ELECTRIC POWER RESEARCH INSTITUTE

Decarbonization of US Energy: Electrification and Beyond

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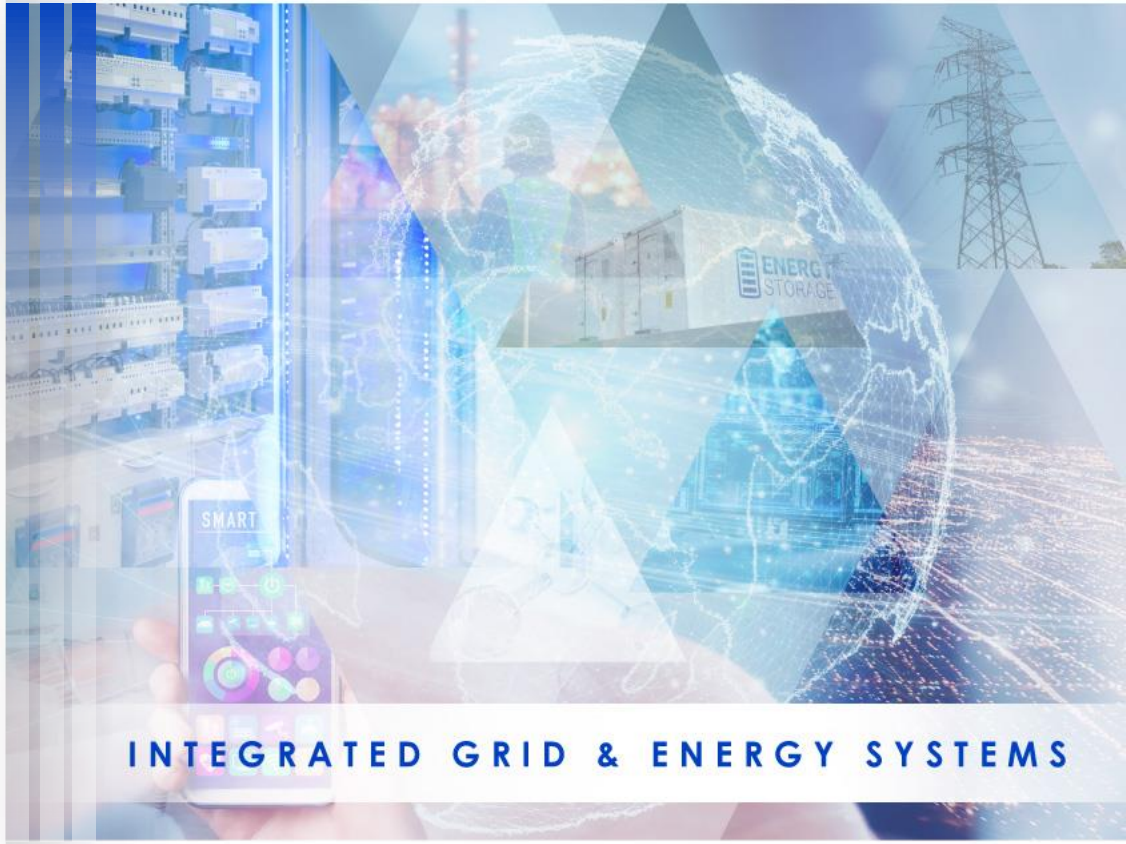
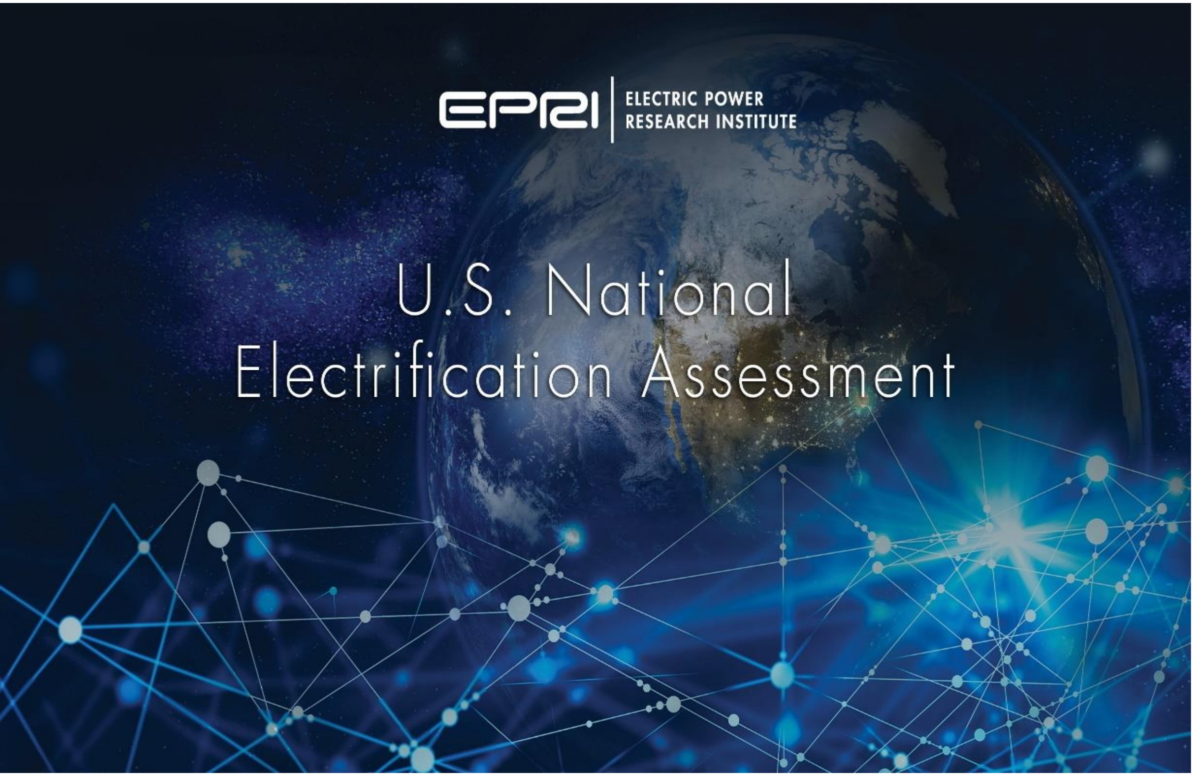


U.S. National Electrification Assessment (USNEA)

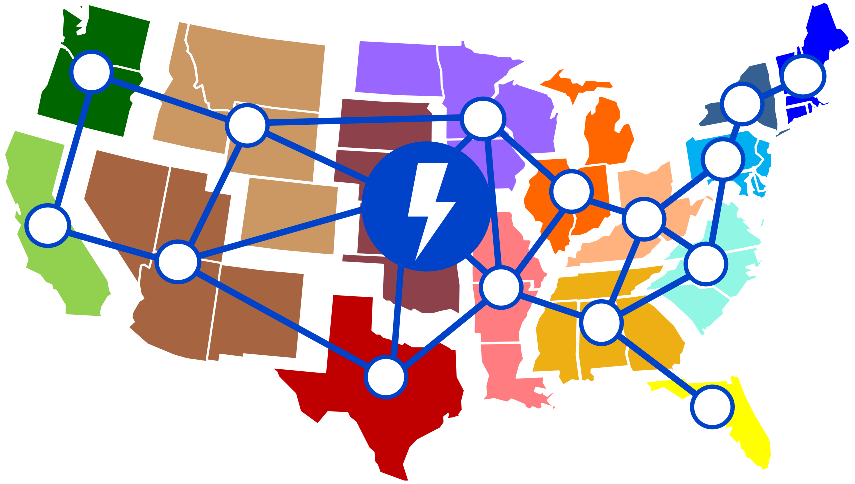


- Economy-wide assessment:
  - Residential, commercial, industrial and transport
- Modeling with endogenous technology adoption from end-user perspective
- Customer decisions integrated with detailed electricity supply model
- Progressive and Transformation scenarios include economy-wide carbon pricing
- Just the beginning… kickstart to EPRI's Electrification Initiative

https://www.epri.com/#/pages/sa/efficientelectrification

US-REGEN Modeling Platform

Electric Generation



Detailed representation of:

- Energy and capacity requirements
- Renewable integration, transmission, storage
- State-level policies and constraints

Synchronized

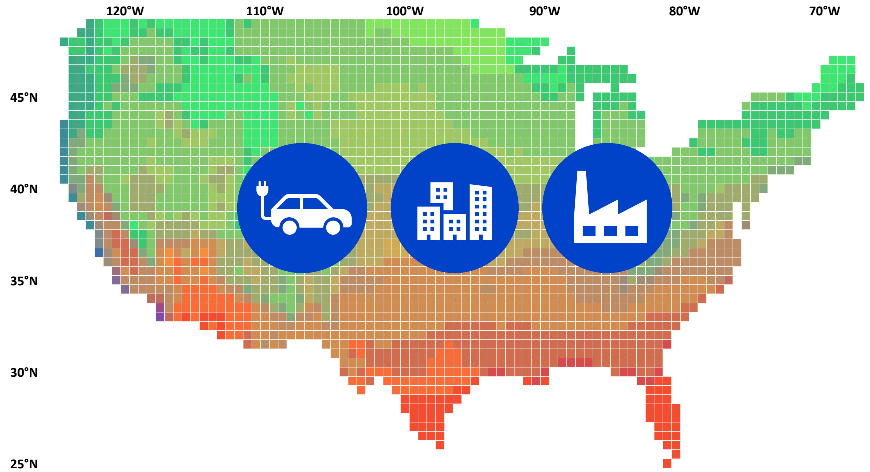
Hourly Load,
Renewables,
and Prices

Model Outputs:

