EPRI's U.S. National Electrification Assessment

Overview and Key Messages



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EPRI-IEA Decarbonization Workshop
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EPRI's US-REGEN End-Use Model Level of Detail by Sector







Cars and Light Trucks

- ICEV
- PHEV
- EV
- FCV
- Autonomous Vehicles

Bus and Passenger Rail
Aviation (domestic)
Aviation (international)

Light Commercial Trucks
Heavy Trucks
Freight Rail (non-energy)
Shipping (domestic)
Shipping (international)
Military

Fuel Transport (rail)
Pipeline

Residential and Commercial

Space Cooling
Space Heating
Water Heating
Clothes Dryers
Cooking
Lighting
Other Appliances
Electronics
Ventilation
Other Building

- Central A/C
- Window A/C
- Air-Source Heat Pump
- Ground-Source Heat Pump
- Electric Furnace/Resistance
- Gas Furnace
- Oil/LPG Furnace
- Wood Furnace/Stove

Agriculture
Construction
Mining (non-energy)
Non-Building Commercial
Water Services

Bulk Chemicals
Iron and Steel
Paper/Pulp/Wood
Food
Cement
Other Manufacturing

- Boilers
- Co-gen Boilers
- Process Heat
- Machine Drive
- Feedstocks
- Facilities

Refining
Upstream Energy Extraction

SECTORS / ACTIVITIES → **END-USES** → **TECHNOLOGIES**

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EPRI's U.S. National Electrification Assessment (USNEA) Scenarios

CONSERVATIVE	*Slower Technology Change*	• *AEO 2017 growth path for GDP and service demands, and primary fuel prices* • *EPRI assumptions for cost and performance of technologies and energy efficiency over time* • *Existing state-level policies and targets*
REFERENCE	*Reference Technology*	
PROGRESSIVE	*Reference Technology + Moderate Carbon Price*	
TRANSFORMATION	*Reference Technology + Stringent Carbon Price*	

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USNEA Key Messages

Electrification Trend Continues	Driven by technological change and consumer choice, further bolstered by policy
Energy Efficiency	Efficient electrification + end-use efficiency lead to falling final energy use
Natural Gas	Remains an important fuel for end-use and electric generation
System Impacts	▪ Improved Environmental Outcomes ▪ Electric Sector Resource Planning

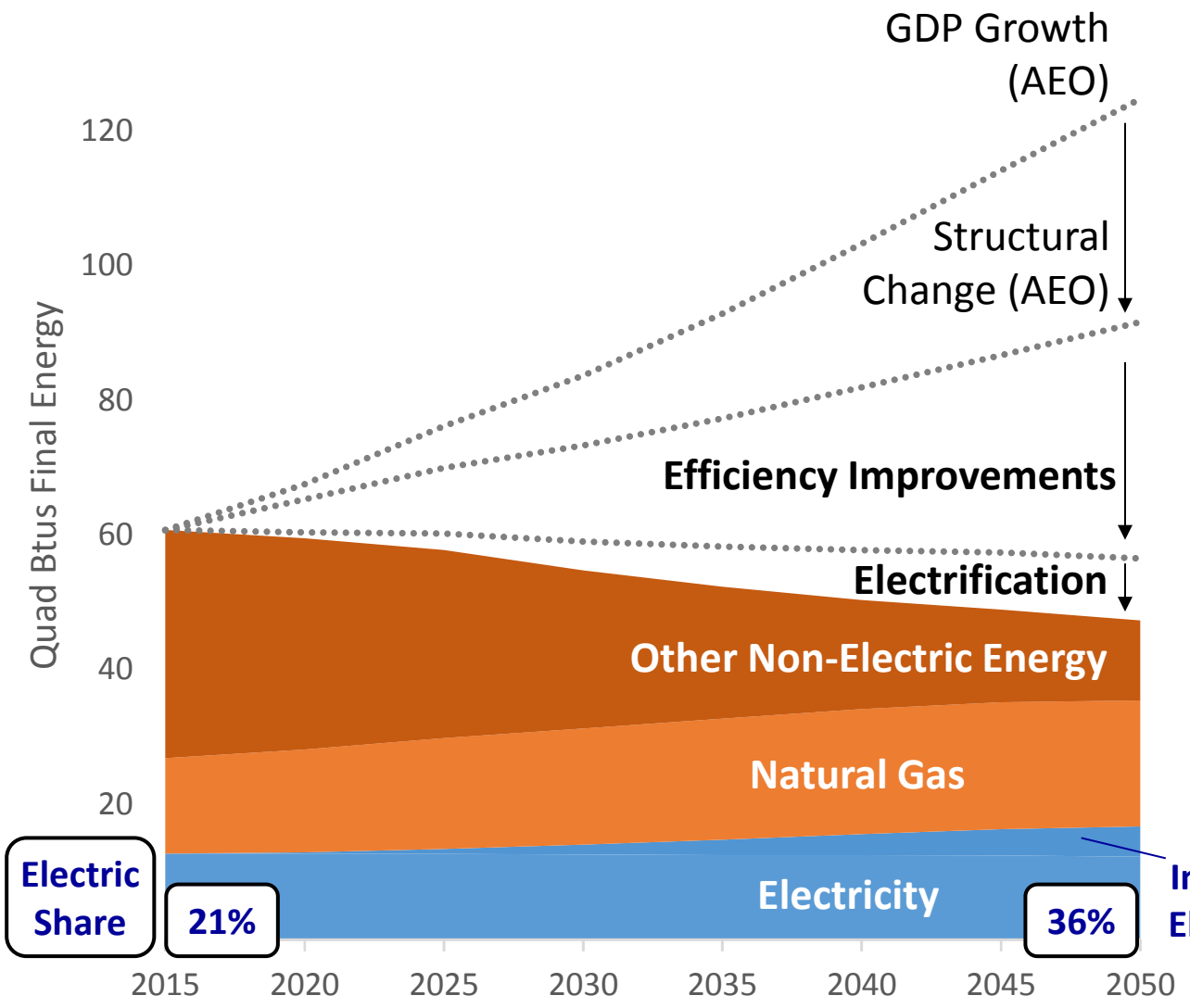
BUT…

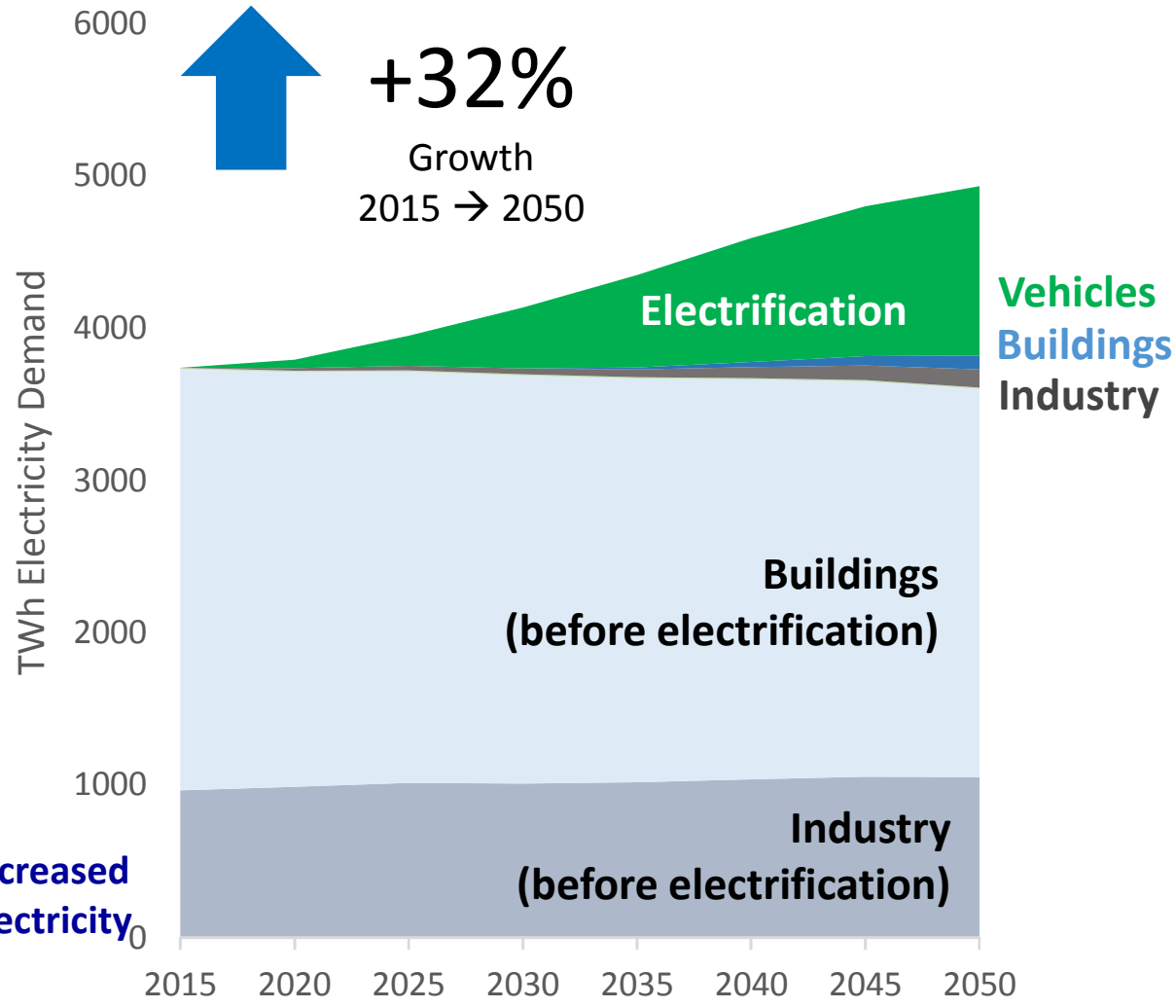
Potential may not be realized on its own due to consumer barriers

