

# U.S. Electrification and Its Implications for Long-Term Fuel Consumption

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**EPRI Washington Seminar**  
July 19, 2018



# EPRI's US-REGEN End-Use Model Level of Detail by Sector



Transportation



Buildings



Industry

## Cars and Light Trucks

- 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

- ICEV
- PHEV
- EV
- FCV
- Autonomous Vehicles

## 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

- Refining
- Upstream Energy Extraction

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

SECTORS / ACTIVITIES

END-USES

TECHNOLOGIES

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

<b>CONSERVATIVE</b>	<i>Slower Technology Change</i>	<ul style="list-style-type: none"><li>• AEO 2017 growth path for GDP and service demands, and primary fuel prices</li><li>• EPRI assumptions for cost and performance of technologies and energy efficiency over time</li><li>• Existing state-level policies and targets</li></ul>
<b>REFERENCE</b>	<i>Reference Technology</i>	
<b>PROGRESSIVE</b>	<i>Reference Technology + Moderate Carbon Price</i>	
<b>TRANSFORMATION</b>	<i>Reference Technology + Stringent Carbon Price</i>	

# 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

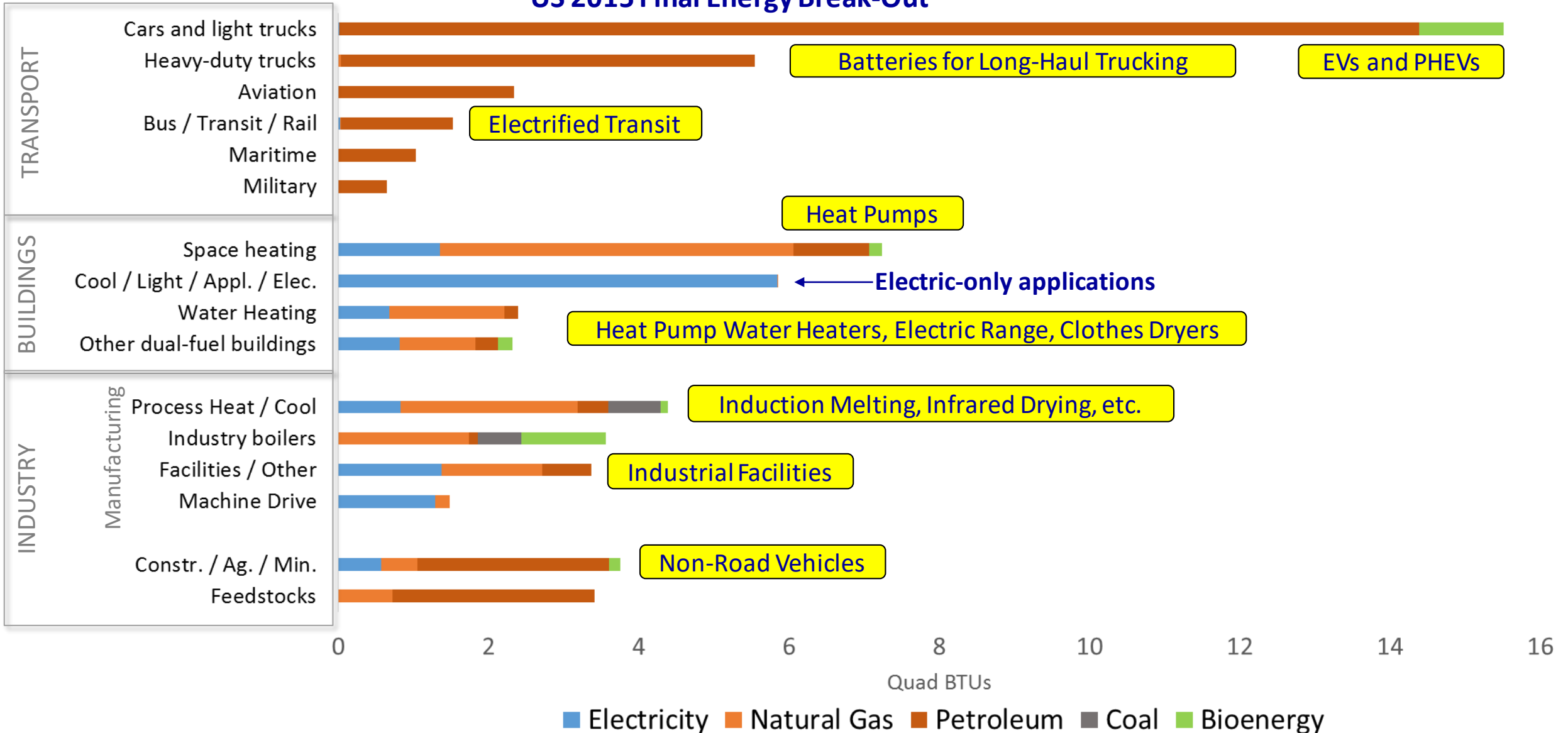
**BUT...**

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

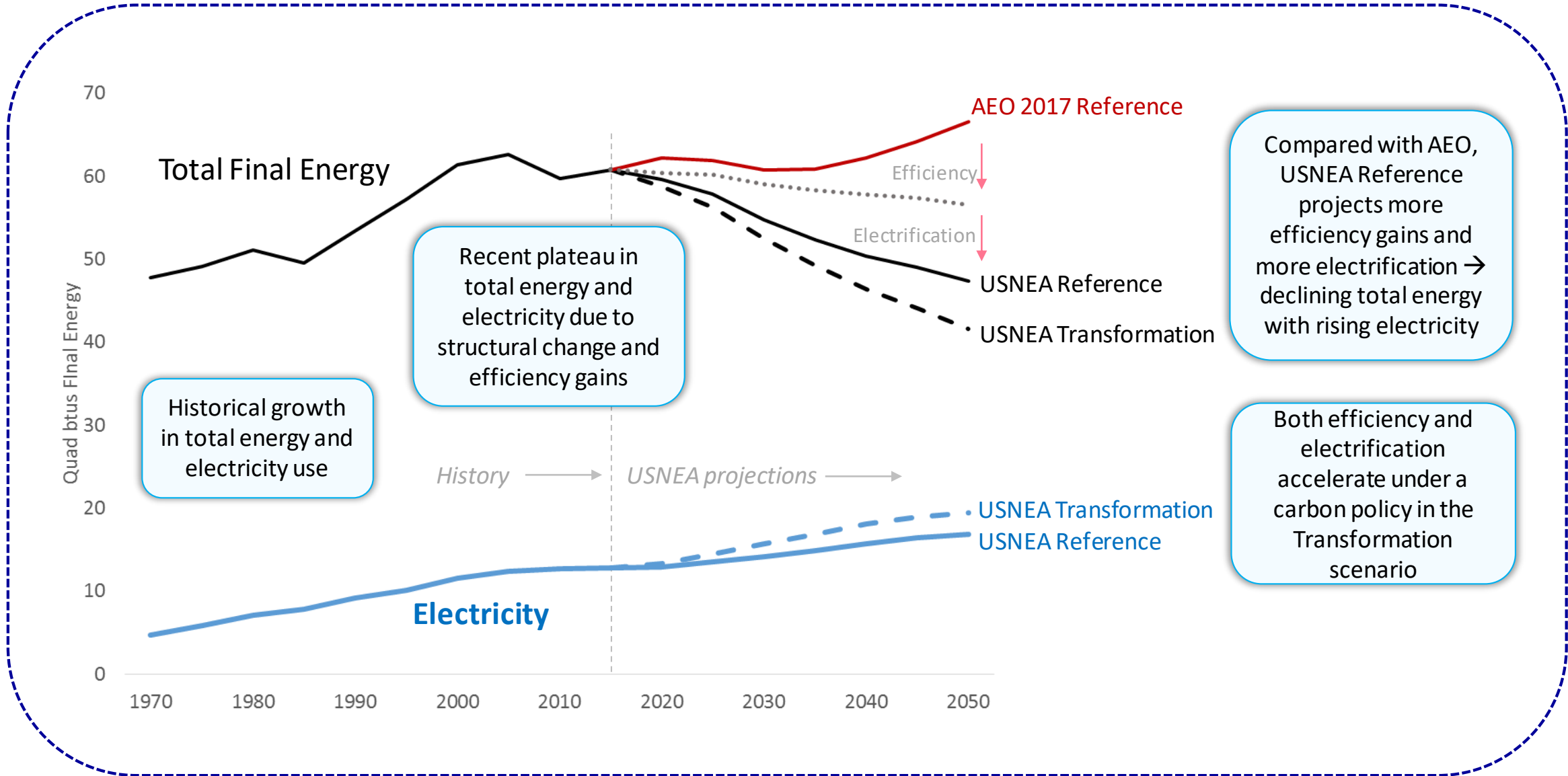
**Pro-active approaches and technology R&D are essential**

# Potential for Efficient Electrification Varies by End-Use Application

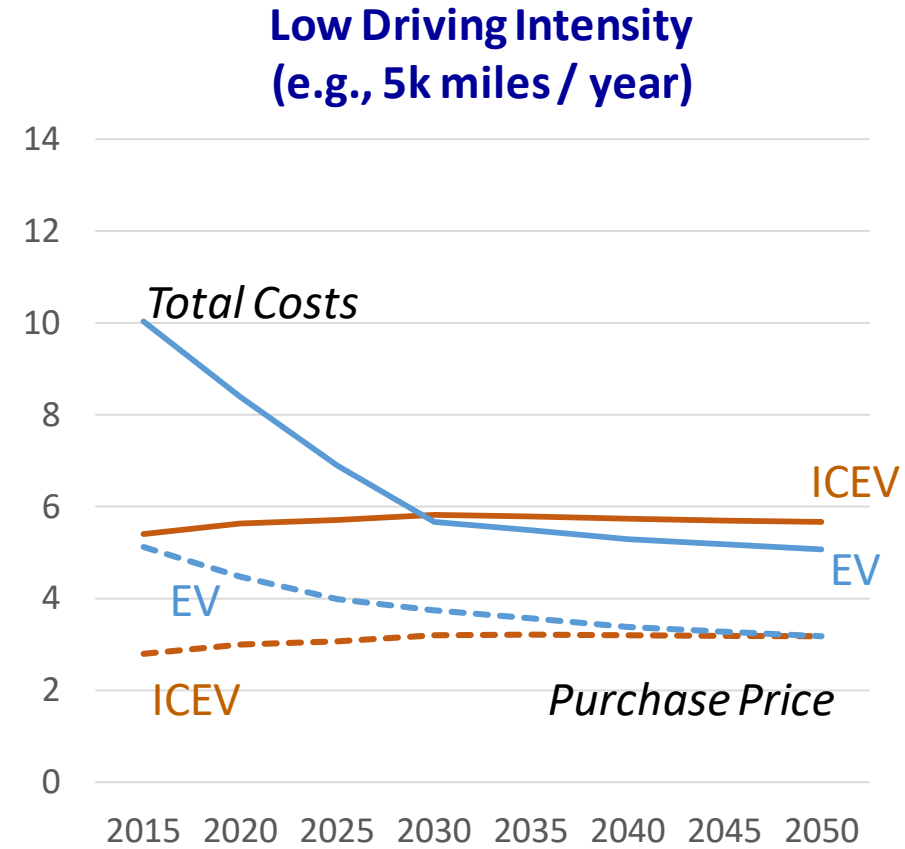
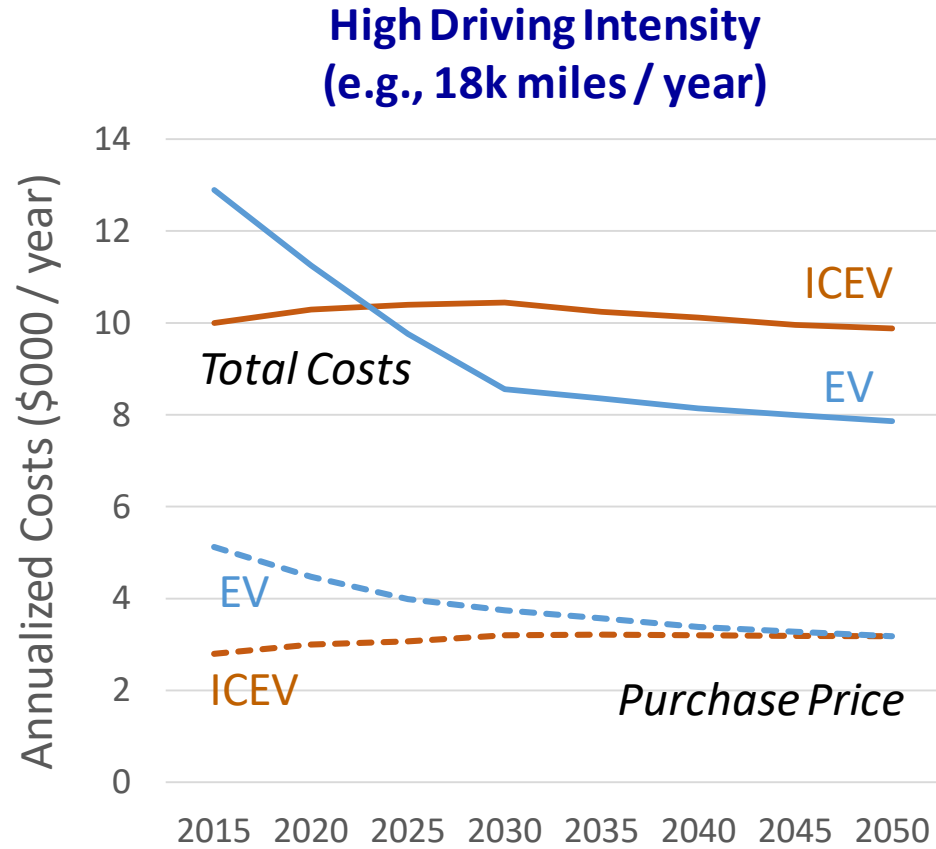
US 2015 Final Energy Break-Out



