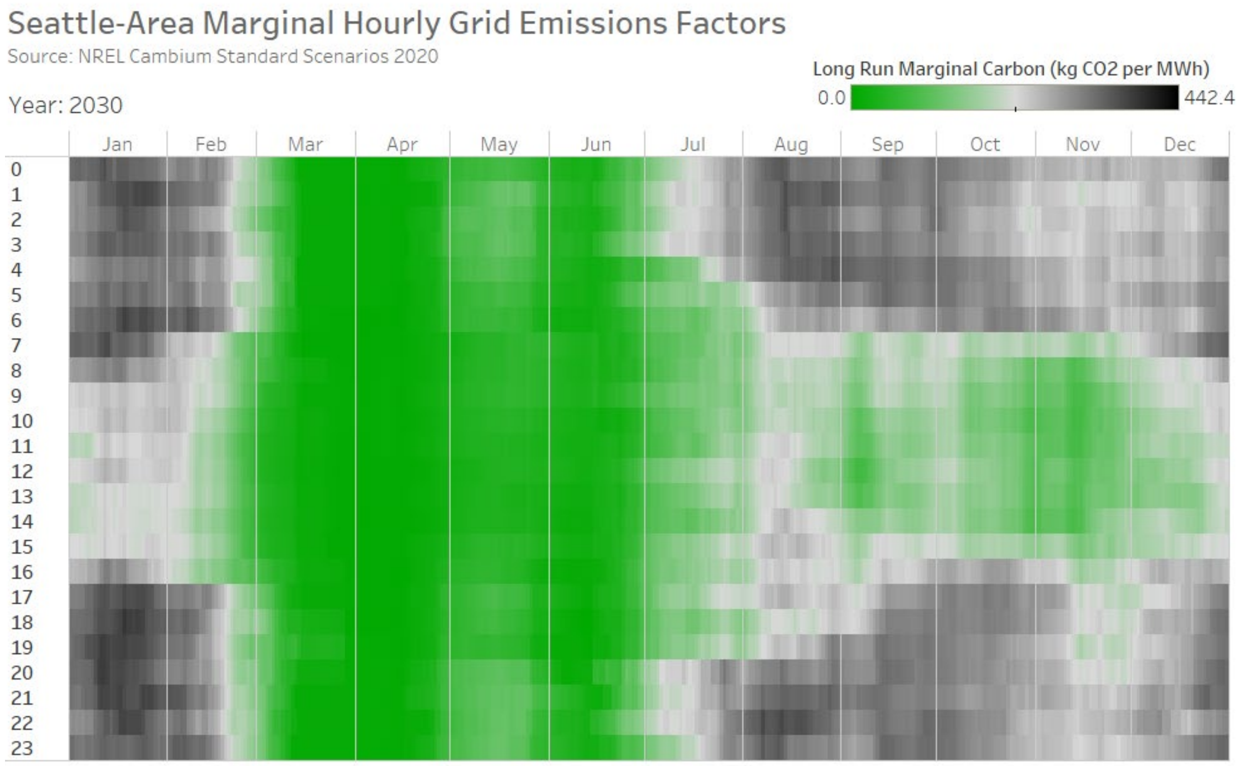
# Building energy use with PV vs. grid carbon




PV clearly changes the load shape in daylight hours…

How about time-of-use focused efficiency and DERs like batteries, microgrids, thermal energy storage, and more?

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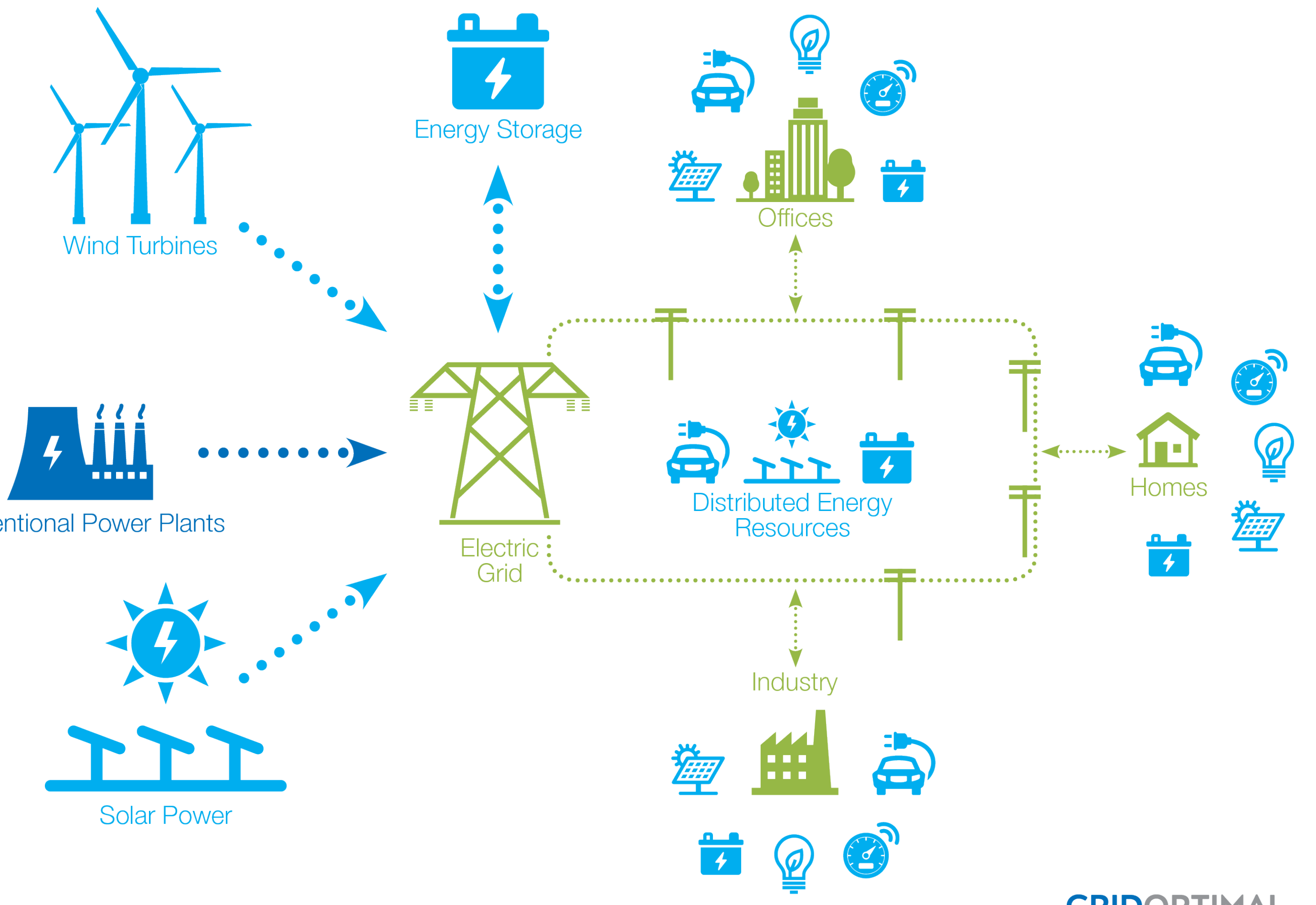
# GridOptimal empowers players on both sides of the meter to actively support the transition to a carbon free grid




