AIA

# Why Net-Zero Isn't Enough

February 14th, 2024

WILLDAN

# Learning Objectives

After the presentation, participants will be able to:

1. Identify and discuss the changes happening to the electric grid
2. Describe non-building solutions to the electric grid challenges
3. Describe how buildings can be designed to assist grid operators in maintaining balance in the electric grid
4. Describe why "net-zero" as the only metric leads to less-than-optimal environmental impacts

# Agenda



01 Evolving Electric Grid Challenge

02 Non-Building Solutions

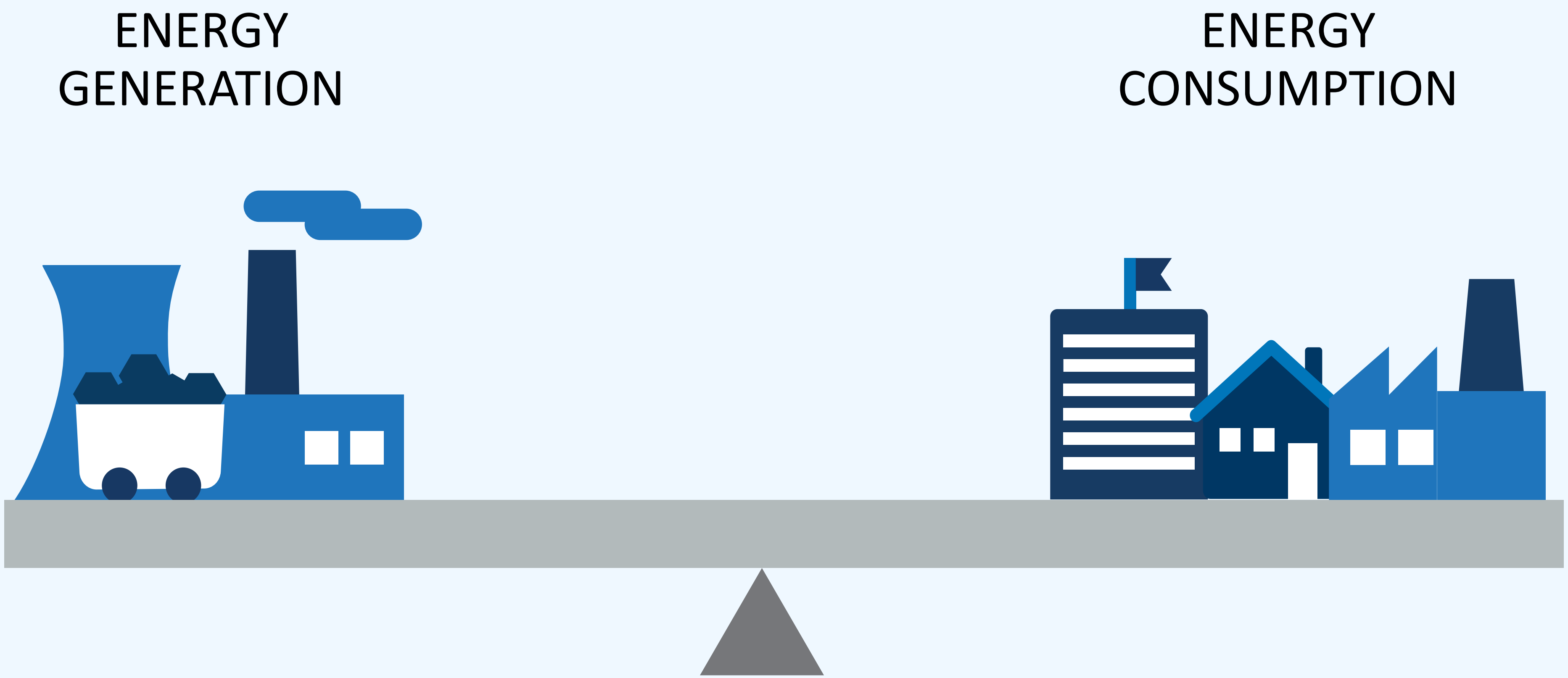
03 Building Solutions

04 Conclusions and Discussion

01

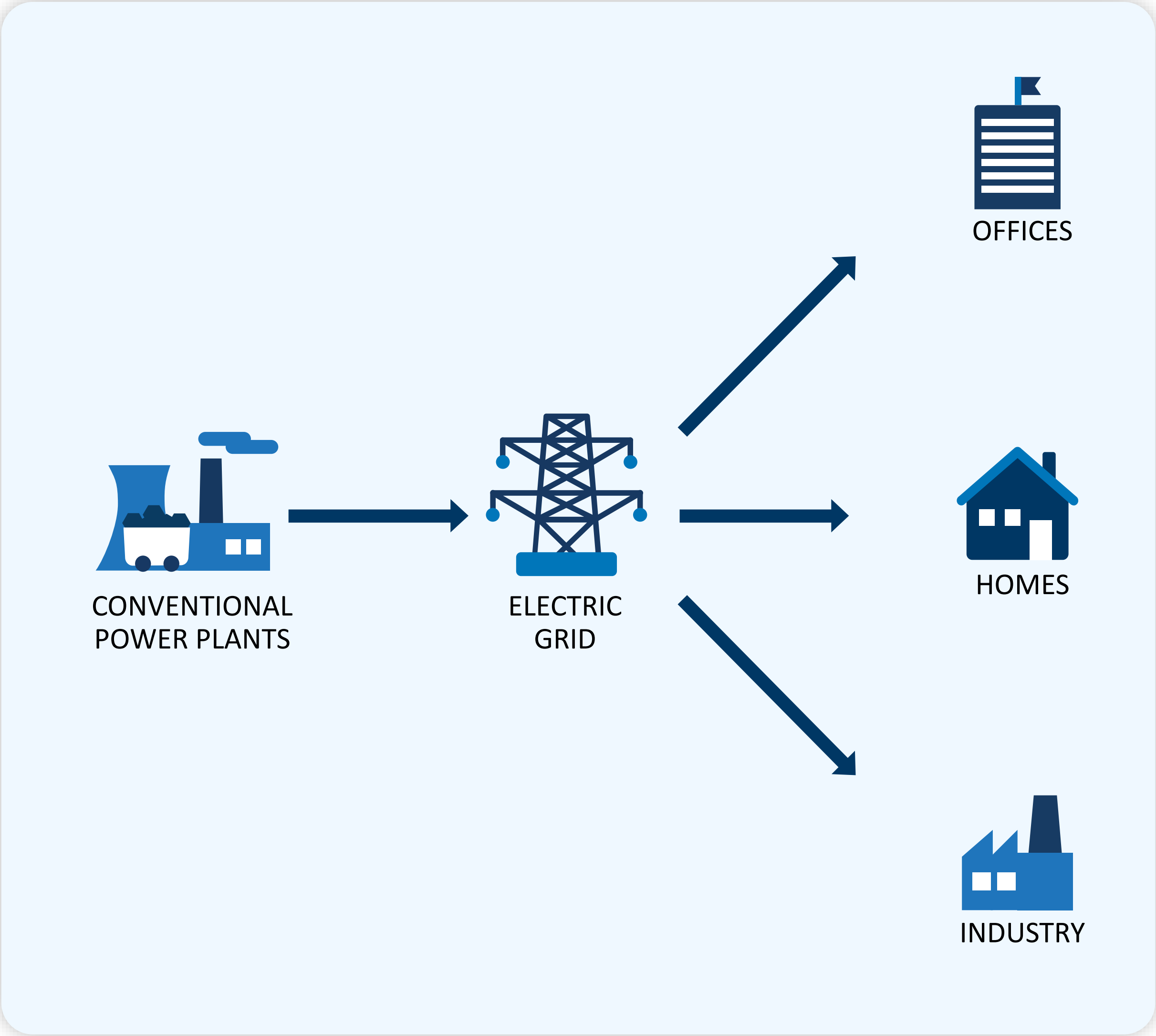
# Evolving Electric Grid Challenge

# Balancing the Grid



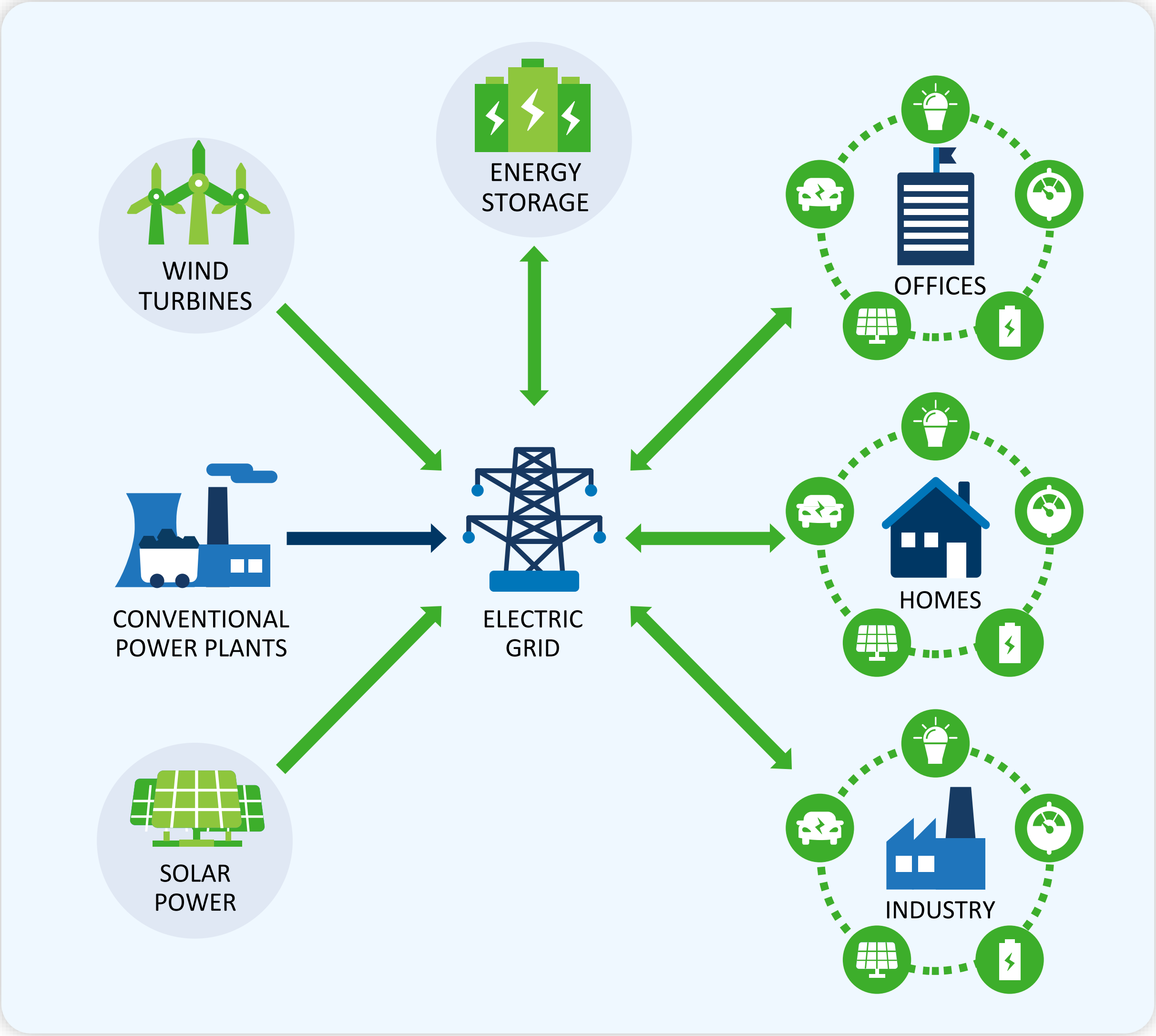
# The Grid Until Recently

- Electricity was generated centrally and could be ramped up or down
- Transmission was two directions, but distribution was one direction