# Total Final Energy Declines While Electricity Demand Increases



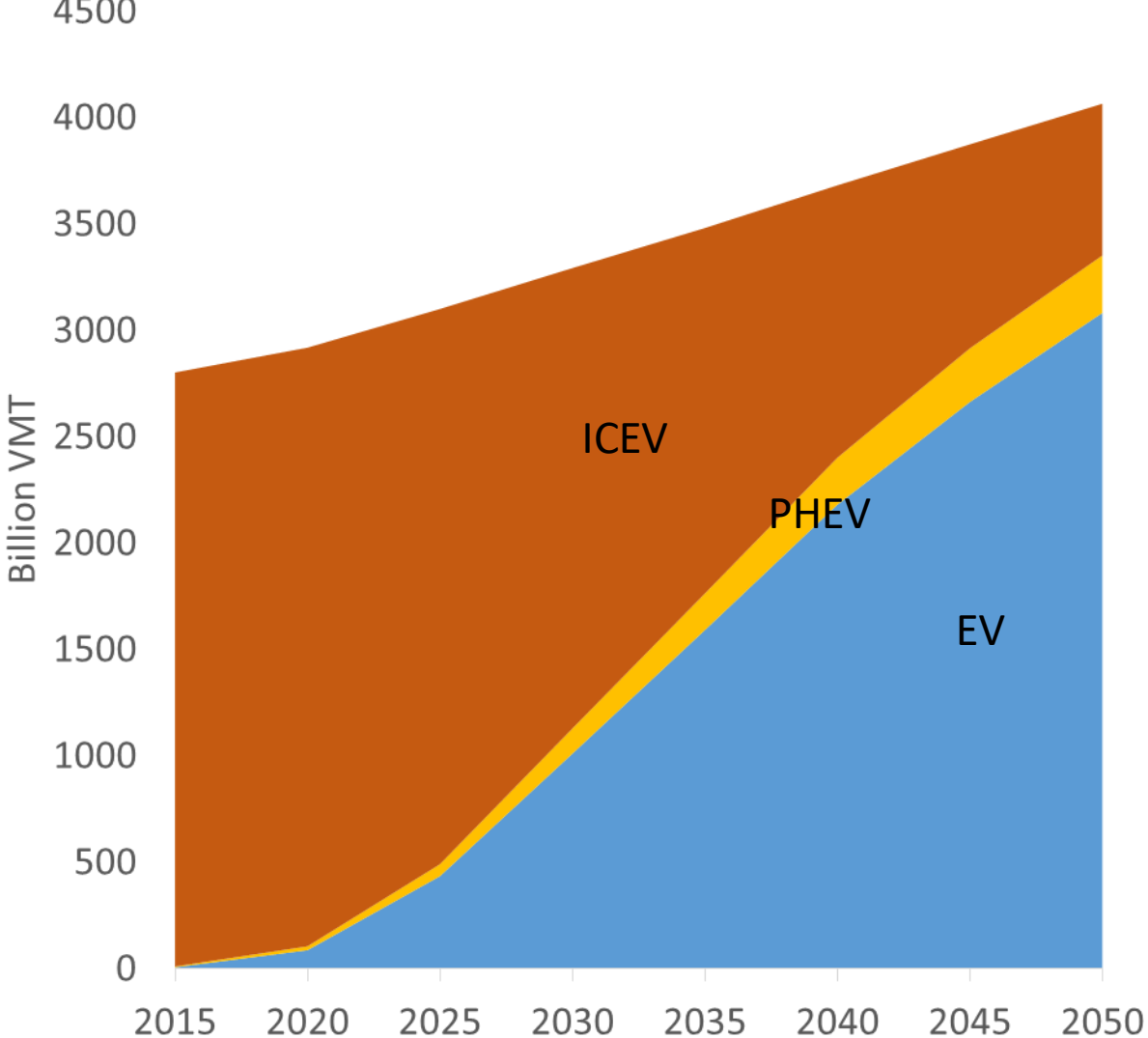
# Transport: Passenger Vehicle Costs for Representative Household



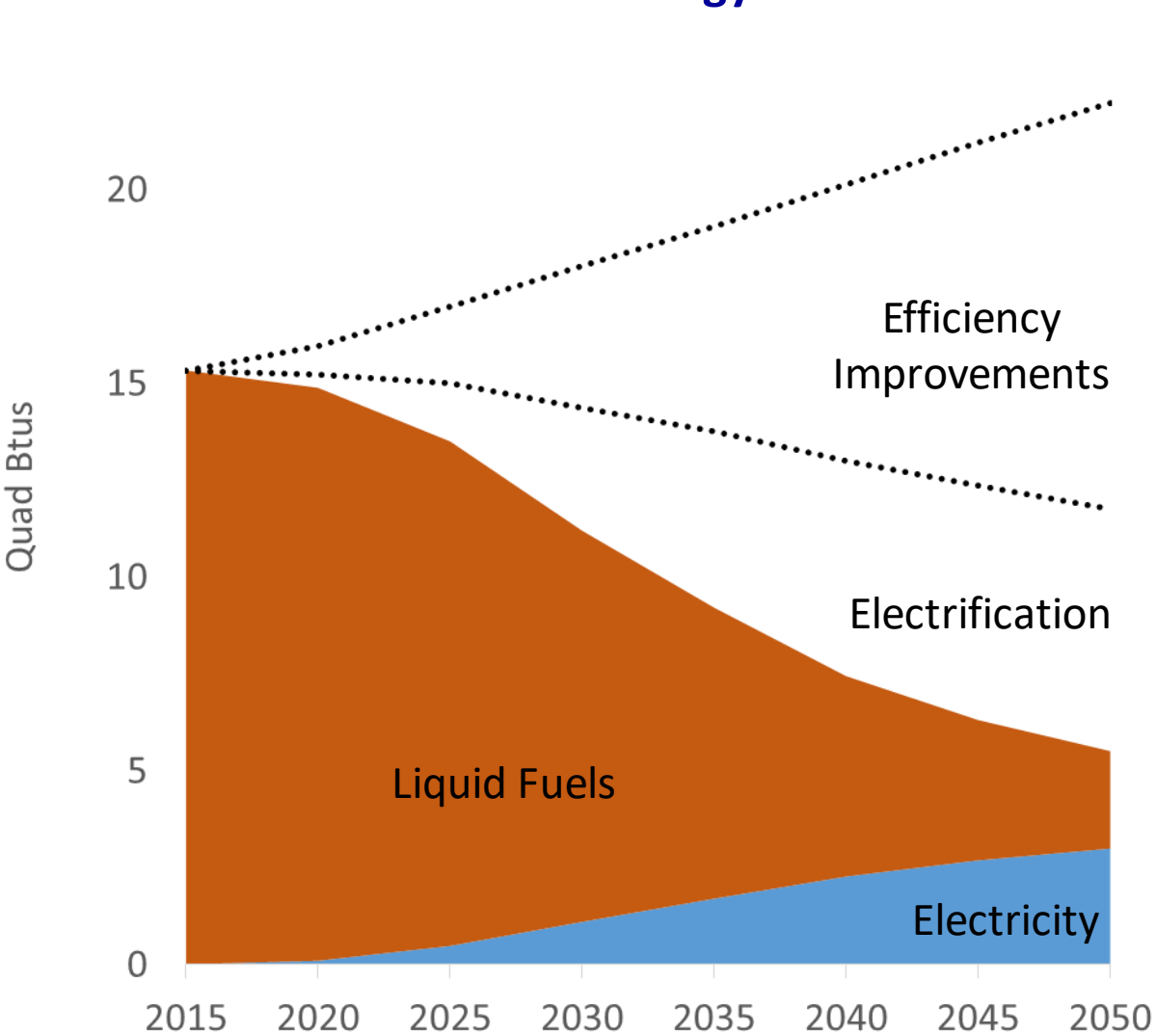
Based on suburban household in NE-Central model region