Economic equilibrium for generation, capacity, and end-use mix

Emissions, air quality, and water

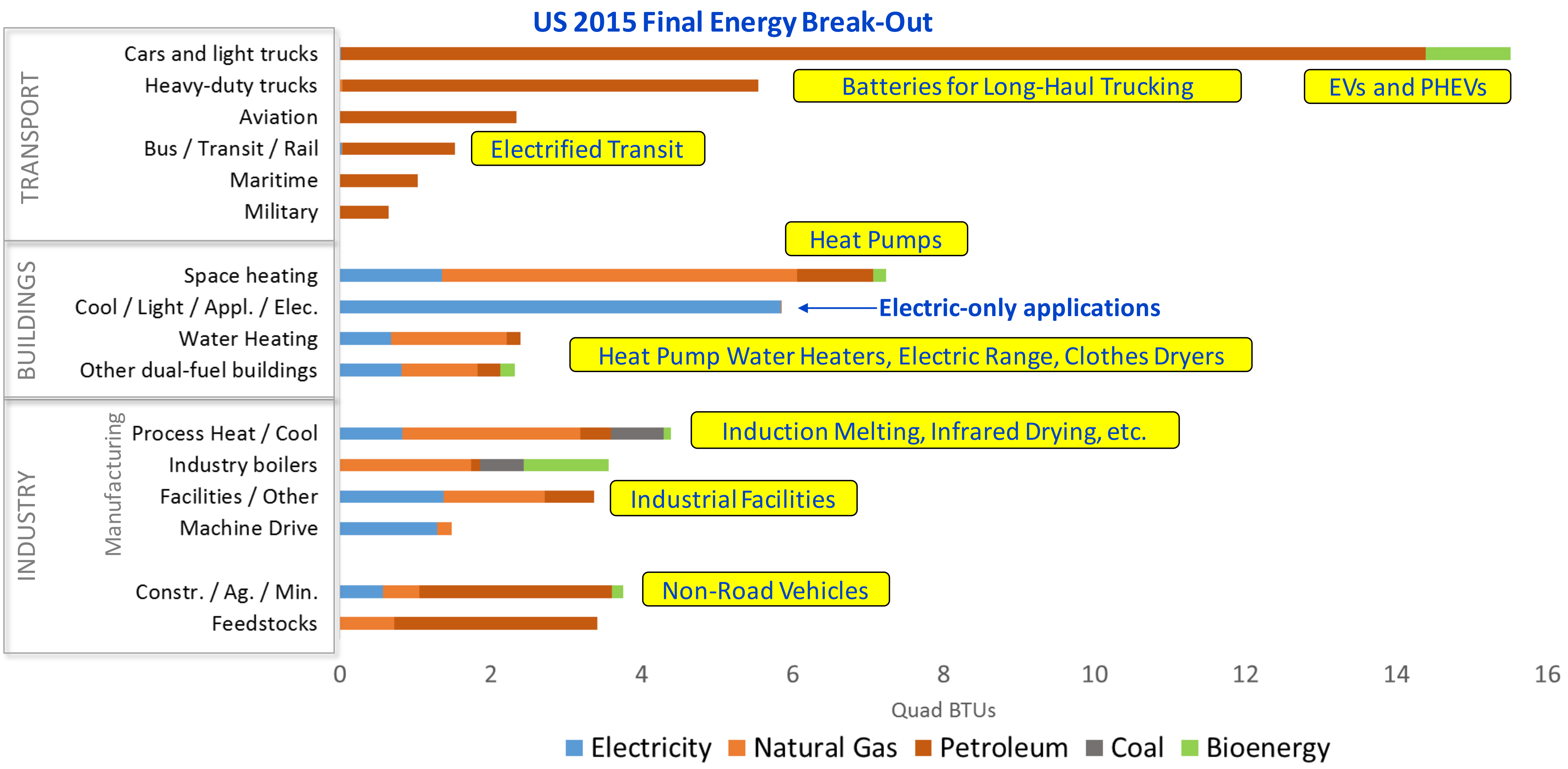
Energy Use



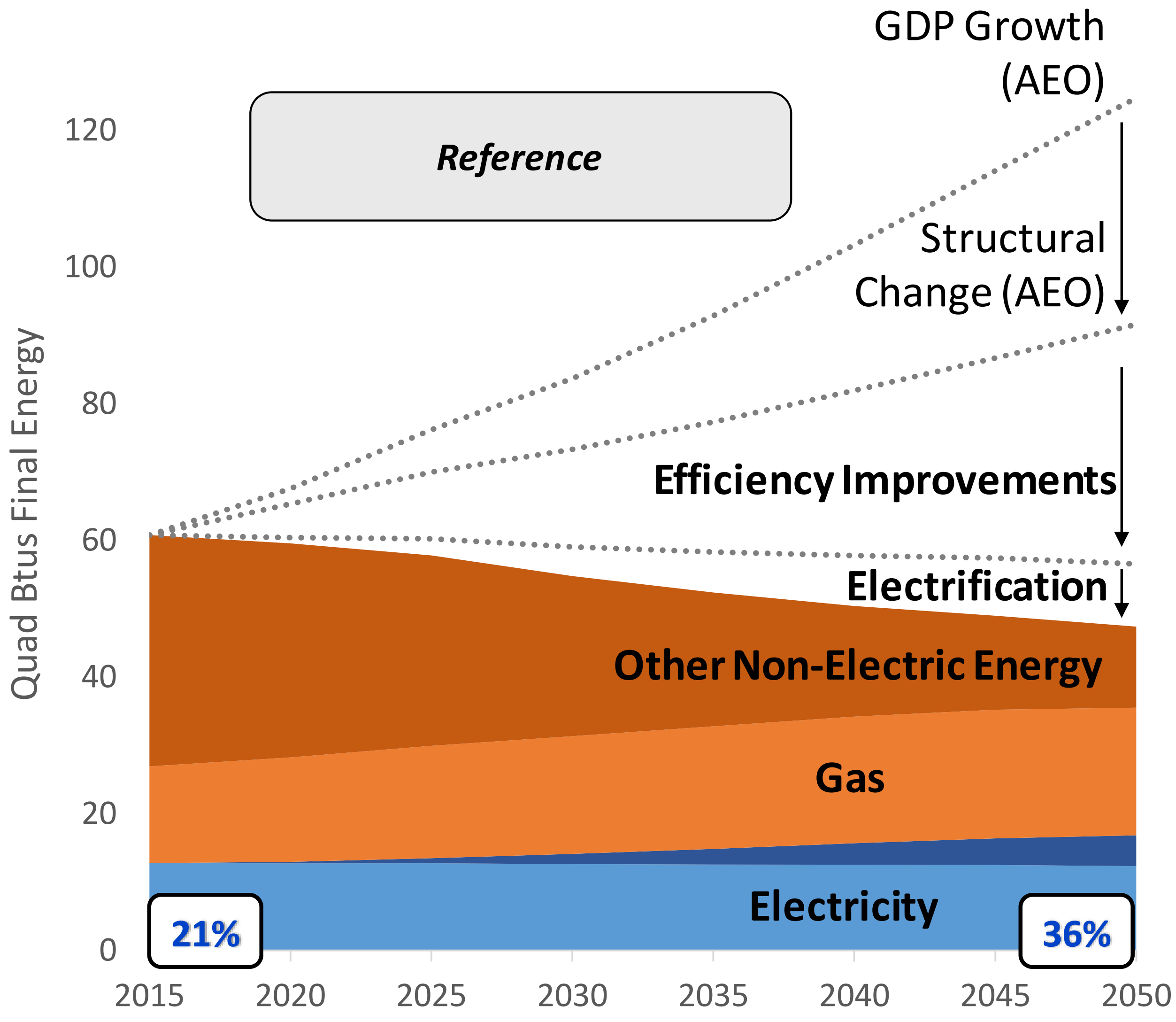
Detailed representation of:

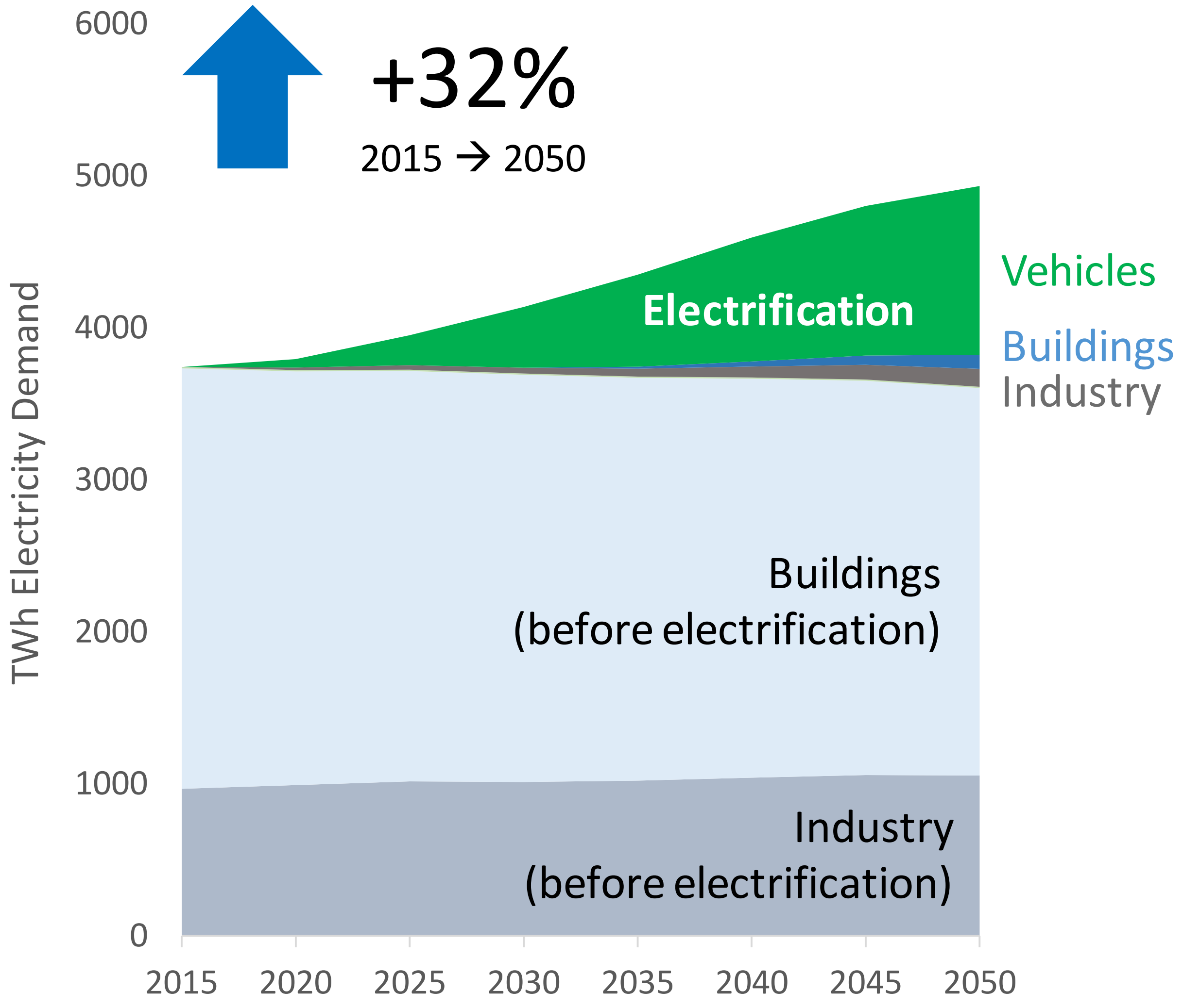
- Customer heterogeneity across end-use sectors
- End-use technology trade-offs
- Electrification and efficiency opportunities