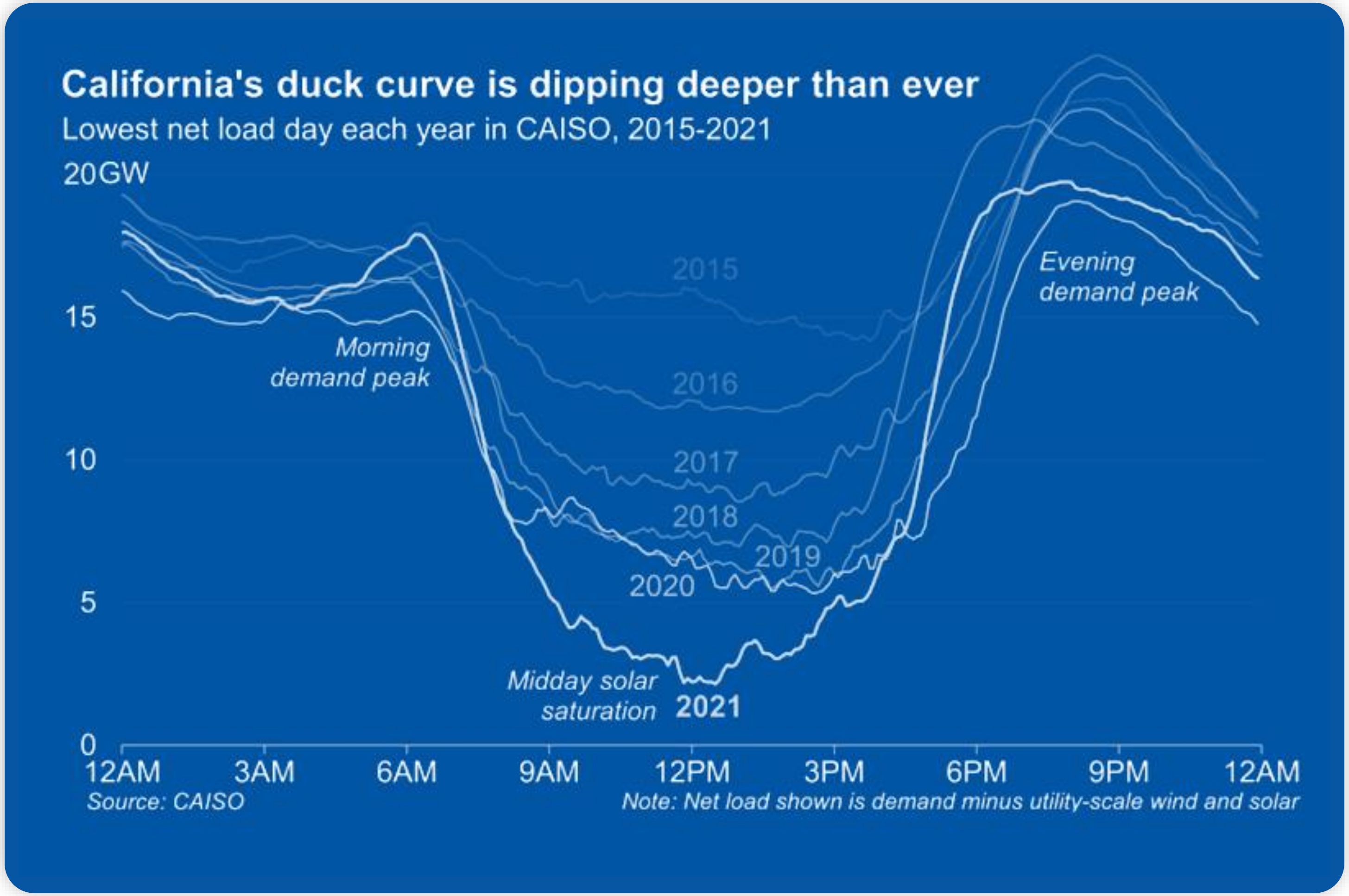


# The Grid of 2030

- Electricity production is distributed and varies based on weather.
- Distributed generation and storage means electricity is produced on both sides of the electric meter.
- Transmission and distribution are multi-directional.



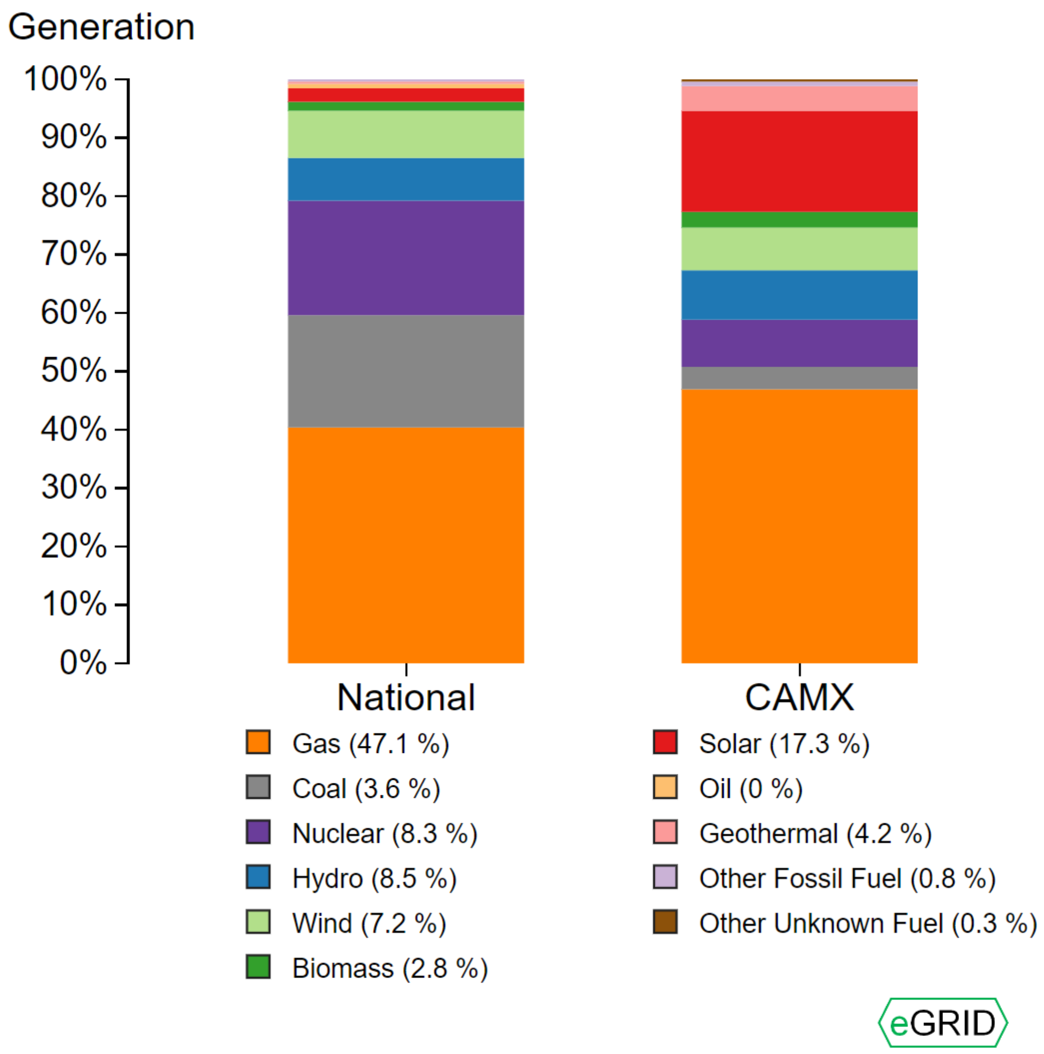
# Widespread Solar Impact on Grid




- Significant reduction in net demand during the day
- Steep ramp-up of demand between 4 pm and 7 pm

**Variable renewable production needs to be balanced with dispatchable power or demand.**

# California's Grid Mix in 2020

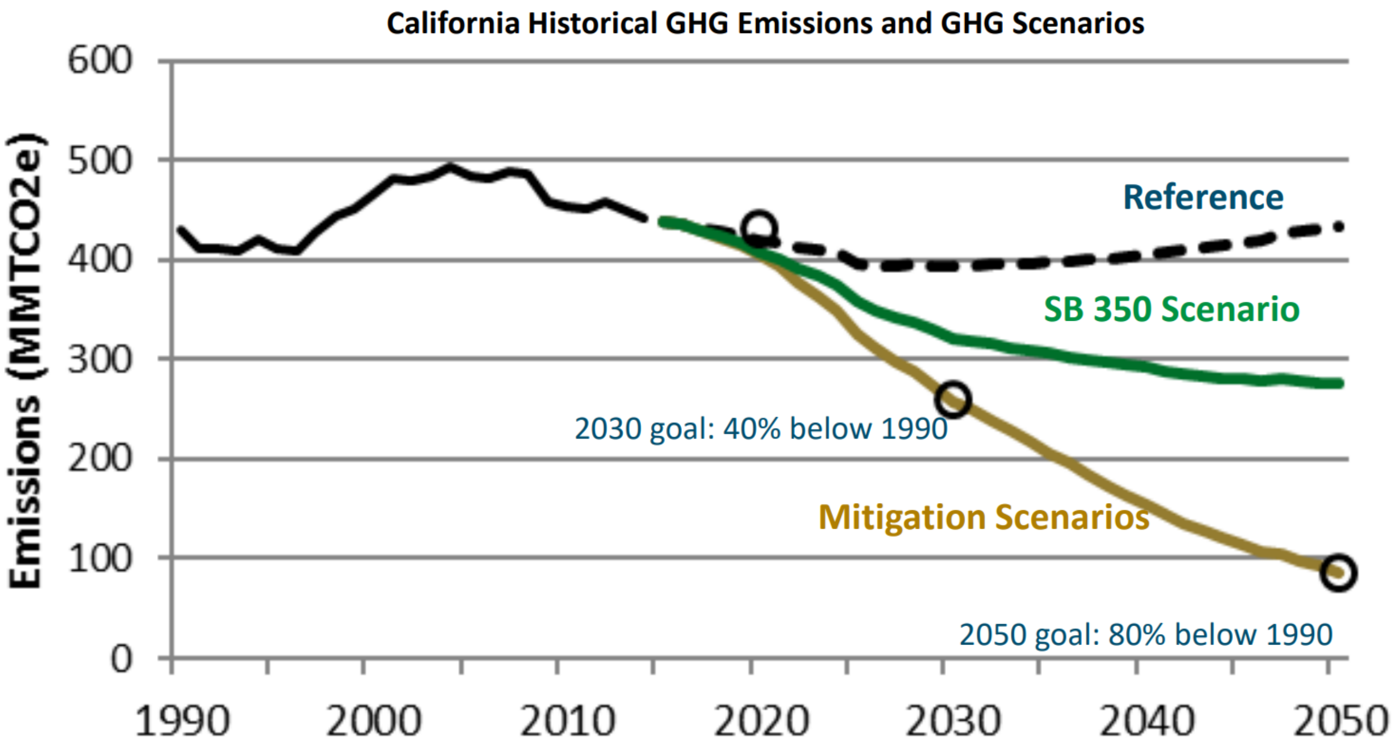



Fuel (CAMX Generation %)