# Reference Projections for US Light-Duty Vehicles

Service Demand



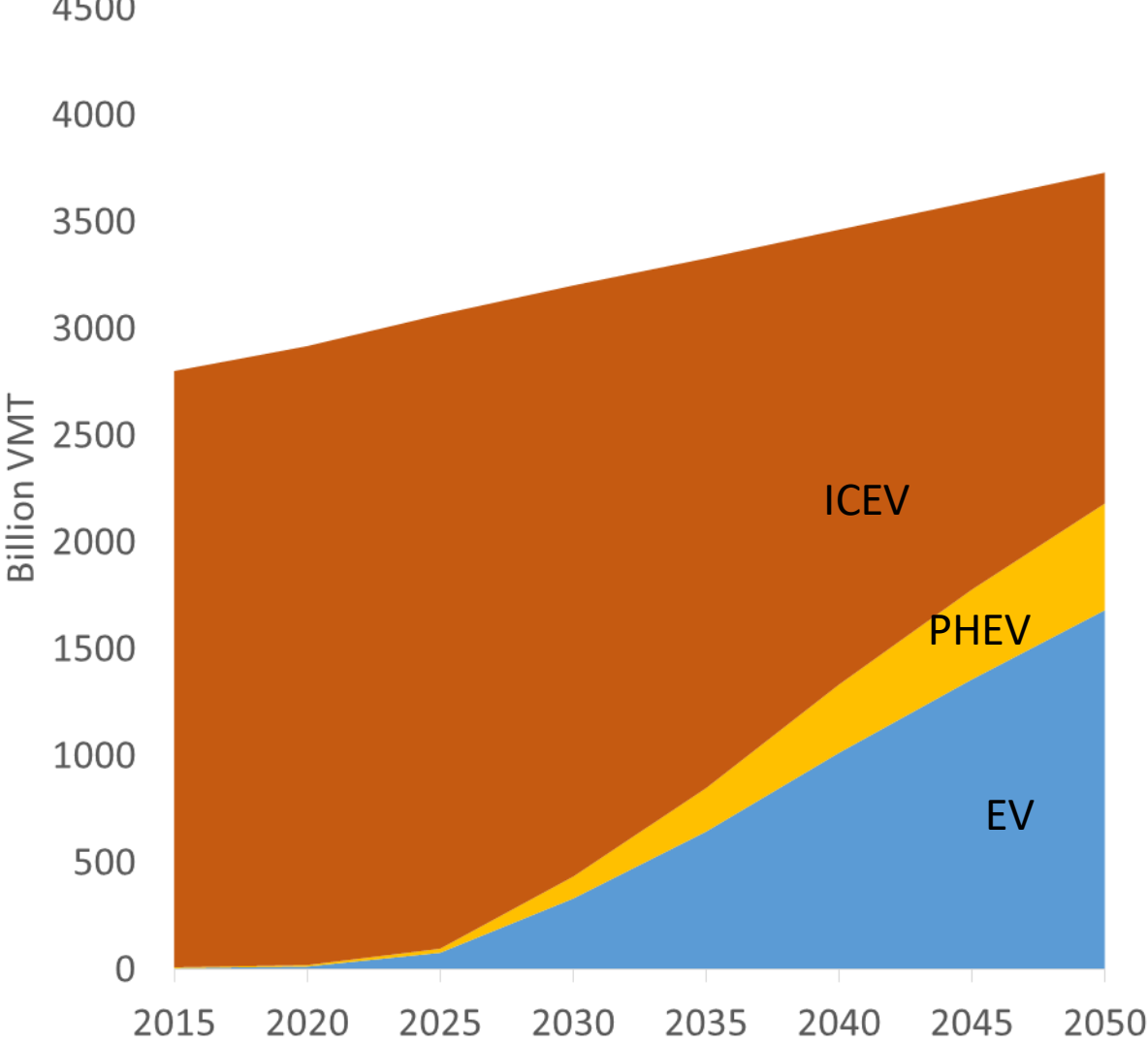
Final Energy



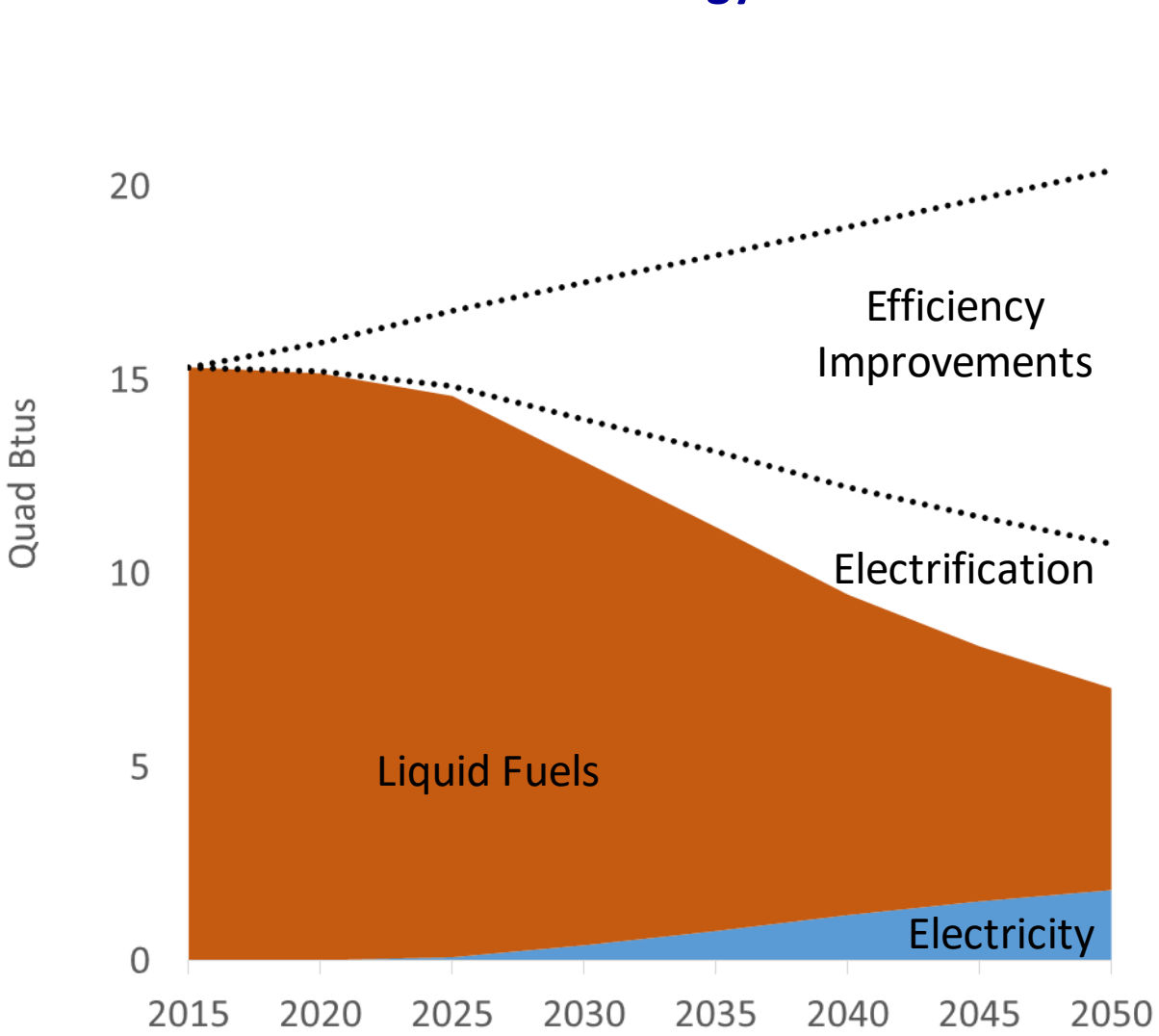


# Conservative Projections for US Light-Duty Vehicles

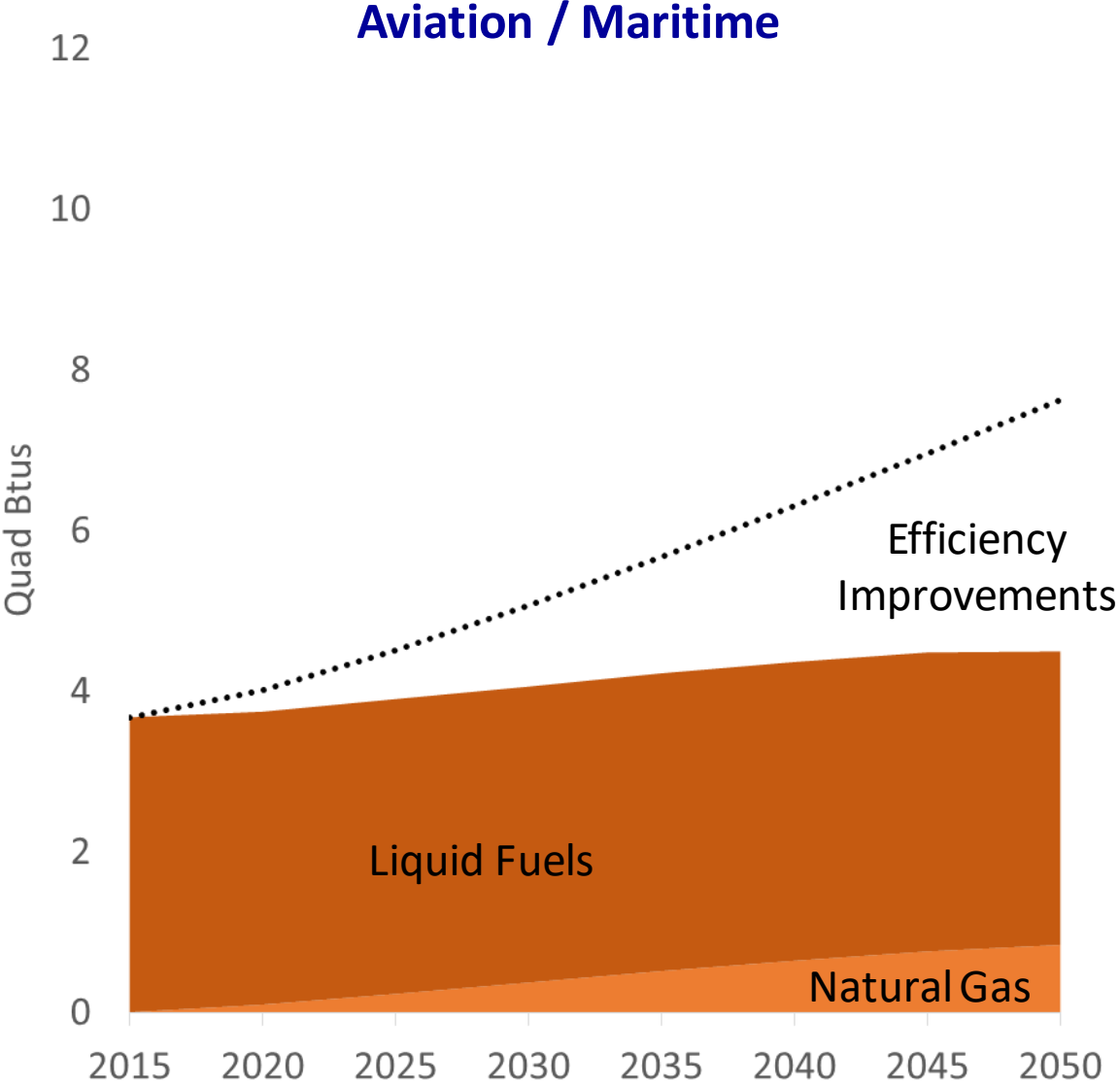
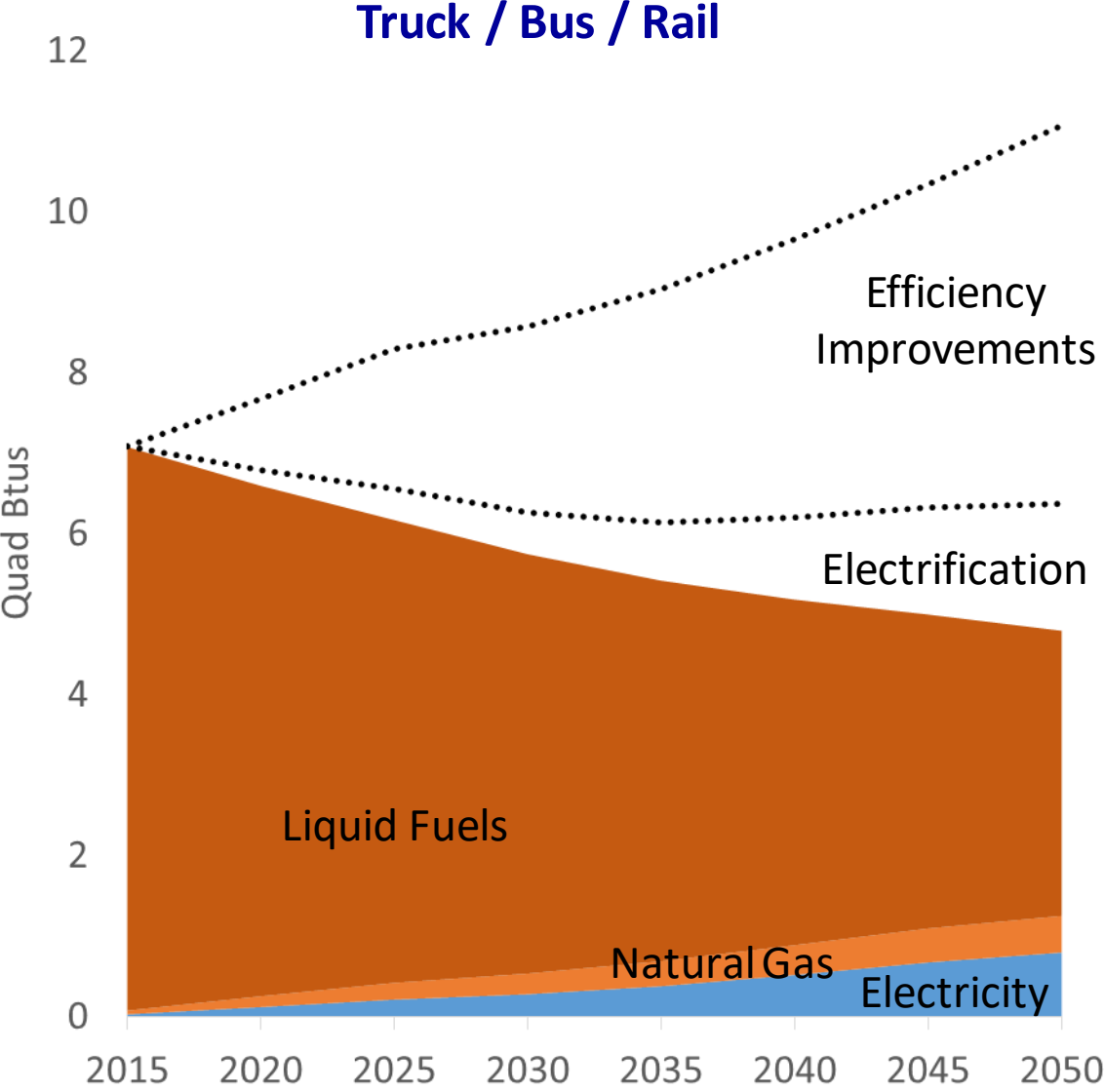
Service Demand



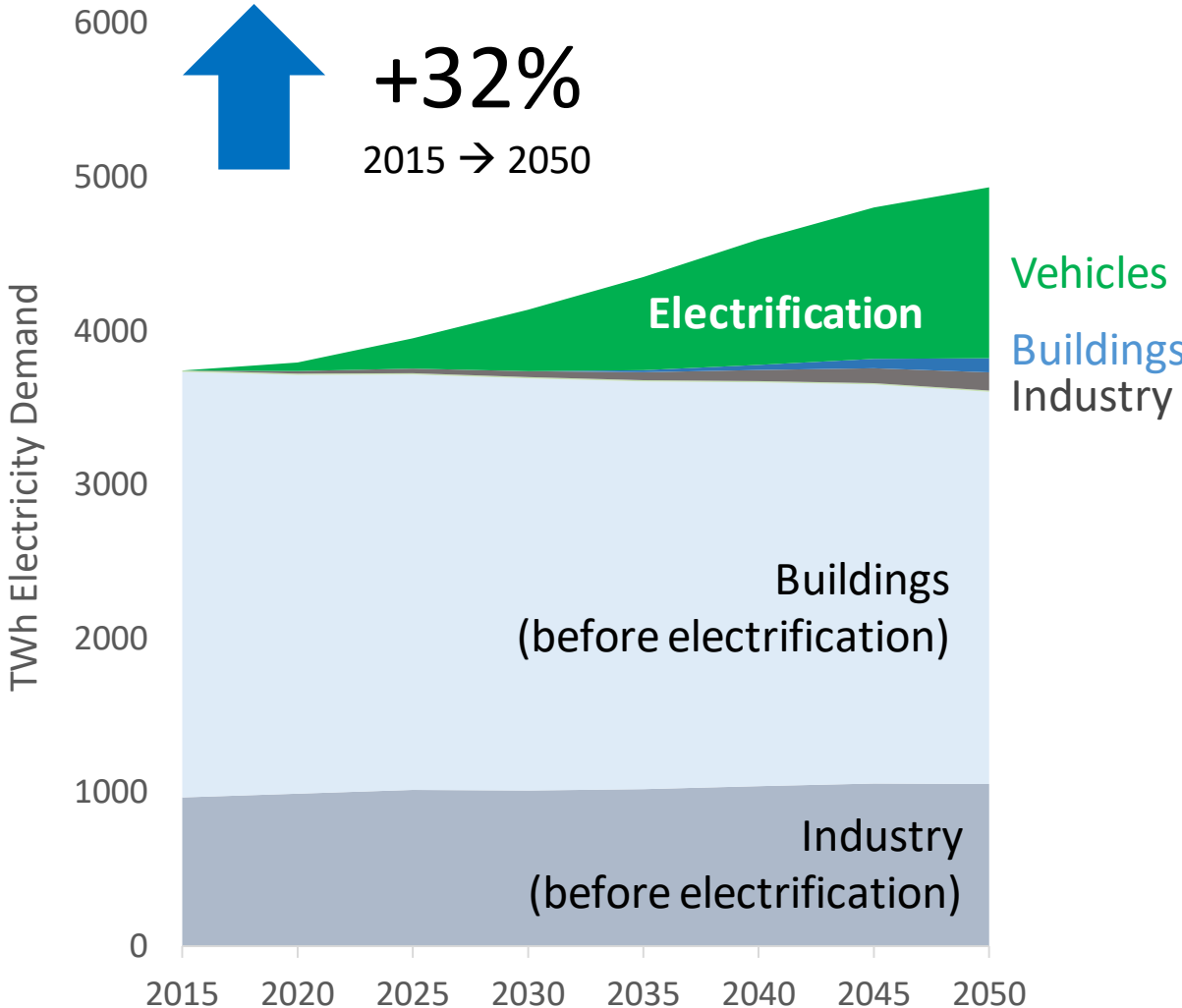
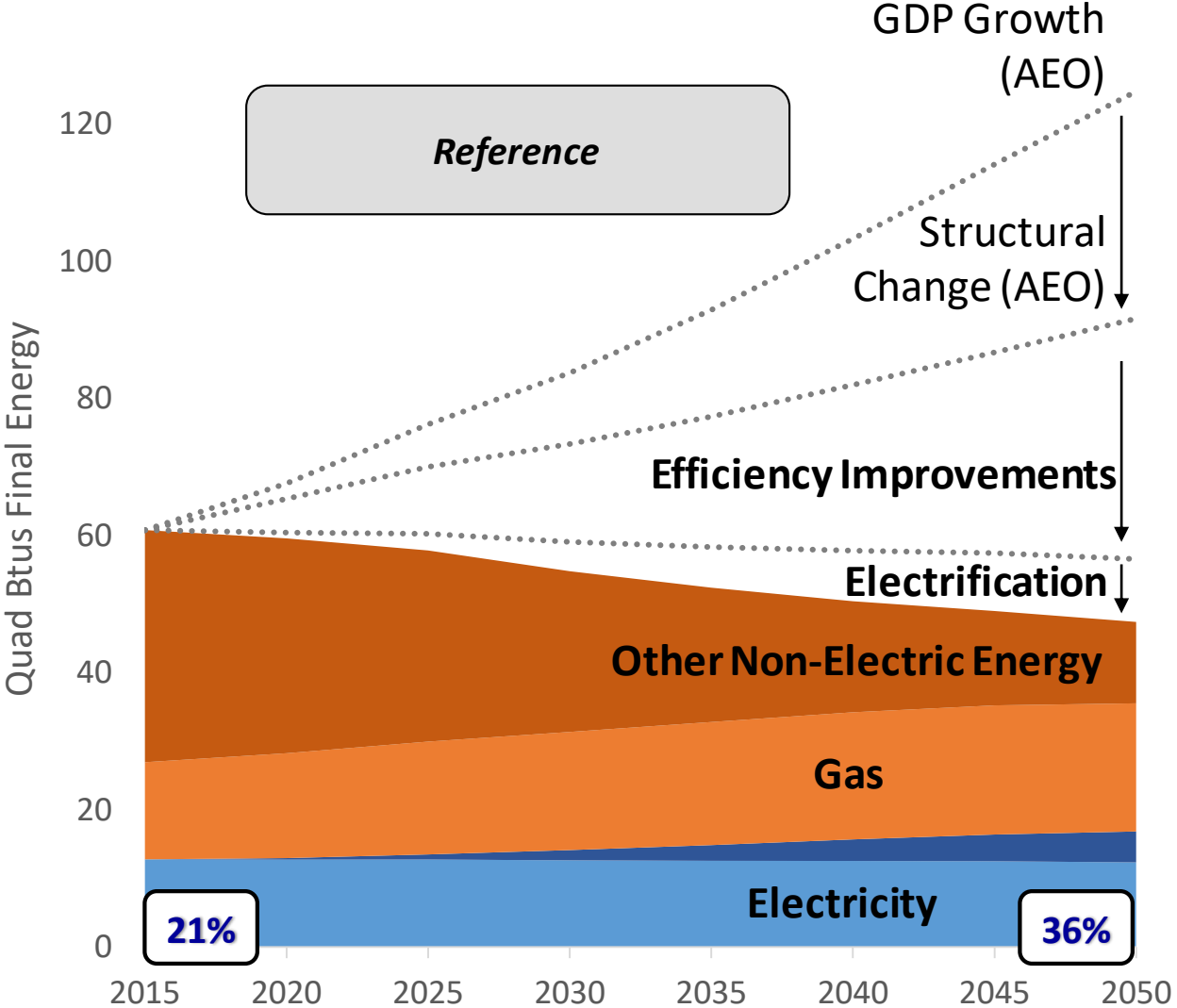
Final Energy



