# Efficient Electrification: Opportunities and Challenges

Tom Wilson
Principal Technical Executive, Integrated Grid and Energy Systems

Minnesota Electrification Stakeholder Meeting
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# EPRI - Independent – Objective – Technically Based

## BORN IN A BLACKOUT

Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research

New York City, The Great Northeast Blackout, 1965

## EPRI'S VALUE

To provide value to the public, our members, and the electricity sector

**THOUGHT LEADERSHIP**

**INDUSTRY EXPERTISE**

**COLLABORATIVE MODEL**

## OUR MEMBERS...

- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding – nearly 25% of EPRI's research, development, and demonstrations
- $415M Annual funding

# Topics for Today

**Analysis – EPRI's US National Electrification Assessment**

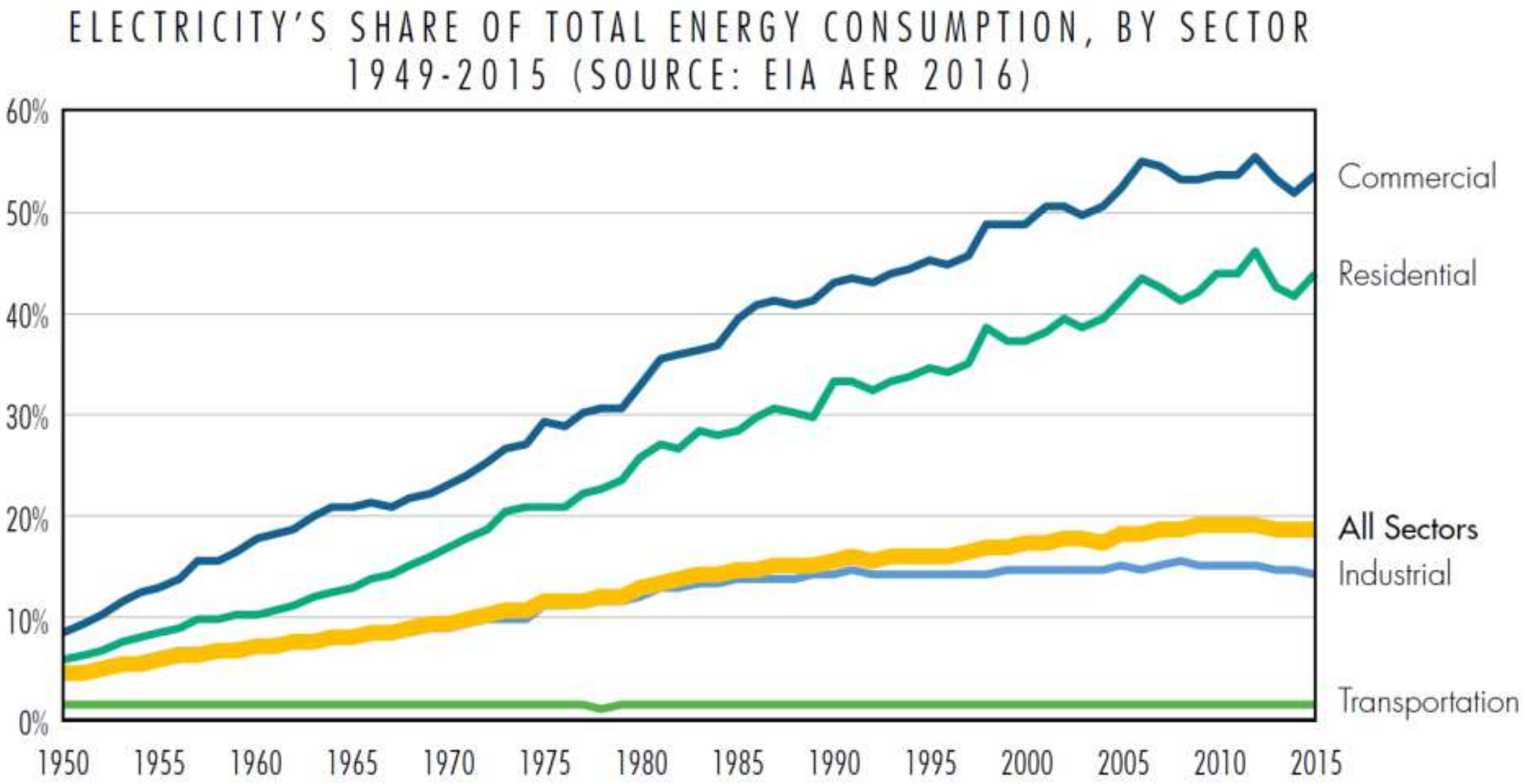
US Regional Perspectives

Regulation -- Updating measures of costs and benefits

Minnesota Perspectives

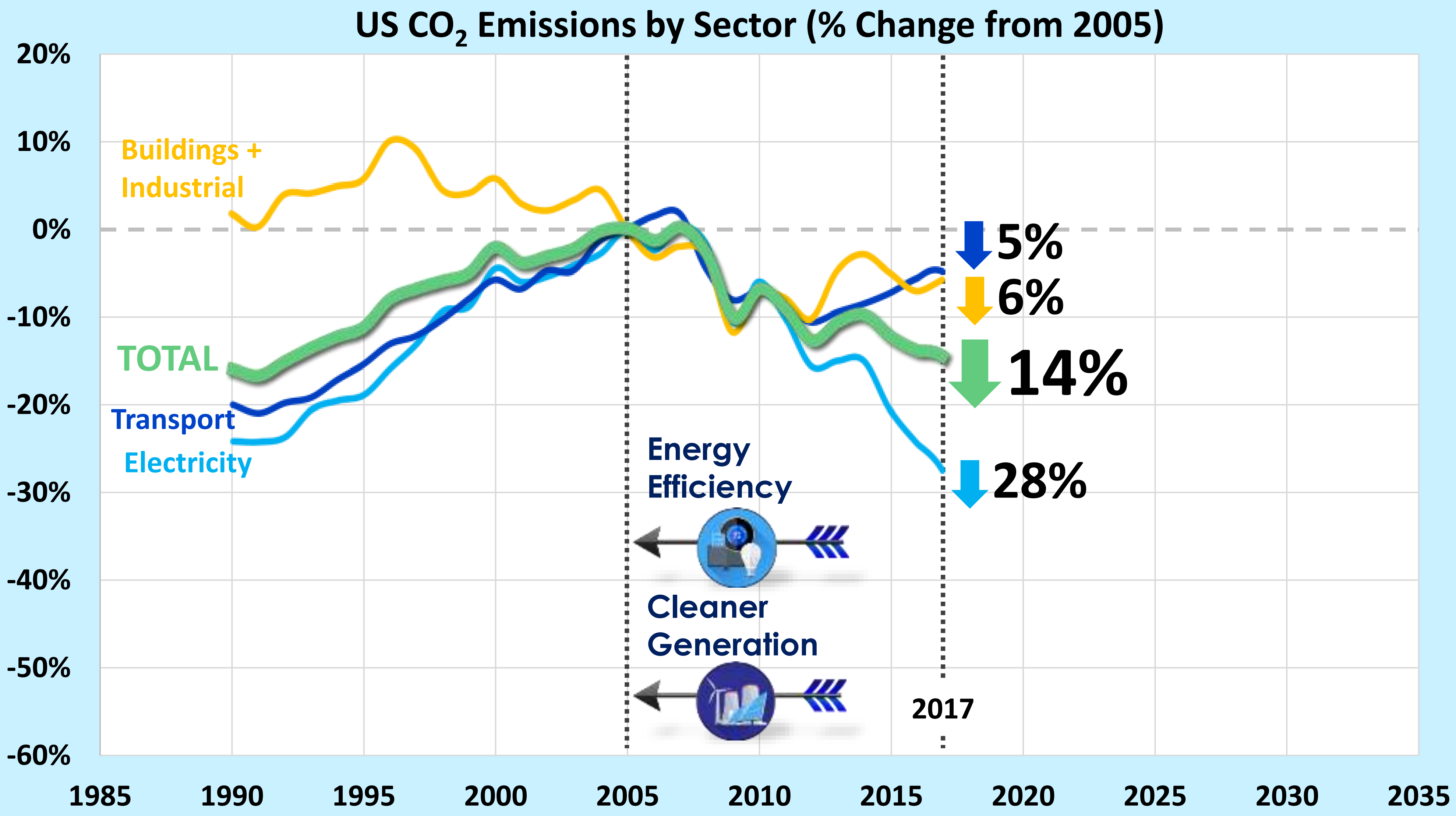