Pro-active approaches and technology R&D are essential

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Efficient Electrification: Reference Scenario

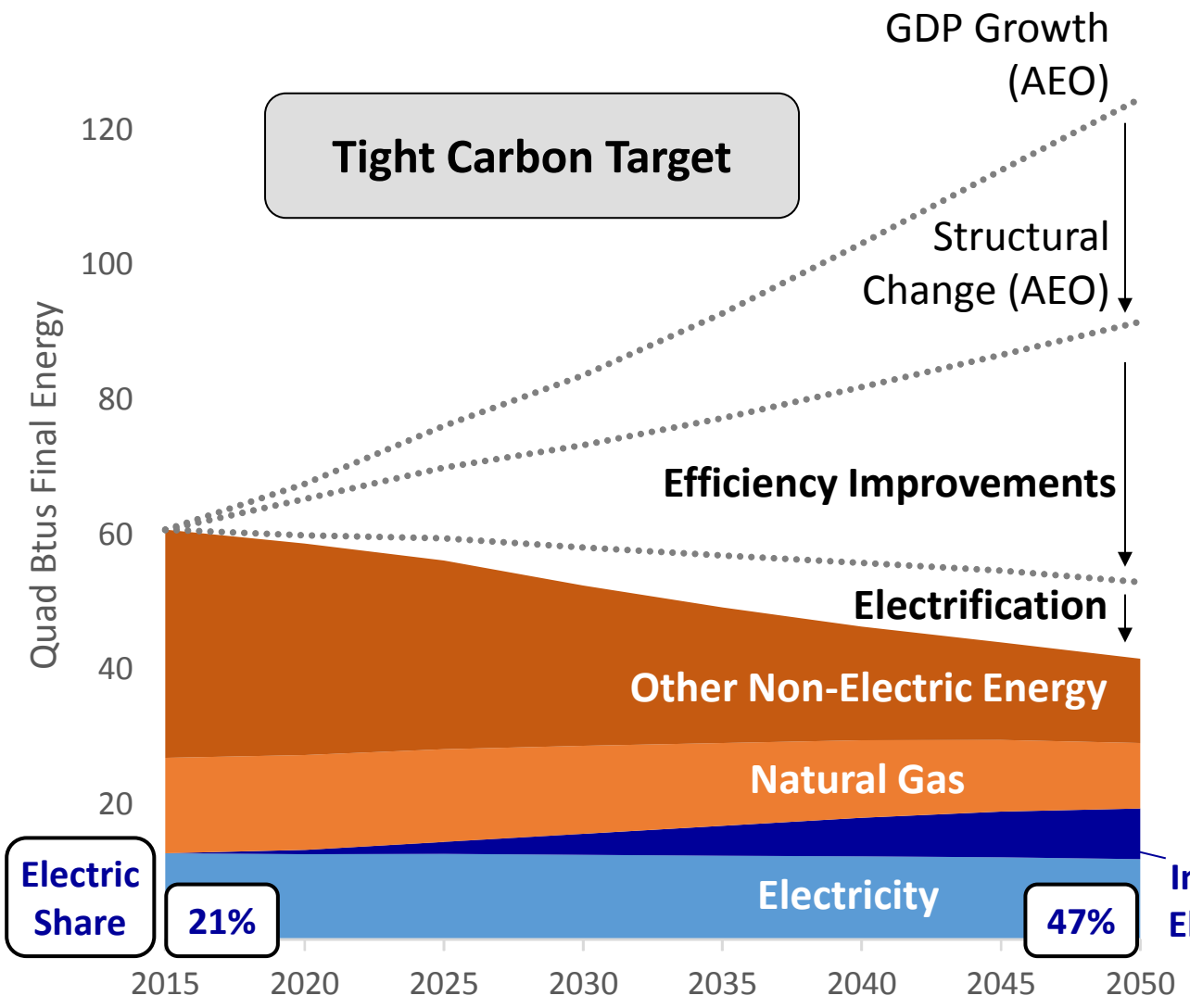


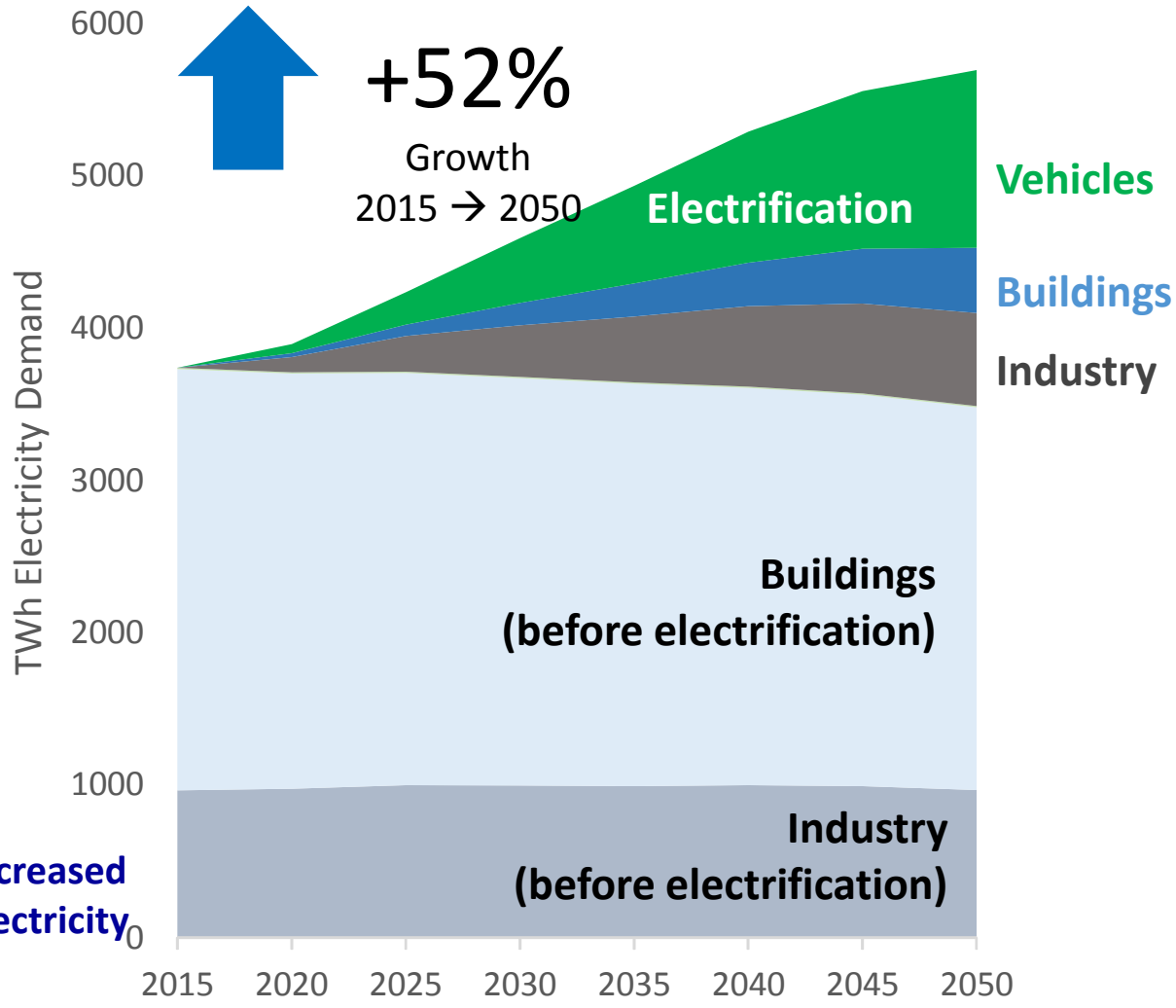


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Efficient Electrification: Transformation