## GridOptimal Technologies and Strategies:

- renewable energy
- energy efficiency
- electric vehicle
- energy storage
- smart connected controls

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# Summary

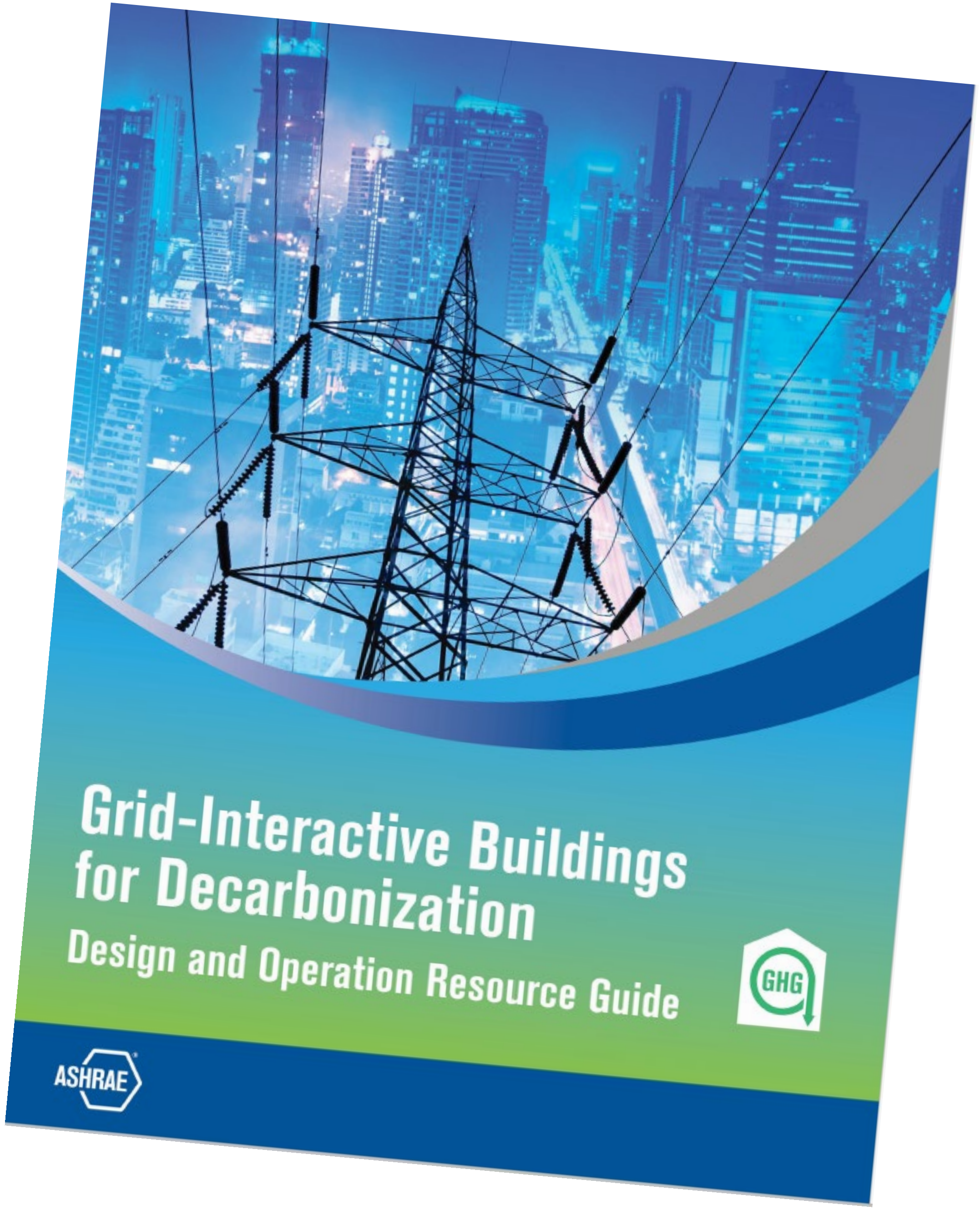
- The way **buildings interact with the electric grid** is evolving rapidly.
- Building owners/operators will face increasing **regulatory and economic pressure** to respond to **changing utility rate and delivery structures**.
- Designers will need to **understand and incorporate strategies** that allow buildings to directly interact with the utility grid.
- Adapting to the ***interactive grid*** will be critical to maintaining **building services and comfort** and to **grid affordability** and **dependability**.
- Buildings and DERs can be **electrical grid decarbonization enablers**.

# Poll #2

- How well-equipped are you to bring GEB concepts to your project teams? (1-5)

Credit: Michael Mathers

# Grid-interactive building basics


Grid-Interactive Buildings for Decarbonization
Design and Operation Resource Guide
GHG
ASHRAE

# Understanding GEB value streams

## Decarbonization

## Resiliency



## Cost Savings



## Regulations

# Value Streams

## Decarbonization

- Reduced direct (on-site) and indirect (generation) emissions by reducing carbon-intensive peak energy use
- Replacement of fossil-fuel based systems
- “Carbon arbitrage” strategies

- Questions to ask:
  - What are the peak carbon hours for the local grid? What are the primary renewable sources? Is the climate heating or cooling-dominated?

# Value Streams

## Resiliency



- Improved passive survivability (maintain occupant comfort + health for longer!)
- Minimizes impact of future utility rate increases
- Community resource in case of natural disasters

- Questions to ask:
  - How many hours of passive survivability do we have? Can we island? Can we go to “emergency mode”?

# Value Streams

## Cost Savings



- Utility bill savings
- Direct payments & other incentives
- Demand charge management
- Avoided exposure to regulatory fees & other costs

- Questions to ask:
  - What is the peak load (in kW) and how much money can we save from reducing it?
  - What tax credits, utility programs, and local incentives are available?
  - What is the regulatory context where the building is located?

# Equity and climate justice are also important considerations

- When considering grid-interactive design/upgrades, consider:
  - Local and regional pollution
  - Risk of power outages
  - Renter vs owner: who pays the bills?
  - First cost impacts – are they passed on?
  - Technical requirements + owner/occupant expertise
  - Language barriers

# Poll #3

- Which of these value streams do you think will resonate strongest with your project teams?