Concluding Remarks

# Electricity Use Has Grown Faster than Total Energy for More than A Century… What Will Happen Next? Or Could Happen?




**Historic growth driven by efficiency, convenience, safety, and low cost**

# Conventional Wisdom about Clean Energy is Rapidly Changing




Historic data from EIA Monthly Energy Review, February 2019

# Efficient Electrification – "Sustainable" Opportunities

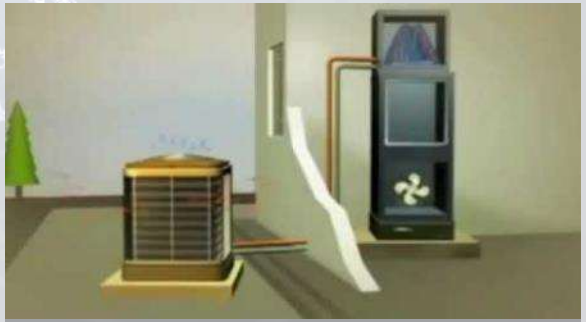
Electric Vehicles


Airport/Port Electrification

Infrared Heating

Advanced Manufacturing

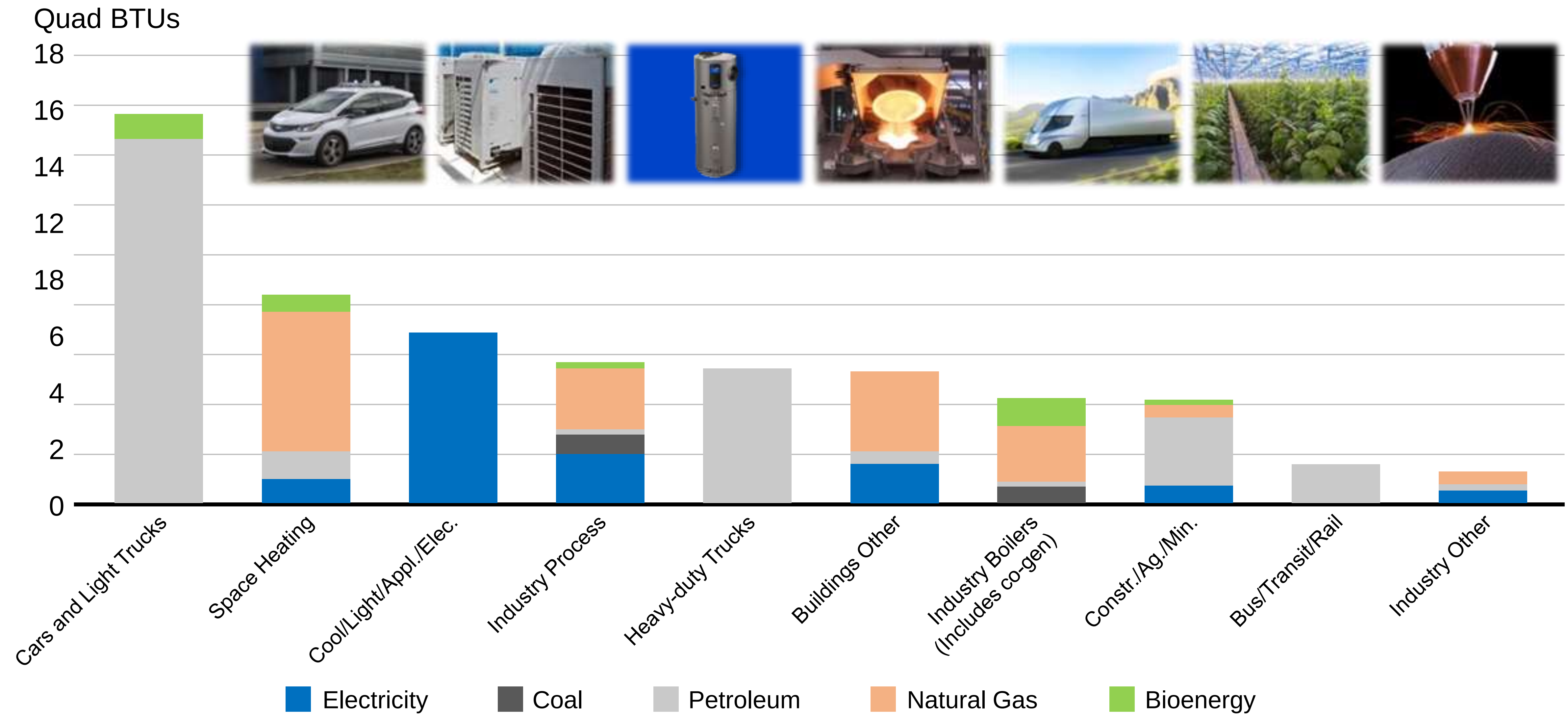
Indoor Agriculture



Hybrid Residential Heating

***Improve Productivity, Reduce Emissions, Reduce Cost, Deliver Other Non-Energy Benefits, and Give Customers Control***

# End Use (Final) Energy Use By Sector




- *Excludes upstream and midstream energy use, e.g., power generation, oil and gas extraction, refining, and pipelines.*

*Adapted from Energy Information Administration*