Potential for Efficient Electrification Varies by End-Use Application

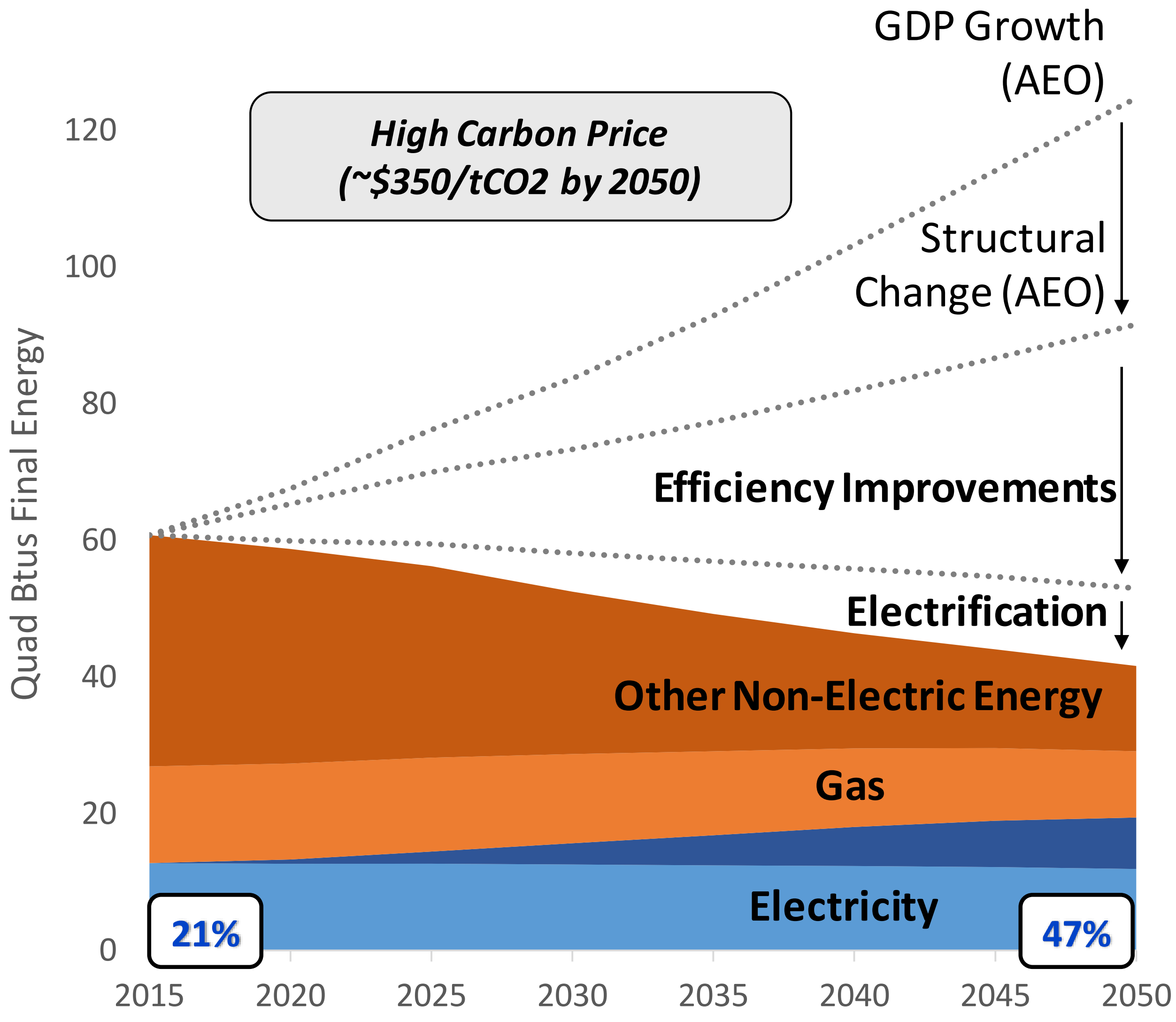


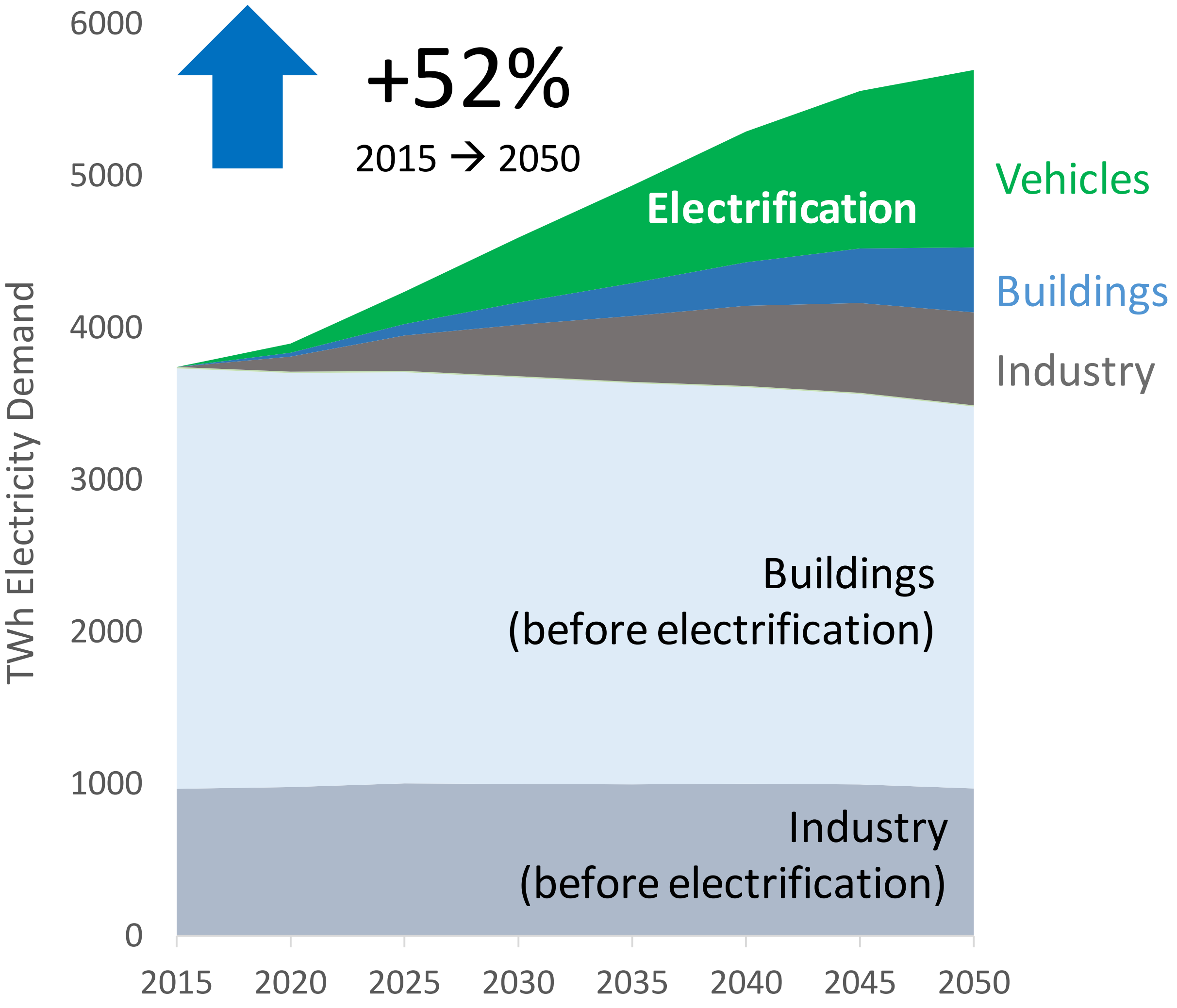
Efficient Electrification: Reference



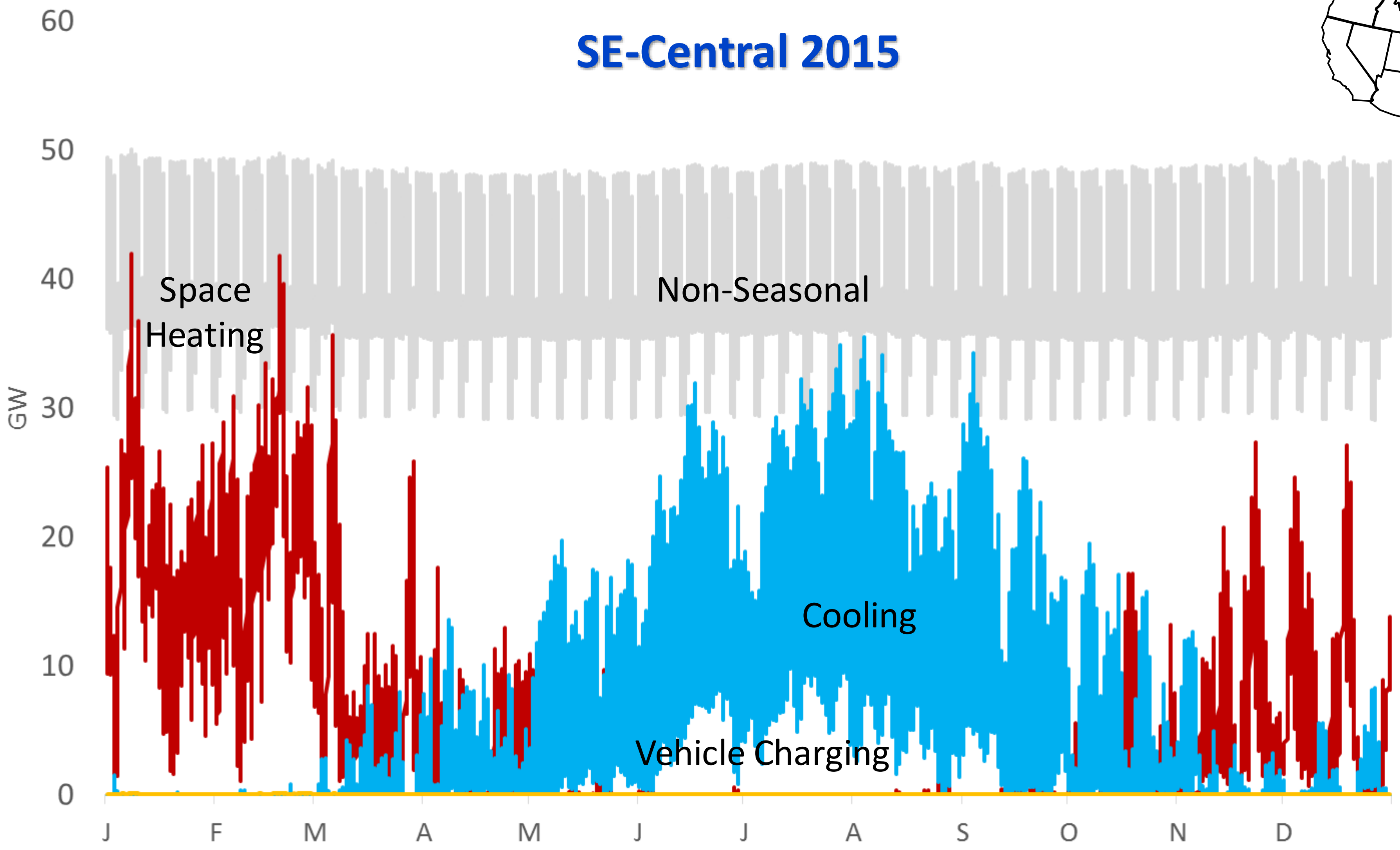


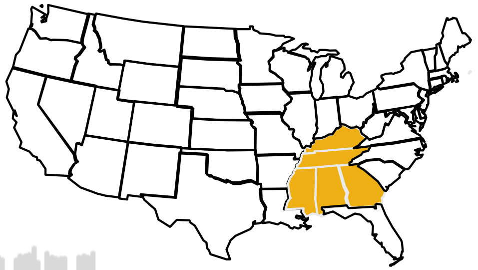
Efficient Electrification: Transformation



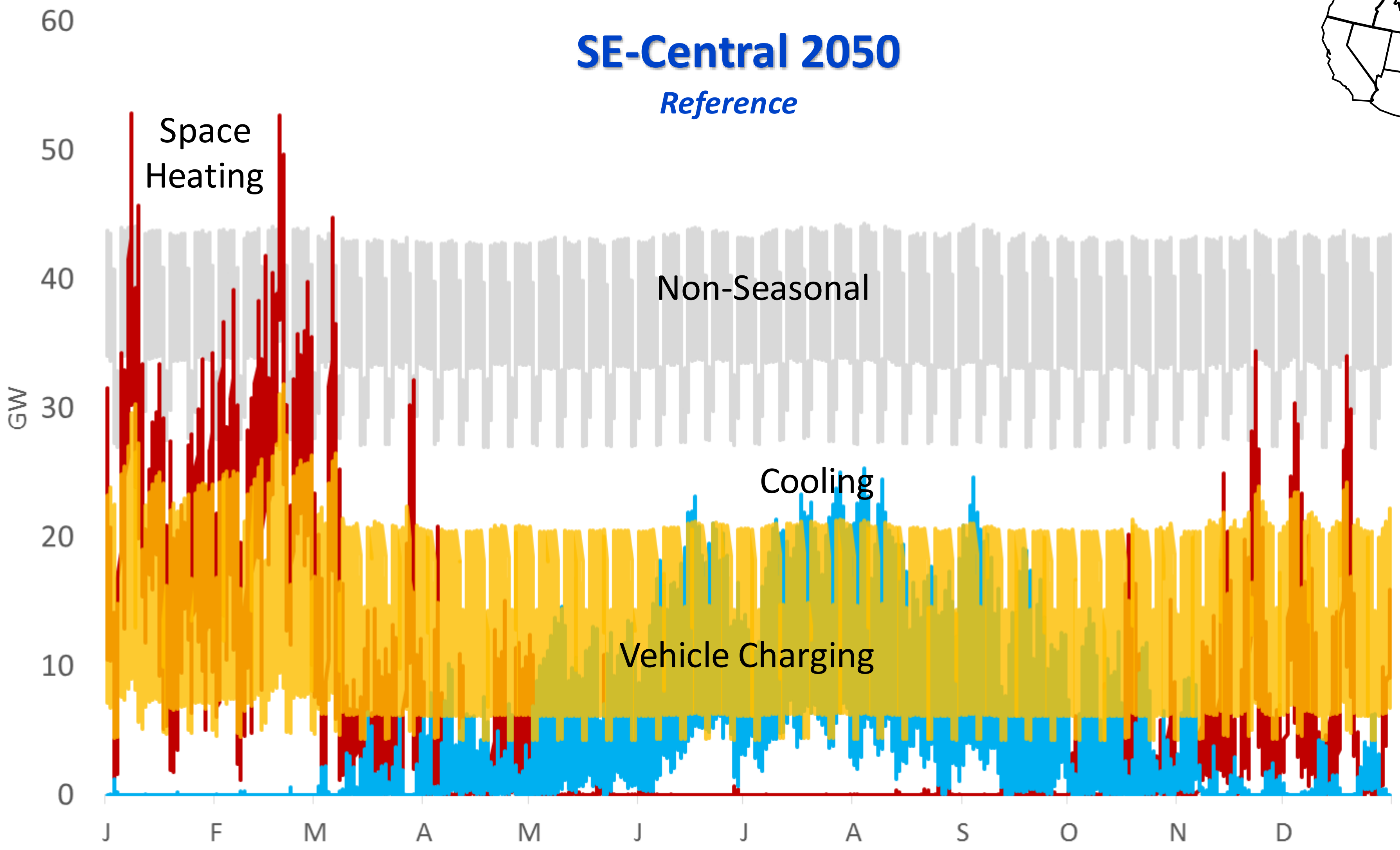


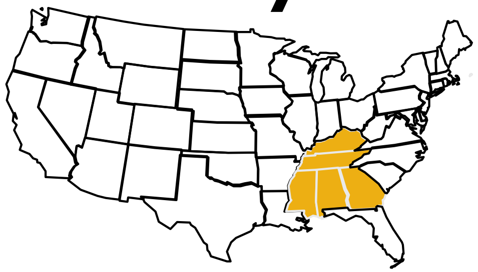
8760 Load Shape by Load Category in Base Year