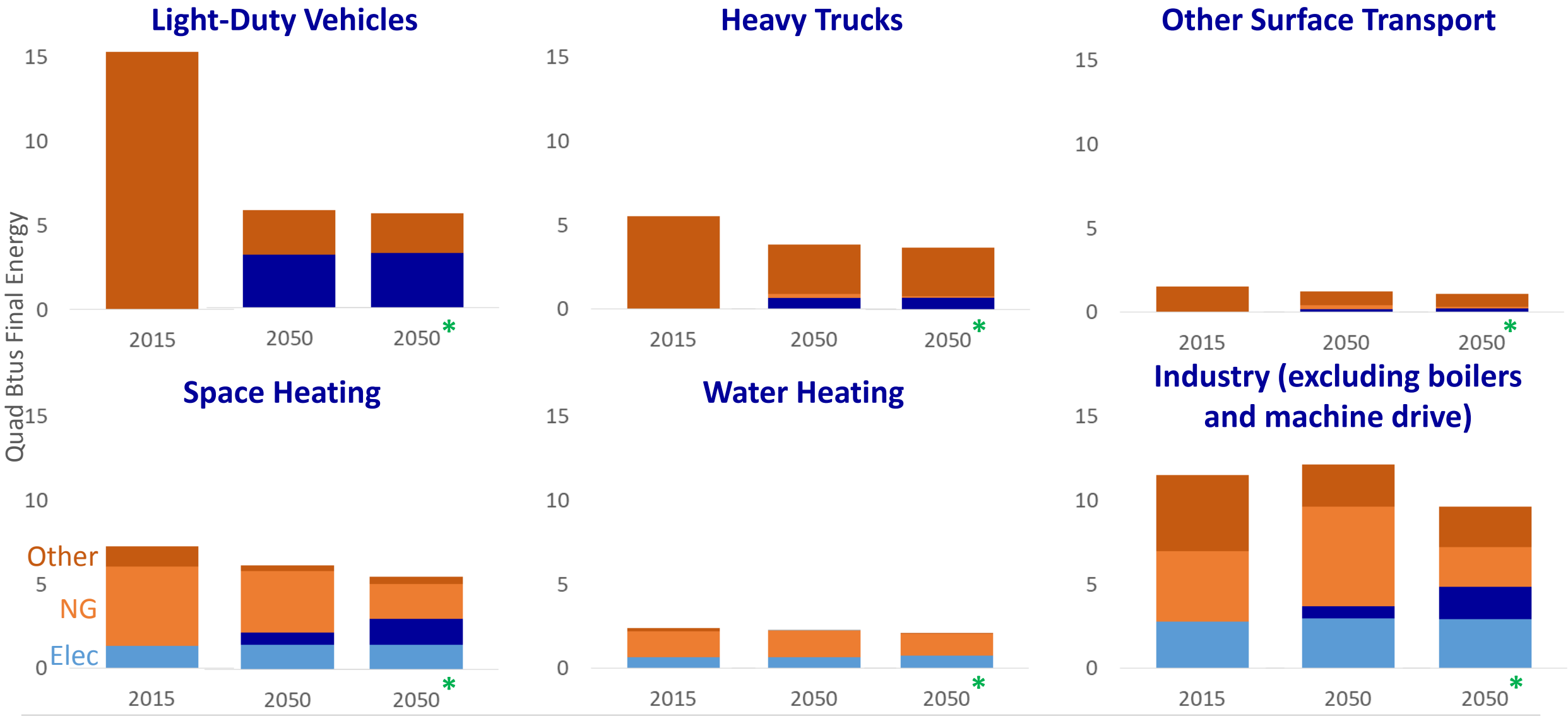


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Efficient Electrification in Key Sectors: Reference Scenario

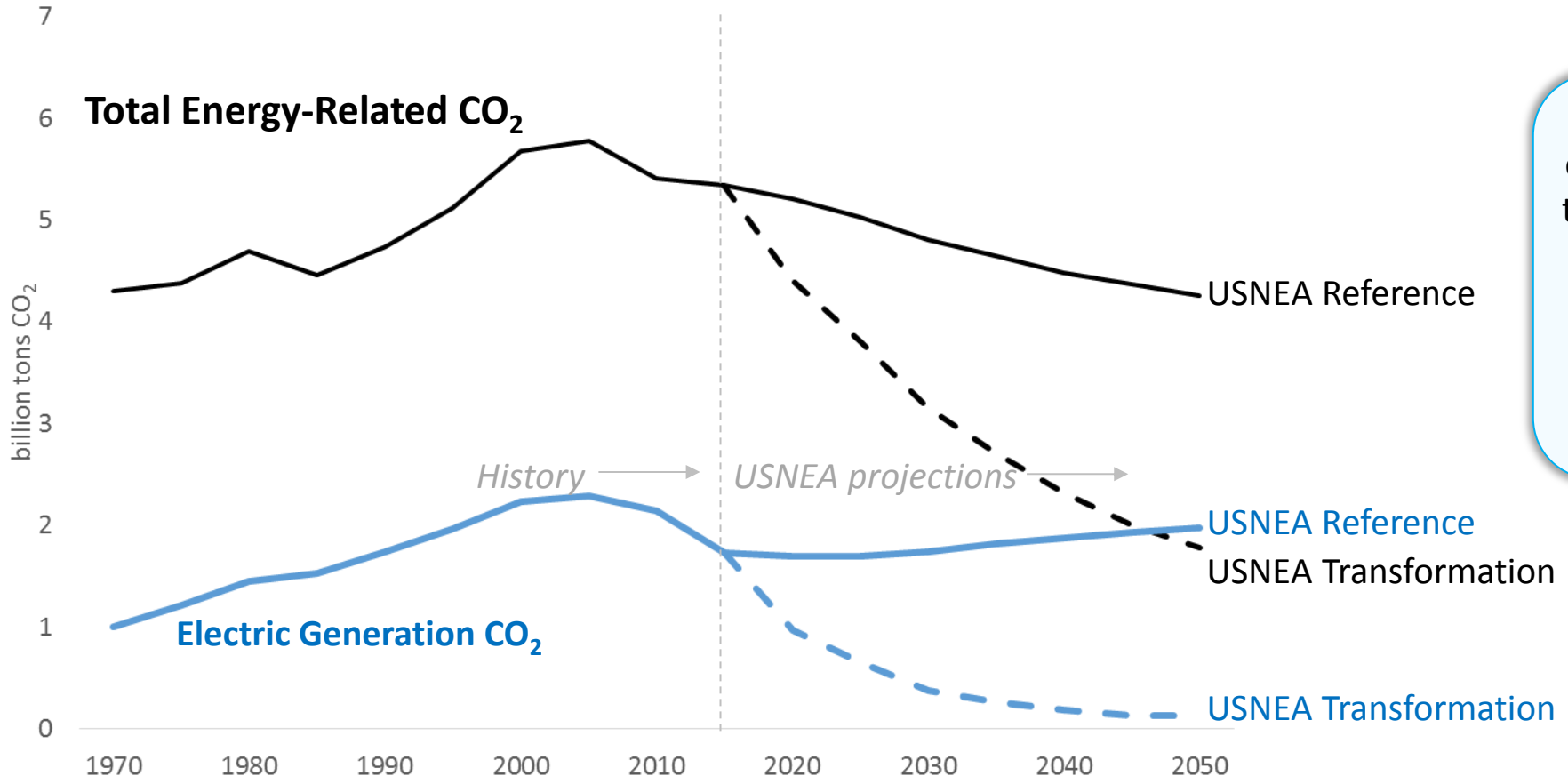
* Transformation



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Total and Electric Generation CO_2 Emissions