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


- Economy-wide assessment:
  - Residential, commercial, industrial and transport
- Customers have broad technology choices and control
- Customer decisions integrated with detailed electricity supply model

- *Just the beginning…*

For more information on EPRI's Efficient Electrification Initiative:
https://www.epri.com/#/pages/sa/efficientelectrification

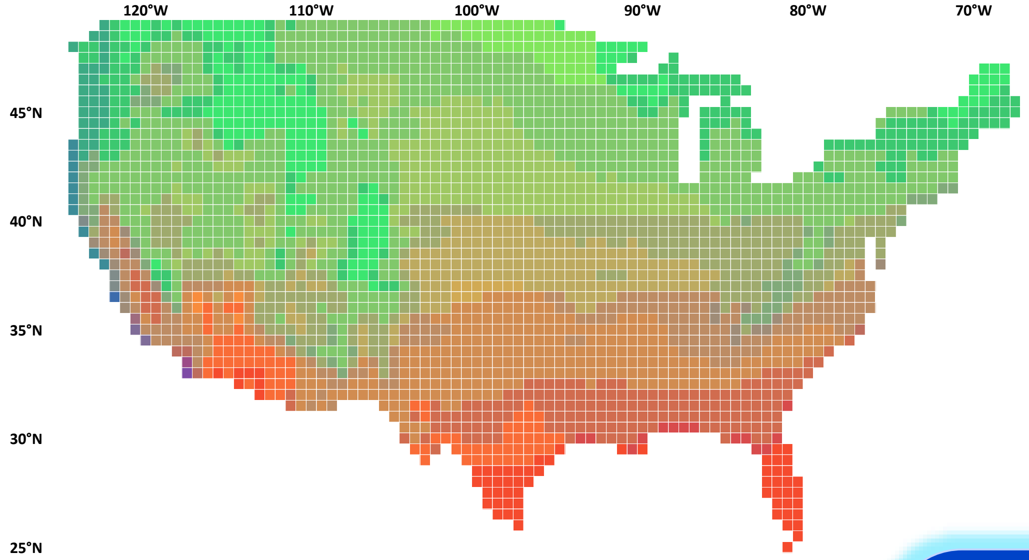
# EPRI's U.S. National Electrification Assessment Scenarios

| | | |
|---|---|---|
| **CONSERVATIVE** | Slower Technology Change | • Annual Energy Outlook 2017 growth path for economic growth (GDP), energy service demands, and primary fuel prices<br>• EPRI assumptions for cost and performance of technologies and energy efficiency over time<br>• Existing state-level policies and targets |
| **REFERENCE** | Reference Technology | |
| **PROGRESSIVE** | Reference Technology + Moderate Carbon Price | |
| **TRANSFORMATION** | Reference Technology + Stringent Carbon Price | |