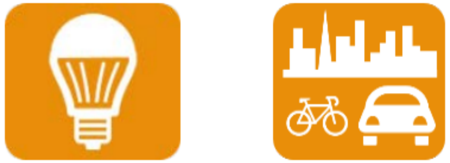
- Compared to National Average
  - Much less coal
  - More renewables
  - More natural gas
- Grid continues to decarbonize with non-dispatchable solar and wind
- Duck curve is going to continue to grow

# Electrification

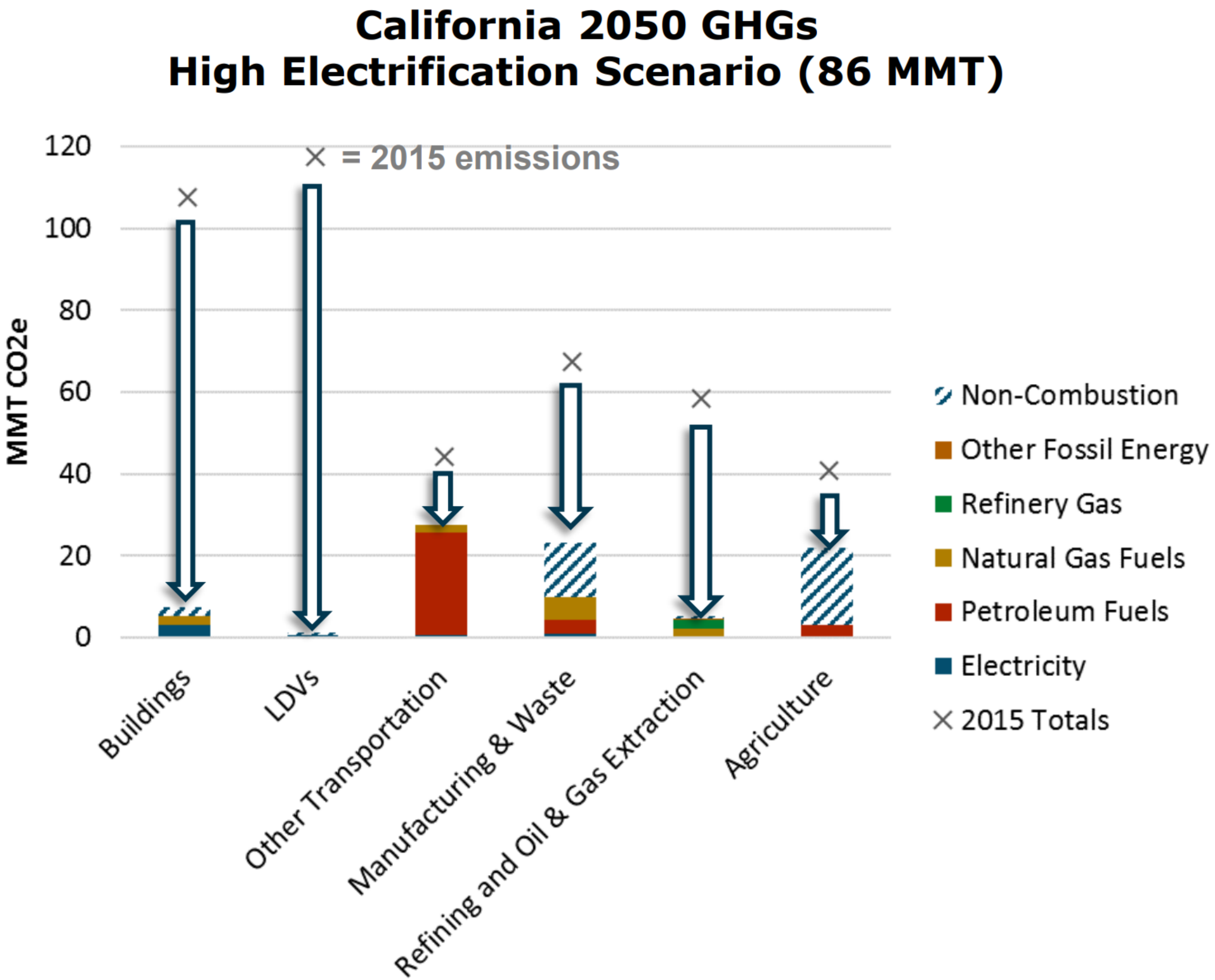
- 2018 CEC Study by E3 evaluated 10 scenarios to achieve 80% GHG reductions by 2050
- Electrification was found to be the lowest cost and lowest risk path to decarbonize



# Four Pillars of Decarbonization

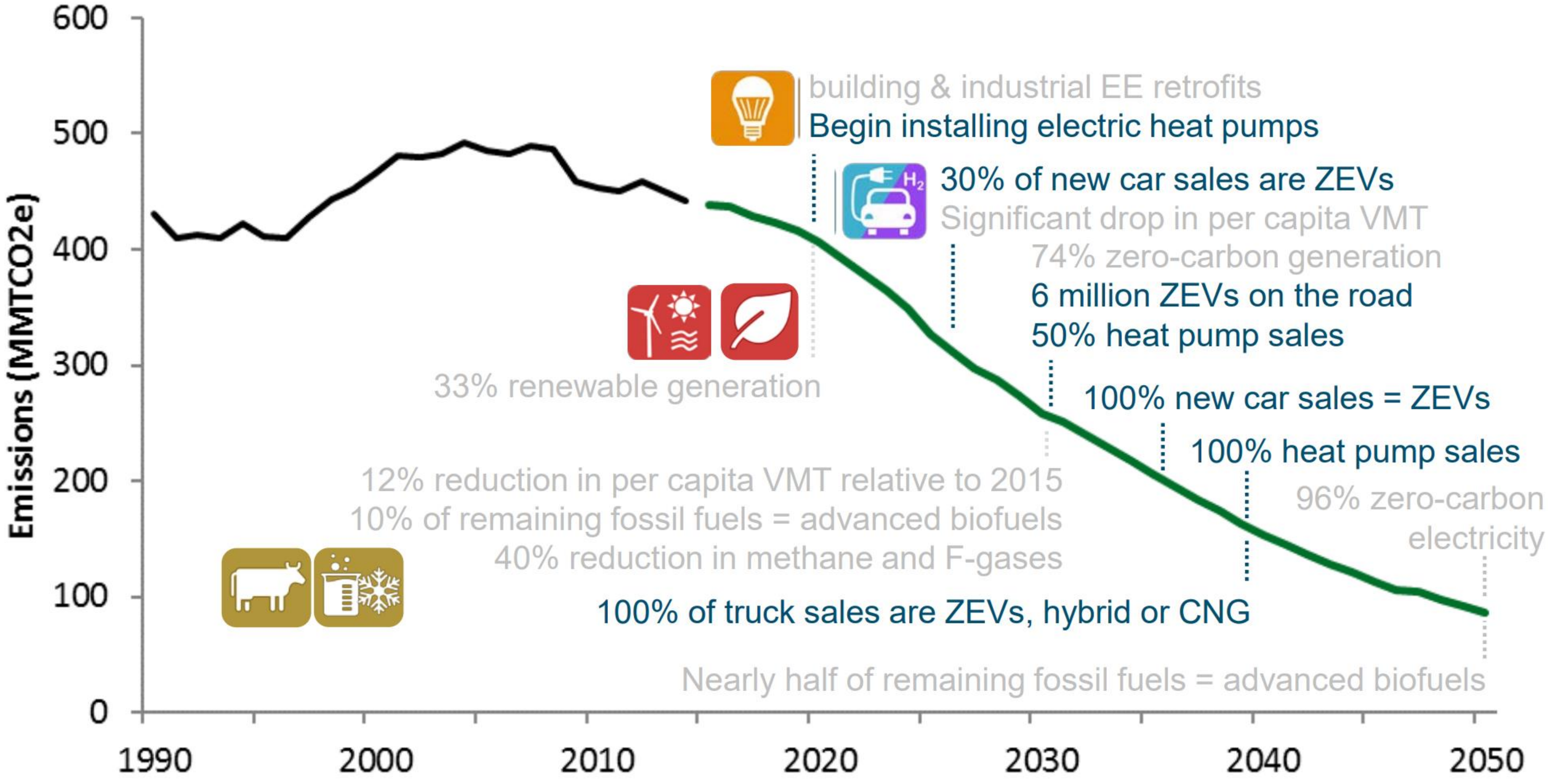
| Energy efficiency & conservation | Electrification | Low carbon electricity | Low carbon fuels |
|---|---|---|---|
|  |   |   |  |
| ✓ Appliance EE<br>✓ Building shells<br>✓ Urban infill | ✓ Heat pumps<br>✓ ZEV cars and trucks | ✓ Renewables & integration<br>✓ Nuclear, fossil with CCS | ✓ Biofuels<br>✓ Electrolytic fuels ($H_2$ and P2X) |