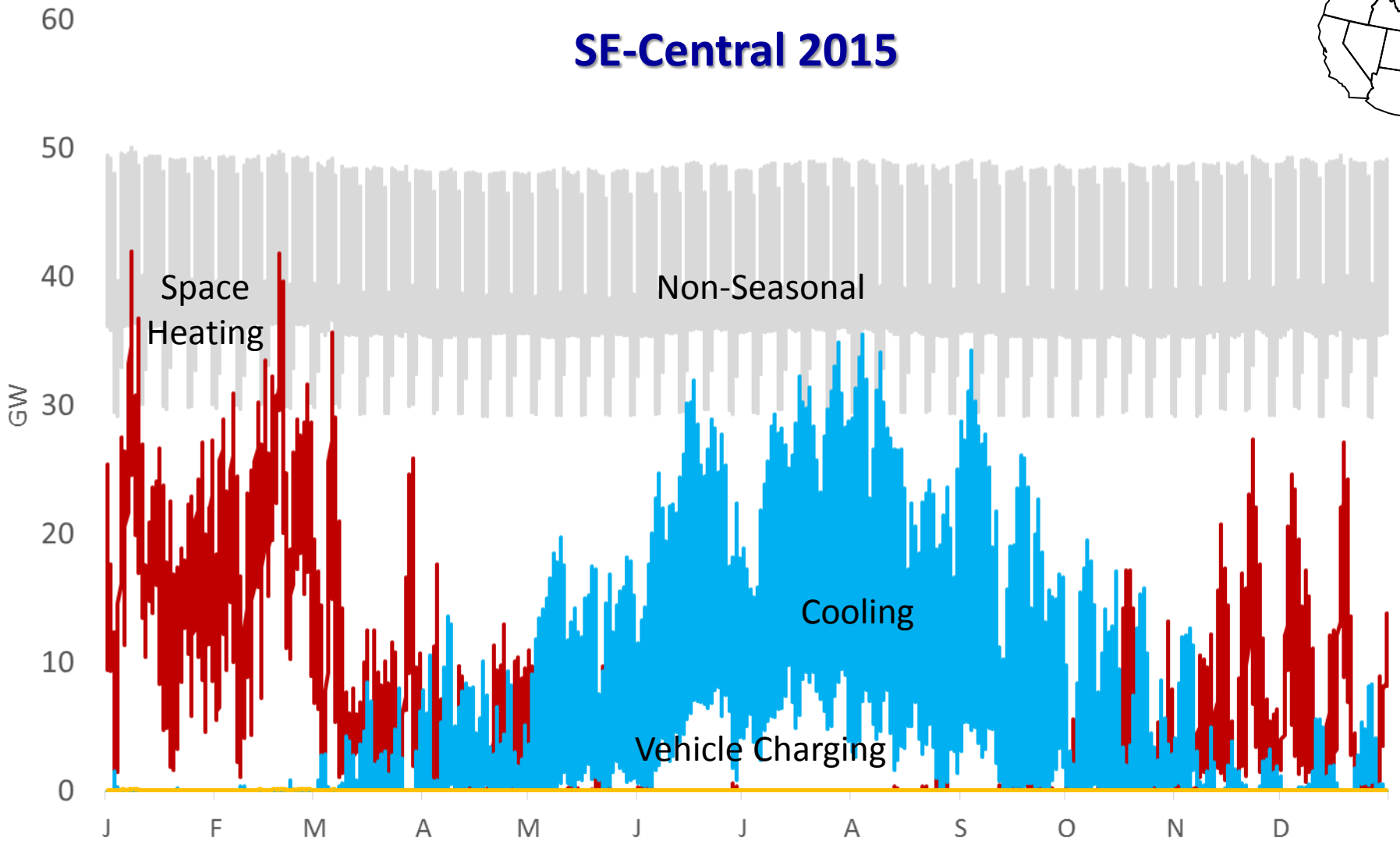
Increasing electrification leads to lower overall CO_2 emissions, even as emissions from electric generation increase in the USNEA Reference

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Base Year Load Shape Reflects Current Technology Stock



SE-Central 2015



How Will Sectoral Loads Change Over Time?

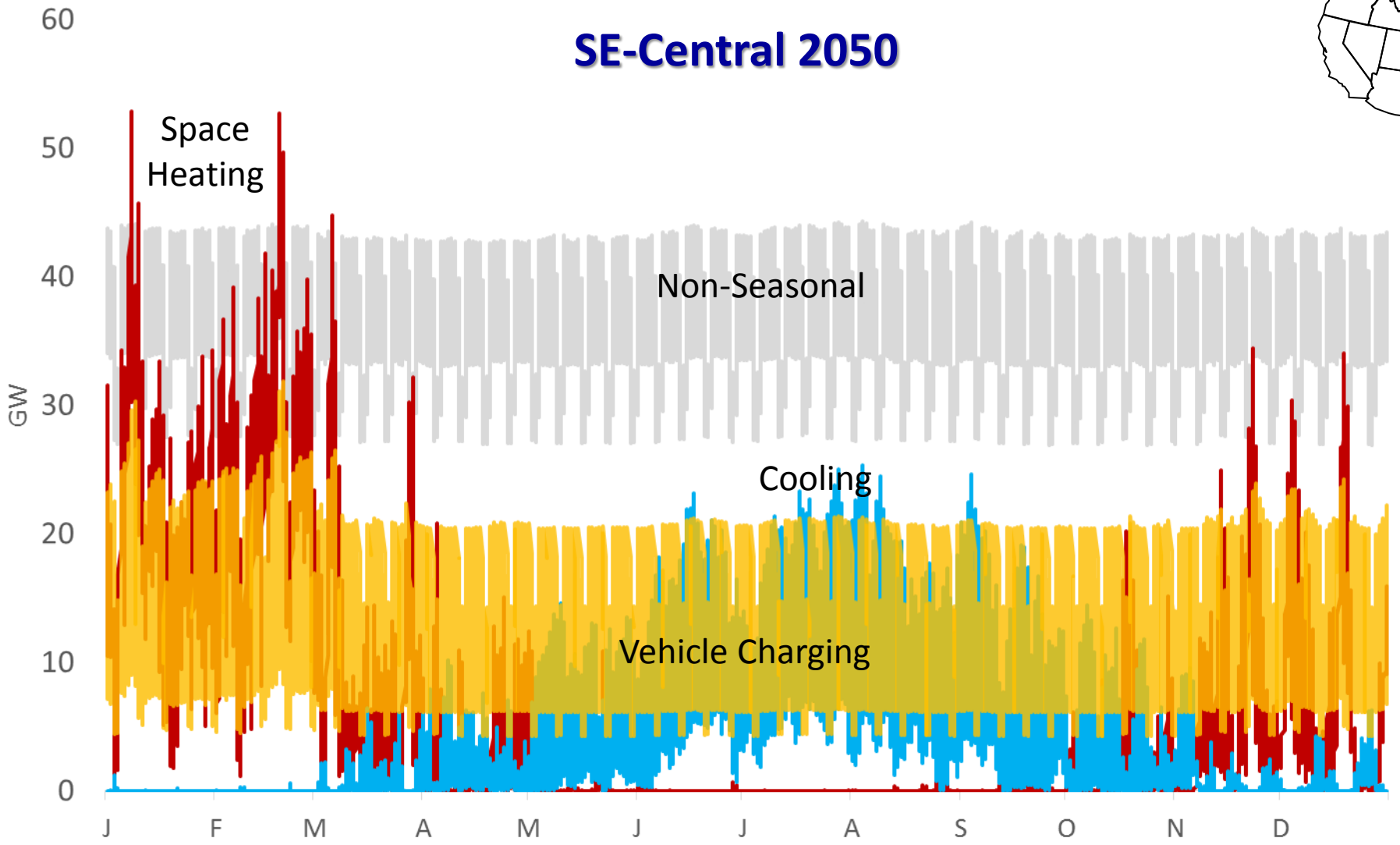
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Reference Projections Reflect Electrification / Efficiency