# US-REGEN Couples Demand Simulation with Electric Generation

*U.S. Regional Economy, Greenhouse Gas, and Energy*

## Energy End-Use




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

Synchronized

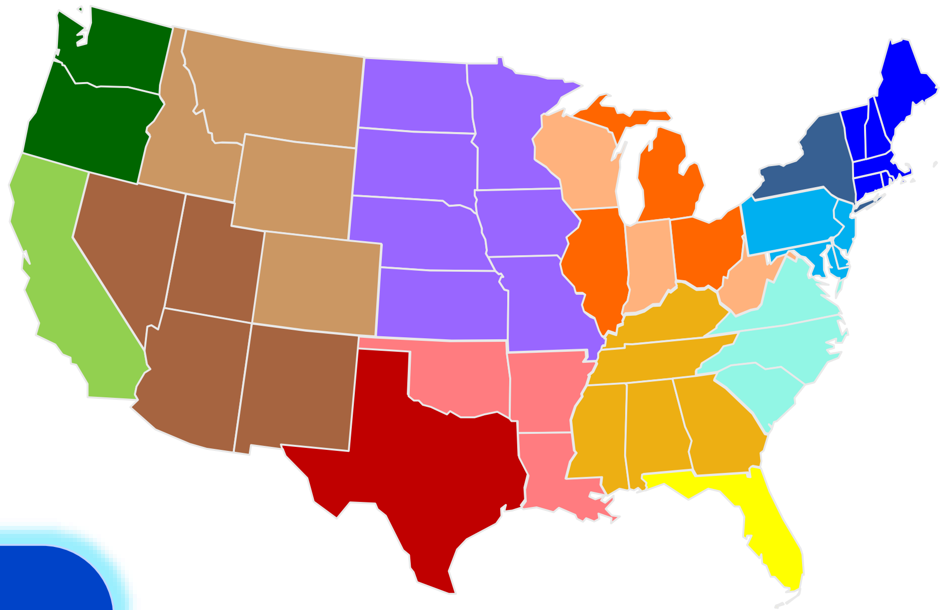
Hourly Load, Renewables, and Prices

**Model Outputs:**

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