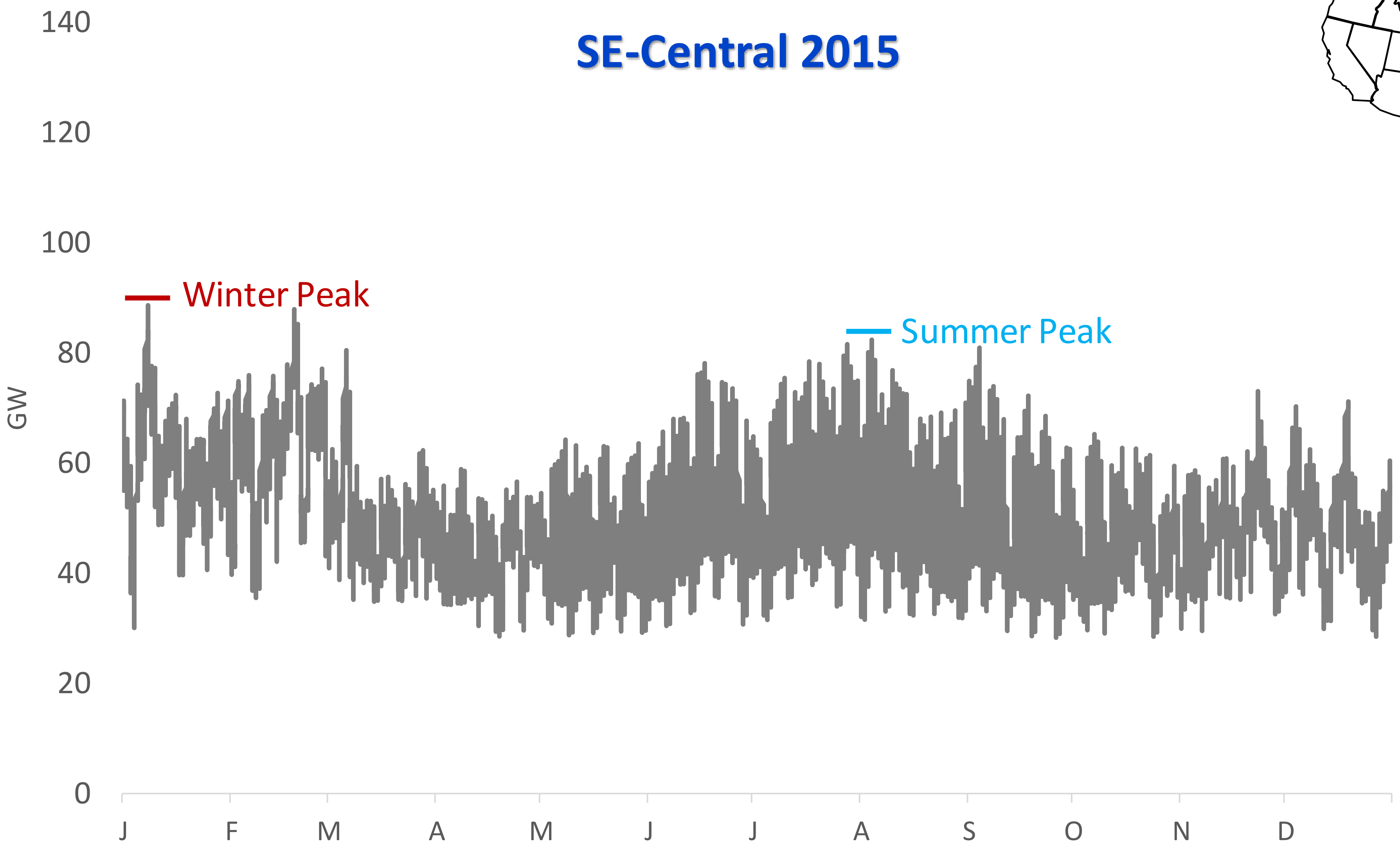


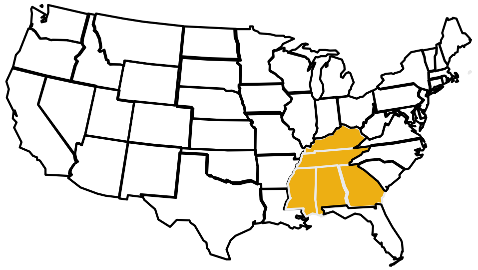
Reference Projections Reflect Electrification / Efficiency