SE-Central 2050



Significant Shift in Pattern and Size of Load

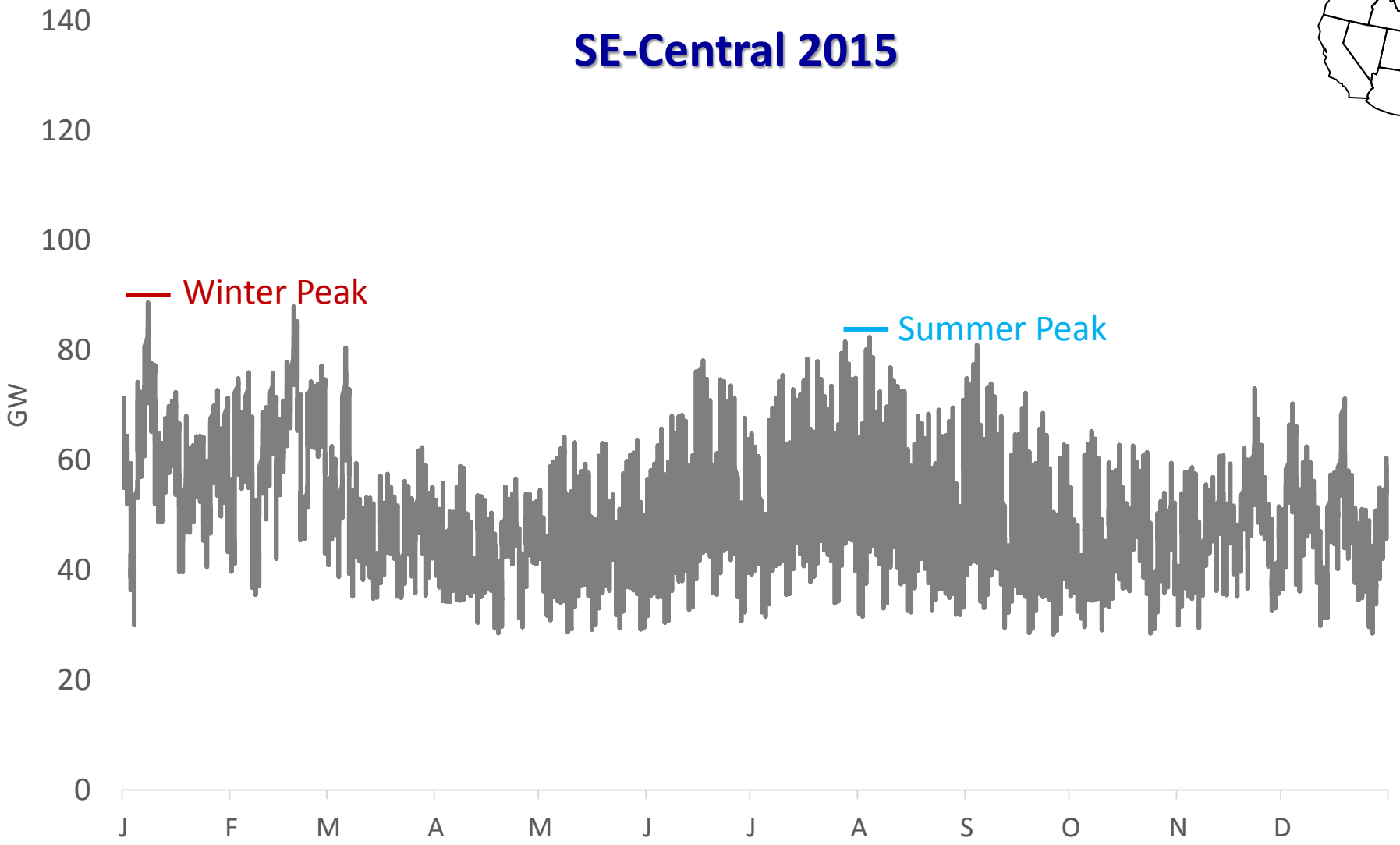
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Aggregate Load Shape Already Has Winter Peak in Some Regions



SE-Central 2015



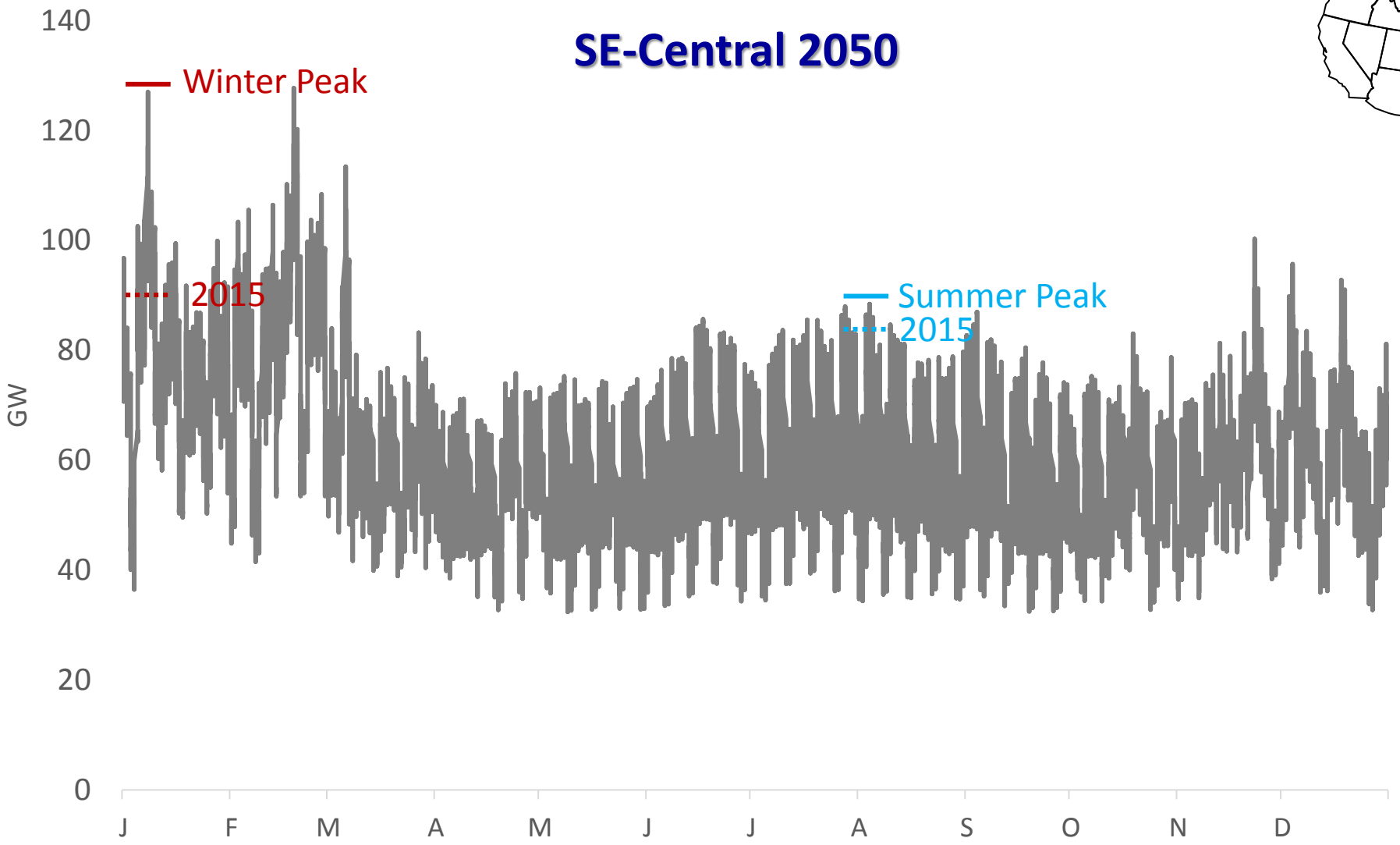
How Stable Are These System Dynamics?

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Aggregate Load Shape Changes from Electrification and Efficiency





Electrification Will Impact Electric Sector Resource Planning

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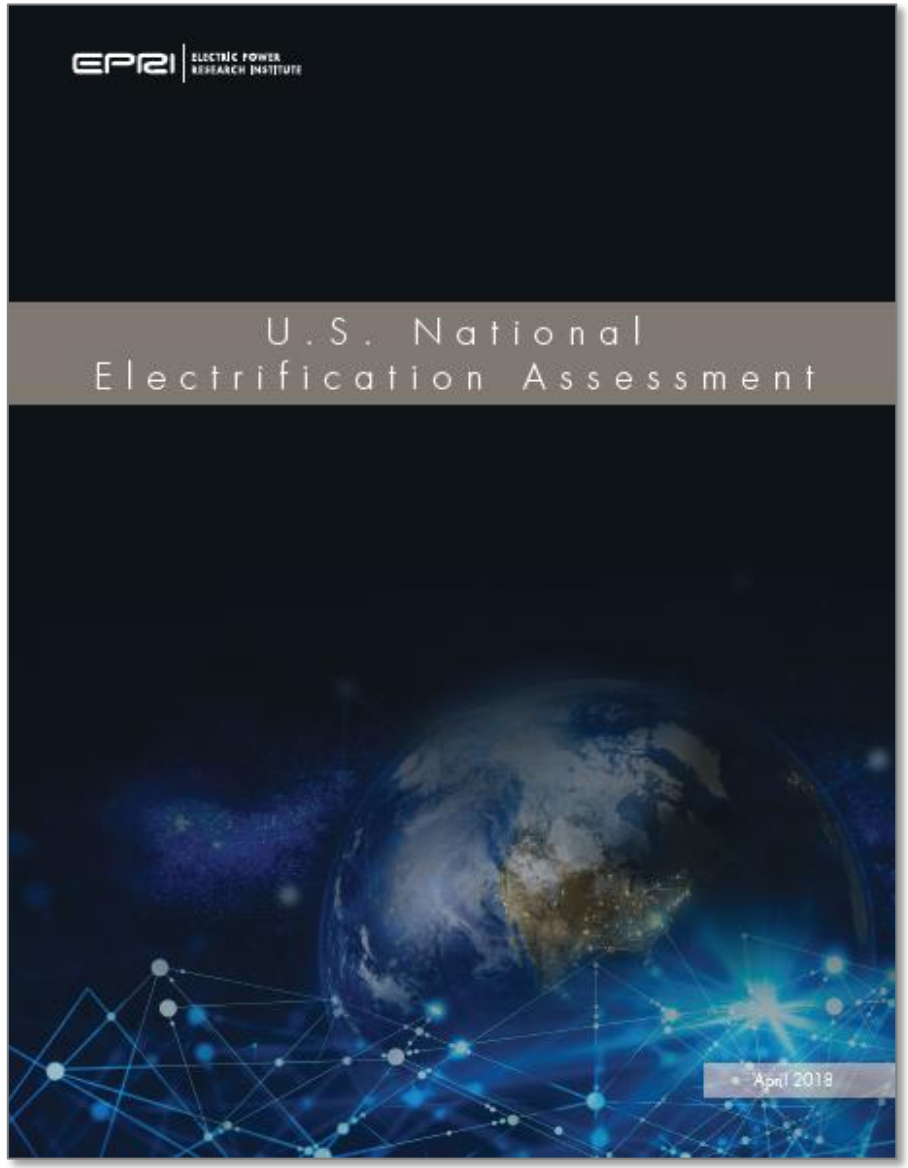
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Next Steps: State-Level Electrification Studies