**Decarbonization**

**Resiliency**

**Cost Savings**

**Regulations**

Credit: Michael Mathers

# Realizing the value: key characteristics of a GEB

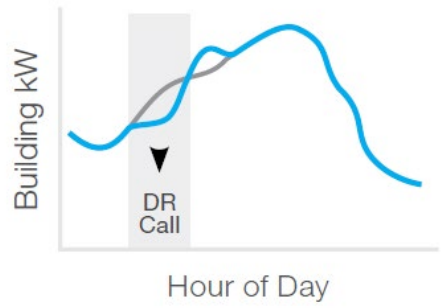
- **Efficient**: Peak load reduction
- **Flexible**: Reduce, increase, shift, or modulate use
- **Controllable**: Co-optimize efficiency, flexibility, and occupant comfort
- **Connected**: 1- or 2-way connections to grid operation

# Efficient & Flexible

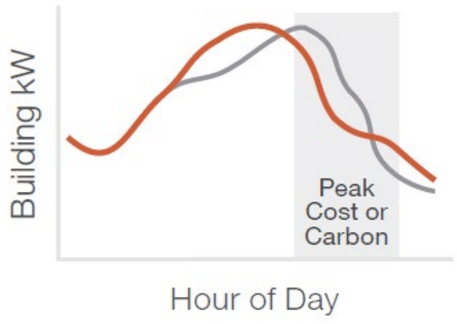
## *Specs at-a-glance*

- **Permanently** reduce peak demand (kW) of designed building by 10%, 20%, etc. vs baseline
- Be able to **shed or modify load** (kW) in a variety of ways:
  - In response to a signal (event-based)
  - Through active load shaping (e.g., pre-conditioning a space, preheating hot water)
  - To provide grid ancillary services (e.g., frequency regulation)

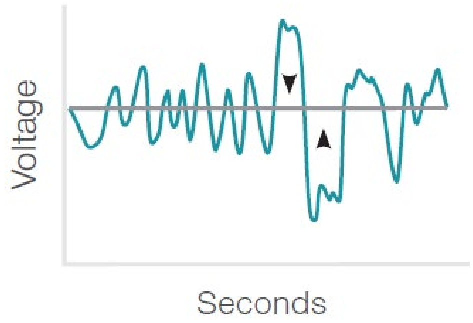
**Demand Response**




**Load Shaping**

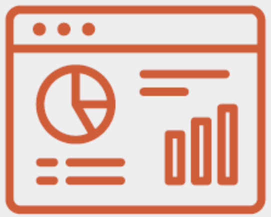



**Ancillary Services**



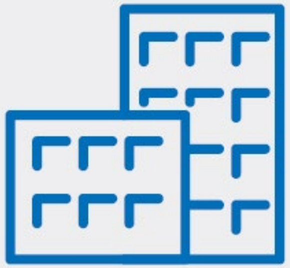
# Controllable and Connected
## *Specs at-a-glance*

- Key building systems should be able to **take a signal** from the grid (or a 3rd party), and then **take action**
- 2-way comms is even better (can report back to grid)
- Communications should be **standardized** (e.g., OpenADR, CTA2045)
- Communications can be at the device level, whole-building level, or use another aggregation approach



**Specifications**

Communications and interoperability are key!



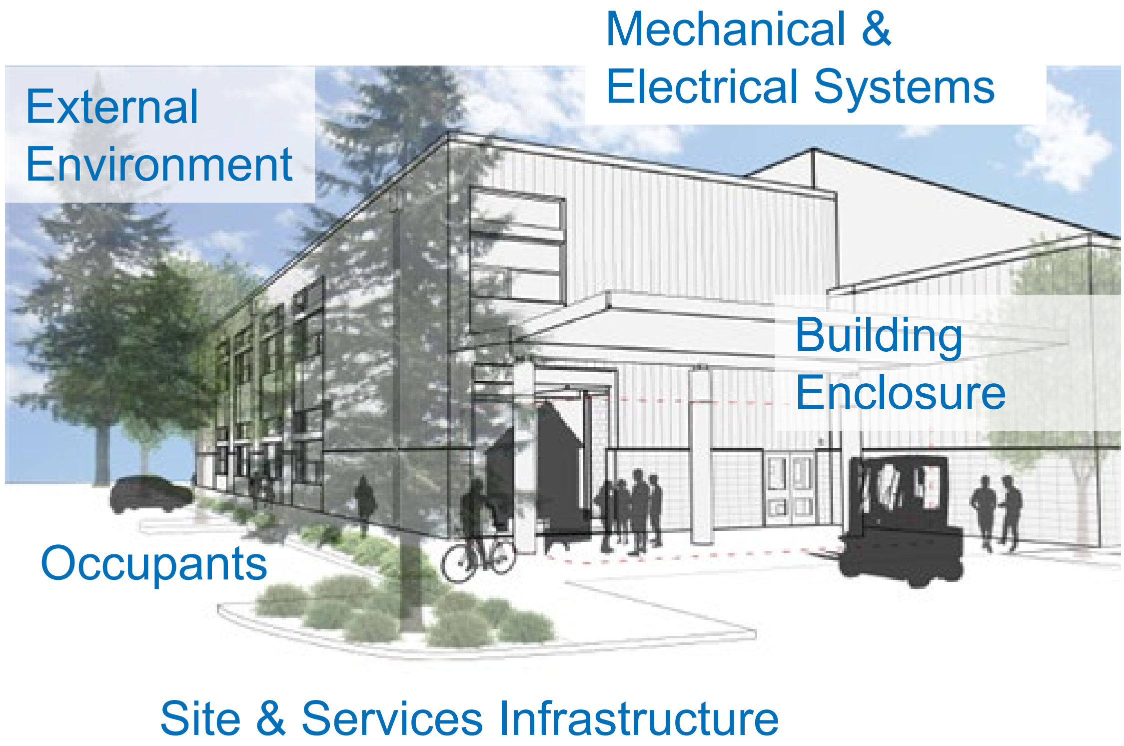
**Operations**

Prioritize automation and occupant comfort!