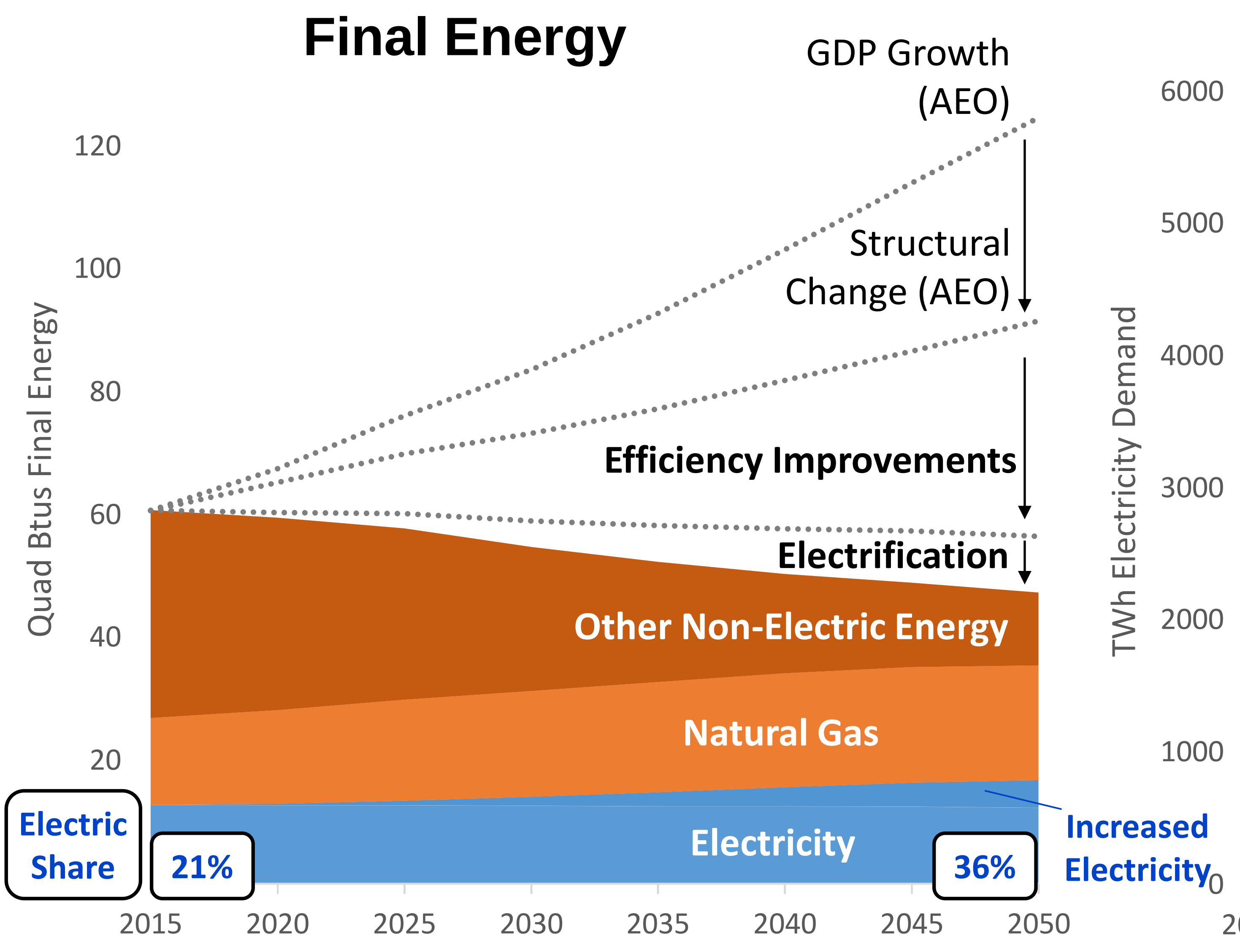
Emissions, air quality, and water use

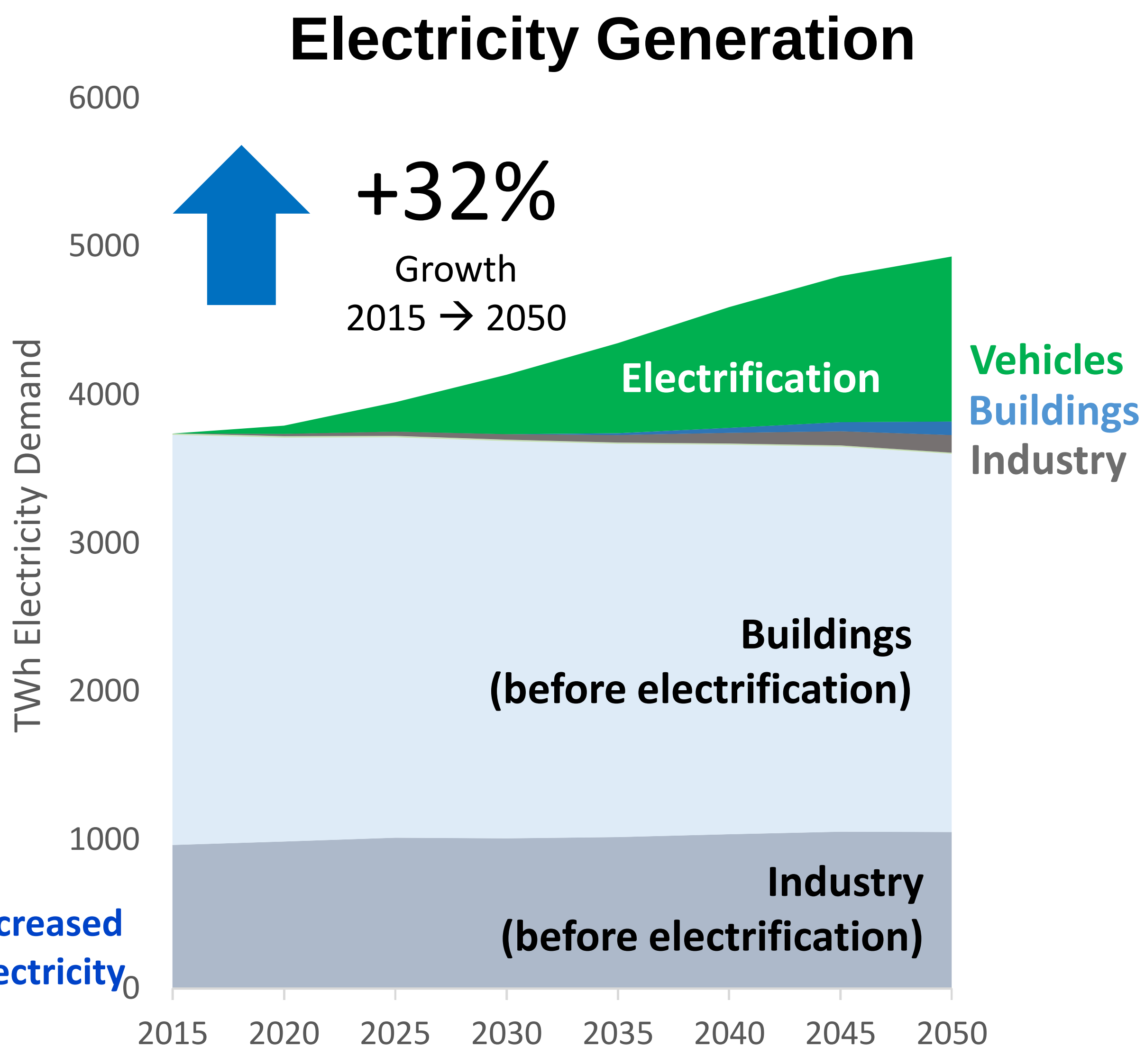
## Electric Generation



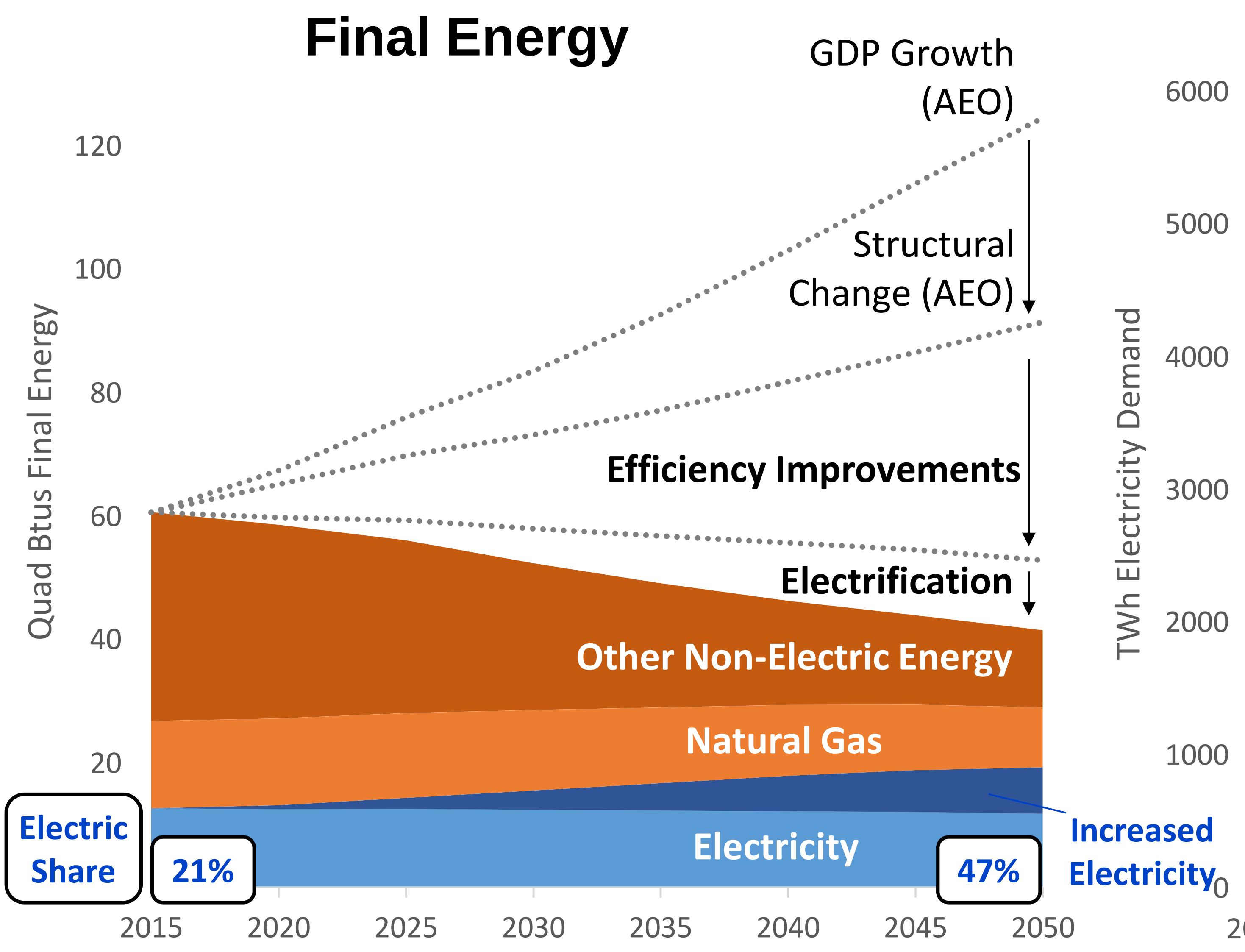
- Investment and dispatch
- Transmission
- Intermittent renewables
- Energy and capacity requirements
- State-level policies and constraints