# Economy Wide Decarbonization Strategies

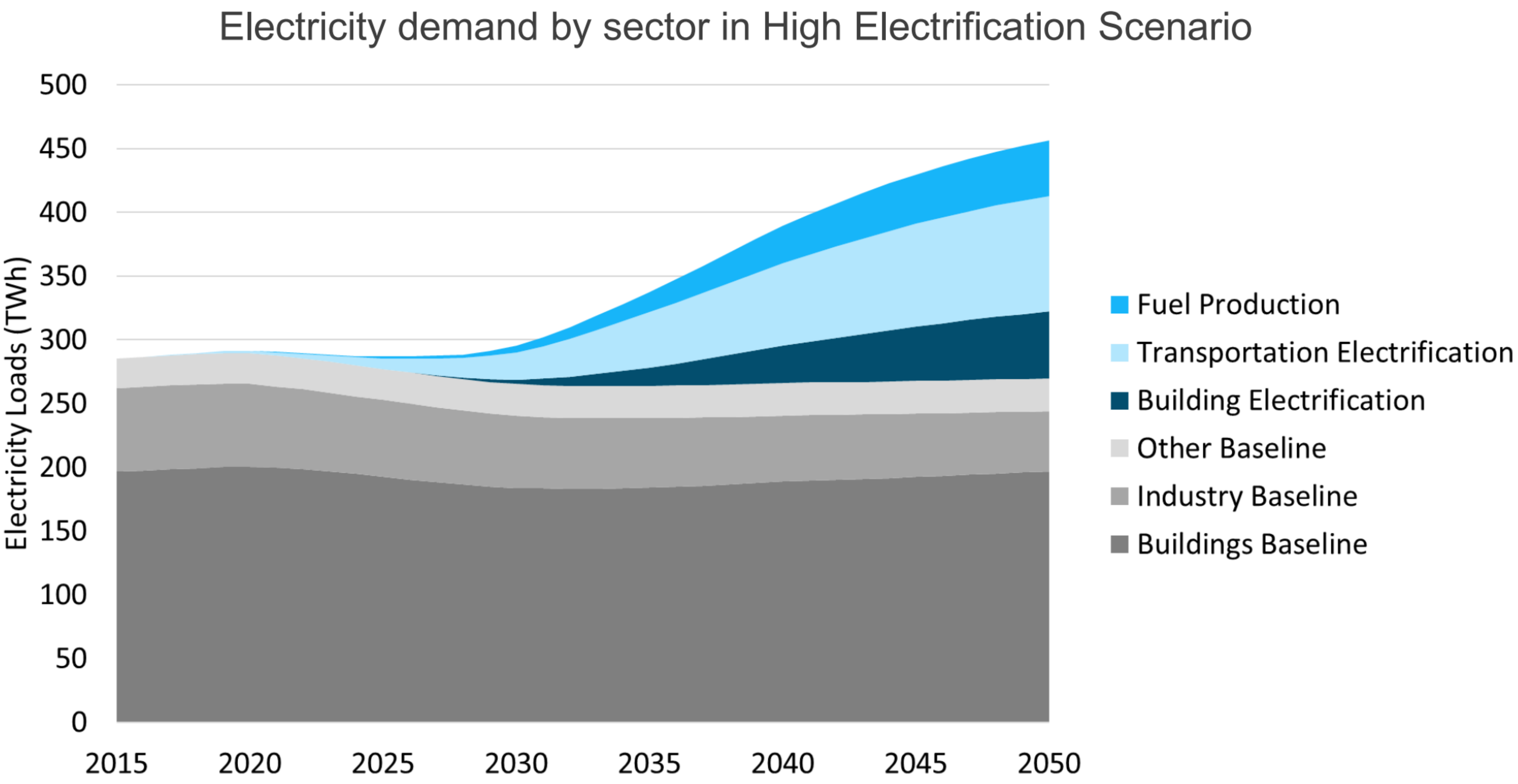



- High electrification of buildings and vehicles leads the way for even more challenging sectors
- Remaining 2050 emissions are from
  - Greight
  - Off-road transportation,
  - Industry,
  - Waste, and
  - Agriculture

# CA Historical GHG Emissions and Reduction Strategies

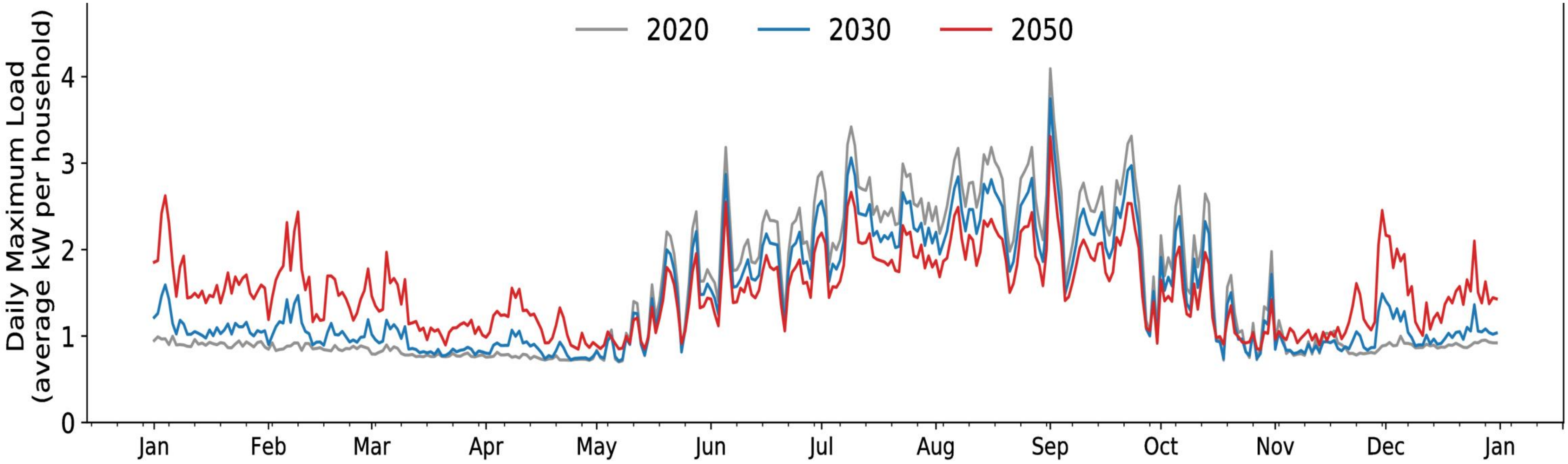


# Electrification Drive Generation Growth



# Impact on System Load Shapes: California

Per household daily peak demand impacts in California during a typical meteorological year

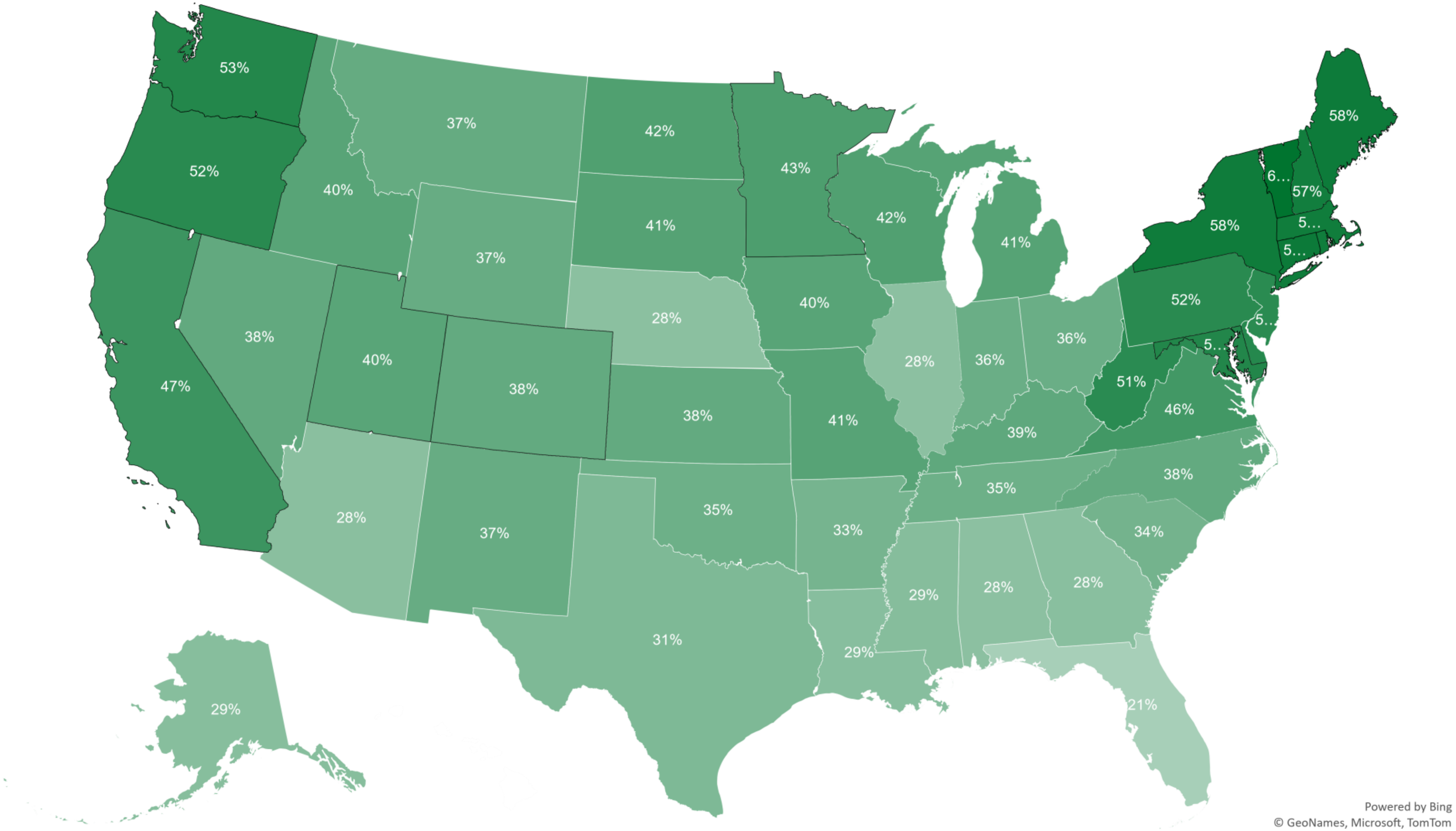



* The average load per household reflects a changing share of natural gas-fueled vs. all-electric homes