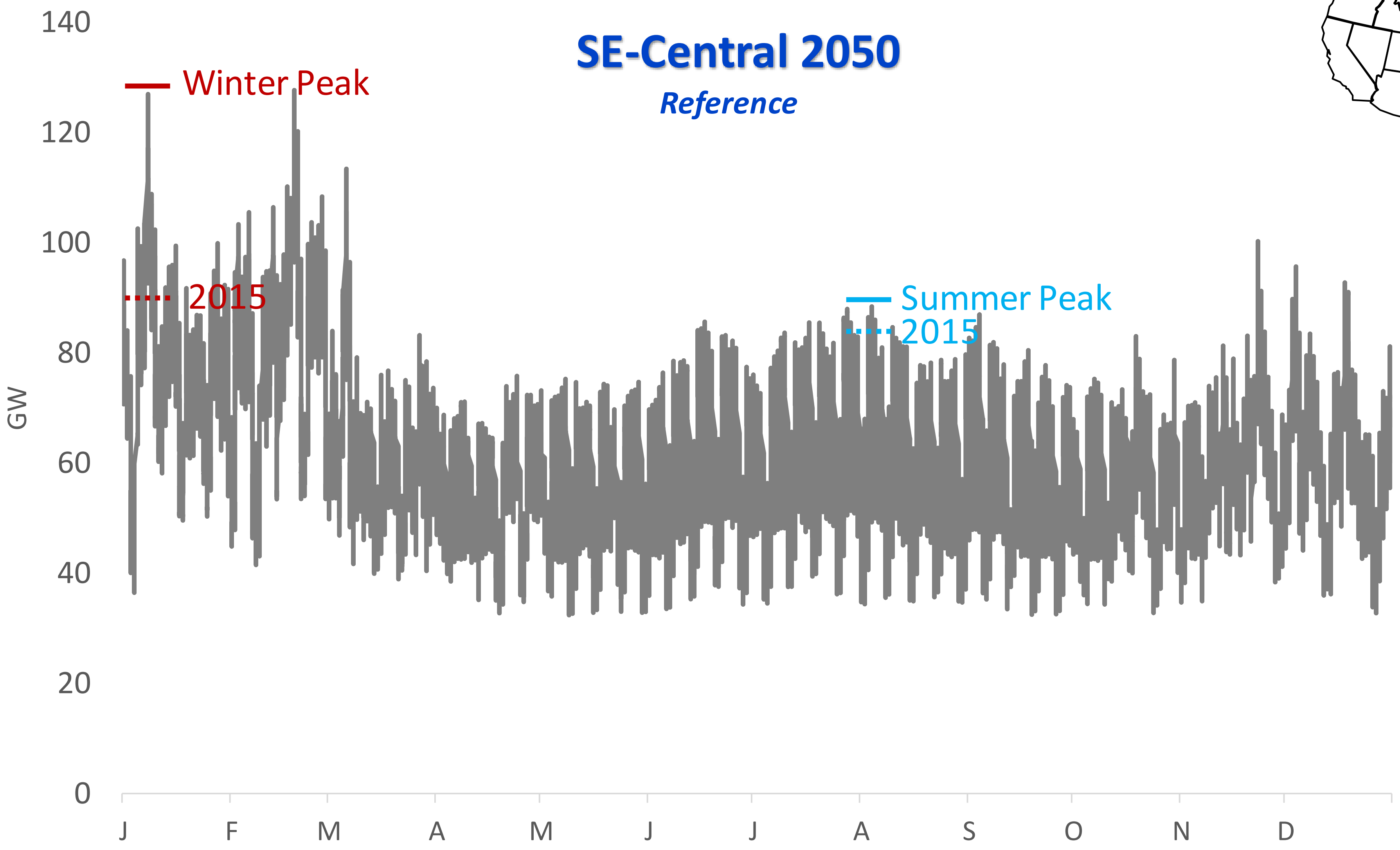


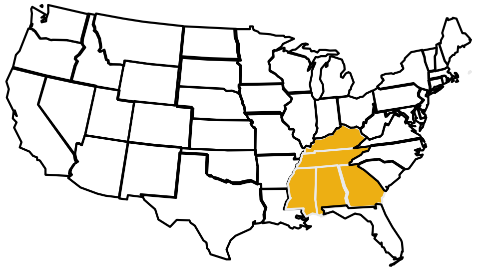
8760 Aggregate Load Shape in Base Year



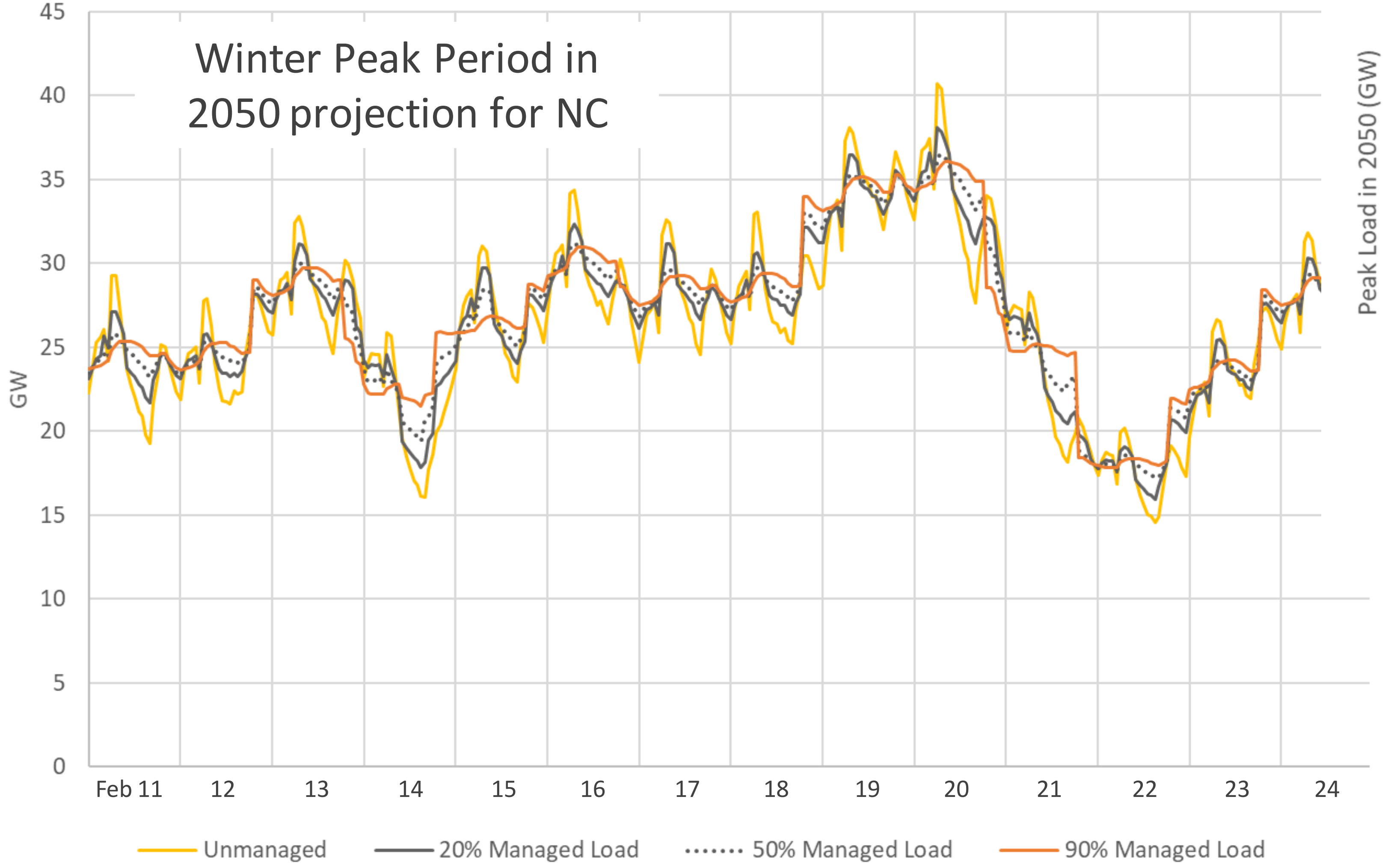


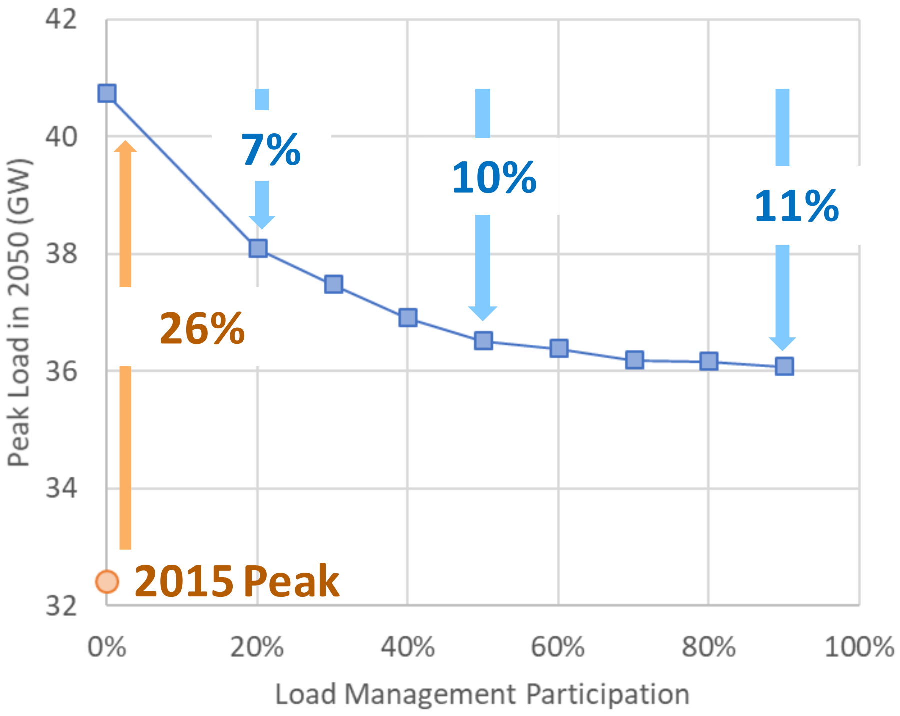
Electrification Drives up Winter Peak





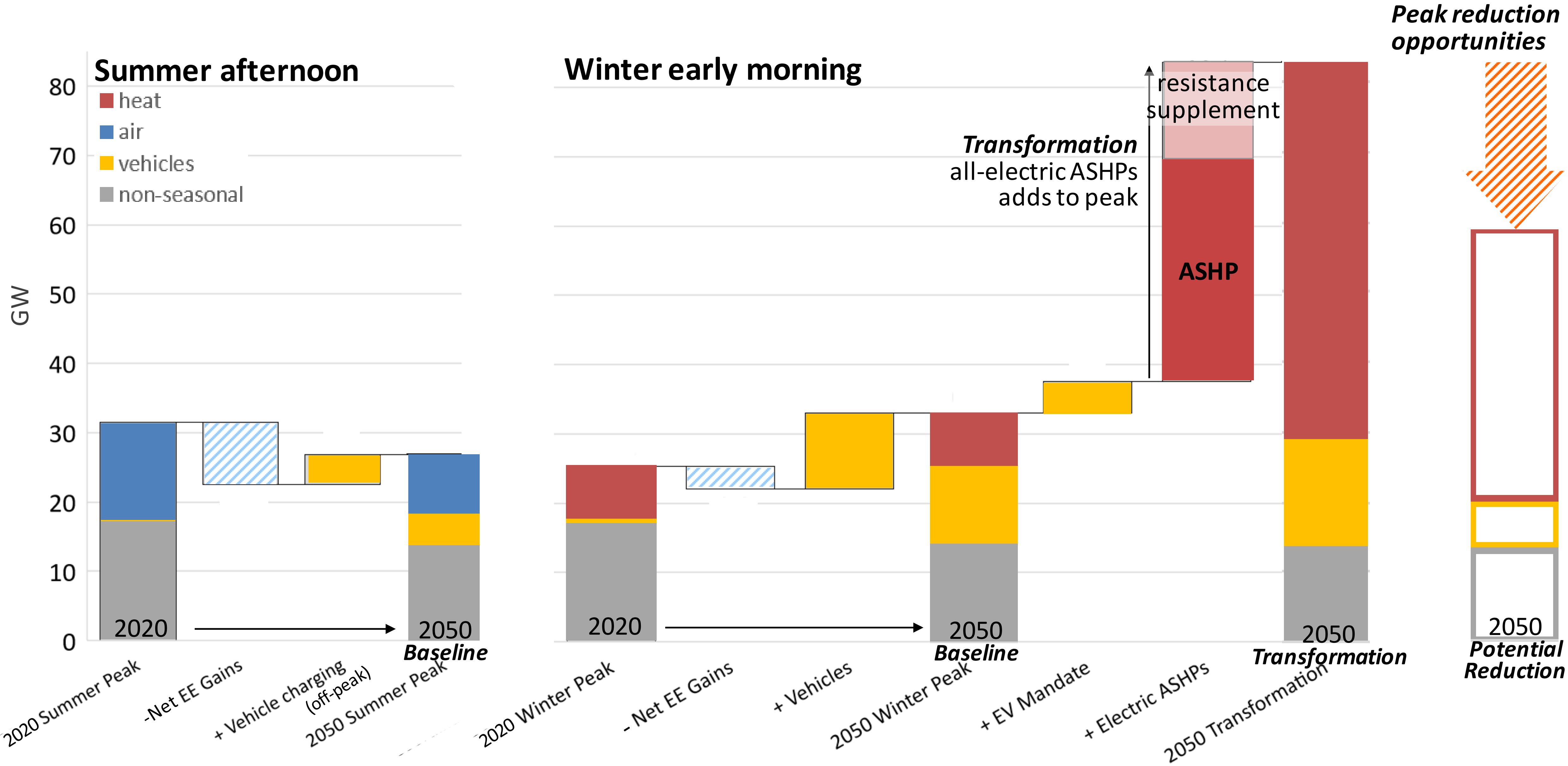