# Systems and technologies

# Specifying building systems

- Everything is connected…take an integrated, whole-building approach
  - Efficiency, flexibility, renewables, and grid optimization
- Key GEB considerations within each system:
  - Basic design requirements and system selection
  - Grid communication/supervisory control requirements




*Source: https://www.pps.net/Page/14926*

# A note about simple, standalone systems

- Buildings with simple, standalone systems (i.e., no BAS) are not exempt from grid-interactivity!
  - Adding communications can make a big difference
- If adding BAS isn't possible, optimize each system individually

> *"Small structures can cut energy use from 27% to 59%, depending upon building type, using economically viable and commercially available technologies. Implementation of these technologies would reduce the overall commercial building energy footprint by 17%."*
>
> -*Nexus Labs*

# Overall GEB modeling considerations

- Iterative and/or parametric energy modeling to explore options
- Design-day peak W/sf (winter and summer):
  - How much can you reduce it? How much is sheddable?
- Focus on end uses that **align with high-net-load hours** (high-cost, high-carbon)
- Use an iterative approach:
  - Baseline (code) → Proposed (EE measures)
  - Proposed → Proposed+ (Flexibility measures)
  - Proposed+ → Post-process Proposed (EV, battery)

# Simple Overall Sizing Strategies

- Find simple and consistent frameworks, for example:
  - Size solar + battery storage + mechanical controls system so that the building has **zero net load** from the utility during the **summer peak** design day from 3-8 pm (peak hours)
    - Can be adapted to use a different peak window
    - Can be “as built” or “design for readiness”
    - Increased heating electrification may make **winter** peak design day more important in the future

# Specs: Envelope

- Follow Advanced Energy Design Guides (AEDG), IgCC, Passive House, or other standards for envelope specs
- Prioritize passive strategies to reduce coincident peak demand
  - Insulation
  - Air tightness
  - Orientation and shading (esp. SW & W facing)
  - Thermal mass
  - Electrochromic glass, other active strategies

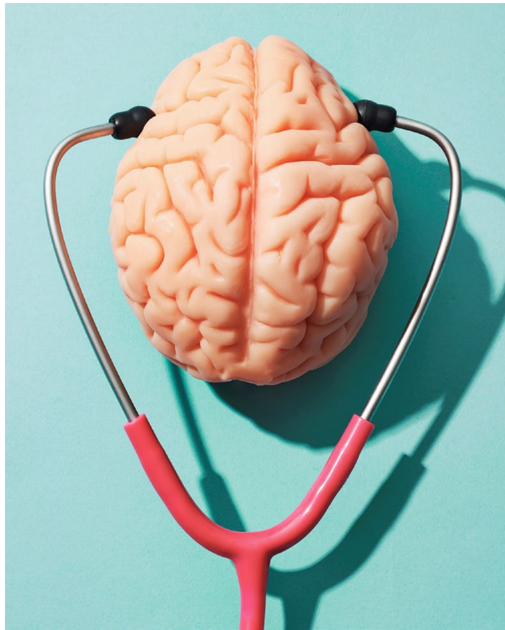
# Modeling considerations: Orientation and Envelope

- Passive orientation and envelope strategies impact building load shape – and flex capability
- Try parametric modeling with different envelope conditions
  - Insulation, air sealing, etc.
  - Cooling load associated with summer afternoon heat influx
- Evaluate results using 8760 model outputs

  =>*Across various value streams*

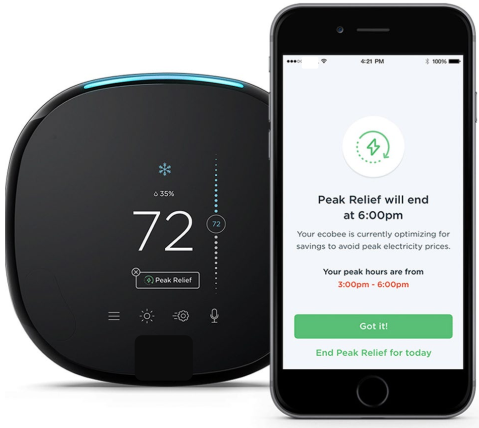
# Specs: Building Automation System

- BACnet (ASHRAE 135)
- Compatible with utility communications + reporting protocol
- Control HVAC + other systems simultaneously; understand the capacity and availability of DERs
  - Many sensors/actuators/control points to consider
- Ideally, remote operability via LAN or internet
- Layer on EMIS or other 3rd party monitoring + optimization application(s)



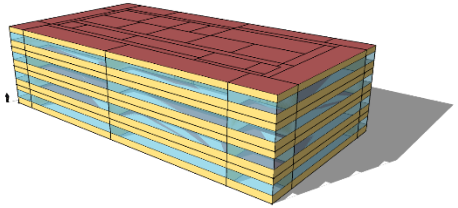
# Specs: HVAC

- All-electric, high-efficiency heat pumps reduce kW during peak
- HVAC Equipment should be smart grid ready
  - At least OpenADR2.0, IEC 62746-10-1, or IEEE 2030.5
- Spec ENERGY STAR connected products where relevant
- Thermostats should be able to play the DR game
  - Compatible with local utility DR program, if present
    - If not, check to see if they have plans for a DR program
  - Is an OpenADR 2.0a VEN
    - Ideally: 2.0b or 3.0

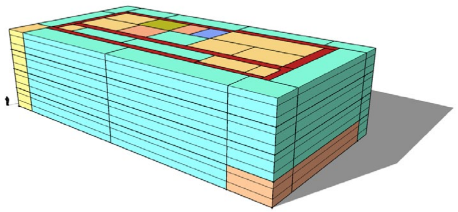


# Modeling considerations: HVAC and Controls

- Building controls present in modeling largely via *schedules*
- Explore different controls schedule/setpoint scenarios across baseline/proposed design/efficiency scenarios
  - Baseline schedule & setpoints
  - Improved schedule & setpoints
  - TOU rate optimizing schedule & setpoints



- Also consider HVAC controls *zoning*



- Evaluate results using 8760 model outputs

  =>*Across various value streams*

# Specs: Water Heating

- Heat pump water heaters (unitary/central) reduce peak kW
- Unitary Water Heaters should be able to play the DR game
  - Most commonly, that's CTA-2045 (EcoPort)
  - Ideally, spec 2045-B level 2
- Spec larger tank and/or mixing valve: increase energy storage
- Tested under demand flex test procedures if possible: AHRI 1430

# Modeling considerations: Water Heating

- HPWH are more efficient… but have a longer recovery time
- Hot water **draw profiles** have a huge impact on whether HPWH are in heat pump mode (efficient, low power) or backup resistance mode (much higher power)
  - Fancy approach: stochastic modeling
  - Basic approach: averages
- Check model assumptions on recirculation loops & how recovery is handled when tanks run low on hot water

# Specs: Lighting

- High-efficiency, daylighting, etc. – minimize peak kW
- Dimmable LED lighting w/ gradual 30 min adjustment
- Centralized controllability
- DR-capable lighting controller
  - At least OpenADR2.0, IEC 62746-10-1, or IEEE 2030.5