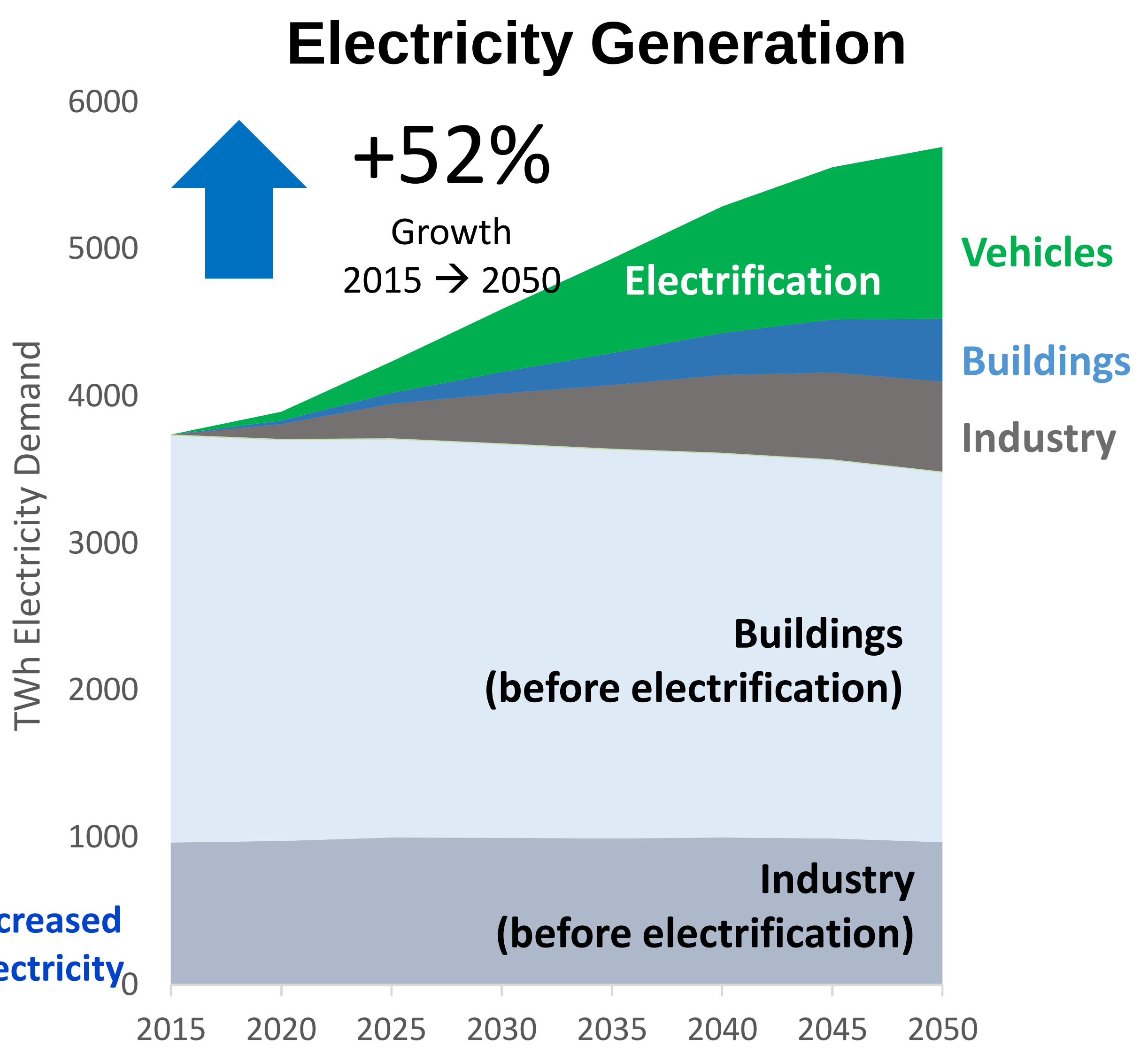
# Efficient Electrification: Reference Scenario