https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf

# Lifecycle GHG Savings from Electrification Are Universal

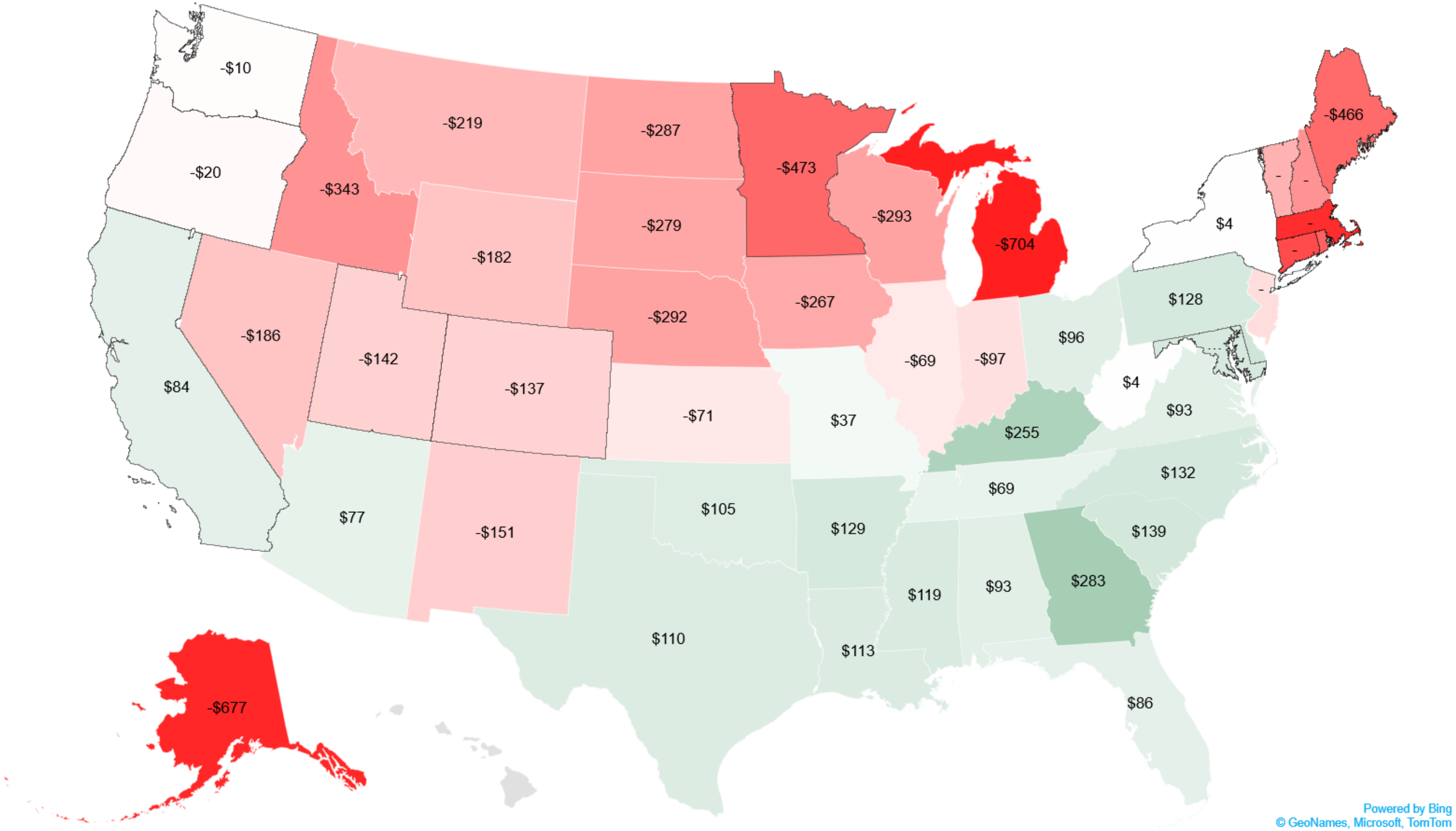
Residential Heat Pump Space and Water Heating (2020 – 2035) vs. Natural Gas and Fuel Oil Shares




E3 Analysis, Electricity Emissions Based on NREL Cambium Generation Standard Scenario

# Annual Bill Change is Regional: Current Average Rates

Residential Heat Pump Space and Water Heating with Current Rates




E3 Analysis, Electric and Gas Rates based on State-average EIA Data

# Things are Getting Much More Complicated for Independent System Operators

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# Non-Building Solutions

# Grid Balancing Toolkit



## Distribution

The sun is always shining, and the wind is always blowing somewhere

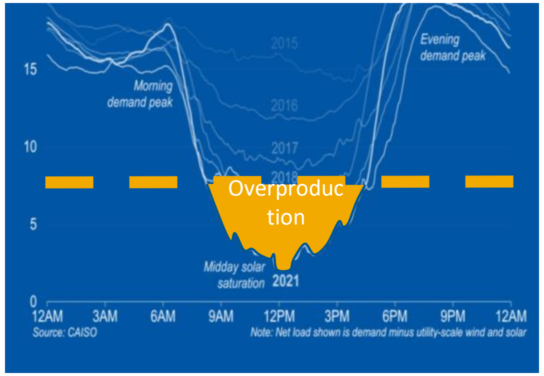
## Peaking Plants

Fossil generation for smoothing the grid

## Storage

Store energy when it's plentiful to be discharged when it's scarce

## Overproduction




Build enough wind and solar to meet your peak loads and overproduce at other times

**Grid-responsive buildings will take less infrastructure and cost.**

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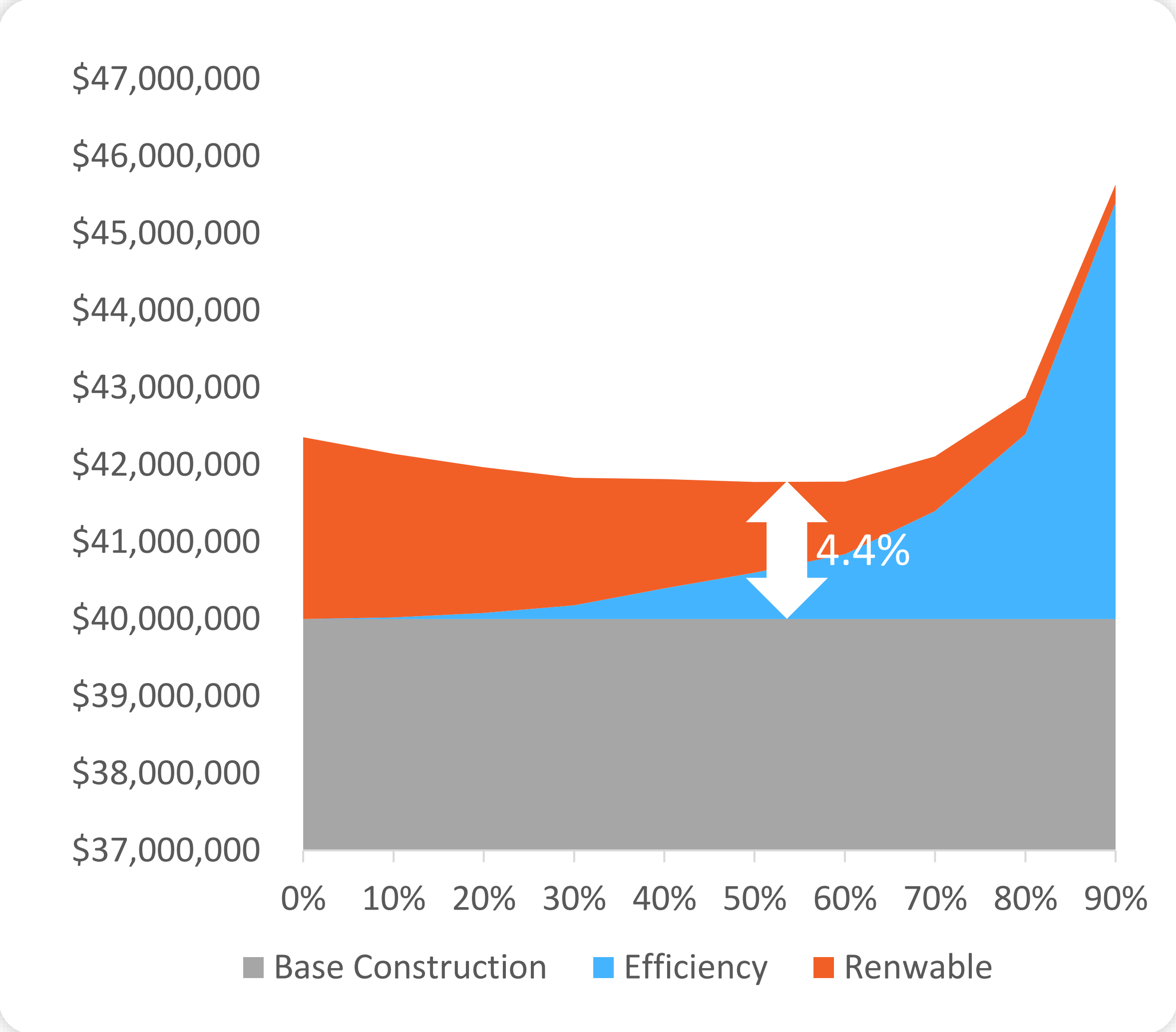
# Building Solutions

# A Parable

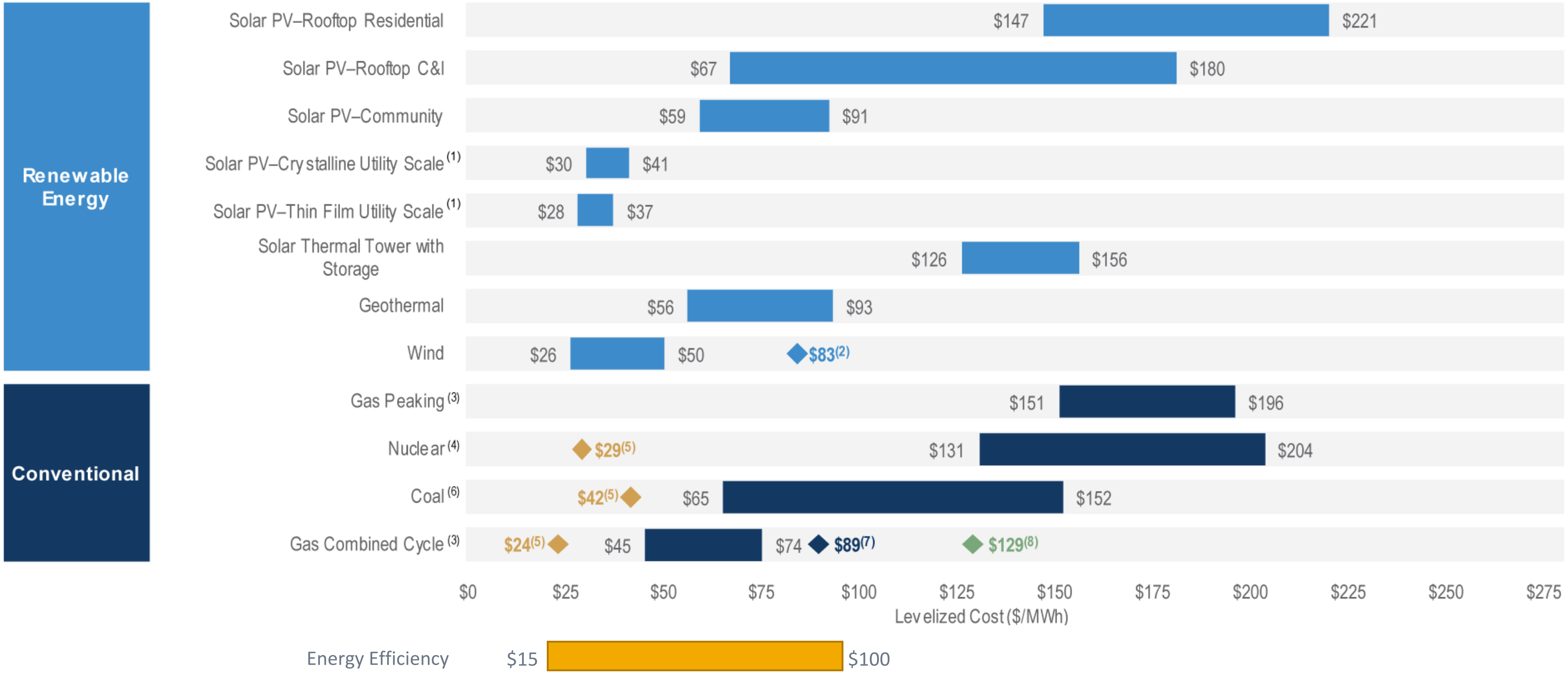
*Net-Zero without considering **holistic grid impacts** is like growing a garden but then going out for ice cream.*