# Modeling considerations: Lighting

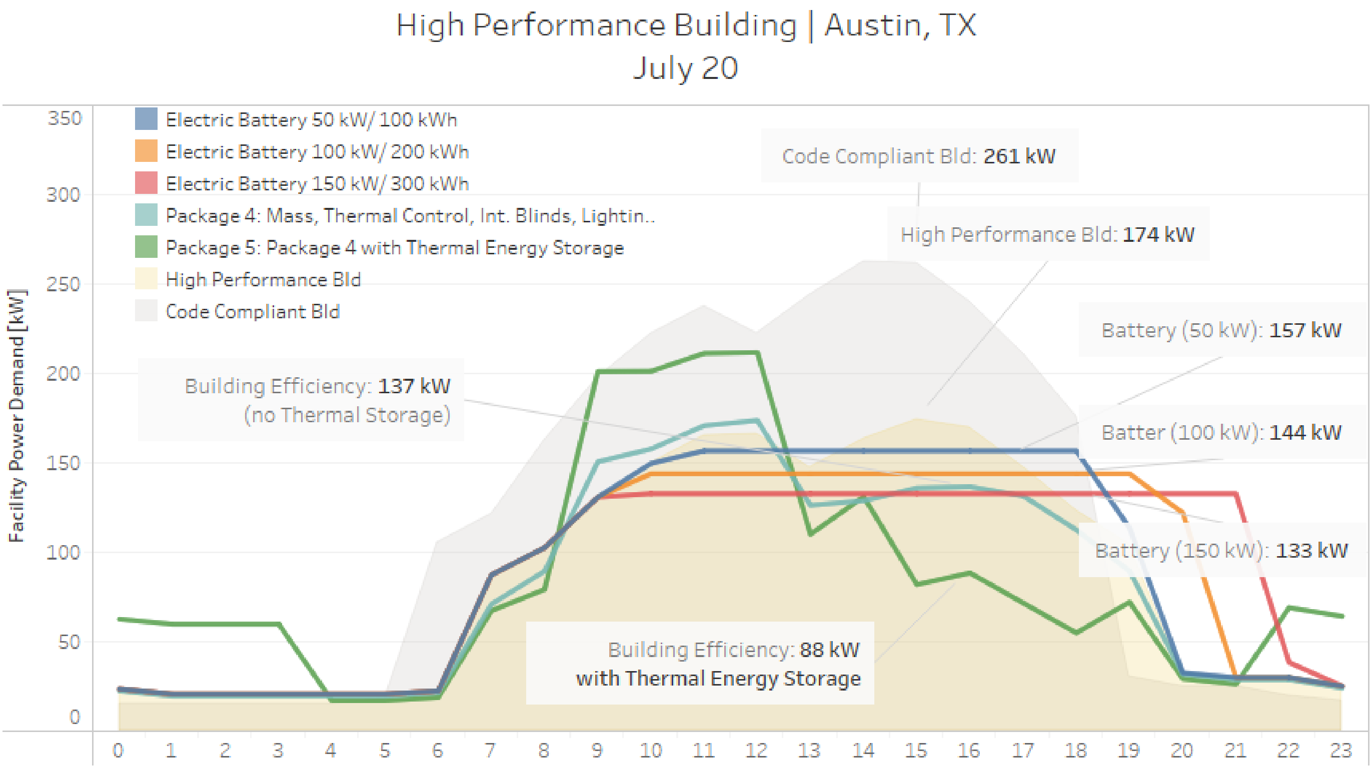
- Mostly, modeling will be parametric based on schedules
  - (Schedules are averages)
- Lighting DR has no bounceback – unlike HVAC and WH DR
- Consider tradeoff between daylighting and lighting DR operations

# Specs: Plugs and MELs

- ENERGY STAR, CEE, other high-efficiency specs
- Identify plug and process loads that may be candidates for load shedding with little to no occupant impact
- Include local temporary override controls to revert to normal operations during DR events
- Spec grid-connective or ENERGY STAR connected appliances where available
- Consider Elevator DR: 1 out of 3 elevators off by DR call

# Modeling considerations: Individual Measures -> Packages

- Be aware of interactive effects!
  - Ex: thermal mass improves kW shed from HVAC controls
  - Ex: high-efficiency HVAC has lower kW, so less to shed
- Bounceback is a real thing, and so is round trip efficiency!
  - HVAC energy bounces up after DR events
  - Precooling, batteries, thermal storage **do not** save energy




Source: Red Car Analytics for GridOptimal, 2019

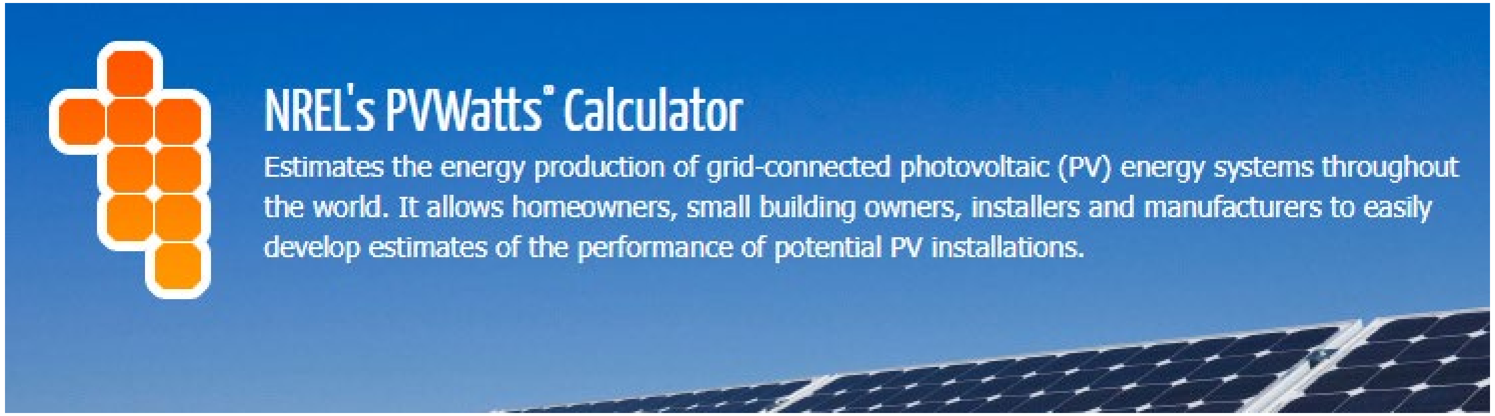
# Specs: Solar PV

- Spec Smart Inverters:
  - UL 1741 v3
  - IEE 1547a-2020
- FEMP 2023 tech spec tool for on-site solar PV
  - https://www.energy.gov/femp/technical-specifications-site-solar-photovoltaic-systems

Photo: Stephen Coffrin

# Modeling considerations: PV

- Easiest to post-process
- Specify with storage and **co-optimize for cost and carbon impact**
- Consider integration with the electrical system: DC-coupled vs AC-coupled




*https://pvwatts.nrel.gov/*

# Specs: Battery Electrical Storage Systems (BESS)

- Capable of independent, scheduled operation for economic optimization
- Can take a DR signal
- Smart inverter (like the PV inverter)
- FEMP 2023 BESS tech specs & checklist
  - https://www.energy.gov/femp/articles/lithium-ion-battery-storage-technical-specifications