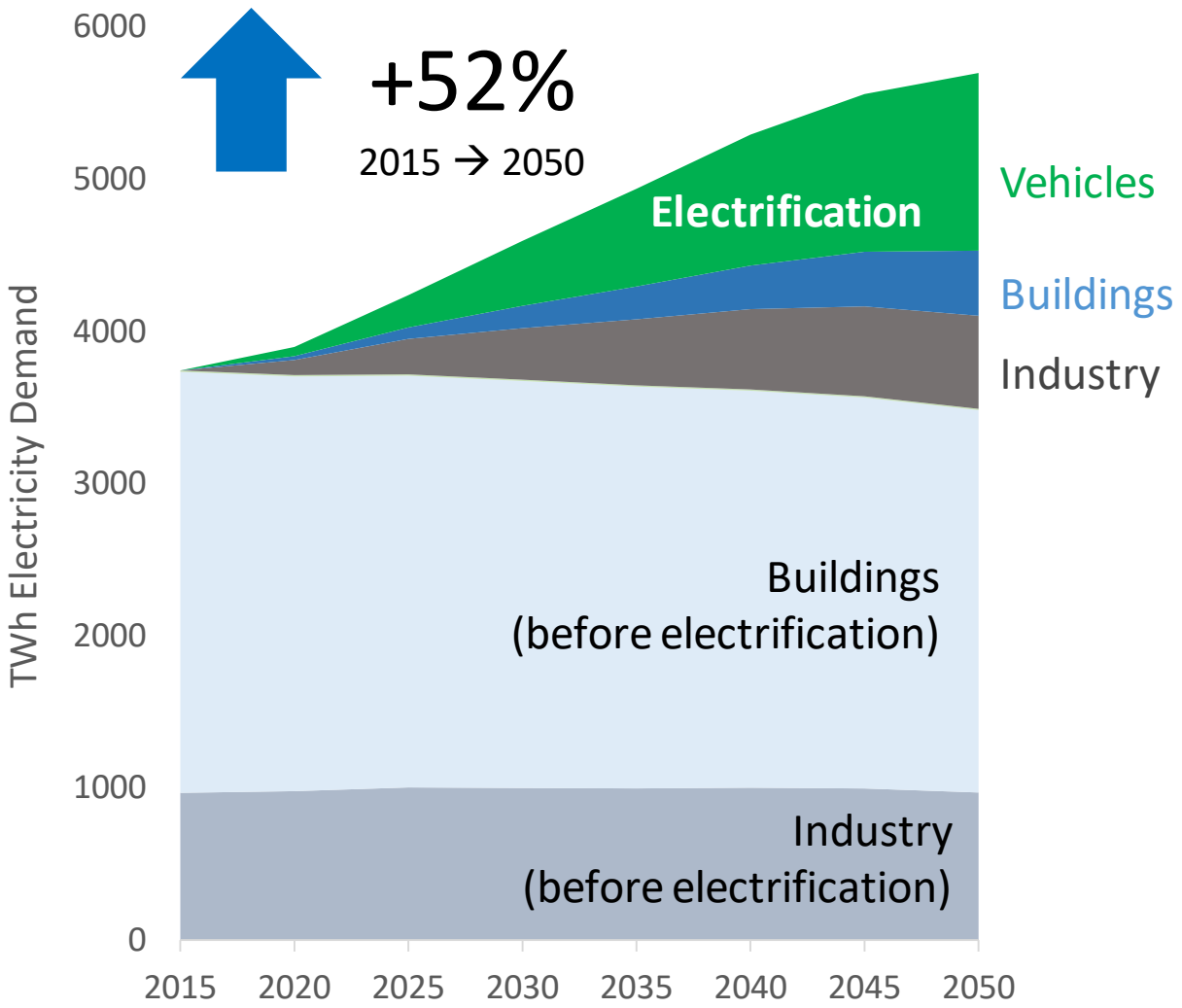
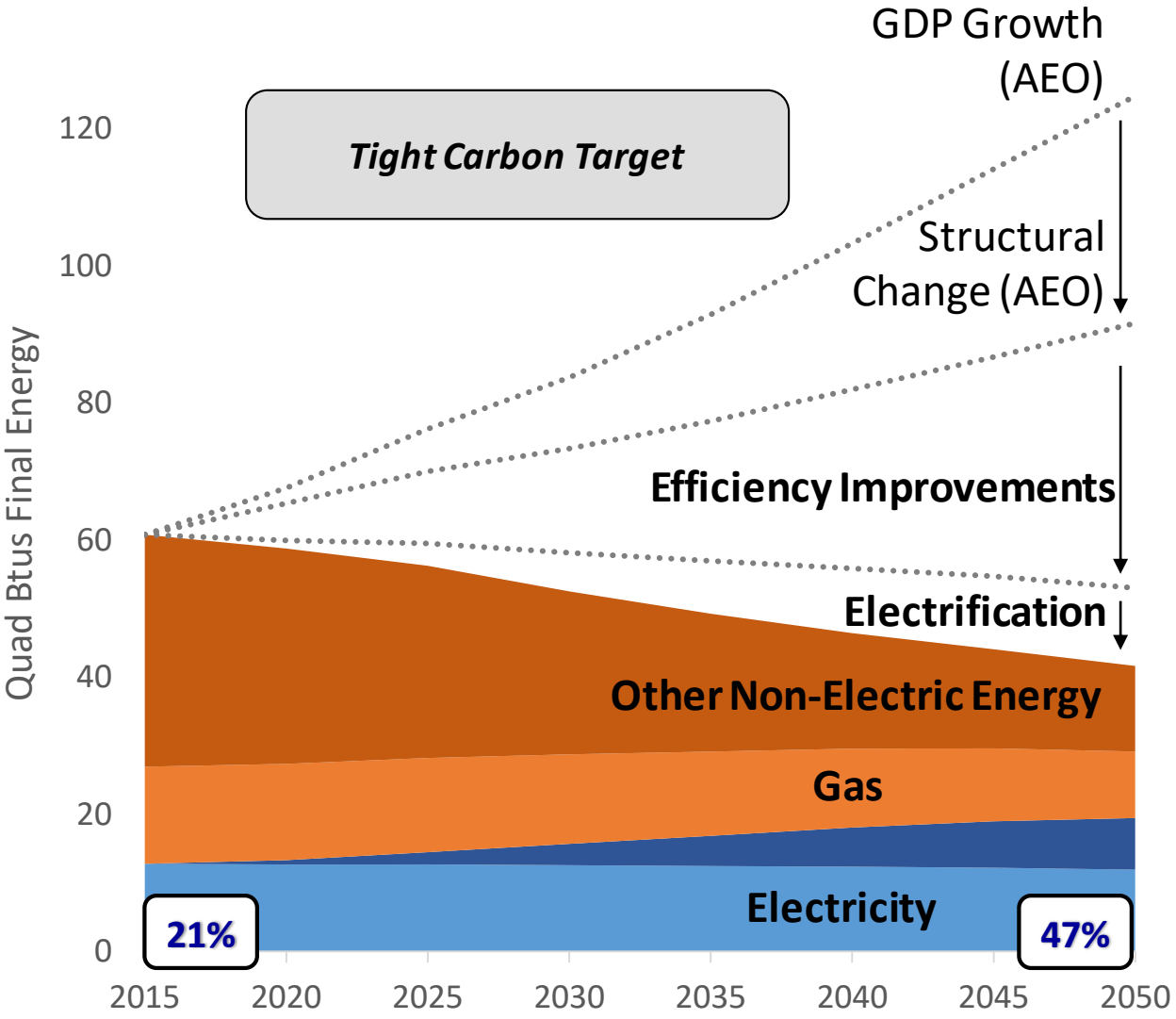
# Reference Projections for Heavy-Duty Vehicles



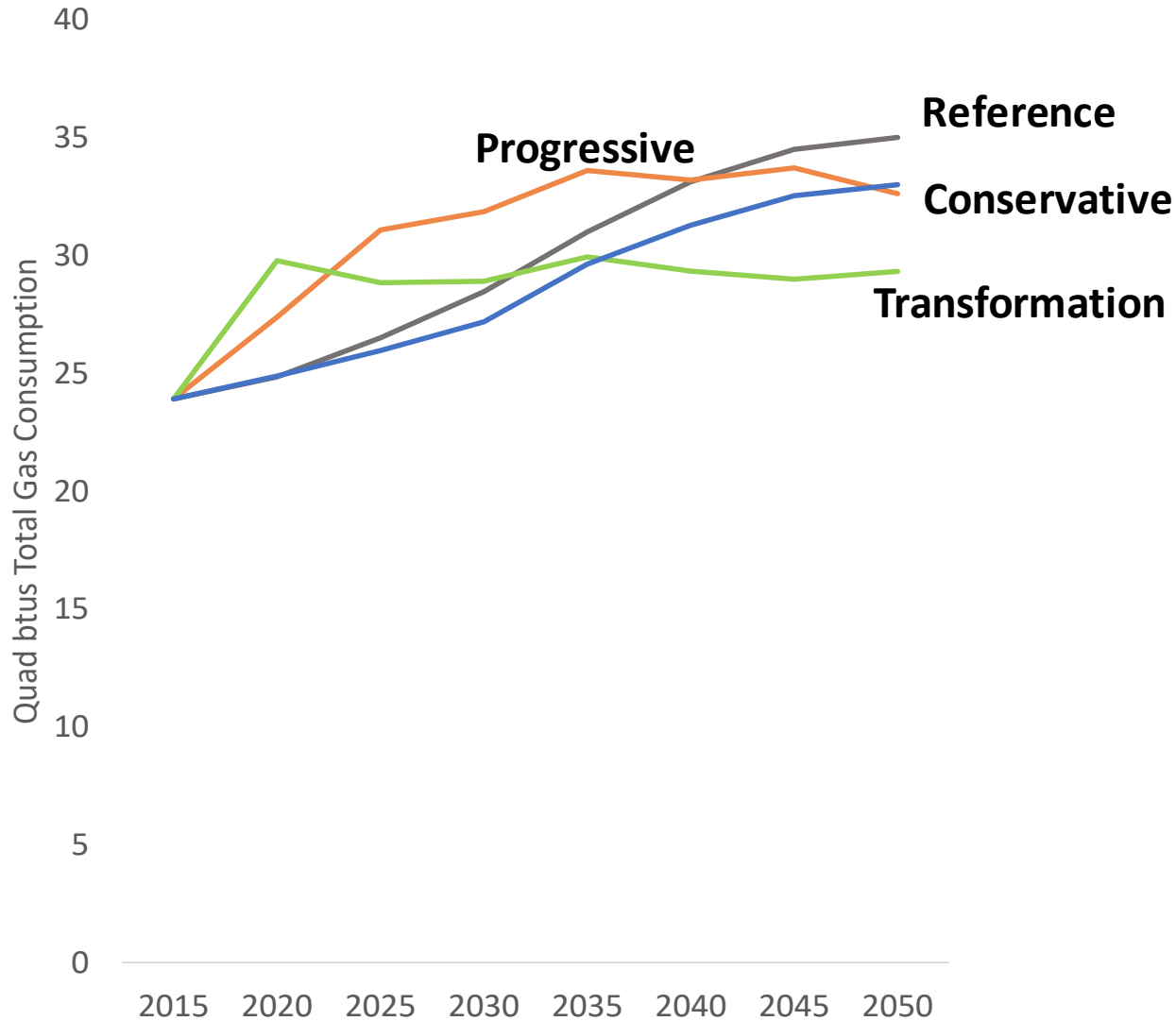
# Efficient Electrification: Reference



# Efficient Electrification: Transformation



# 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

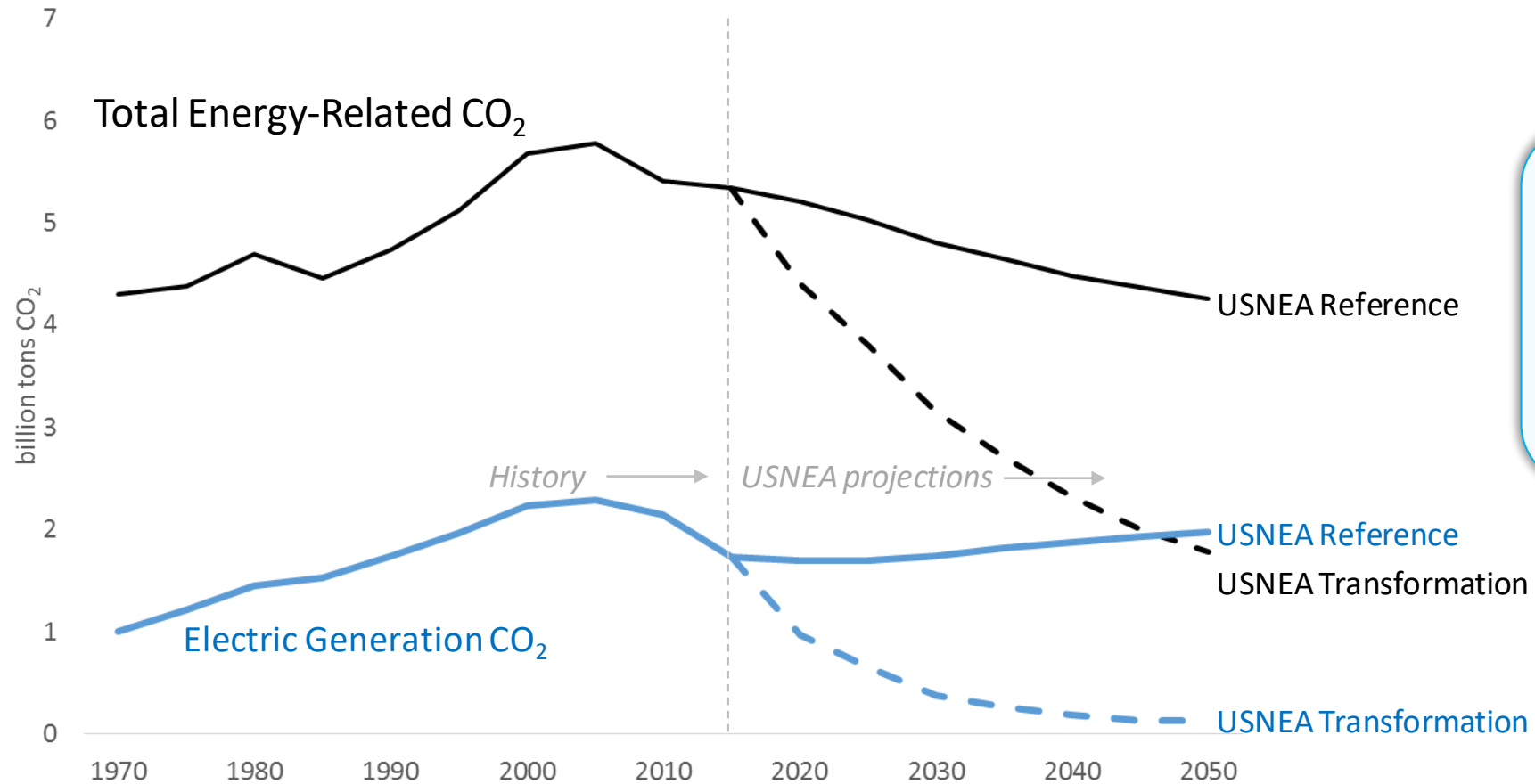
### Industry

- Oil to gas fuel switching

### Carbon Price Impacts

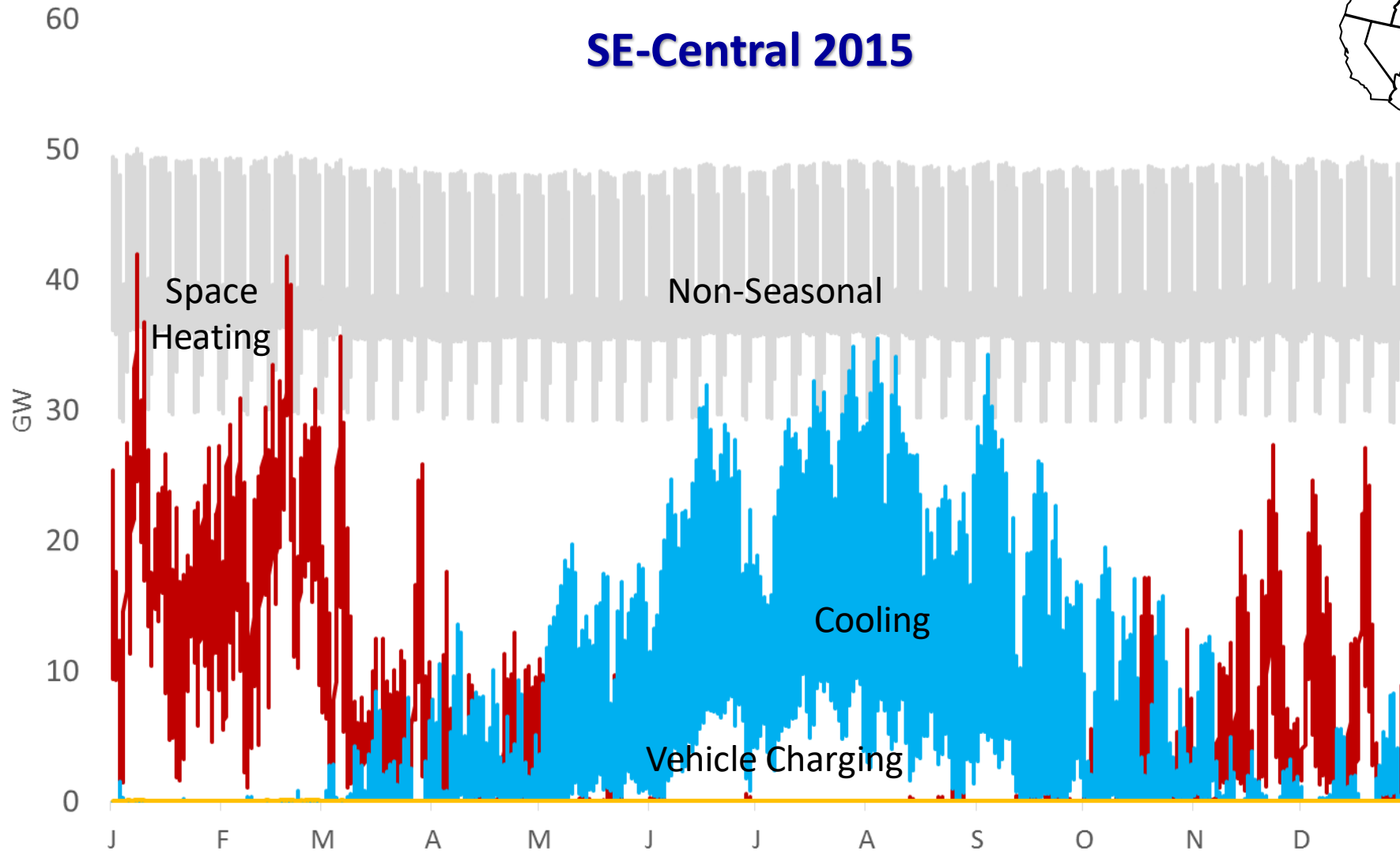
- Decreased use in buildings and industry is offset by generation with CCS