Active management of EV charging and space conditioning can reduce peak load by up to 5 GW in North Carolina





50% participation of households in load management programs enables most of the peak reduction benefit

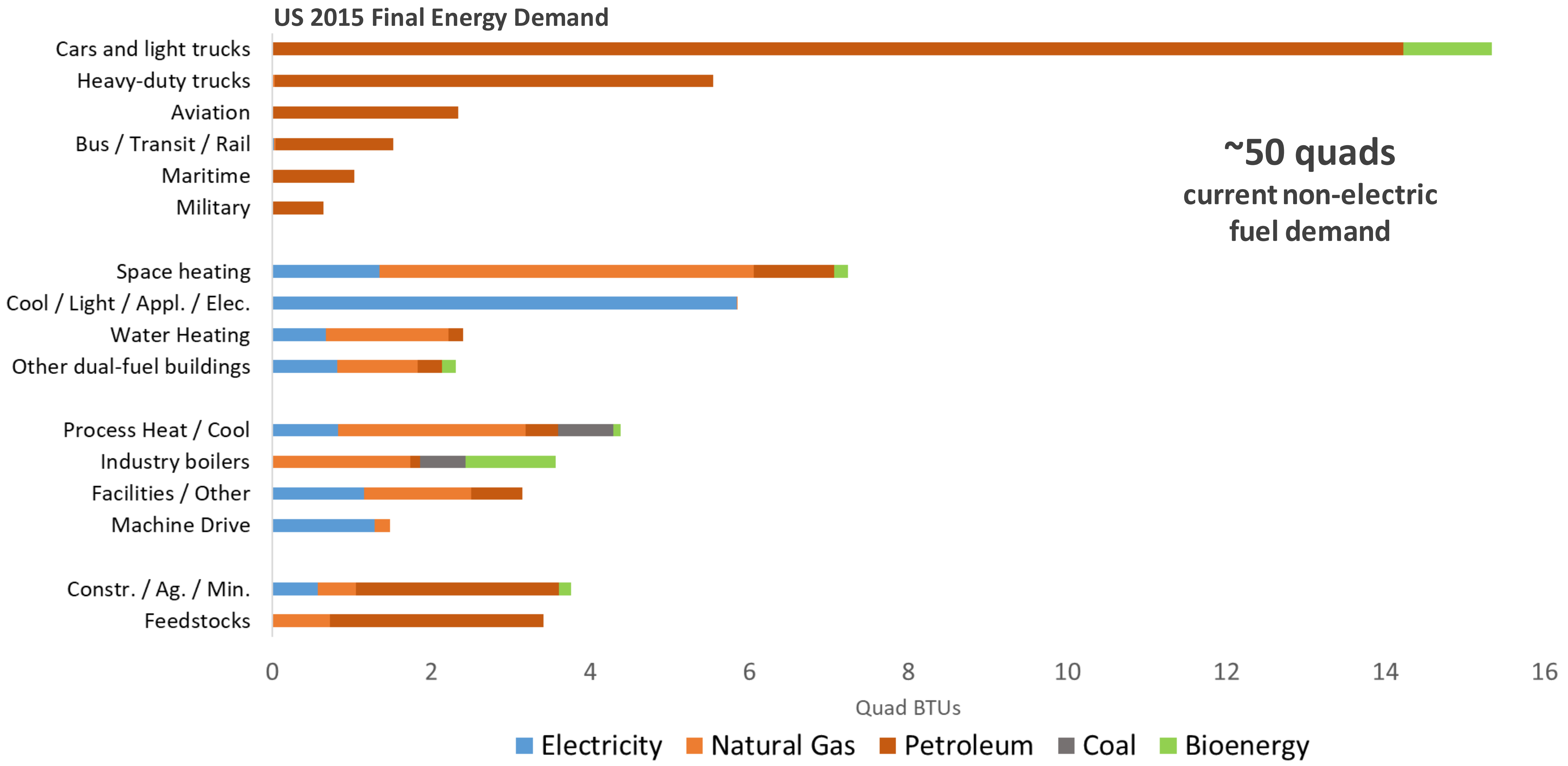
Contributions to future peak demand in New York