# Efficient Electrification: Transformation (tight carbon target)

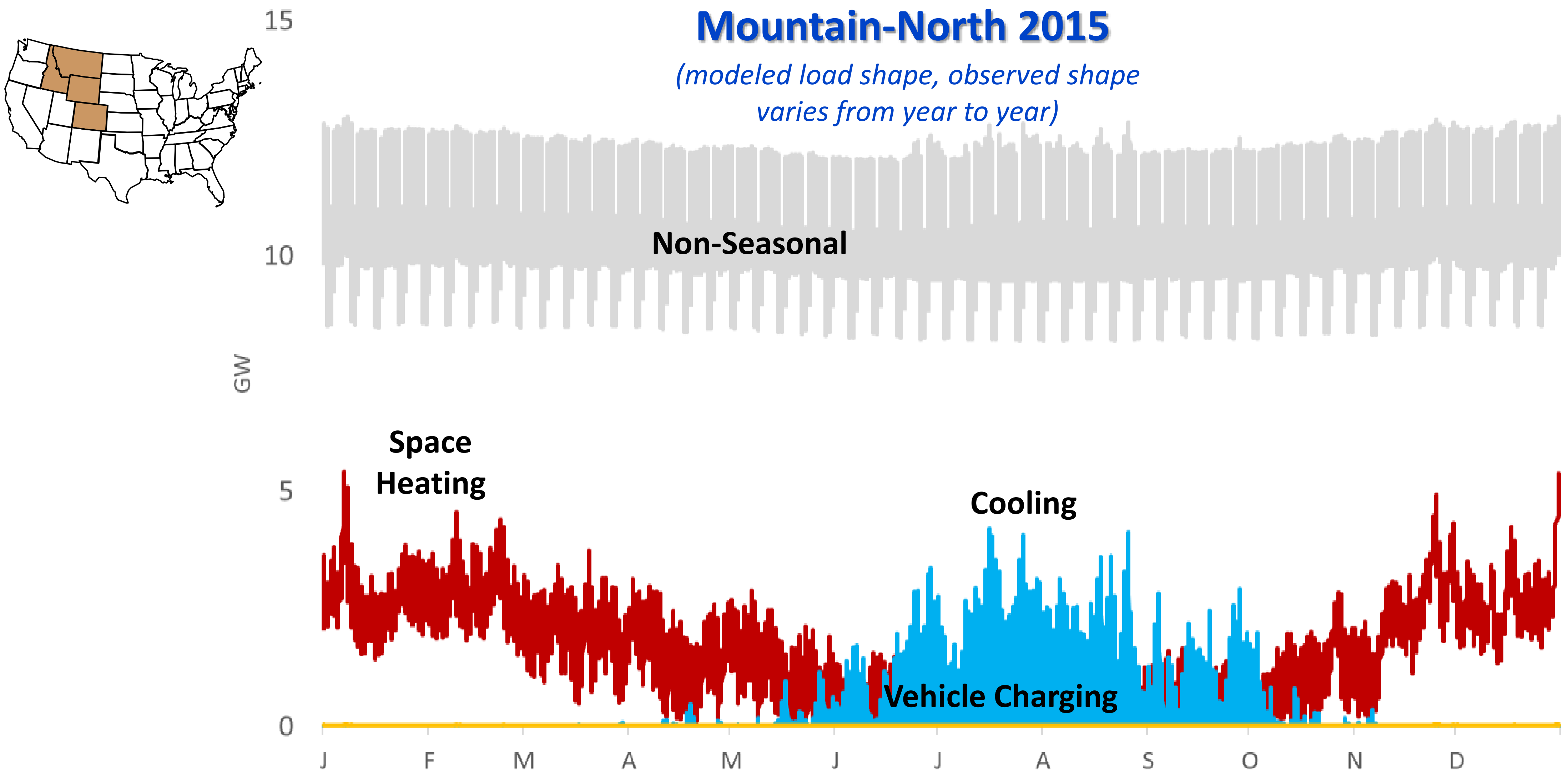


# U.S. National Electrification Assessment (USNEA) – Results

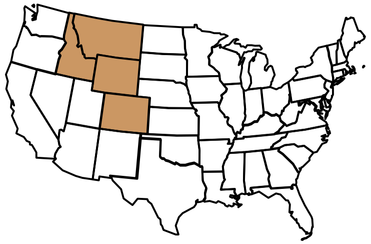
| SCENARIO (Electricity Portion of Final Energy in 2015 & 2050) | Total Final Energy | Electric Load | Natural Gas | Economy Wide $CO_2$ |
|---|---|---|---|---|
| CONSERVATIVE (21% & 32%) | 20% | 24% | 33% | 19% |
| REFERENCE (21% & 36%) | 22% | 32% | 40% | 20% |
| PROGRESSIVE (21% & 39%) | 27% | 35% | 31% | 57% |
| TRANSFORMATION (21% & 47%) | 32% | 52% | 18% | 67% |