# Total and Electric Generation CO<sub>2</sub> Emissions



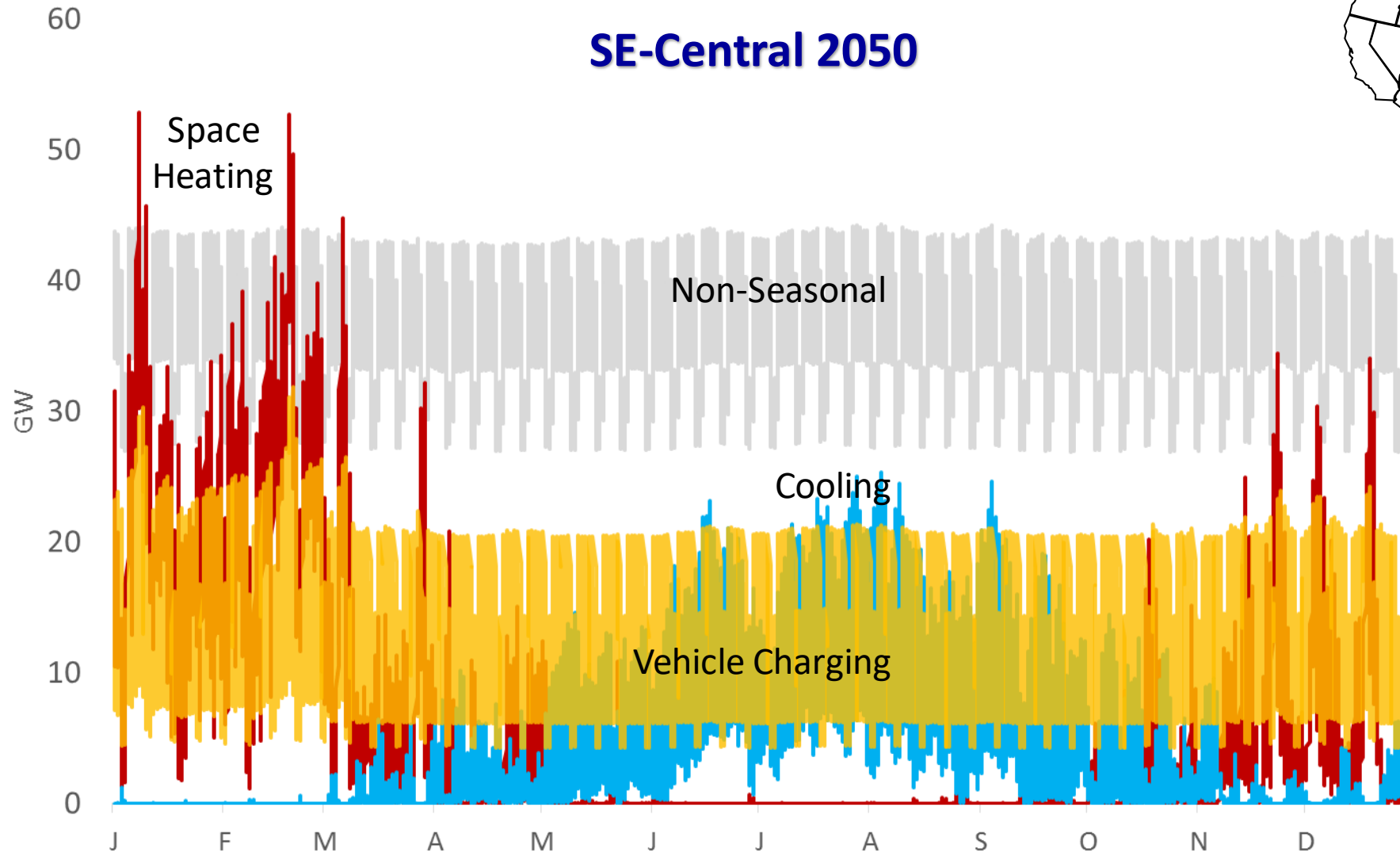
Increasing electrification leads to lower overall CO<sub>2</sub> emissions, even as emissions from electric generation increase in the USNEA Reference

# Base Year Load Shape Reflects Current Technology Stock



How Will Sectoral Loads Change Over Time?

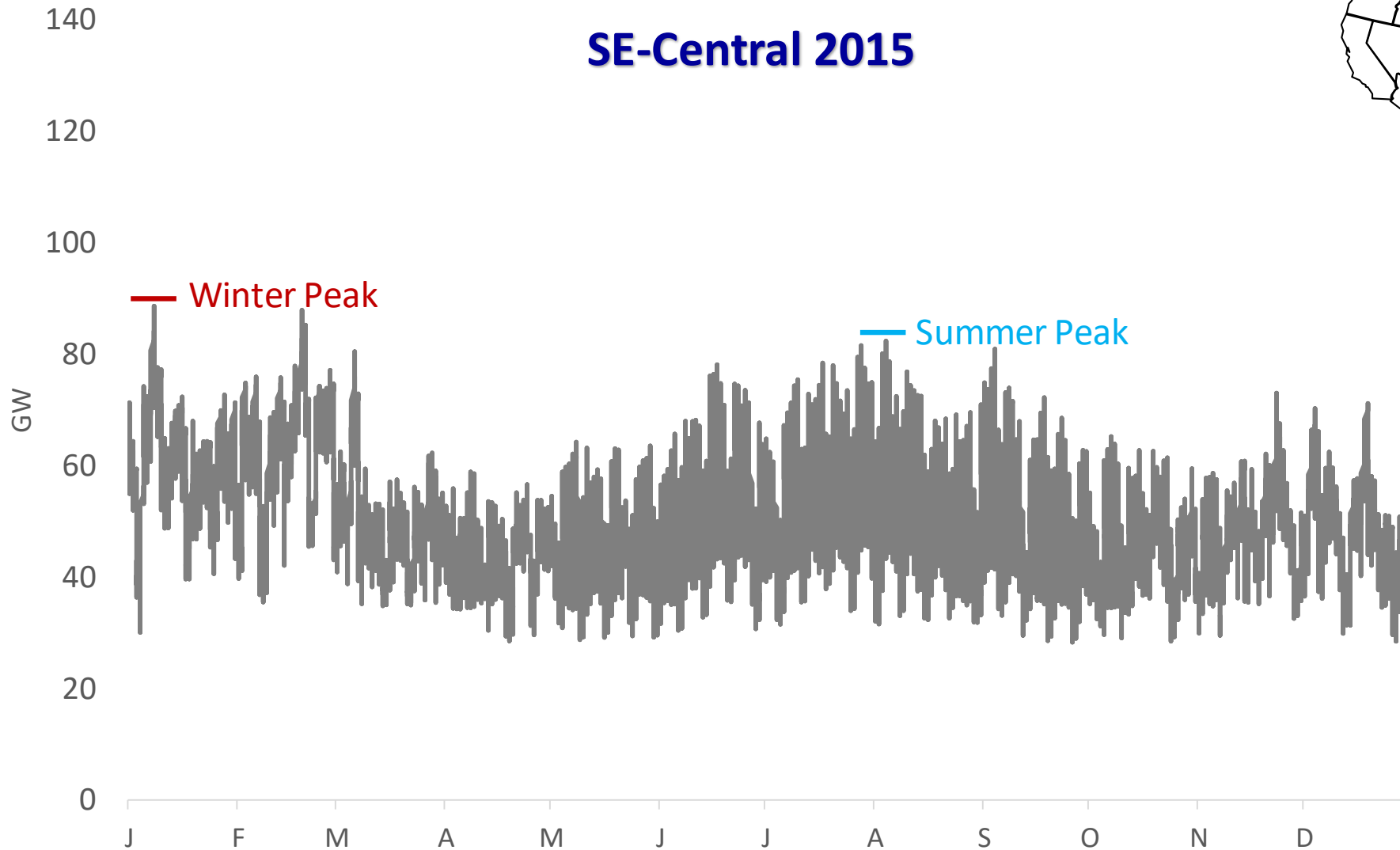
# Reference Projections Reflect Electrification / Efficiency