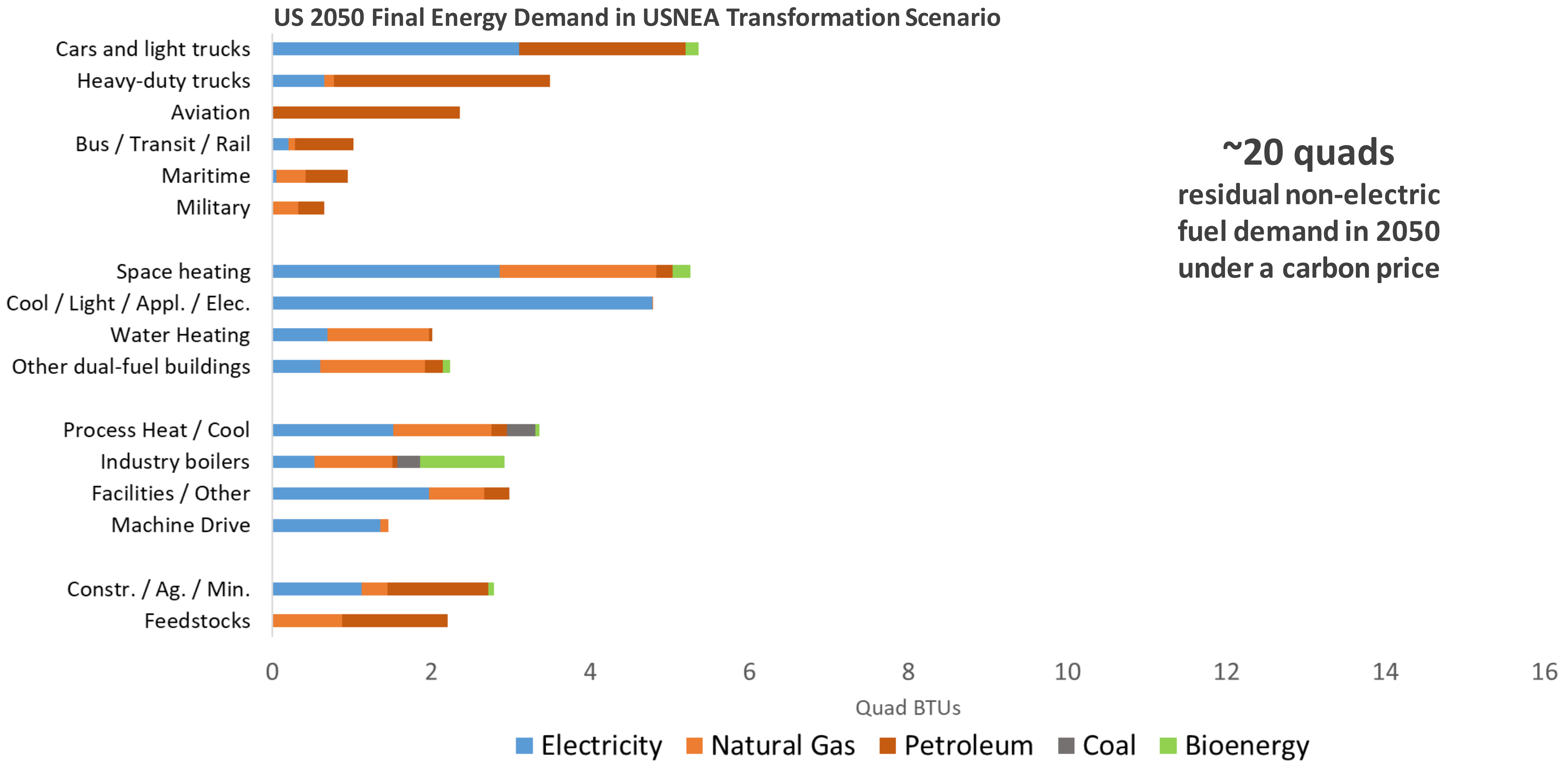
What are the limits of electrification?

- For many direct uses of fossil fuel, electricity is the first-best alternative low-carbon fuel:
  - Light-duty vehicles
  - Space heating in milder climates
  - Water heating and other building uses (including cooking)
  - Non-road and short-haul MD/HD vehicles (e.g. buses, delivery)
  - Some applications in industry and long-haul heavy transport
- Electrification is more difficult in a few key applications:
  - Space heating in the coldest climates
  - Certain industrial processes
  - Certain transport applications, e.g. long-haul aviation

Opportunities for Electrification of End-Use Energy

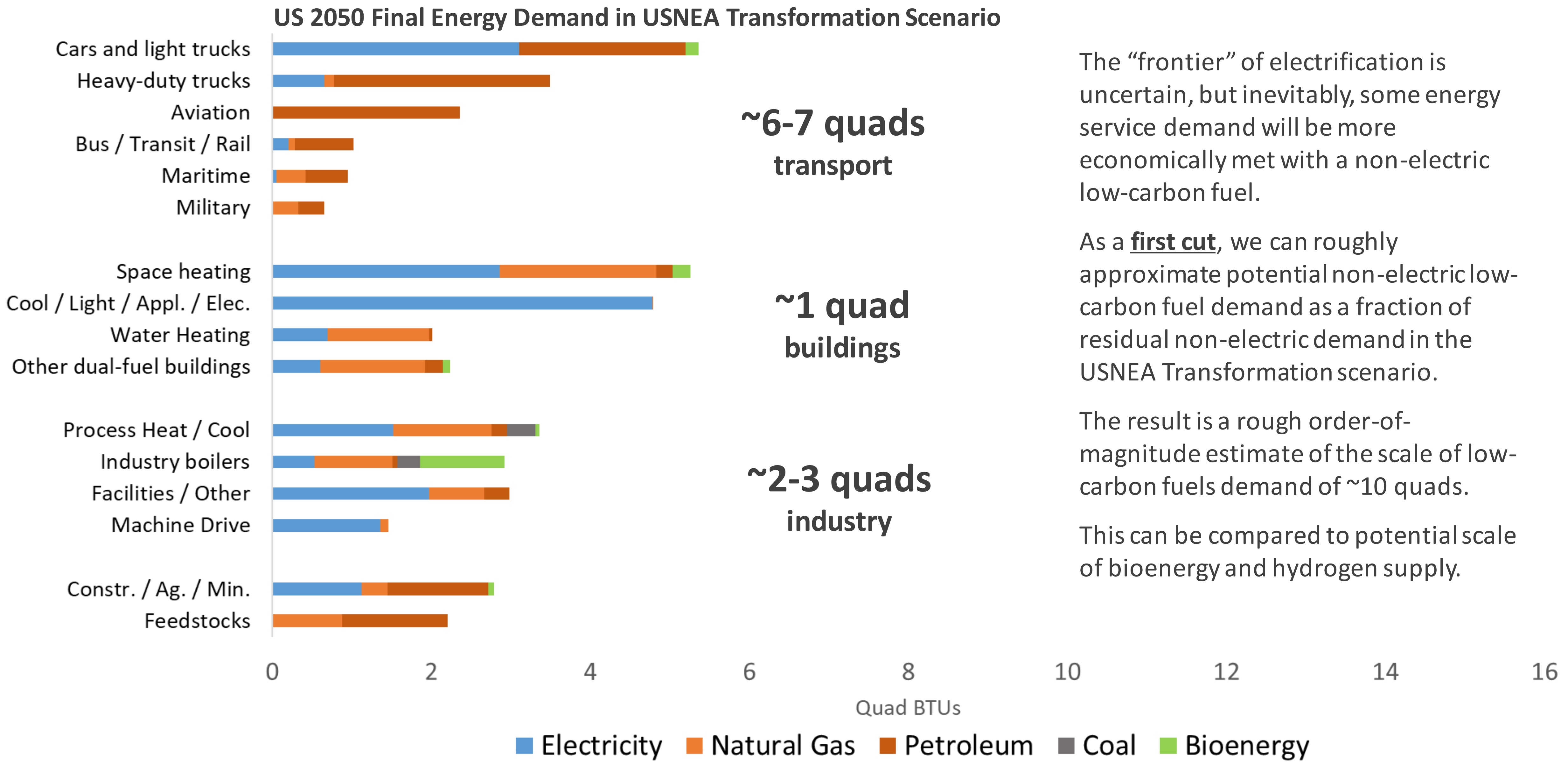


Significant Electrification, but Not Everywhere



~20 quads
residual non-electric fuel demand in 2050 under a carbon price

Potential Non-Electric Low-Carbon Fuel Demand



The "frontier" of electrification is uncertain, but inevitably, some energy service demand will be more economically met with a non-electric low-carbon fuel.