# Efficiency First

- Focusing on efficiency first:
  - Minimizes capital costs for net-zero
  - Minimizes grid infrastructure
  - Improves occupant comfort
    - Fewer drafts
    - Warmer/cooler surfaces
- But efficiency has lengthening paybacks the further you go, and solar has shortening, so there is an optimal trade- off



# Lazard Levelized Cost of Energy Comparison

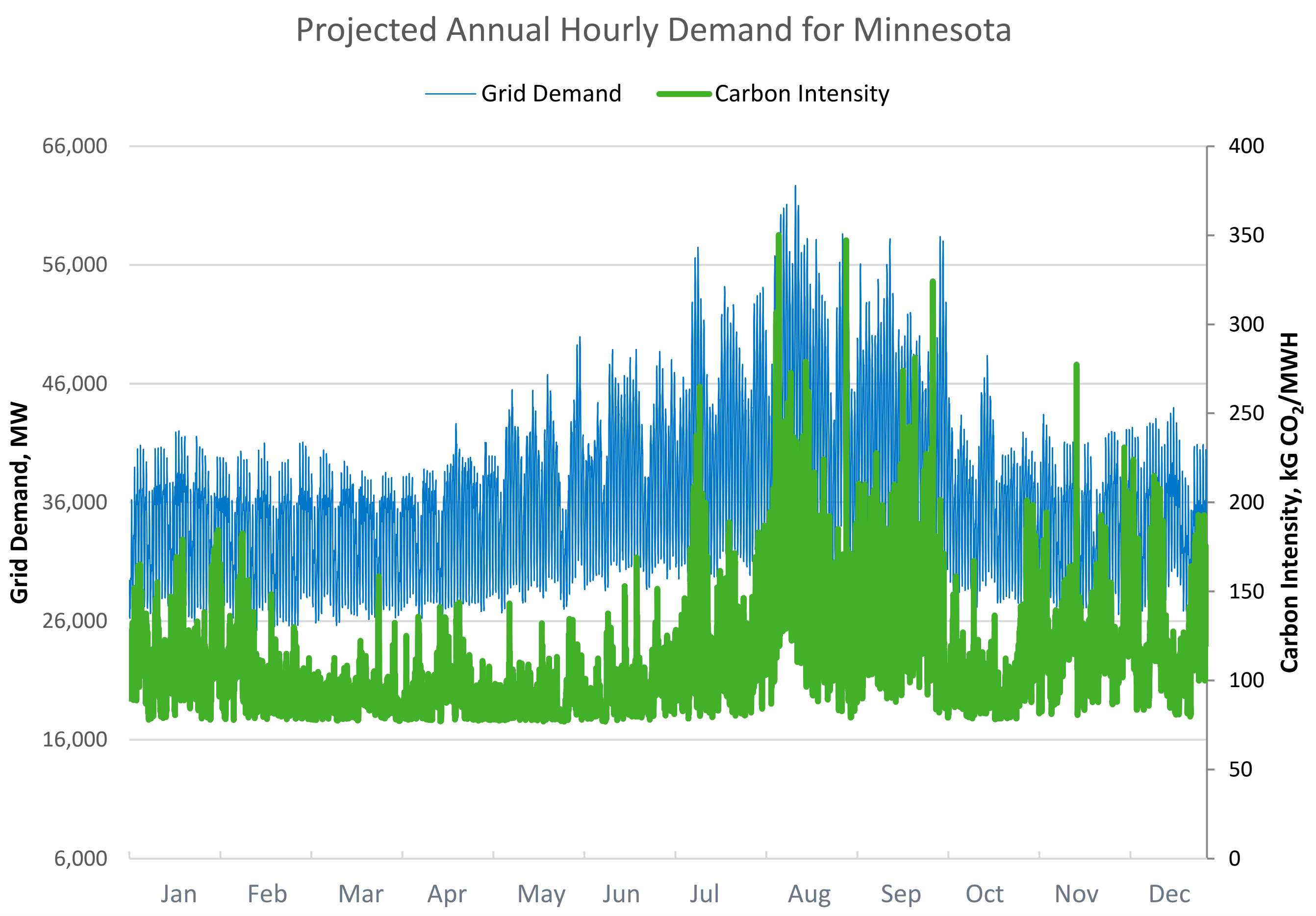


*"If you want to go fast, go alone,*
*If you want to go far, go together."*

***African Proverb***

# Demand and Carbon Intensity in CA



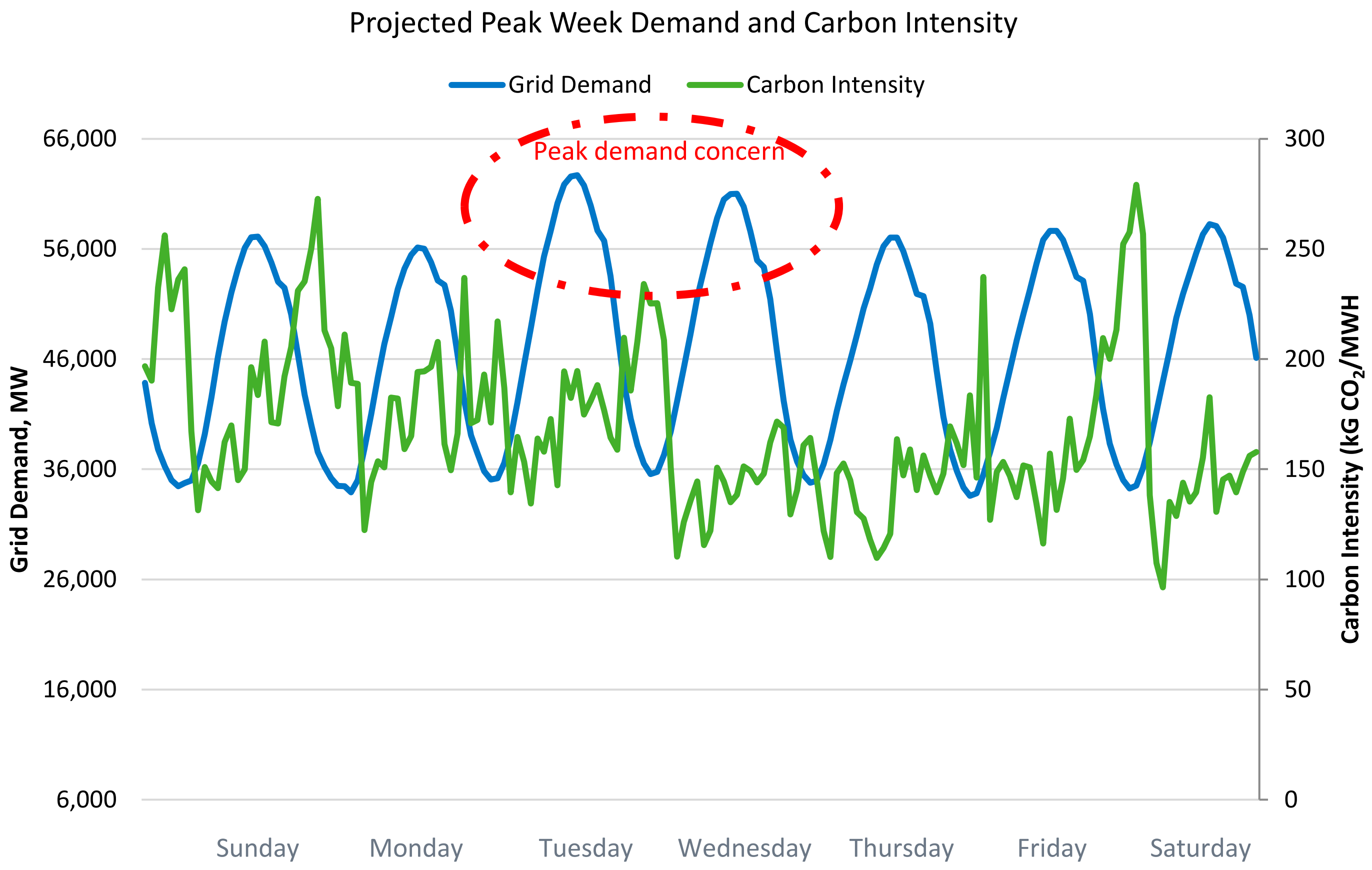



- Grid is designed to meet peak load with a safety factor
- Peak demand is in July through September afternoons
  - Demand response or peak load shaving
- Carbon intensity is highest in the summer, but varies a lot across the day.
- Load flexibility can avoid highest demand and carbon intensity
  - Dimming lights
  - Precooling with solar energy
  - Relaxing thermal setpoints
  - Service hot water tank temperature