**Significant Shift in Pattern and Size of Load**

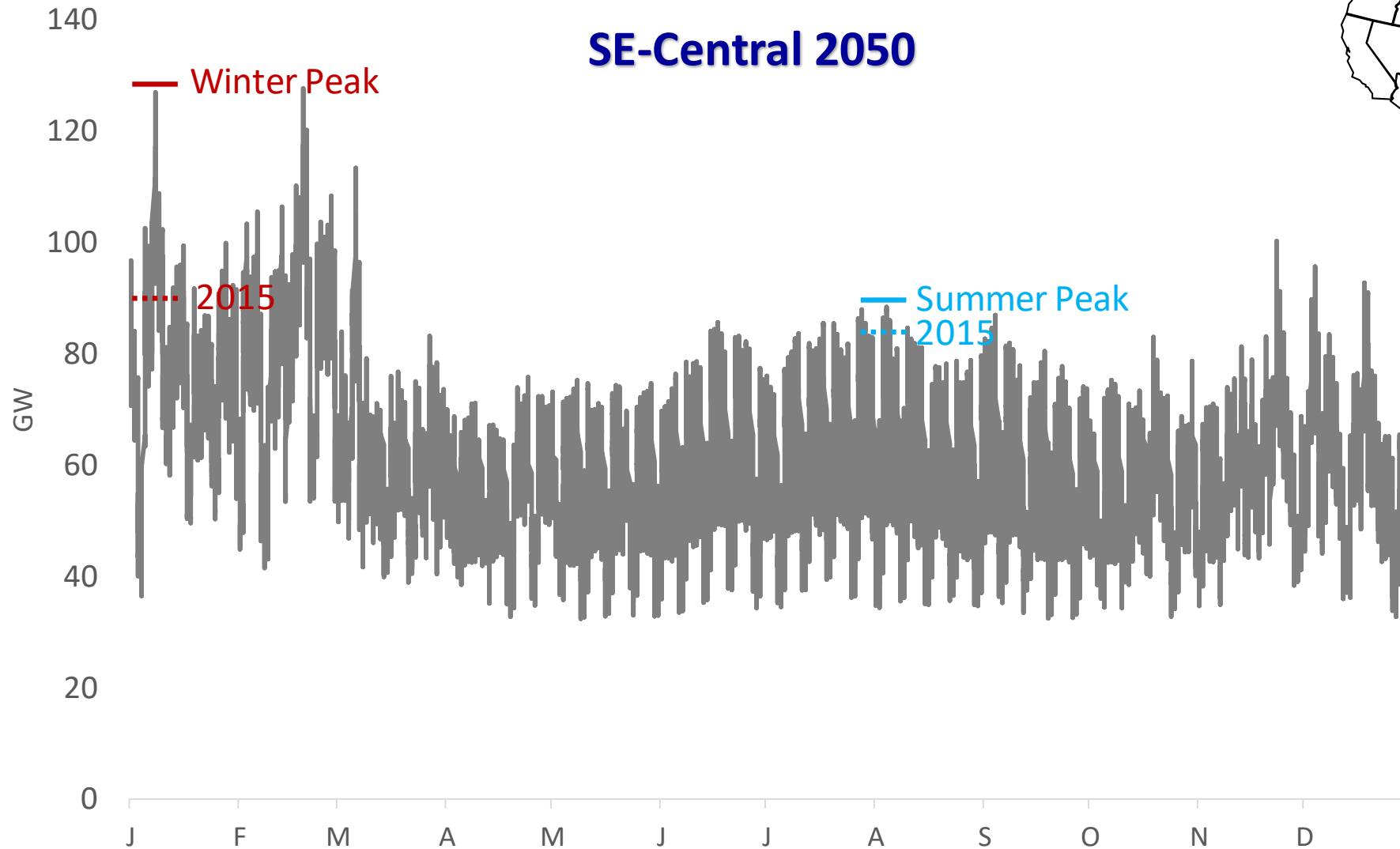


# Aggregate Load Shape Already Has Winter Peak in Some Regions



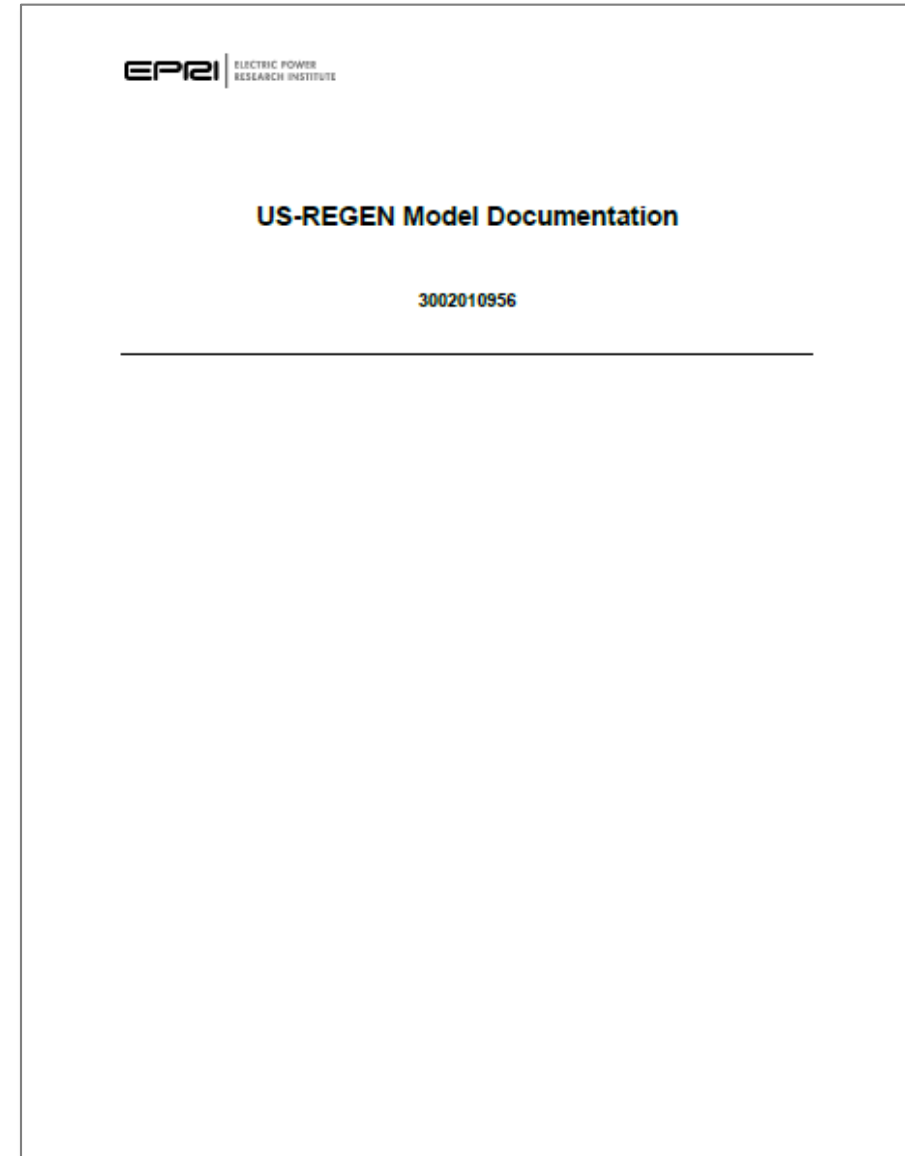
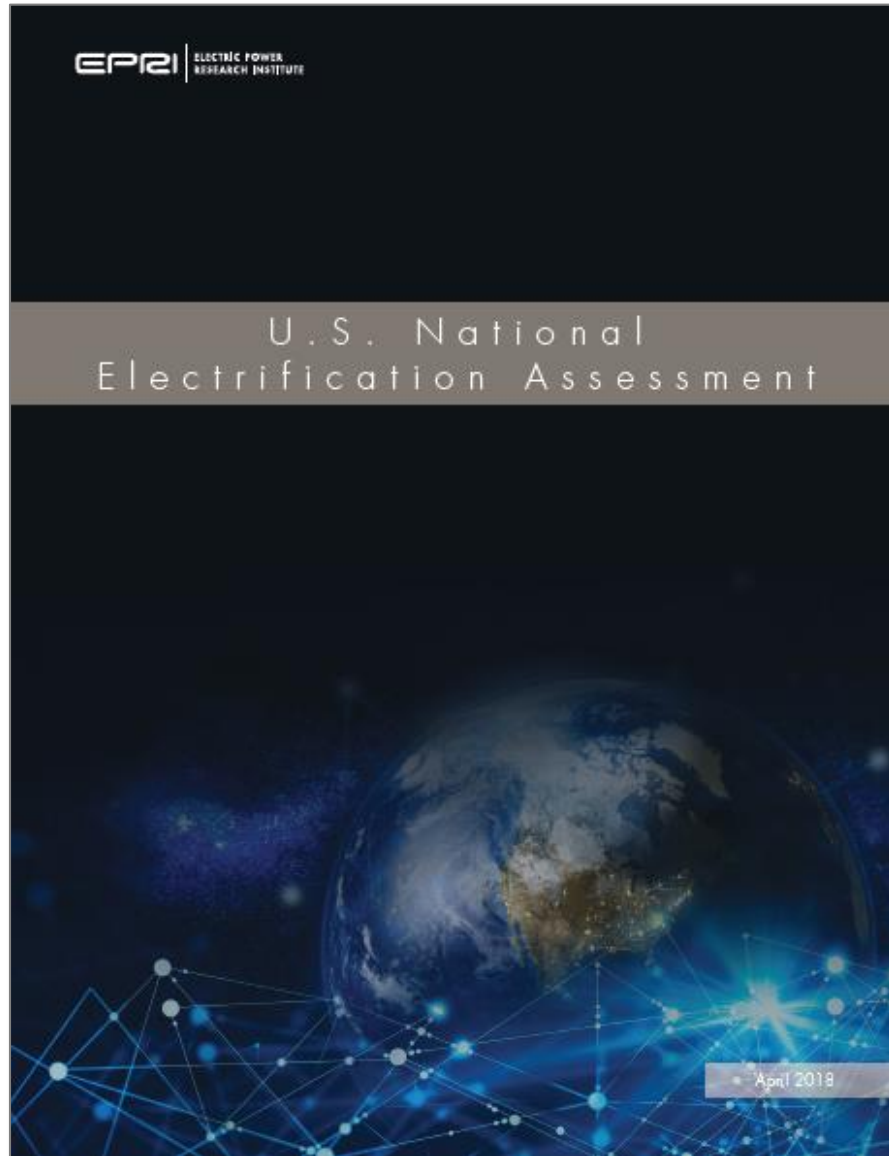
How Stable Are These System Dynamics?

# Aggregate Load Shape Changes from Electrification and Efficiency



**Electrification Will Impact Electric Sector Resource Planning**

# For More Information





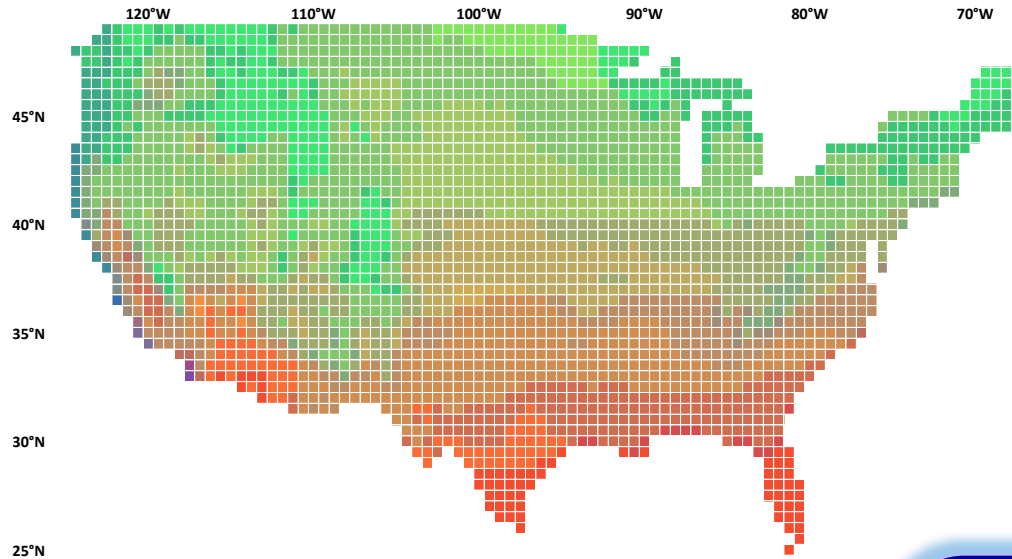
# Together...Shaping the Future of Electricity

# Key Assumptions for USNEA Scenarios

	CONSERVATIVE	REFERENCE	PROGRESSIVE	TRANSFORMATION
Light-duty vehicle costs	<b>Slower decline in battery costs</b>	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	<b>State RPS + \$15/tCO<sub>2</sub> in 2020, rising at 7%</b>	<b>State RPS + \$50/tCO<sub>2</sub> in 2020, rising at 7%</b>
End-use sector policies	None	None	<b>\$15/tCO<sub>2</sub> in 2020, rising at 7%</b>	<b>\$50/tCO<sub>2</sub> in 2020, rising at 7%</b>

# USNEA Modeling Approach: US-REGEN

## Energy Use



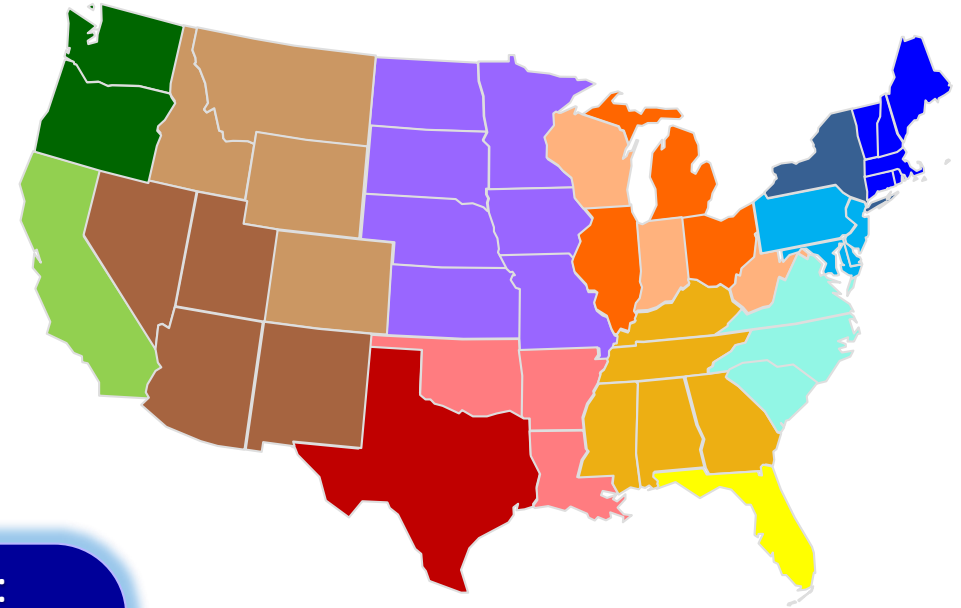
- Climate zones
- Building types
- Household characteristics
- Industrial mix
- End-use technology detail

Synchronized



Hourly Load,  
Renewables,  
and Prices

## Electric Generation



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

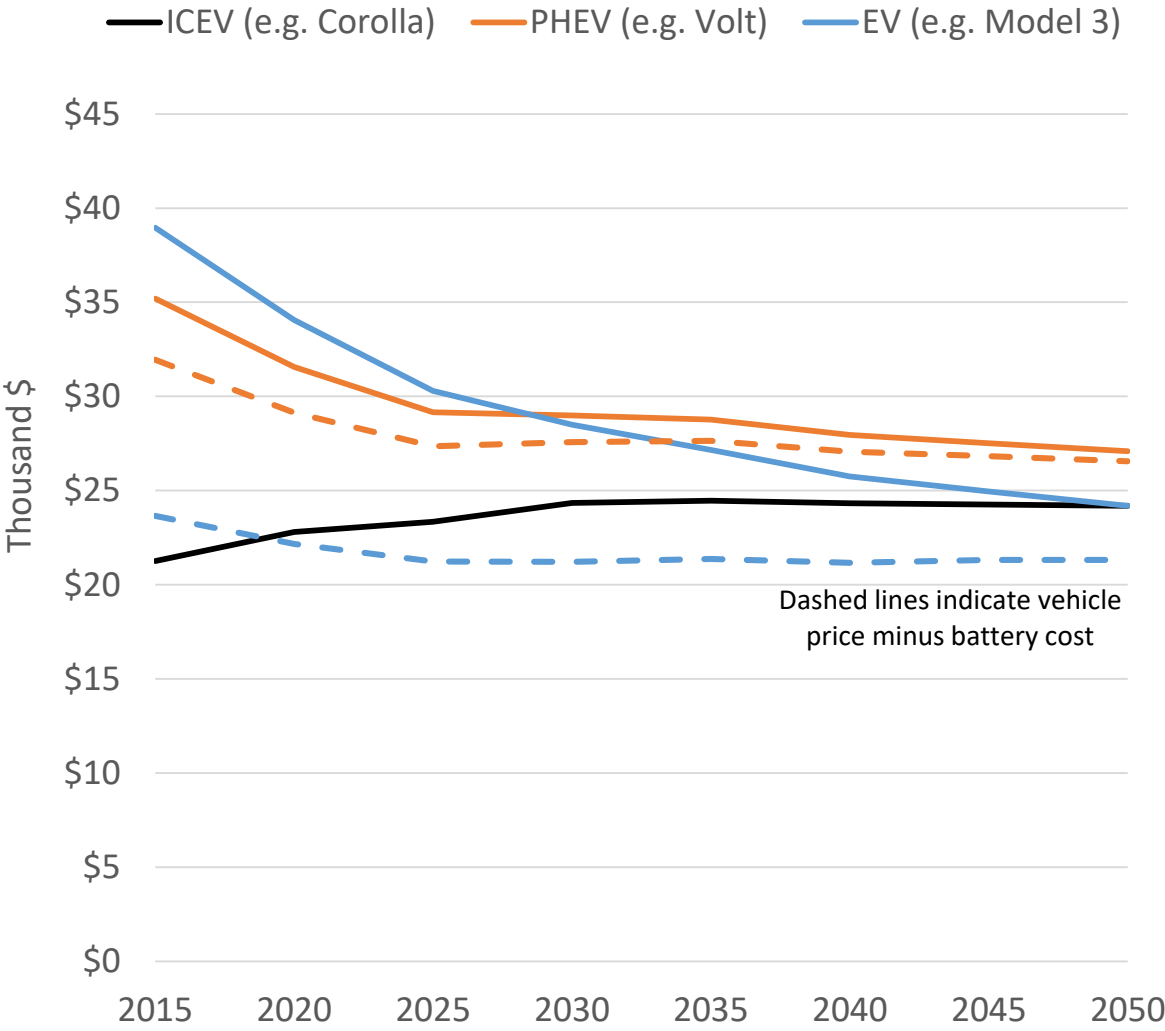
### Model Outputs:

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

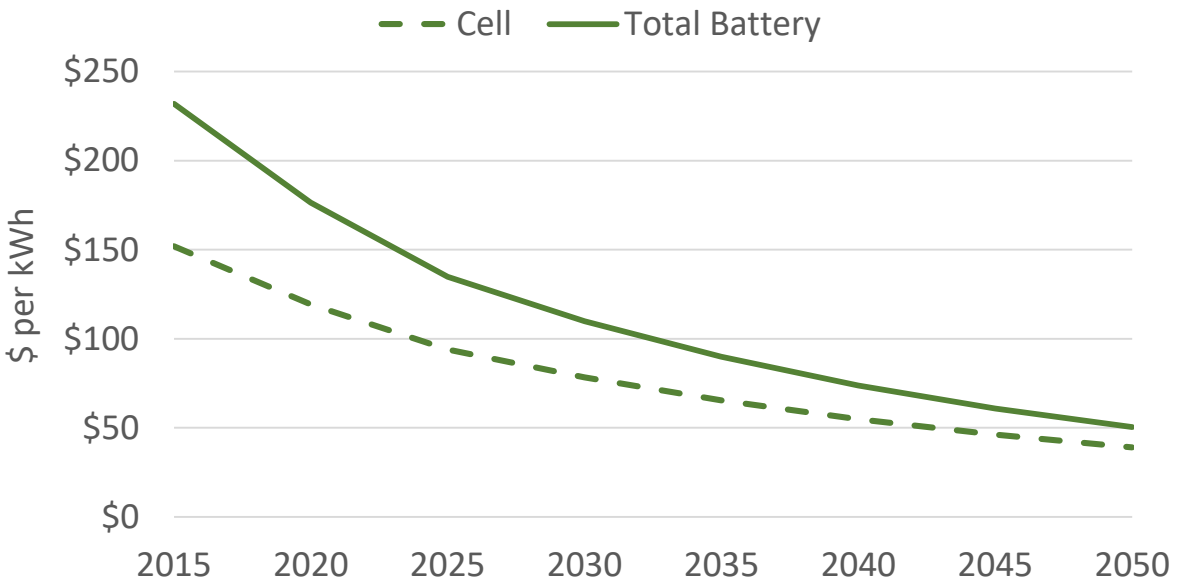
Emissions, air quality,  
and water

# Reference Scenario; Vehicle Cost and Performance

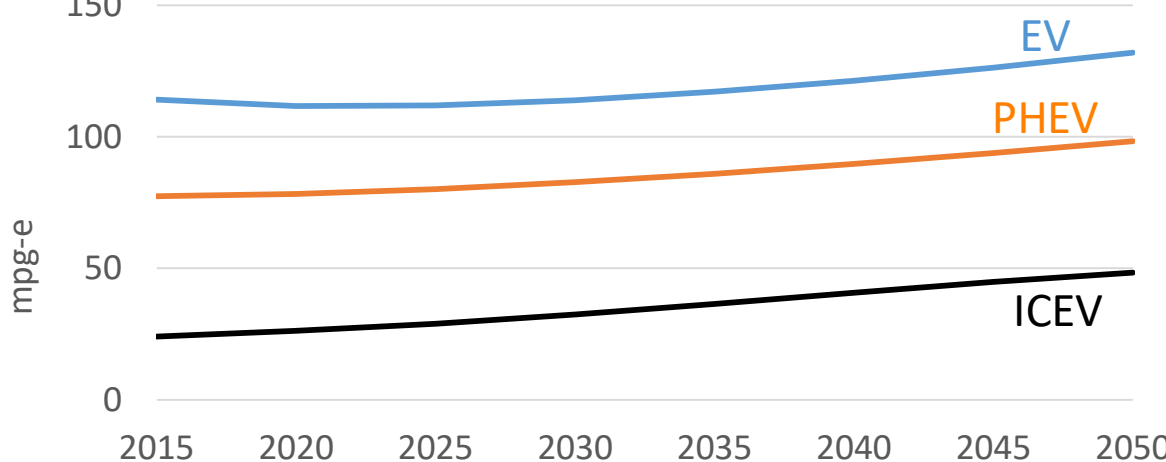
Total New Vehicle Purchase Price



Battery Price

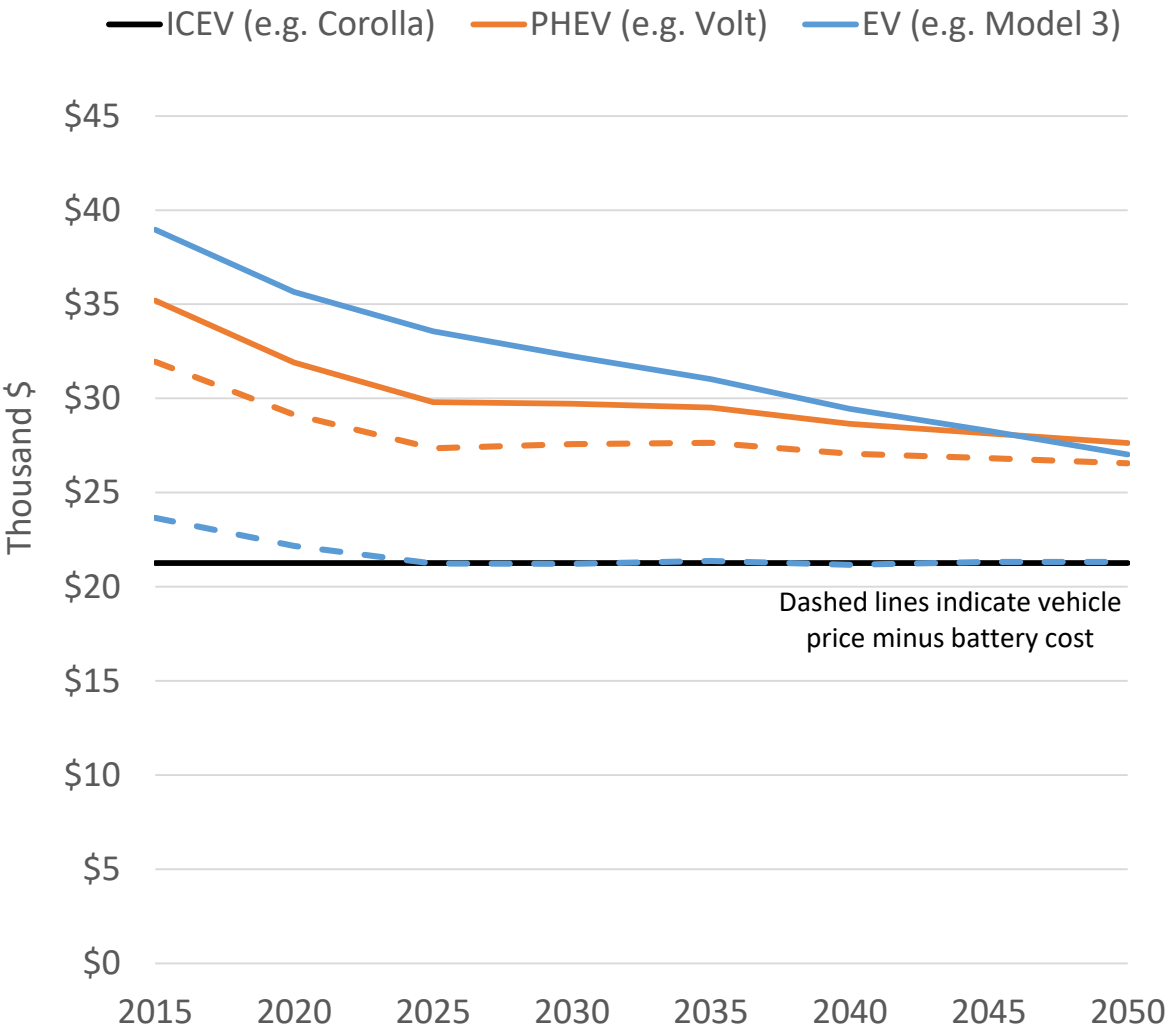


New Vehicle Efficiency

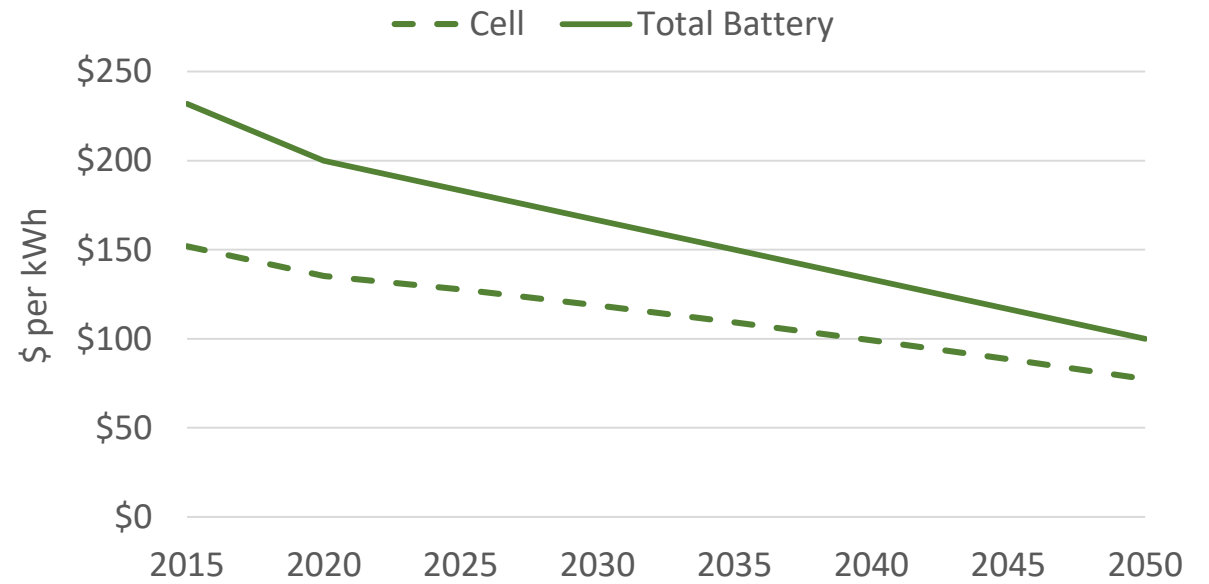


# Conservative Scenario; Vehicle Cost and Performance

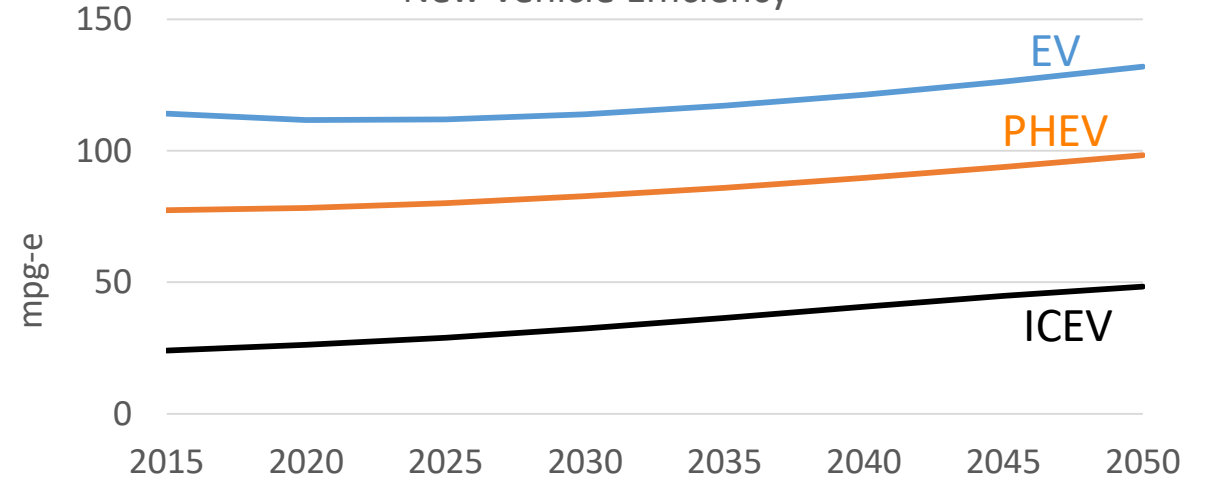
Total New Vehicle Purchase Price



Battery Price