As a **first cut**, we can roughly approximate potential non-electric low-carbon fuel demand as a fraction of residual non-electric demand in the USNEA Transformation scenario.

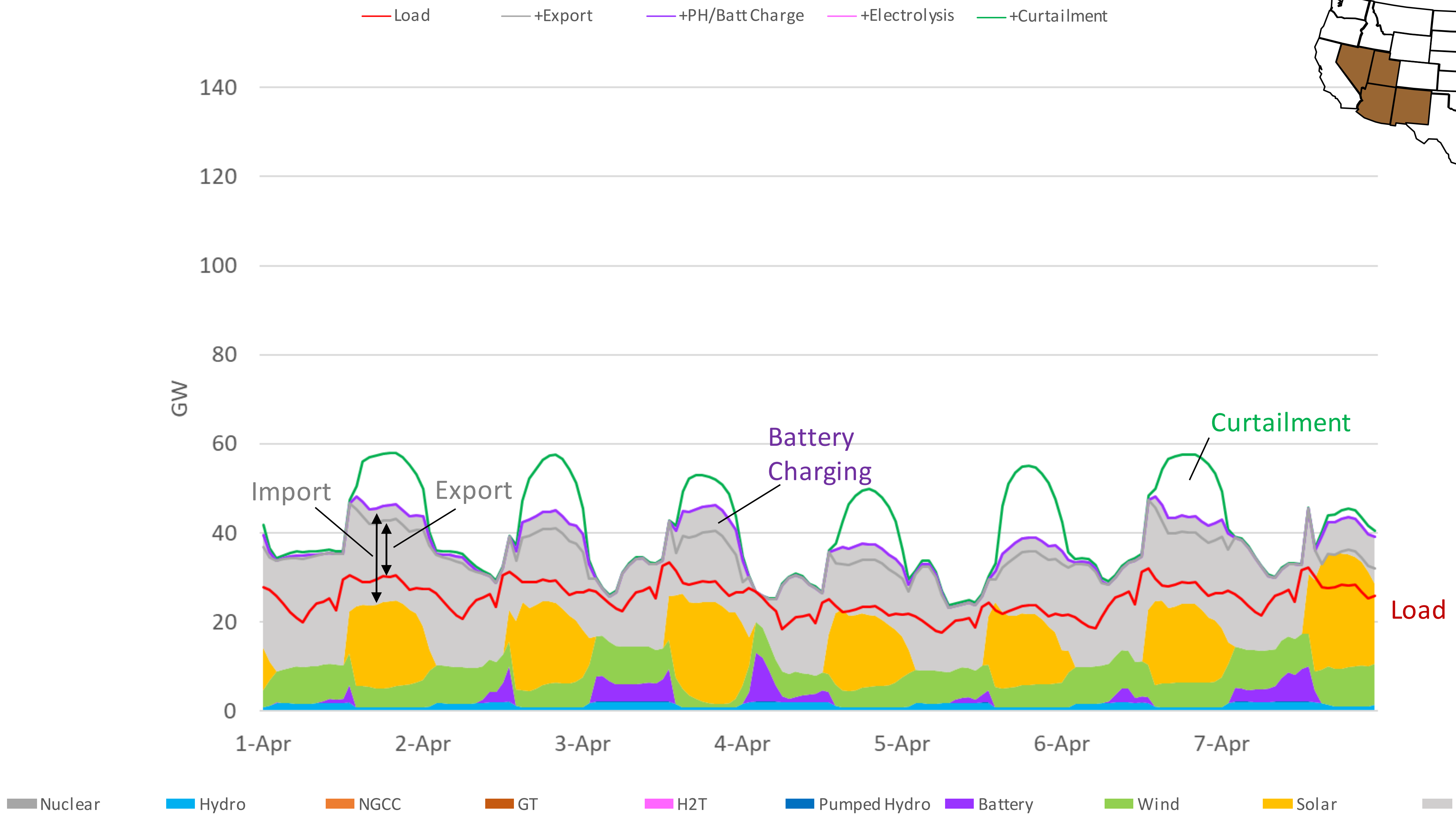
The result is a rough order-of-magnitude estimate of the scale of low-carbon fuels demand of ~10 quads.

This can be compared to potential scale of bioenergy and hydrogen supply.

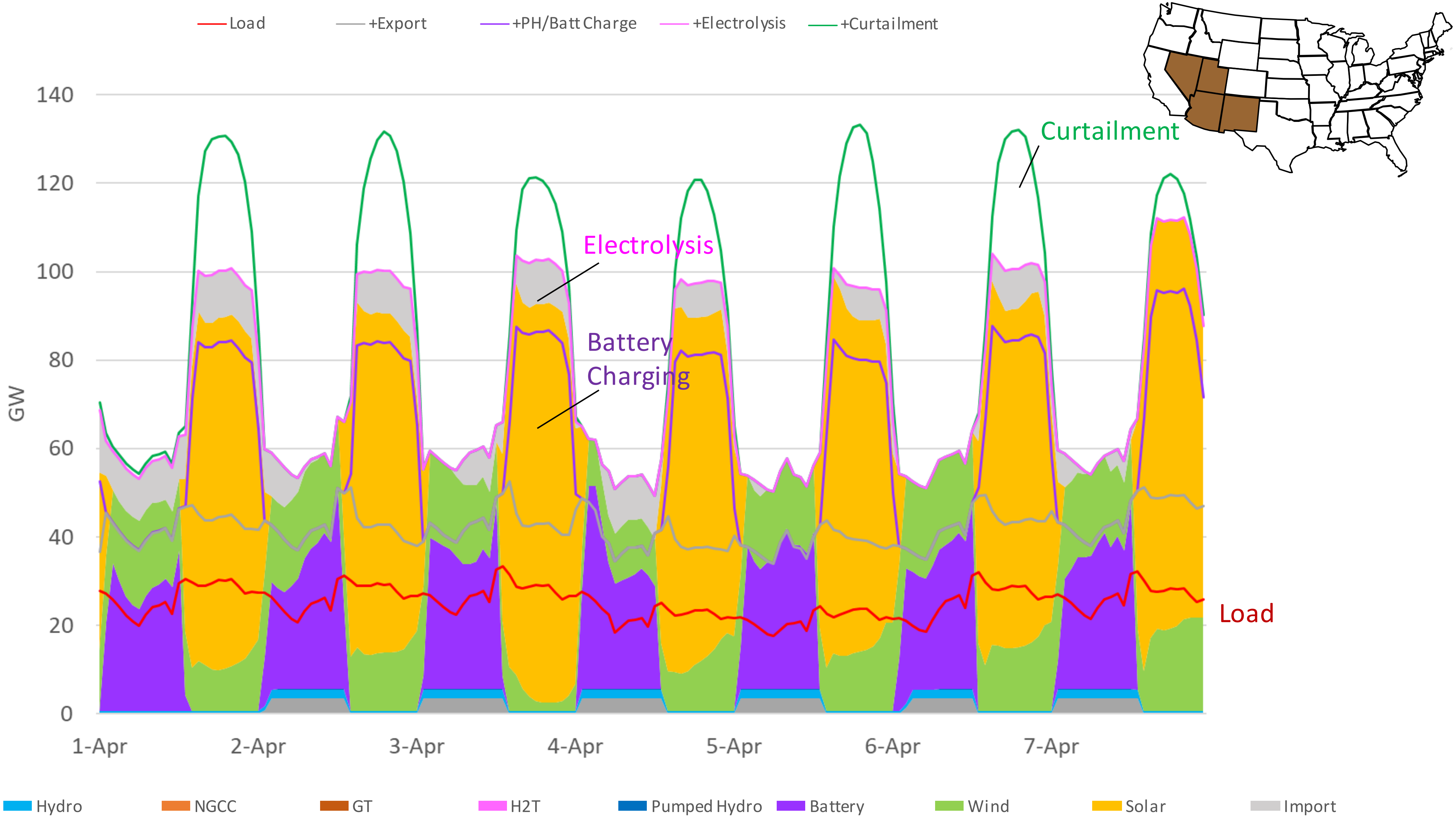
How does 1 quad of end-use demand for electrolytic H2 affect the electric sector? Simulation for WECC

- Impacts on capacity/generation mix (with a $100/tCO2 price):
  - More solar + **batteries**
  - Reduces NGCC and GT capacity/energy/emissions
  - Increases nuclear (i.e. Palo Verde) capacity factor 53% → 76%
  - Decreases wind/solar curtailment:
    - Wind: 6% → 3%
    - Solar: 9% → 3%
- Decreases (wholesale) electricity price by ~5%
- Electrolysis has ~60% capacity factor / avg. elec price of $30/MWh
  - Translates to $2.25/kg LCOH (or $19/mmbtu), *before* delivery
- Introduces much more variability / ramping / operational challenges

Mountain-South $100/tCO2 Scenario Example Dispatch



Mountain-South $100/tCO2 + Nele H2 Demand



Key Takeaways

- Technological improvements are making electrification an economical choice in several key sectors (especially LDVs), drives efficiency, lower emissions, and changing load patterns
- Opportunities for flexibility value (especially vehicle charging)
- Barriers to adoption remain
- Electrification doesn't make sense in all applications (even with a carbon price) → low-carbon fuels, e.g. hydrogen
- Electrolytic "green" hydrogen does have synergies with low-carbon electric generation in terms of lower costs, better asset utilization, but also increases demand for batteries, could fundamentally change how electric system is operated

Together…Shaping the Future of Electricity