# Modeling considerations: BESS

- Set reserve capacities with resiliency goals in mind
  - May differ by season
- **Co-optimize for cost and carbon impact** when defining system dispatch strategy/control
  - Don’t focus on cost alone, lest batteries *increase* carbon emissions

# Specs: Electric Vehicle Supply Equipment (EVSE)

- Grid-connective EVSE
  - OCCP, IEC 63110-1
- Spec ENERGY STAR connected chargers where possible
- Automatic load management system (ALMS) to manage peak load & costs
- Consider bidirectional charging
- Build for both current & future capacity

# Modeling considerations: EVSE

- Probably post-processed (spreadsheets) on top of modeled 8760s
- Modeling ALMS ca be a little kludgy
- **Co-optimize for cost and carbon impact** when exploring managed charging expectations

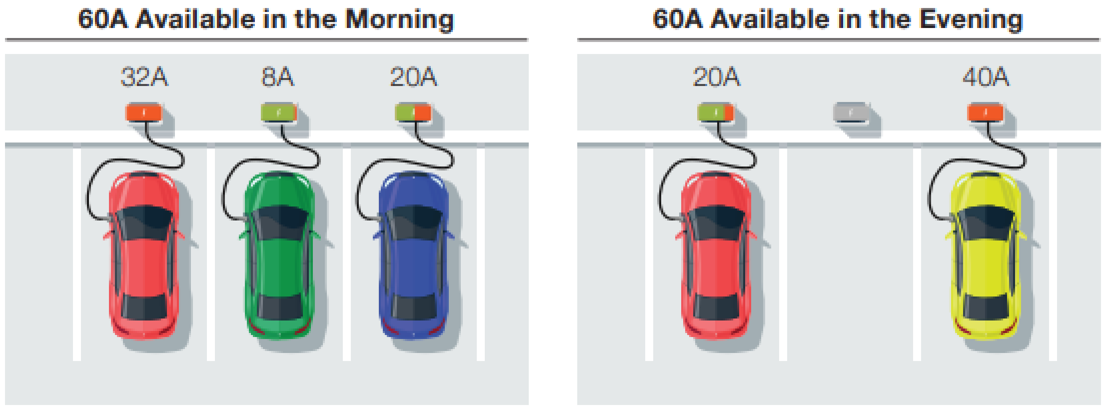


Figure 2: Dynamic Load Management

*https://localenergycodes.com/download/1617/file_path/fieldList/ALMS%20Fundamentals.pdf*

# Specs: Others

- Thermal energy storage
- Refrigeration
- Data centers
- Irrigation and pumping
- Pools and spas

# Major Findings and Key Recommendations

- General Best Practices Include:
  - ❑ Utilize energy efficiency solutions to decrease **overall energy** and **peak electricity** consumption
  - ❑ Decarbonize when upgrading building systems: **go electric**
  - ❑ Enable **demand flexibility via controls** to reduce carbon emissions (and, prefer automated controls)
  - ❑ Co-optimize operations to **minimize carbon** emissions and **energy costs** while **maximizing resiliency**
  - ❑ Evaluate other key objectives relevant to the building (**resiliency, health, equity**)
  - ❑ Make a plan for **cybersecurity**
  - ❑ **Commission** and **maintain** systems properly
  - ❑ Provide owner, operator, and occupant **education**

Photo: ehdd

# Poll #4

- Which building systems are you confident in your ability to model – for the purposes of optimizing grid integration outcomes?

Credit: Michael Mathers

# Communicating the value of GEBs

# Bringing it back to the value streams

## Decarbonization

## Resiliency



## Cost Savings



## Regulations

# Bridging the gap between designing + decision-making

Vs.

# Make the model work for you

- Models are the critical step to translate system/technology investments and energy efficiency measures to:
  - Lifetime cost savings
  - GHG emission reductions
  - Resilience capacity
  - Thermal comfort and other occupant satisfaction metrics
- Adopting resilient building construction practices, as in codes, saves on average $11 for every $1 invested (NIBS)
- Build on work that is already done!

# Handy Factsheets with 80/20 Solutions


DESIGN GUIDANCE FACTSHEET

GRIDOPTIMAL™ BUILDINGS INITIATIVE

NREL Research Support Facility | Golden, CO
Credit: Dennis Schroeder

## Optimizing Building-Grid Integration in Office Buildings

This factsheet recommends selected high-impact building design and operational strategies for office buildings.

Factsheets are available for other building types and for specific regions across the US.Office buildings can save costs, reduce carbon emissions, and help advance energy system decarbonization through time-of-use energy efficiency, smart devices, connected controls, and distributed energy resources such as onsite/community solar and energy storage. The recommendations in this factsheet are based on a wide variety of research, including building-scale and grid-scale simulation modeling and on-the-ground GridOptimal pilot project experience.

Managed EV Charging
Energy Efficiency
Smart HVAC Controls
Plug Load Management
Energy Storage
Offices


DESIGN GUIDANCE FACTSHEET

GRIDOPTIMAL® BUILDINGS INITIATIVE

## Optimizing Building-Grid Integration in the Northwest U.S.

As we transition to a clean energy future, building equipment will need to optimize opportunities for grid integration and demand flexibility. Through three years of study, the GridOptimal Initiative has developed recommendations for selected high-impact building design and operational strategies for homes and buildings. They are based on a wide variety of research, including building-scale and grid-scale simulation modeling and on-the-ground GridOptimal pilot project experience.