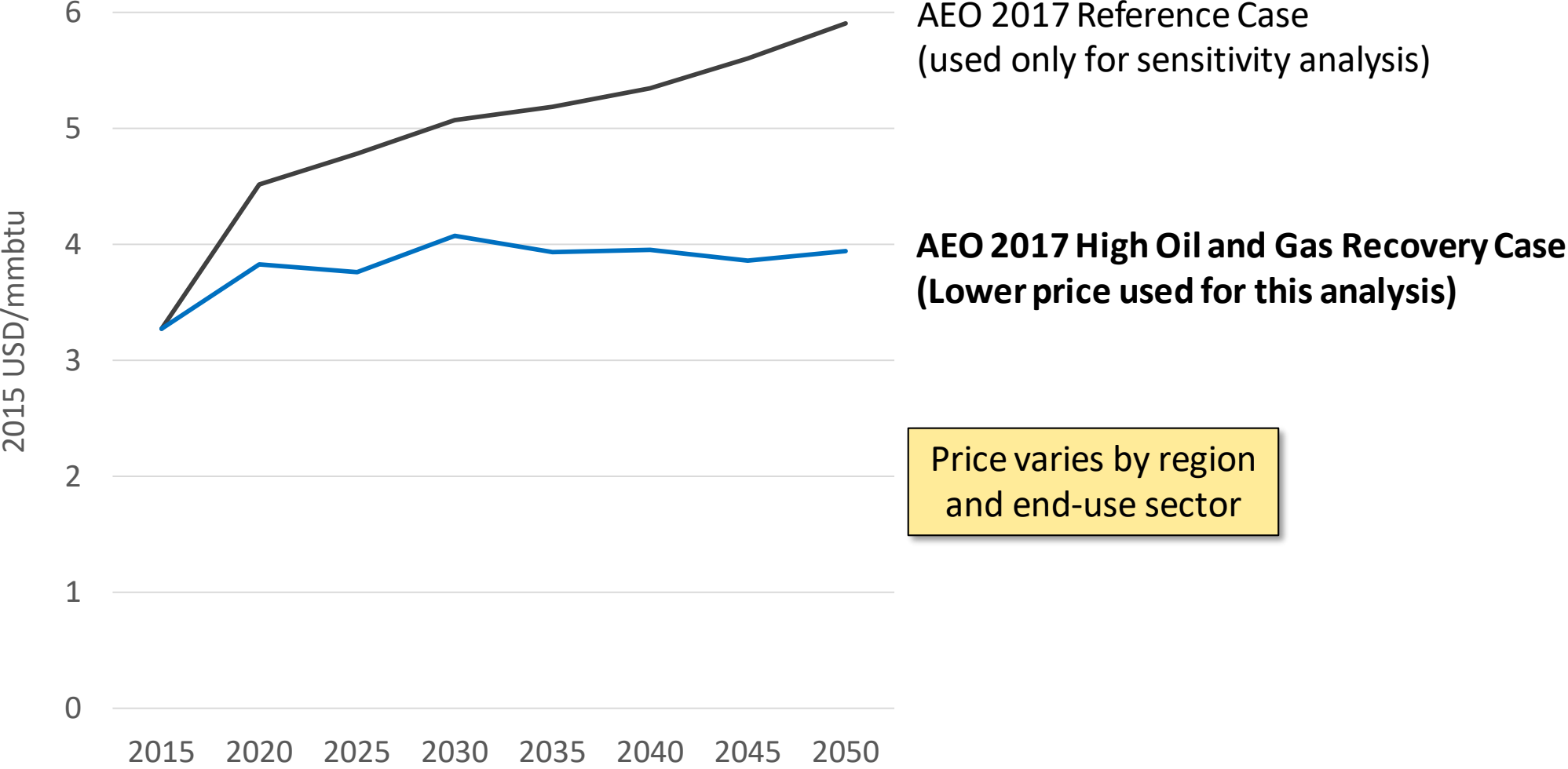


New Vehicle Efficiency

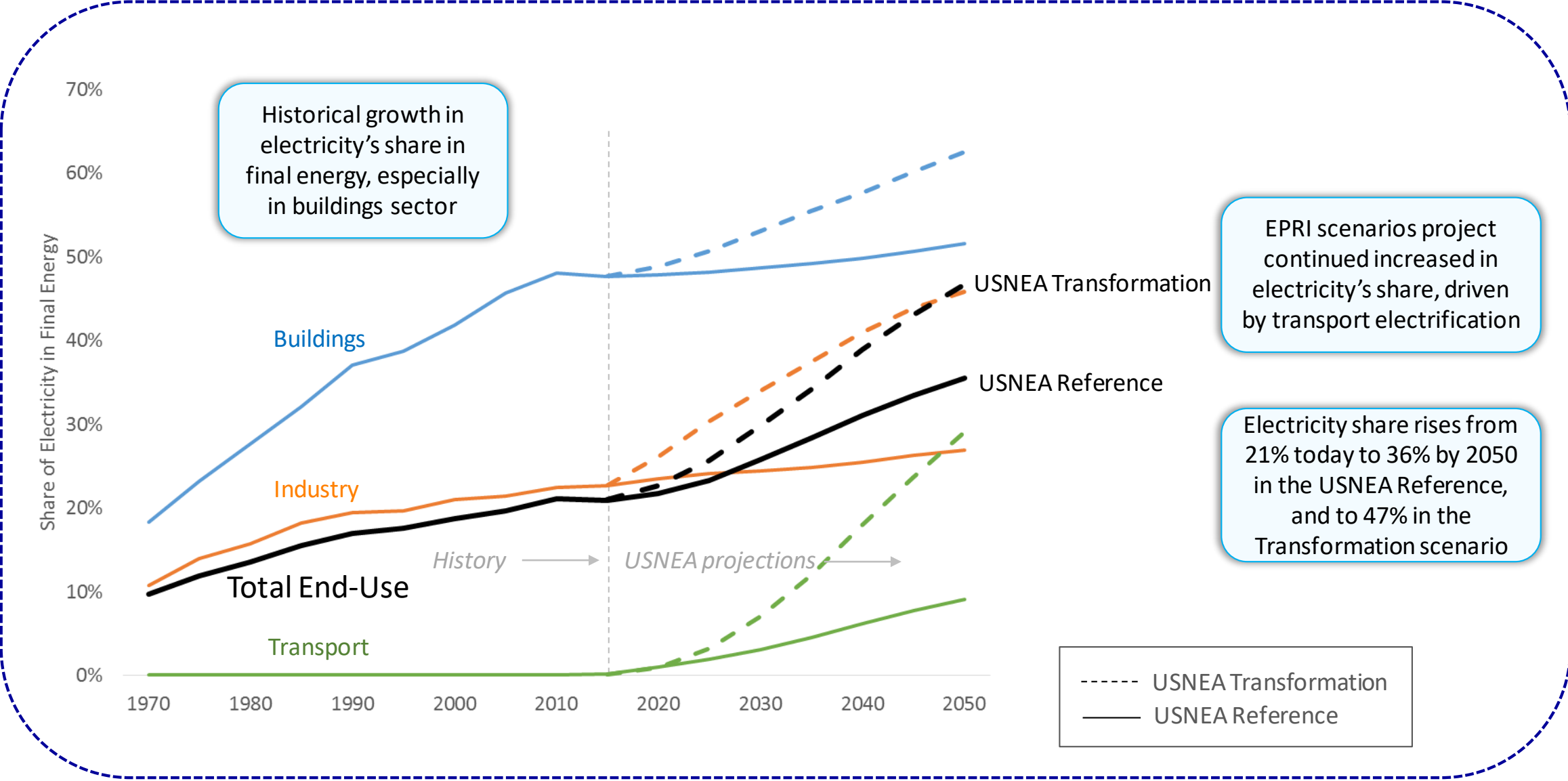




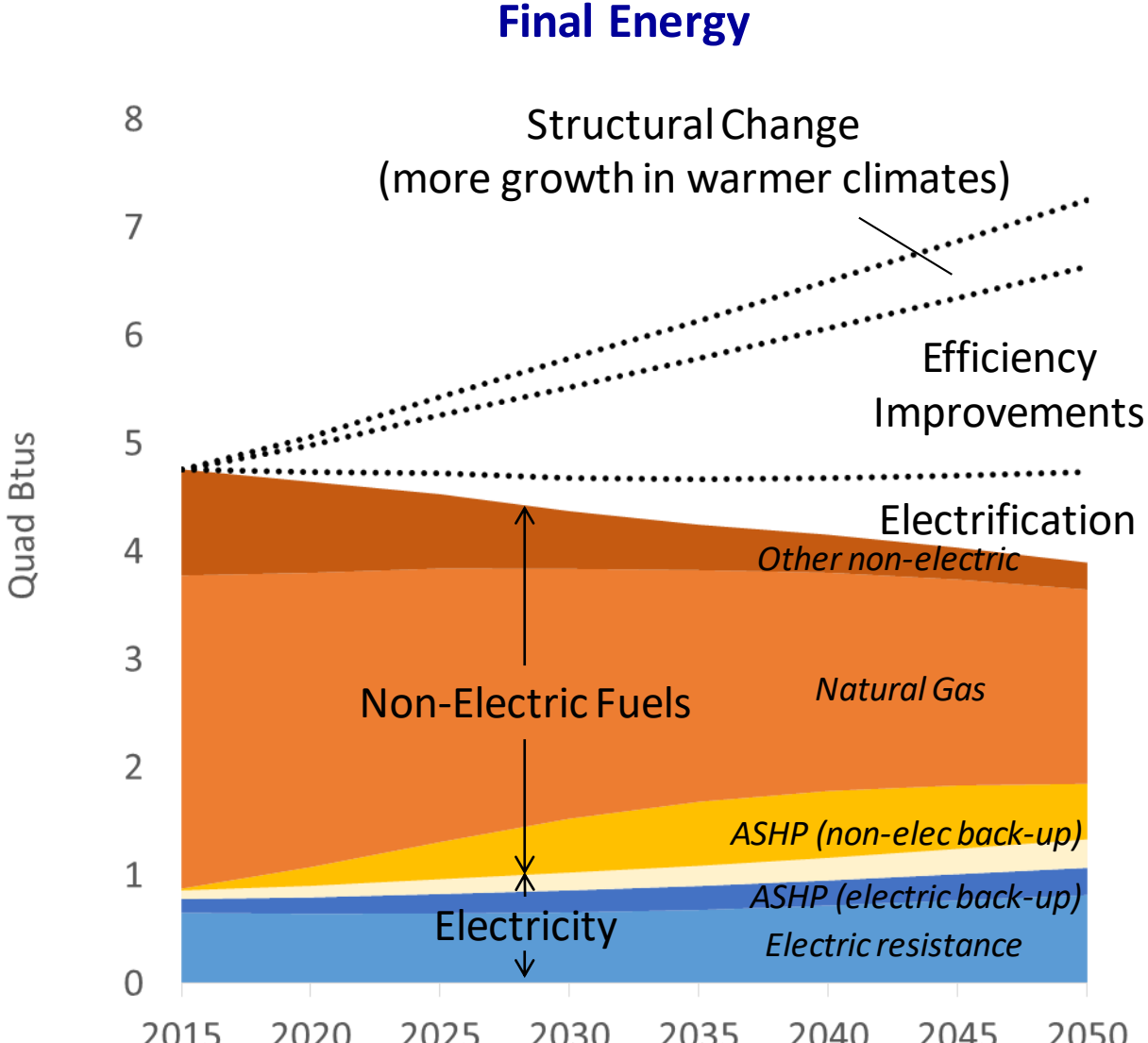
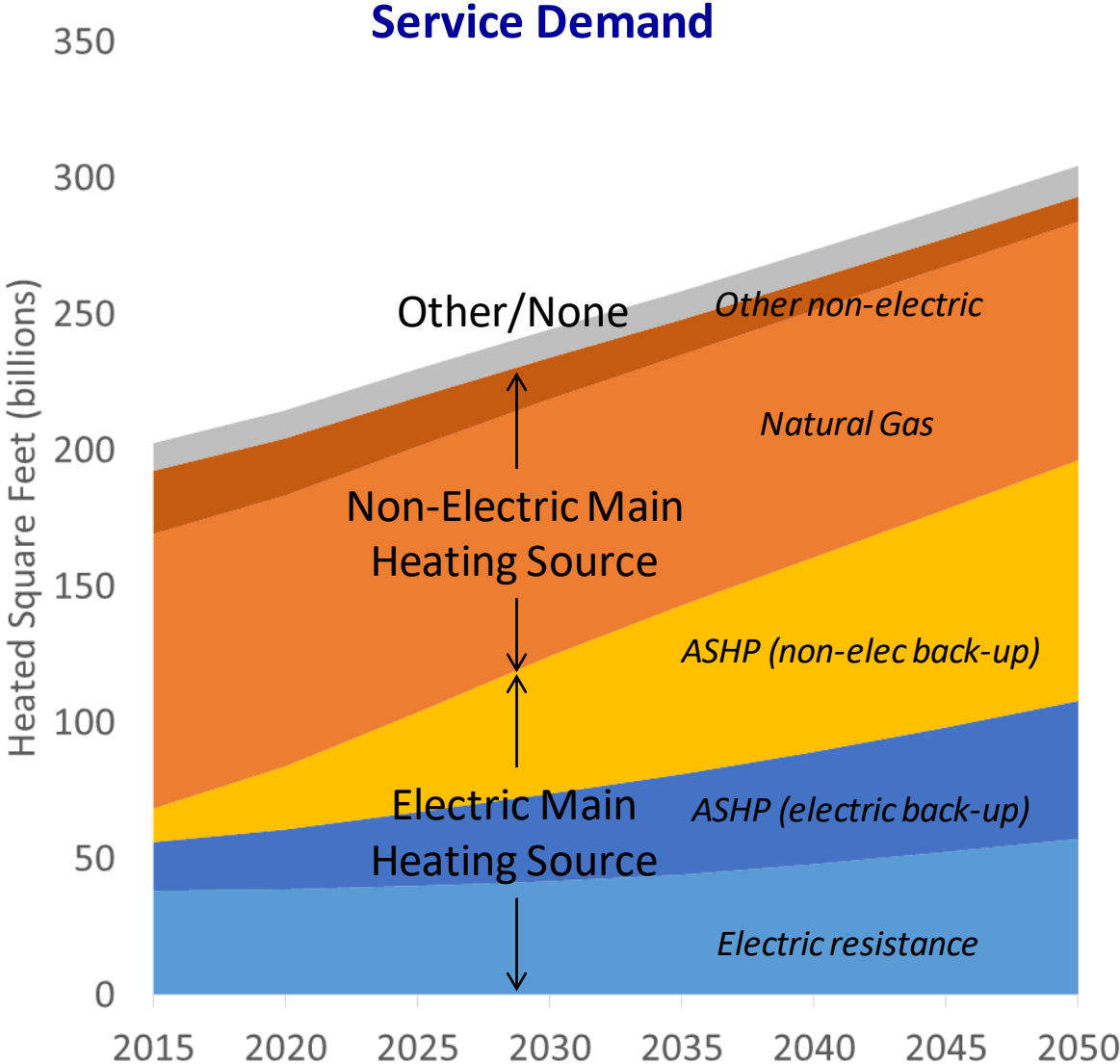
# National Average Wholesale NG Price Paths



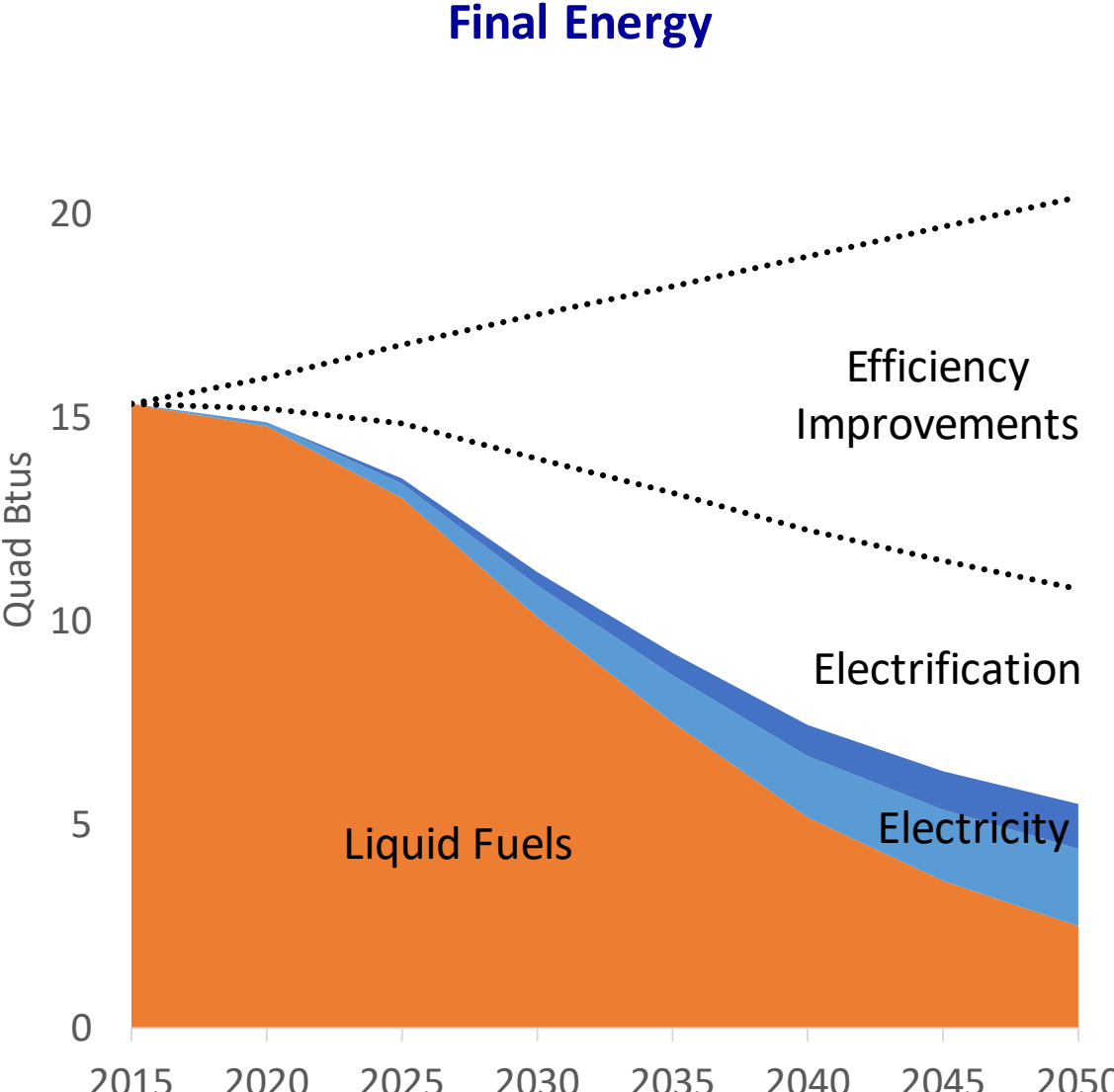
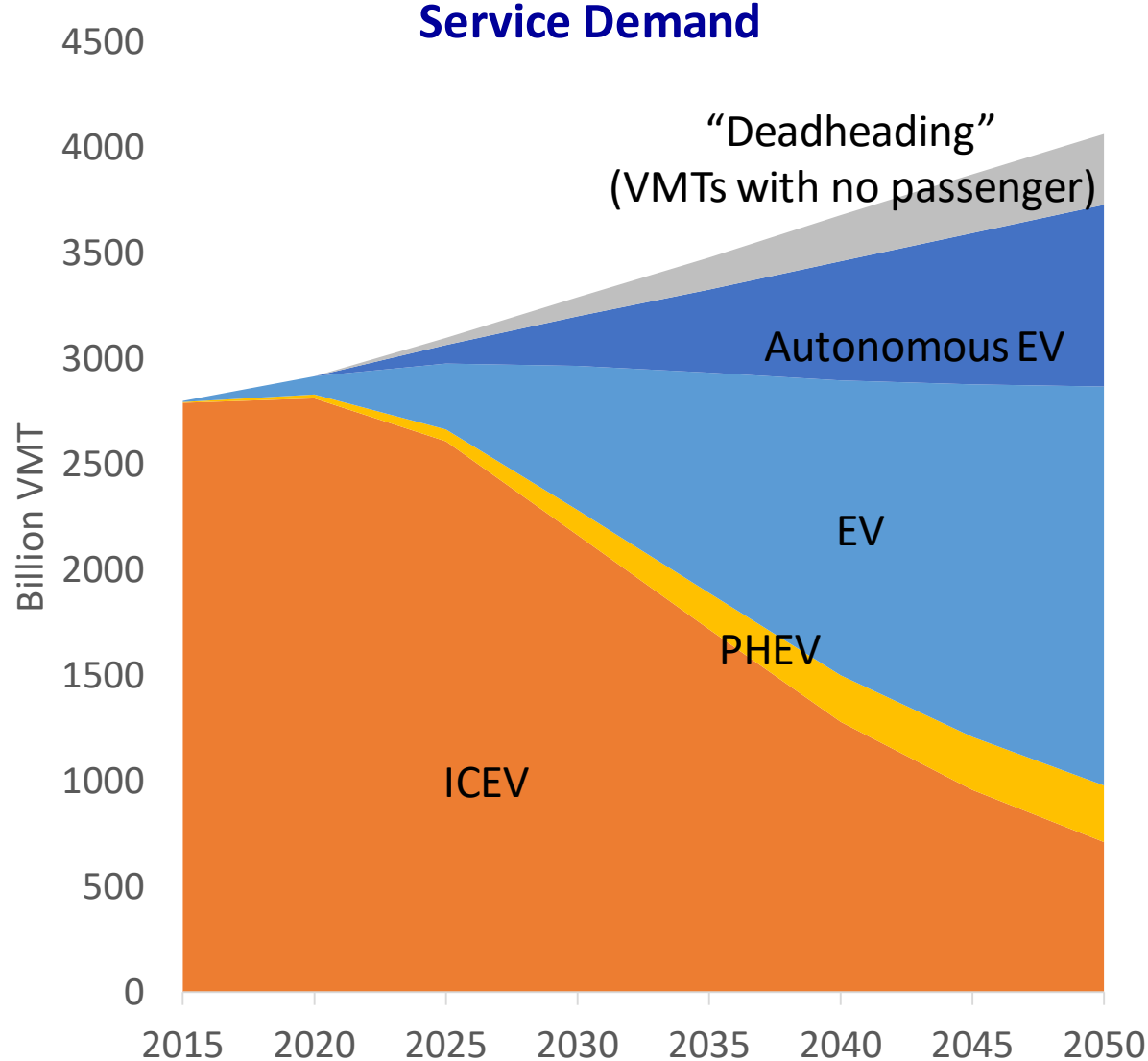
# Electricity's Share in Final Energy Grows Over Time



# Reference Projections for US Residential Space Heating



# Reference Projections for US Light-Duty Vehicles



# Electric CO<sub>2</sub> Intensity and Total Emissions