- Criteria pollutant emissions and air quality
- Further structural disaggregation
  - Steam/hydronic vs. vented building systems
  - Access to natural gas
  - Availability of home charging
  - Non-road vehicles
- Implications of non-volumetric pricing
- Potential value of flexible loads, esp. vehicle charging
- Impacts on T&D resource planning

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For More Information



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US-REGEN Model Documentation

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Together…Shaping the Future of Electricity

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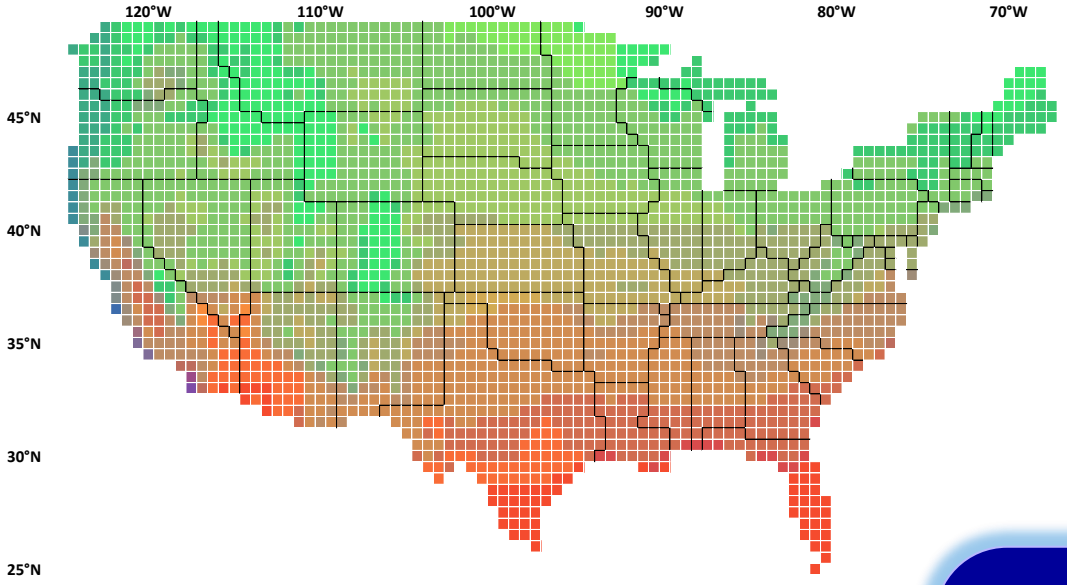
Key Assumptions for USNEA Scenarios

	CONSERVATIVE	REFERENCE	PROGRESSIVE	TRANSFORMATION
Light-duty vehicle costs	**Slower decline in battery costs**	EPRI/ANL estimates	EPRI/ANL estimates	EPRI/ANL estimates
Other technology costs	EPRI estimates	EPRI estimates	EPRI estimates	EPRI estimates
Efficiency Improvements	EPRI estimates	EPRI estimates	EPRI estimates	EPRI estimates
Economic growth / service demands	AEO 2017	AEO 2017	AEO 2017	AEO 2017
Primary fuel prices (NG, oil)	AEO 2017 Low Price Case	AEO 2017 Low Price Case	AEO 2017 Low Price Case	AEO 2017 Low Price Case
Electric sector policies	State RPS only	State RPS only	**State RPS + $15/tCO2 in 2020, rising at 7%**	**State RPS + $50/tCO2 in 2020, rising at 7%**
End-use sector policies	None	None	**$15/tCO$_2$ in 2020, rising at 7%**	**$50/tCO$_2$ in 2020, rising at 7%**

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USNEA Modeling Approach: US-REGEN

Energy Use



- Climate zones
- Building types
- Household characteristics
- Industrial mix
- End-use technology detail

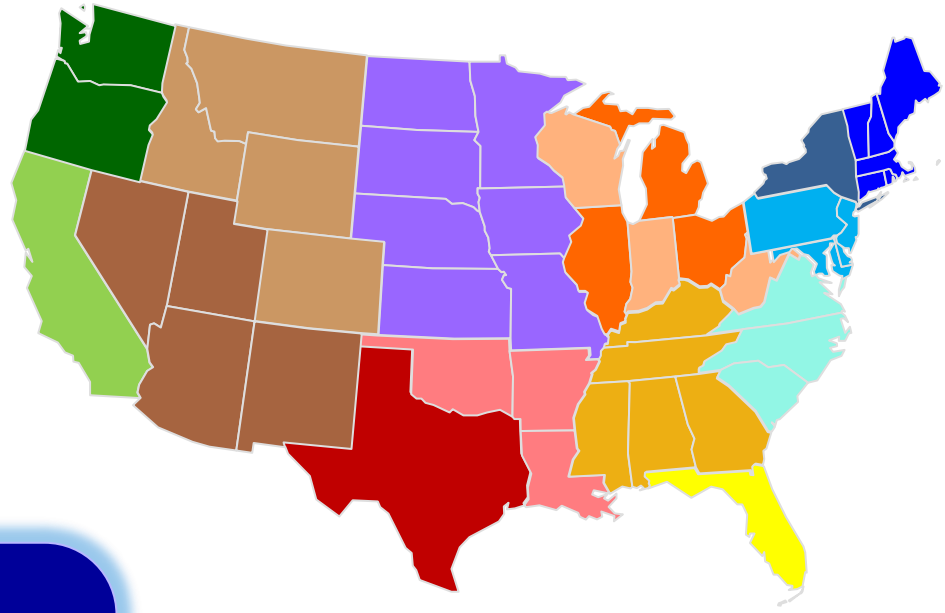
Synchronized Hourly Load, Renewables, and Prices

Model Outputs:

Generation, capacity, prices, and end-use mix

Emissions, air quality, and water

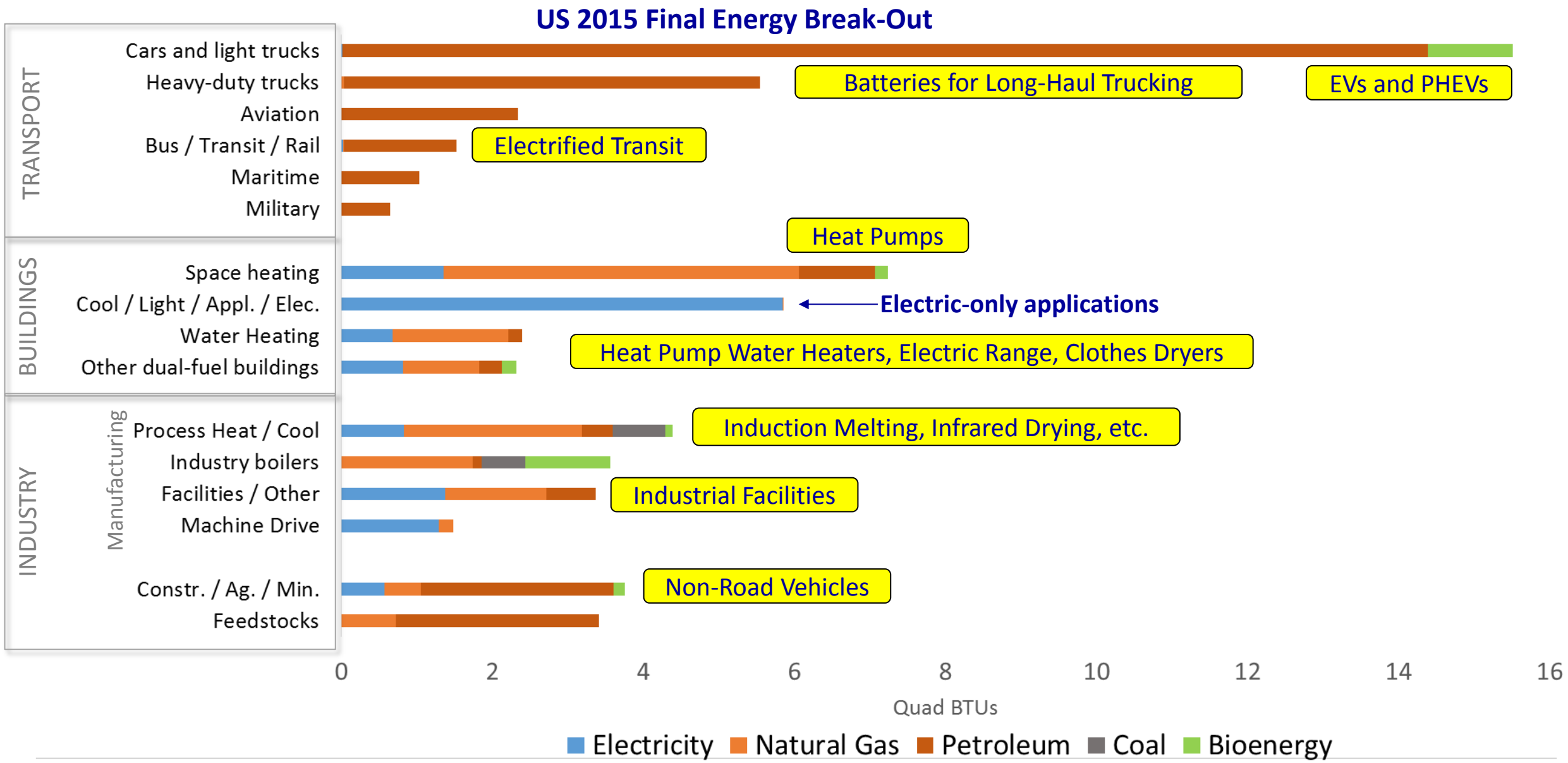
Electric Generation



- Investment and dispatch
- Transmission
- Intermittent renewables
- Energy and capacity requirements
- State-level policies and constraints

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Potential for Efficient Electrification Varies by End-Use Application



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Model Projections of EV Economic Potential in Reference Case



Battery costs continue to fall rapidly

Car manufacturers develop wide range of EV models with ~300 mile range

Home or work charging is available for most drivers

EV maintenance costs are lower

NG prices remain low, moderate increase in oil price

ICEV fuel economy continues to improve



Economic Potential

EV / PHEV are most economical choice for **75%** of potential new vehicle decisions by **2030**

(90% by 2050)

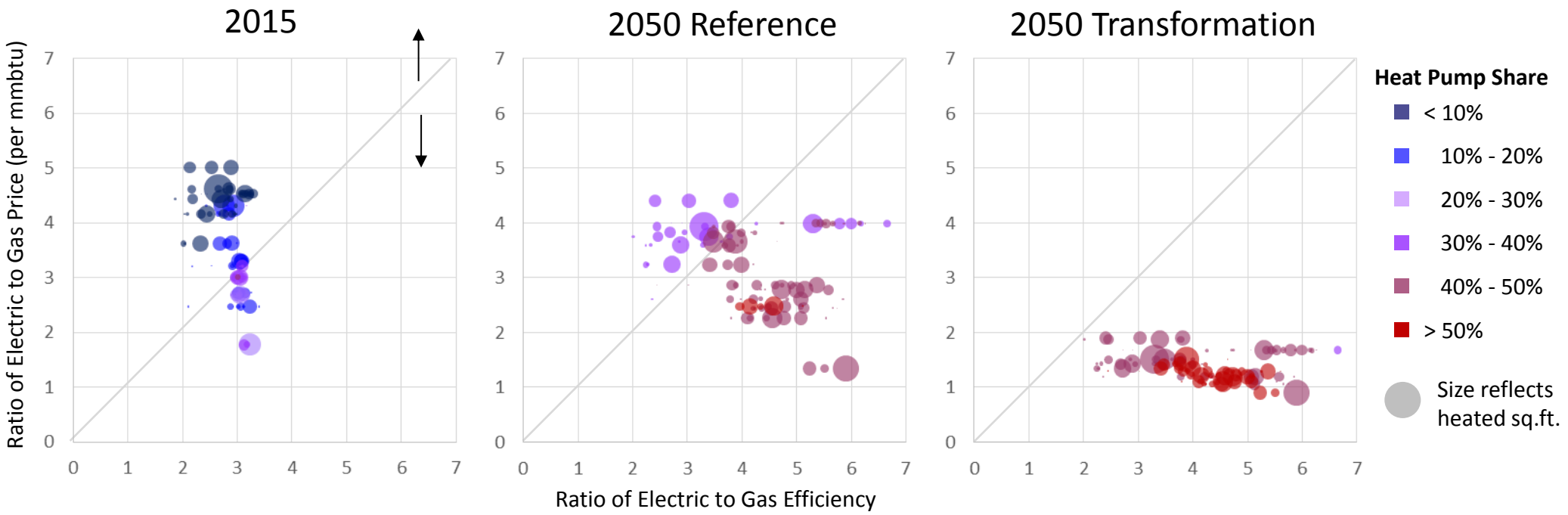
Adoption

EV / PHEV represent **40%** of new vehicle market by **2030**

(75% by 2050)

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Heat Pump Economics Vary by Region, Improve Over Time



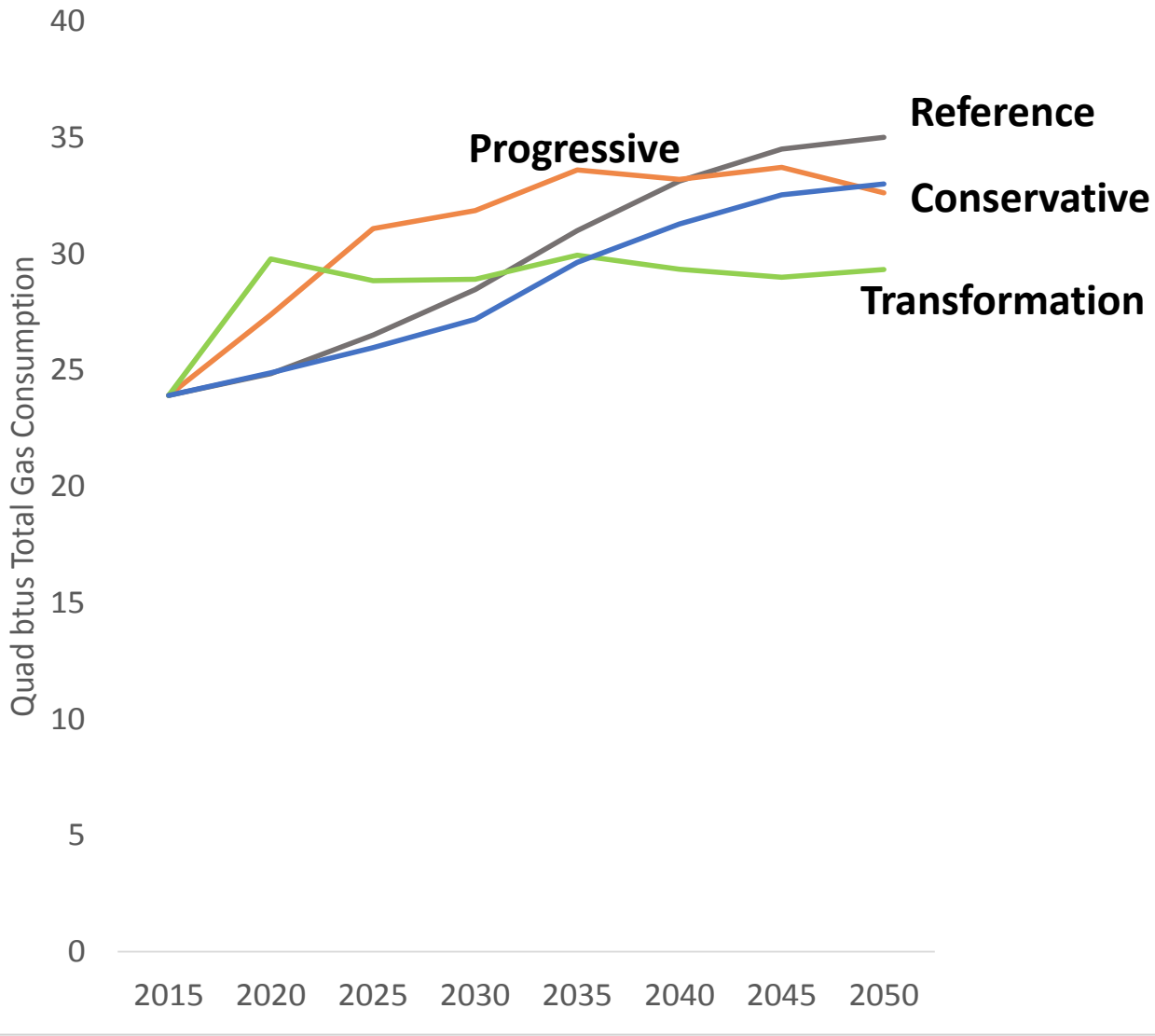
Currently heat pumps are cost-effective only in certain regions with both favorable climate and relative prices