## Carbon Intensity Varies within the Same Range Across the Year

# Demand and Carbon Zoomed In



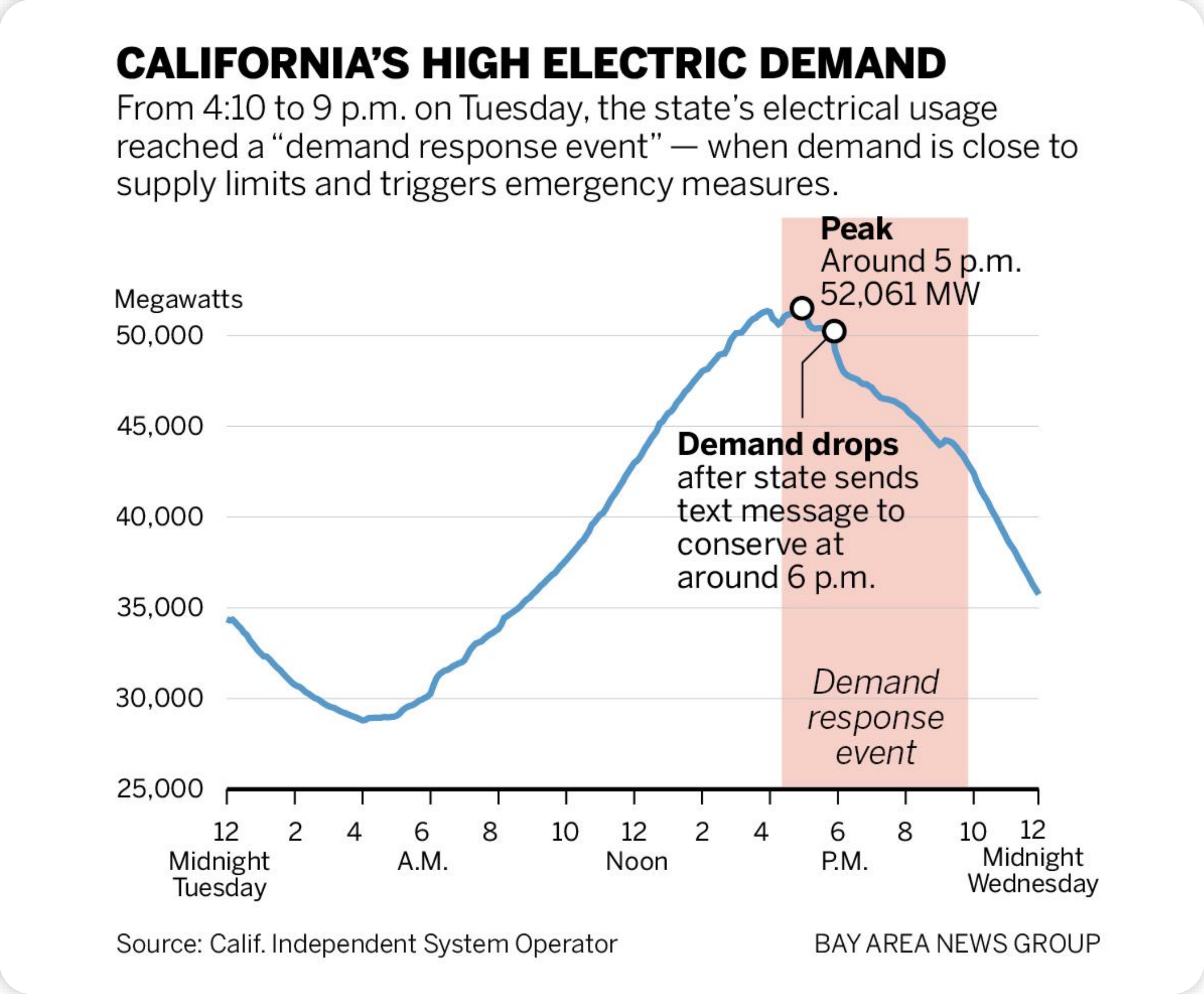



- Reducing demand for several hours on Tuesday and Wednesday reduces grid capacity needs by 5%.
- Demand response also provides defense against increased peaks caused by heat waves and climate change

**Demand and Carbon Intensity varies widely over the day and year.**

# California Independent System Operator Example





# Shape, Shift, Shed, Shimmy to a Cleaner Grid



| | |
|---|---|
| Shape | Reshape customer load profiles with advance notice of months or days-heat pump water heaters with pre-heating |
| Shift | Move energy from high demand to times with surplus renewable energy-precooling a space |
| Shed | Load curtailment to control peak-dimming lights, relaxing setpoints |
| Shimmy | Slight changes to reduce peak demands-delaying a motor start by 15 minutes |

*Source: LBNL and E3's 2025 California Demand Response Potential Study*

# GridOptimal® Building Initiative

- Effort led by NBI to develop metrics for grid interaction
- Uses NREL Standard Scenarios 2021 Cambium demand and long-run marginal carbon forecasts for 2036-2044
- Hourly inputs for typical year for
  - Building demand-no flexibility
  - Building demand-with flexibility
  - Building demand-with short-term flexibility
  - Building gas demand
  - Building renewable energy generation

GRIDOPTIMAL®
BUILDINGS INITIATIVE


NREL’s Cambium Database

# Grid Optimal Metrics



| | |
|---|---|
| Grid Peak Contribution | Degree to which building demand contributes to load on the grid during system peak hours |
| Onsite Renewable Utilization Efficiency | Building's consumption of renewable energy generated onsite (not exporting to grid) over a year |
| Grid Carbon Alignment | Degree to which the building demand contributes to upstream (grid) carbon emissions over a year |
| Energy Efficiency vs. Baseline | Percent better than code (annual total energy use) |

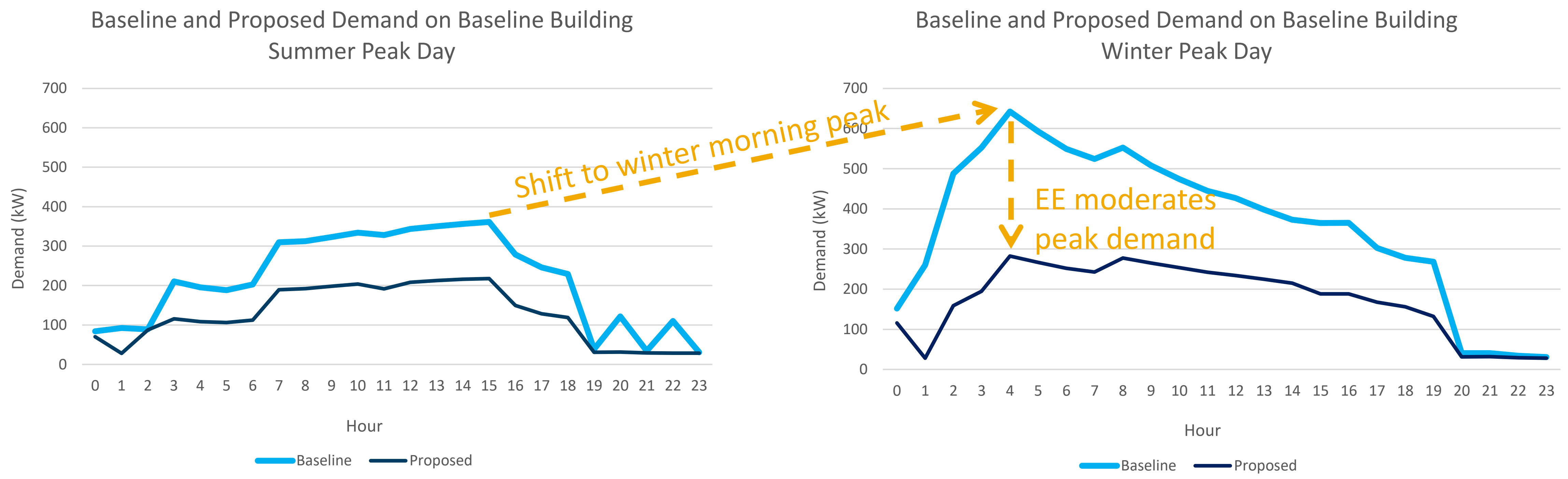
# Grid Optimal Metrics (Continued)



| | |
|---|---|
| Short-Term Demand Flexibility | Building's ability to reduce demand (shed) for 1 hour |
| Long-Term Demand Flexibility | Building's ability to reduce demand (shed) for 4 hours |
| Dispatchable Flexibility | Building's ability to automatically reduce demand (shed) for 15 minutes, controlled by utility/ third party |
| Resiliency | Building's ability to island from grid and/or provide energy for critical loads for 4-24 hours; motors soft-start capability to help grid restart after outage |