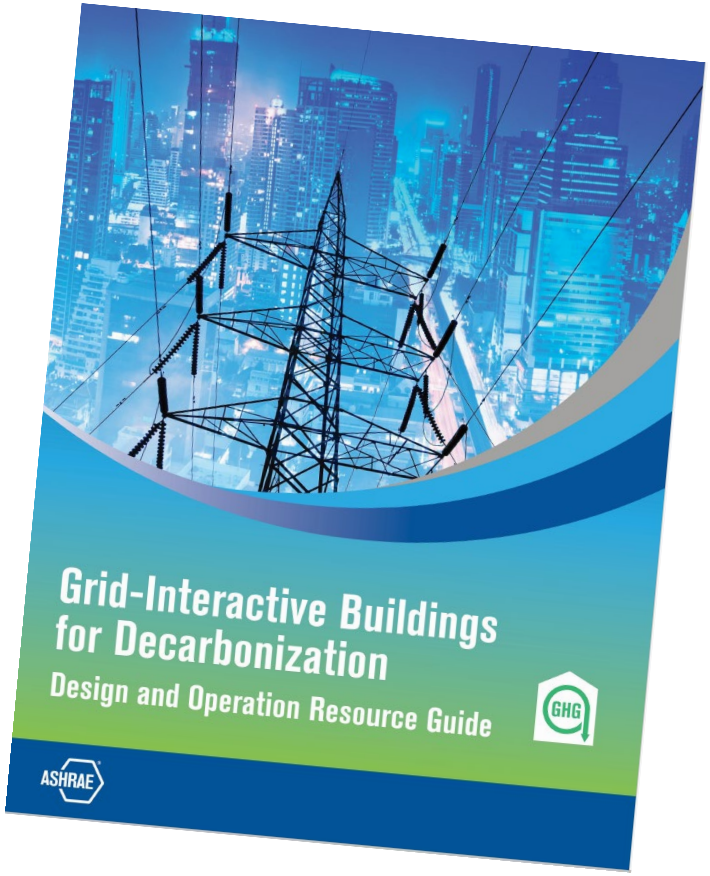
This factsheet recommends selected high-impact building design and operational strategies for homes and buildings specifically tailored for the Northwest U.S. Factsheets are available for other regions and for specific building types. The region's many hydroelectric dams provide bountiful, affordable, low-carbon electricity and help balance more variable renewables such as wind and solar, but as electricity demand grows and the region's climate changes, new solutions will be needed to meet demand throughout the year. Buildings across the region are uniquely positioned to play an important role in improving building-grid integration through time-of-use energy efficiency, smart devices, connected controls, and distributed energy resources such as onsite/community solar and energy storage. The recommendations in this factsheet are based on a wide variety of research, including building-scale and grid-scale simulation modeling and on-the-ground GridOptimal pilot project experience.

While the recommendations outlined in this factsheet are specifically tailored for the Northwest U.S., factsheets are available for other regions and for specific building types. Visit newbuildings.org/resource/gridoptimal-design-guidance

https://newbuildings.org/resource/gridoptimal/

# ASHRAE Grid-Interactive Buildings for Decarbonization Design and Operation Resource Guide

- Recently published resource from ASHRAE's Task Force for Building Decarbonization
- NBI was lead author, supported by PAE
- Offers more in-depth explanation of many of today's concepts
- $52 for ASHRAE members ($74 if not)




https://www.techstreet.com/ashrae/standards/grid-interactive-buildings-for-decarbonization-design-and-operation-resource-guide?product_id=2574822

# GridOptimal Measure Impact Analysis Tool

Introduction | GO Results | Grid Carbon | Grid Demand | Load Shapes | GO Results Viewer | Cost Impact

## GridOptimal Measure Impact Analysis Tool

GRIDOPTIMAL® BUILDINGS INITIATIVE

nbi new buildings institute

Welcome to the GridOptimal® measure impact analysis tool. This interactive dashboard allows you to review the potential grid benefits of various efficiency and demand flexibility measures across climate zones and building types.

### About GridOptimal

The GridOptimal Buildings initiative, launched by New Buildings Institute in partnership with the U.S. Green Building Council (USGBC), is a national coalition committed to better integrating buildings into utility grid management strategies. GridOptimal supports least-cost grid decarbonization by promoting demand flexibility and time-of-use energy efficiency to reduce peak system load on the grid, ease distribution congestion, and empower buildings and utilities to build a more resilient future for both building and our electric grid. Learn more at our website.

### About the tool

This tool summarizes the key findings from the GridOptimal Initiative, which pulled together leading modeling and research in the field of demand flexibility and energy efficiency, then evaluated the impact of those measures using our GridOptimal metrics in order to understand the grid-related impacts of these measures beyond simple energy savings. The tool allows users to compare the impacts of various efficiency and demand flexibility strategies in order to support decisionmakers across the building industry, including designers, utilities, and building operators.

There are several pages in this tool through which you can navigate via the tabs at the top of the page:

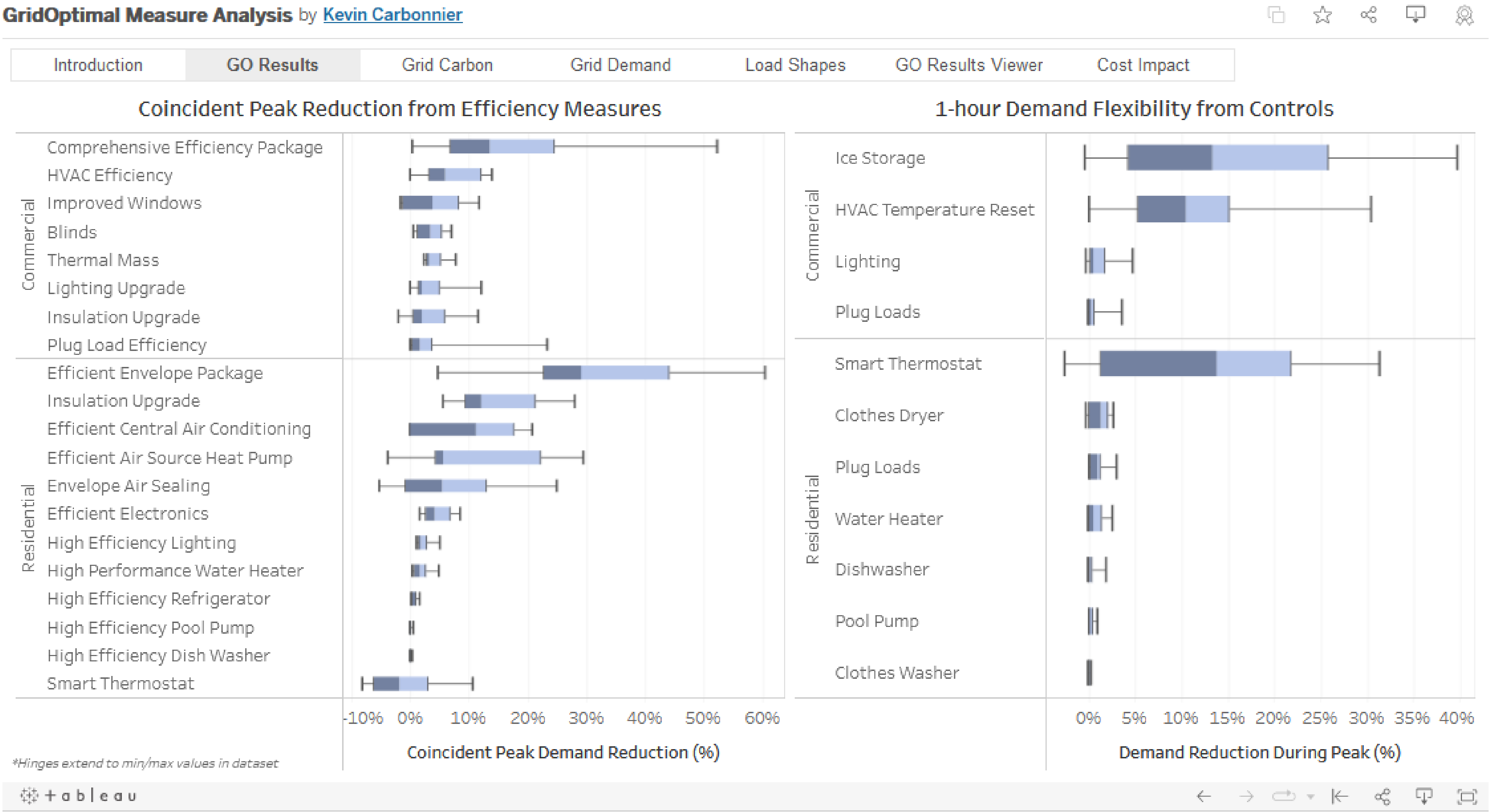
1. **GridOptimal Results** provides a summary of the measure impacts on grid peak contribution reduction and 1-hour demand flexibility potential across climate zones and building types.
2. **Grid Carbon** allows users to explore marginal carbon intensity patterns in their state to understand which hours of the day are best to avoid consuming energy to reduce your carbon impact.
3. **Grid Demand** highlights hours of high stress for the grid which is at the core of the GridOptimal metrics. Limiting demand during these hours controls costs and improves grid reliability.
4. **Building Load Shapes** offers users a detailed view into the hourly impacts of various efficiency and demand flexibiilty measures by plotting measures and their resulting load shapes.
5. **GridOptimal Results Viewer** allows users to dig deeper into results and plots the detailed results for each measure, climate zone, and building type.
6. **Cost Impact** explores the customer utility cost impacts of each measure (energy and demand), calculated using typical rate structures for select utilities