With performance improvements, and rising relative gas prices, especially with carbon pricing, heat pumps become more competitive in more regions over time

- Above the line, gas furnace has lower operating costs
- Below the line, heat pump has lower operating costs

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Total Natural Gas Demand Rises in All Scenarios

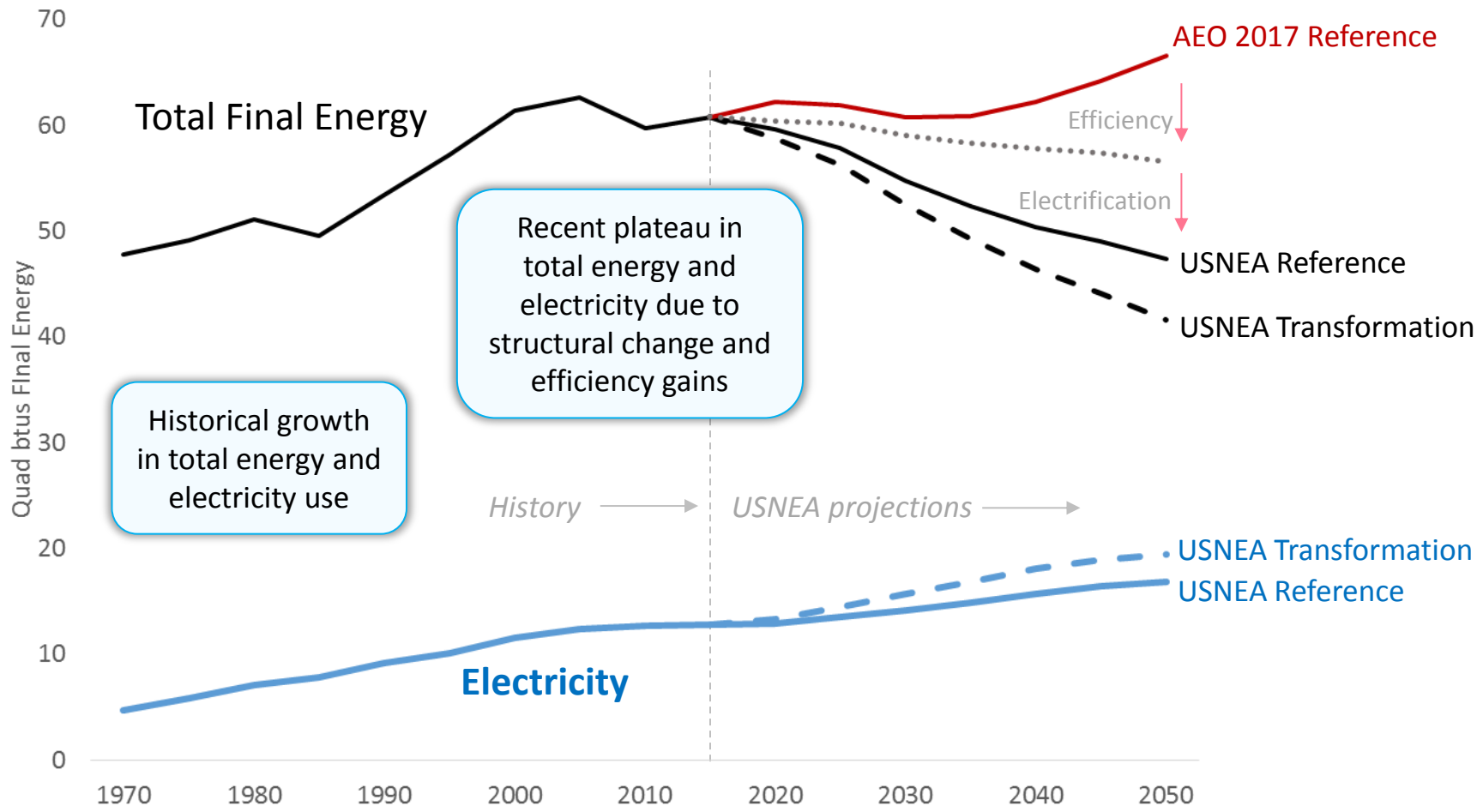


Drivers for Natural Gas Demand

Electric Generation	▪ Expanded NGCC use (+ CCS with carbon price)
Buildings	▪ Retains role in both primary heating and heat pump back-up
Industry	▪ Oil to gas fuel switching
Carbon Price Impacts	▪ Decreased use in buildings and industry is offset by generation with CCS

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Total Final Energy Declines While Electricity Demand Increases



Recent plateau in total energy and electricity due to structural change and efficiency gains

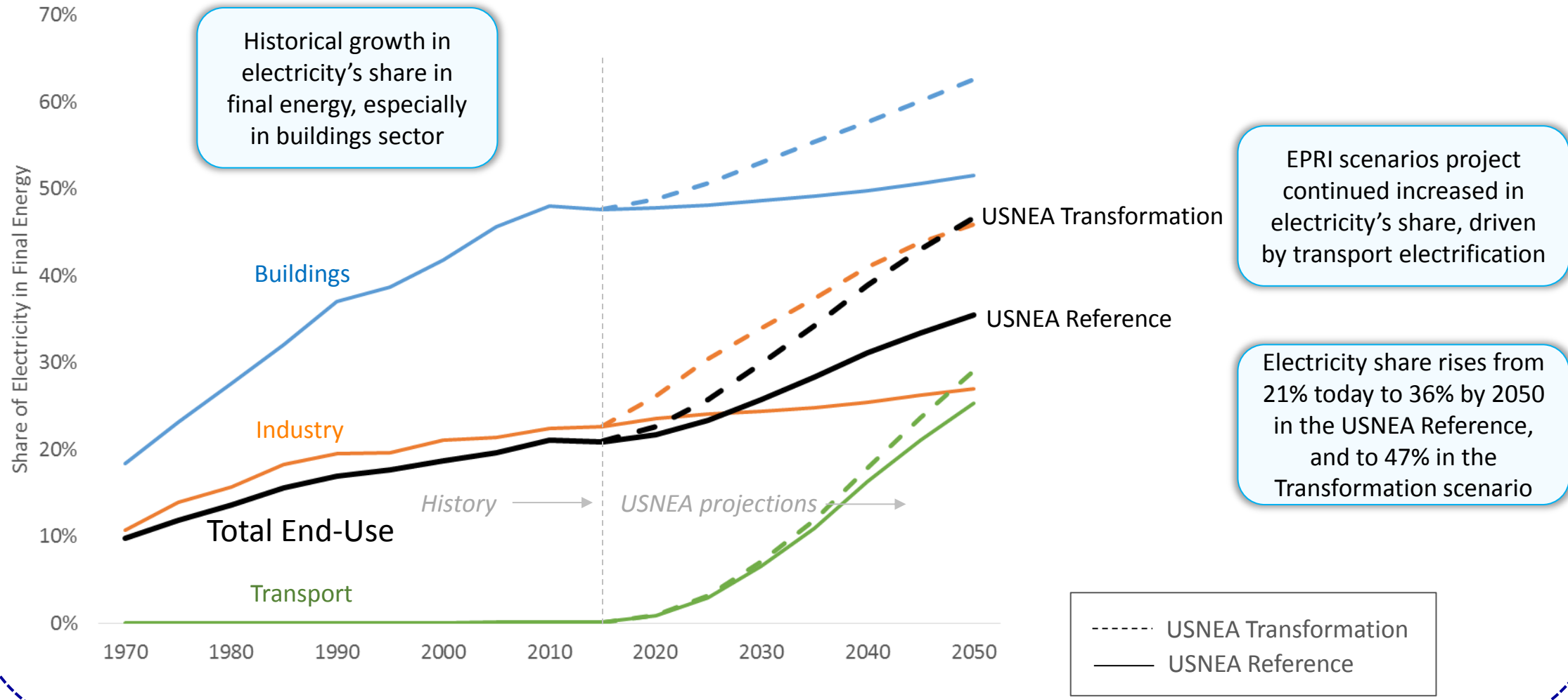
Historical growth in total energy and electricity use

Compared with AEO, USNEA Reference projects more efficiency gains and more electrification → declining total energy with rising electricity

Both efficiency and electrification accelerate under a carbon policy in the Transformation scenario

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Electricity's Share in Final Energy Grows Over Time



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