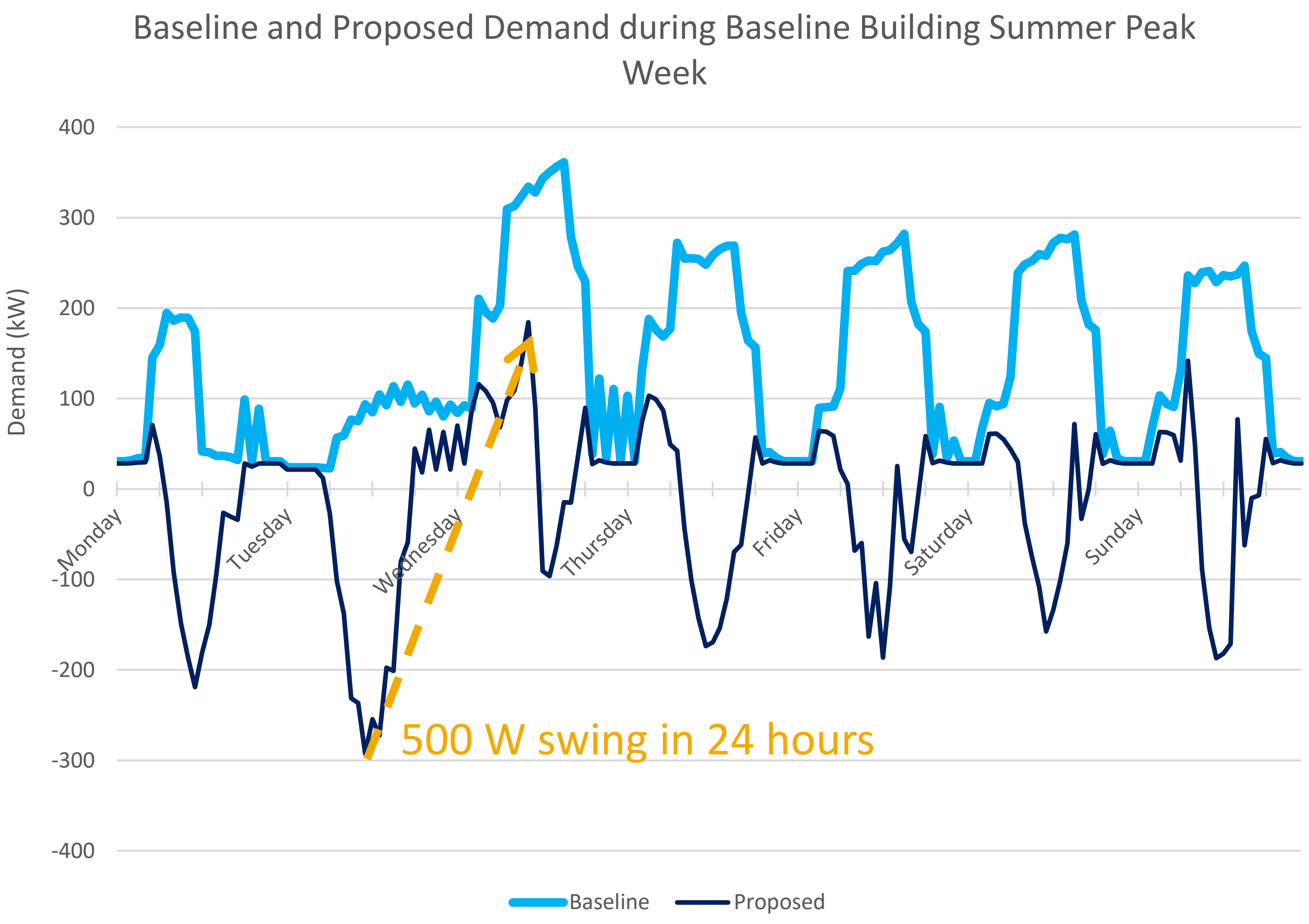
# Sample Results: Peak Day





# Peak Week with Solar



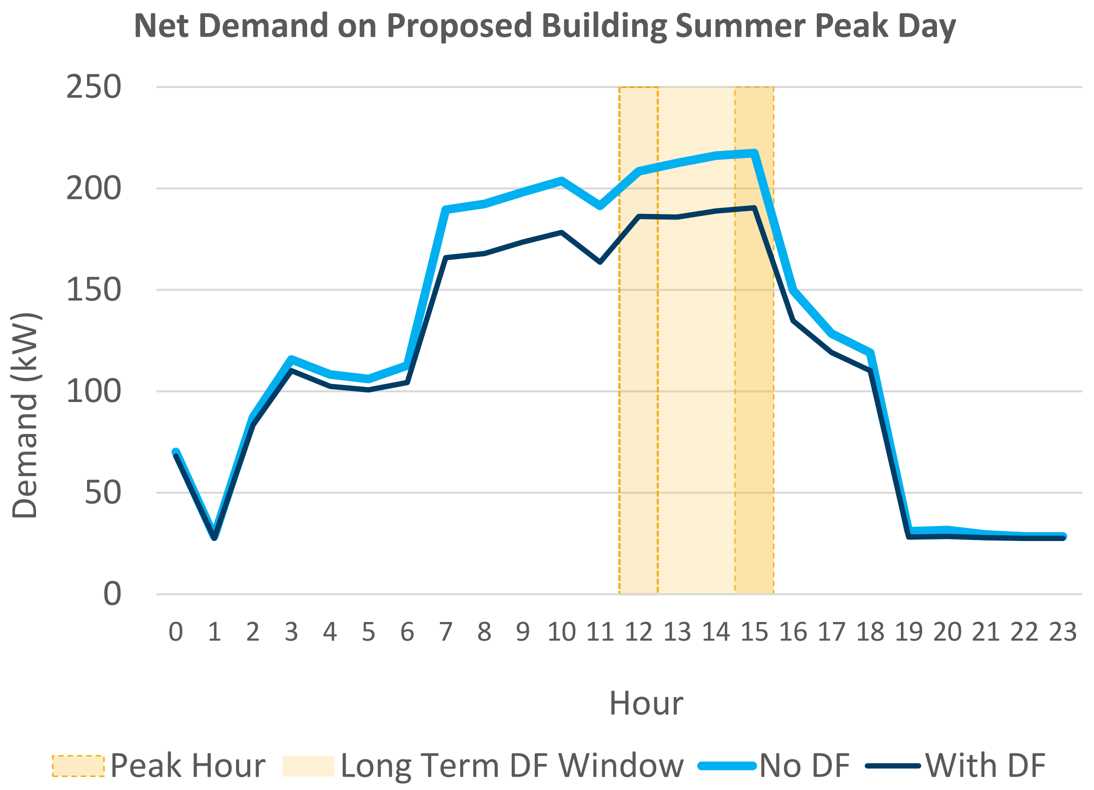


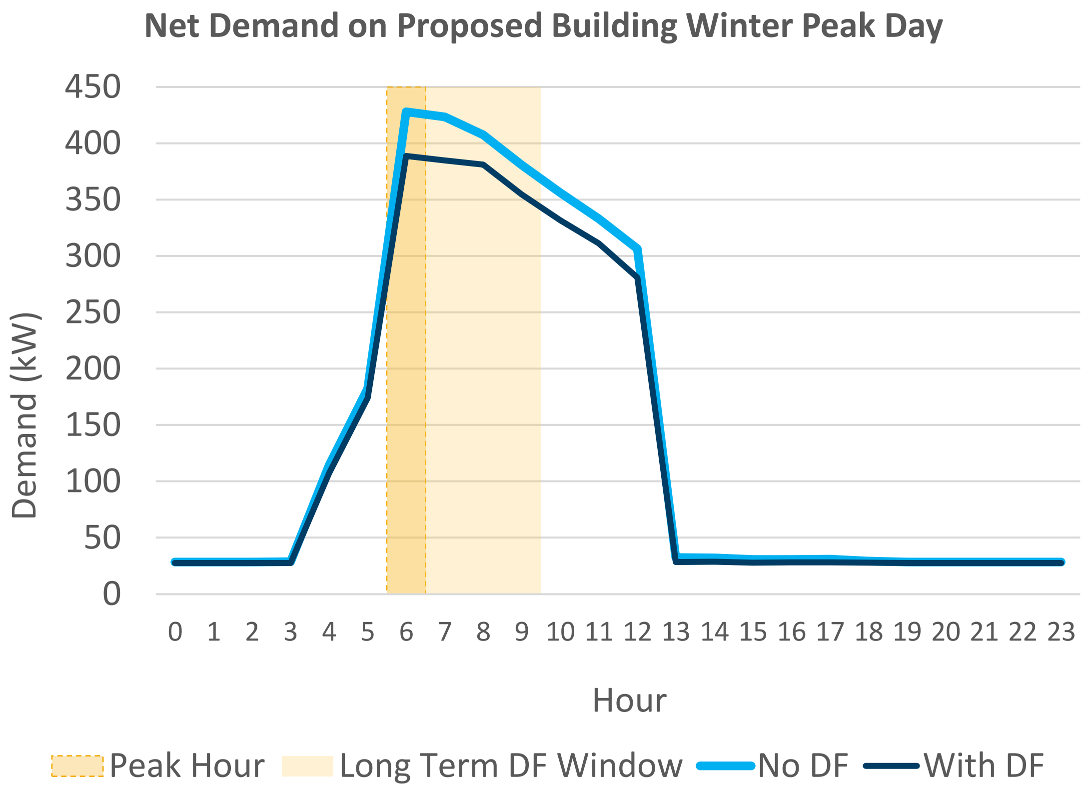

- Tuesday is July 4th, and the building exports nearly 300 kW
- Wednesday, it imports 200 kW: a swing of 500 kW
- For this week, the largest grid need is for exporting energy
- As we approach a 100% renewable grid, we need to design buildings to use or store the energy they generate.

**Energy exports can create as much stress on distribution as demand.**

# Sample Demand Flexibility Results





# Building Strategies to Consider

- Face solar panels west to provide late afternoon generation
- Include automated demand response in HVAC, lighting, and service hot water
- Use energy when renewable is available
  - Preheat hot water to a higher temperature when solar is available and mix it back down to 120 degrees
  - Precool apartments mid-afternoon rather than when people get home at 5 pm or 6 pm
- Design efficient shells that can coast through demand response events
- Minimize winter peak demand


https://www.greenbuildingadvisor.com/article/to-prove-a-point-melt-some-ice

# Strategies to Minimize Winter Peaks



| | |
|---|---|
| Ground Coupling | Use district or building wellfields as thermal battery to improve cold weather heat pump efficiency; Increases efficiency year-round, but large capital cost with current drilling costs |
| Battery Storage | Provide batteries to meet peak winter demand; also provides demand flexibility during peaking events |
| Thermal Storage | Provide phase-change material thermal storage packaged with heat pumps to reduce peak demand |
| Improved Building Envelopes | Air-sealing and insulation to reduce thermal demand; Center for Energy and the Environment (CEE) studies have found $4,000 of weatherization on a typical residence keeps demand growth down from electrification |
| Gas Backup | Provide gas backup heat during the lowest temperature days; In Quebec, the electric utility is making payments to the gas utility that are lower than the grid investments they'd otherwise need to make |

# Policy Strategies



- Promote rapid electrification.
- We know how to get to 90-95% decarbonized grid, the last 5-10% we can figure out as we get closer.
- Expand efficiency programs to include grid optimization.
- Remember good policy is more nuanced than good slogans.
- Electricity rates need to be designed to encourage electrification
  - E.g. rates that spread fixed costs by meter rather than by kWh

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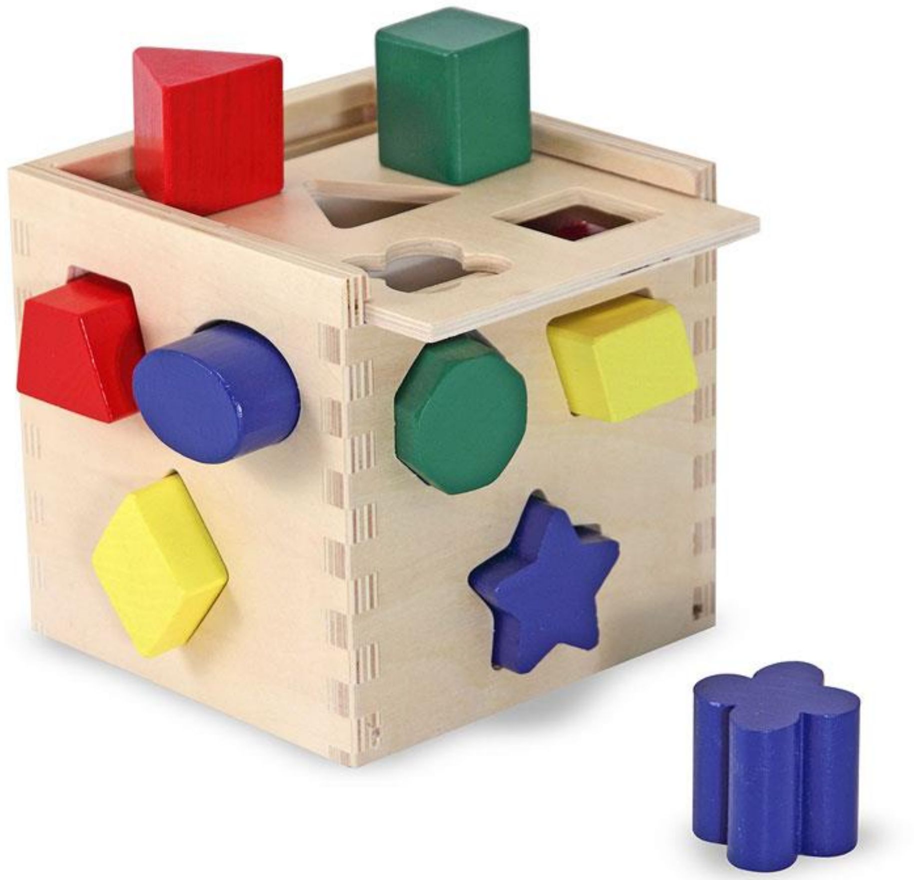
# Conclusions and Discussion

# Conclusions

- Good design is a multi-variant optimization, just setting a goal of net-zero isn't enough.
- Variable energy generation, distributed energy, and more extreme weather events are making the grid more challenging to keep balanced.
- Net-zero buildings that don't focus on efficiency and grid interactions may make the grid less stable by contributing to the "duck curve."
- Architects and engineers can help by designing buildings that reduce their load during grid peaks and enabling demand flexibility.
- Large energy exports can be just as challenging to the grid as large energy demand.
- Modeling of the grid and of buildings can help us find the right technologies and approaches for each building.



# Questions?

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