### Acknowledgments and Data Sources

• The following leading utility and energy efficiency organizations provided critical financial support to the GridOptimal Buildings Initiative: Austin Energy, American Public Power Association, Efficiency Vermont, Energy Trust of Oregon, Pacific Gas & Electric, Sacramento Municipal Utility District, and Southern California Edison.
• Red Car Analytics provided foundational proof-of-concept modeling for an office building in several climate zones that helped NBI develop the GridOptimal metrics.
• Jingjing Liu, Rongxin Yin, and Mary Ann Piette of Lawrence Berkeley National Lab (LBNL) graciously shared early results from their DOE BTO funded project: *Framework & Method to Define Flexible Loads in Buildings*.
• Jared Langevin (LBNL) guided NBI through their team's extensive modeling datasets behind this important research, published in 2021: US building energy efficiency and flexibility as an electric grid resource.

https://public.tableau.com/app/profile/kevin8000/viz/GridOptimalMeasureAnalysis/Intro

# GridOptimal Measure Impact Analysis Tool



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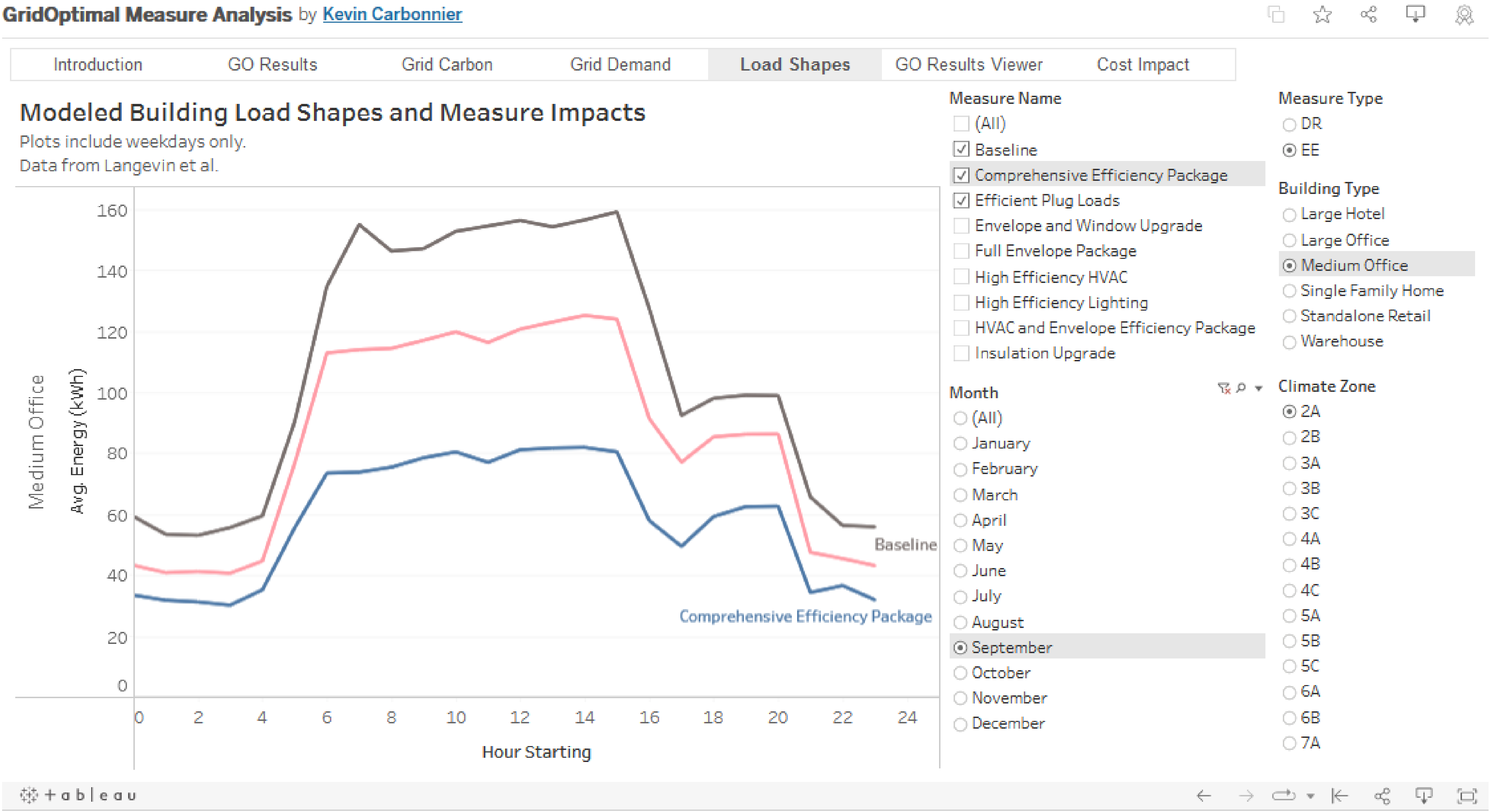

# Final Thoughts

- Don’t forget the **80/20 solutions**!
- Key targets:
  - Reduce **coincident peak** demand
  - Enable smart grid **communications**
- **Efficiency** is a core grid integration strategy
- Strategies with **multiple value streams** will carry the day (when it comes time to decide where to invest limited $)

# Time for Questions and Conversations

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