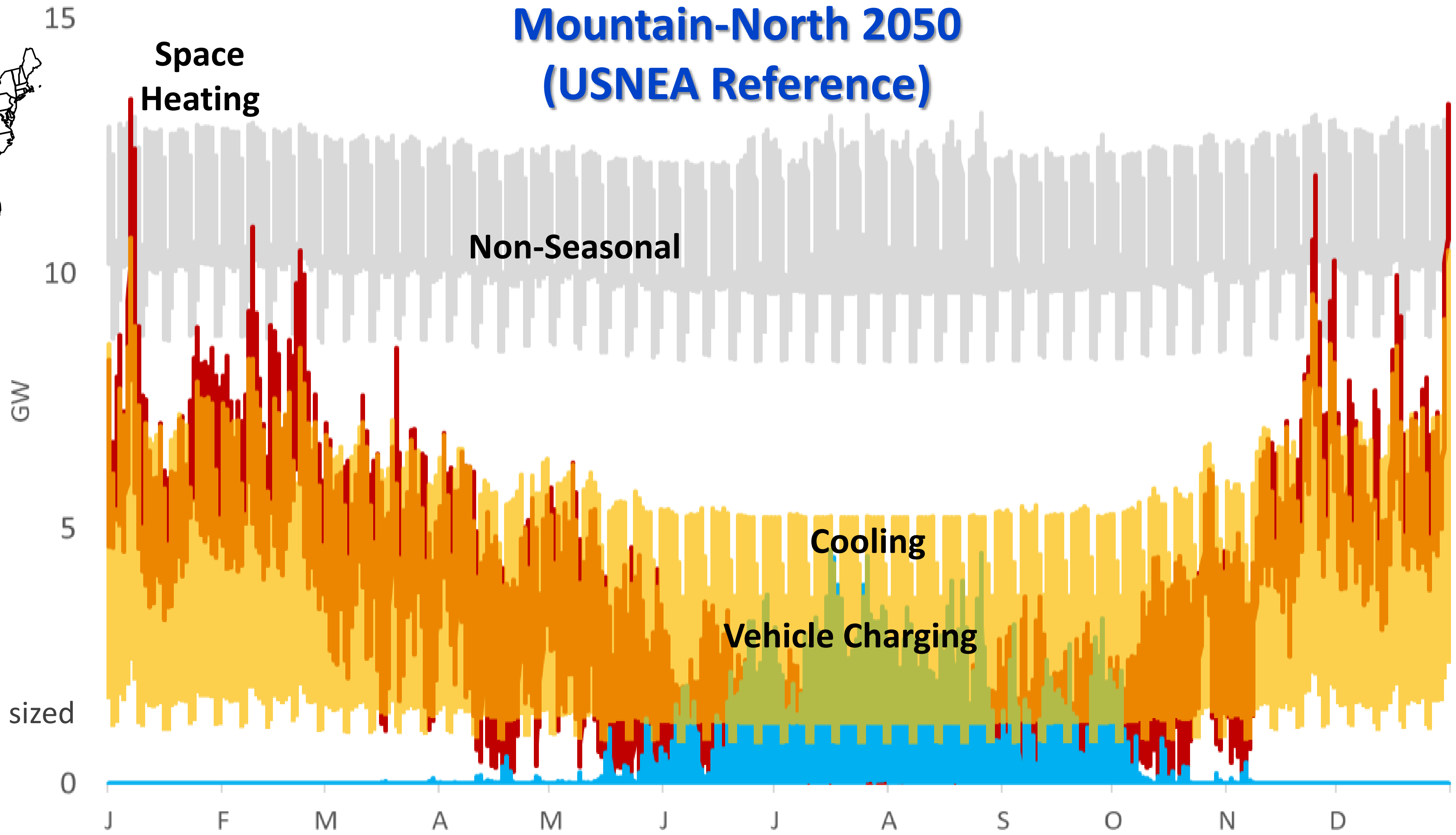
# Current Load Shapes by End-Use




**How Will Sectoral Loads Shift Over Time?**

# Projected Load Shapes by End-Use

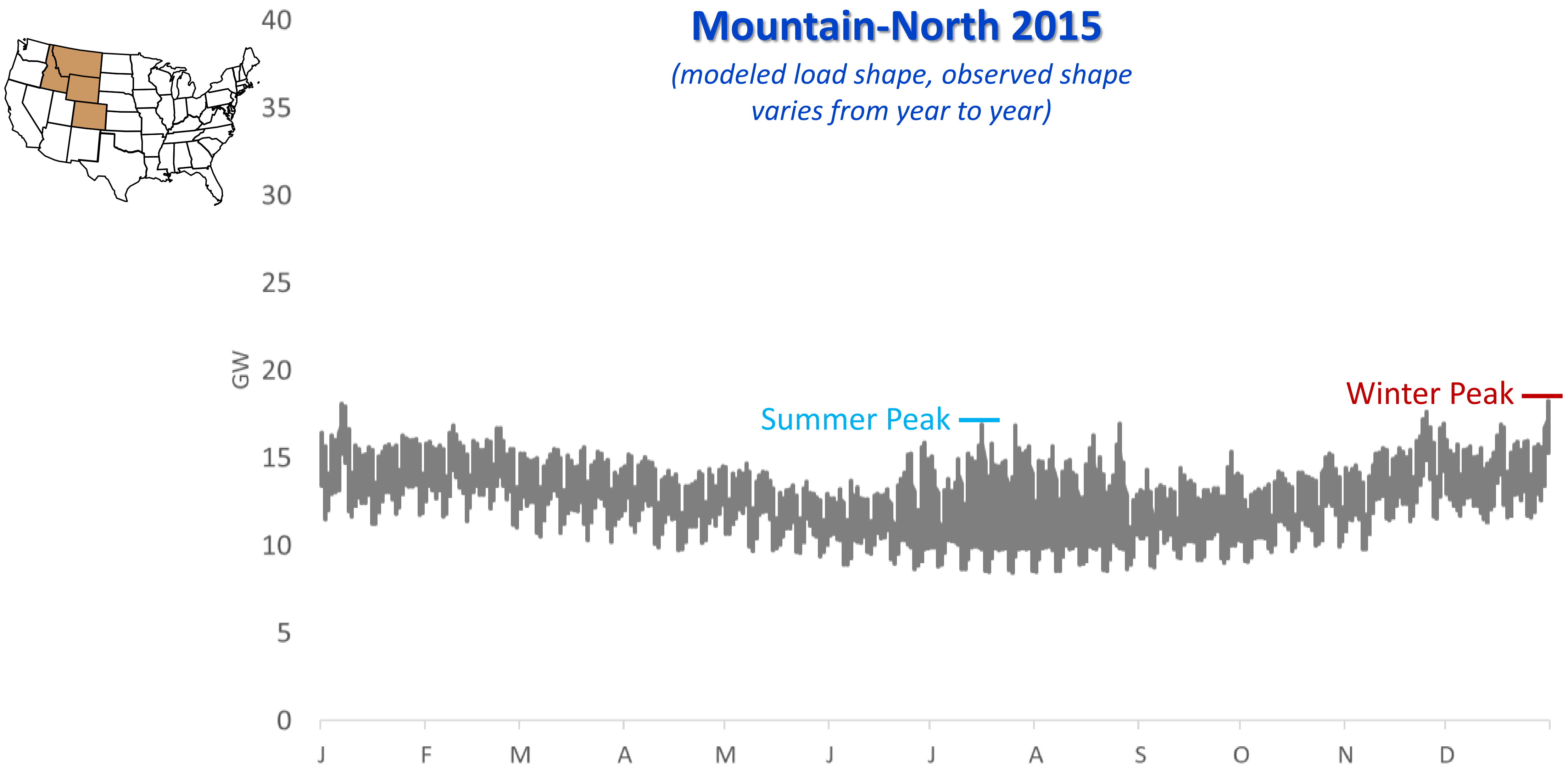





Note: Heat pump sized for cooling load

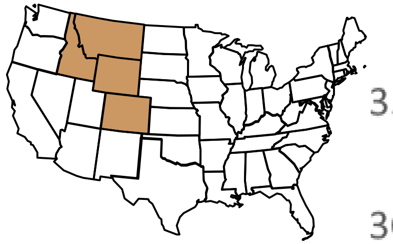
**Significant Potential Shift in Pattern and Size of Load – Large Opportunities to Shape Load**

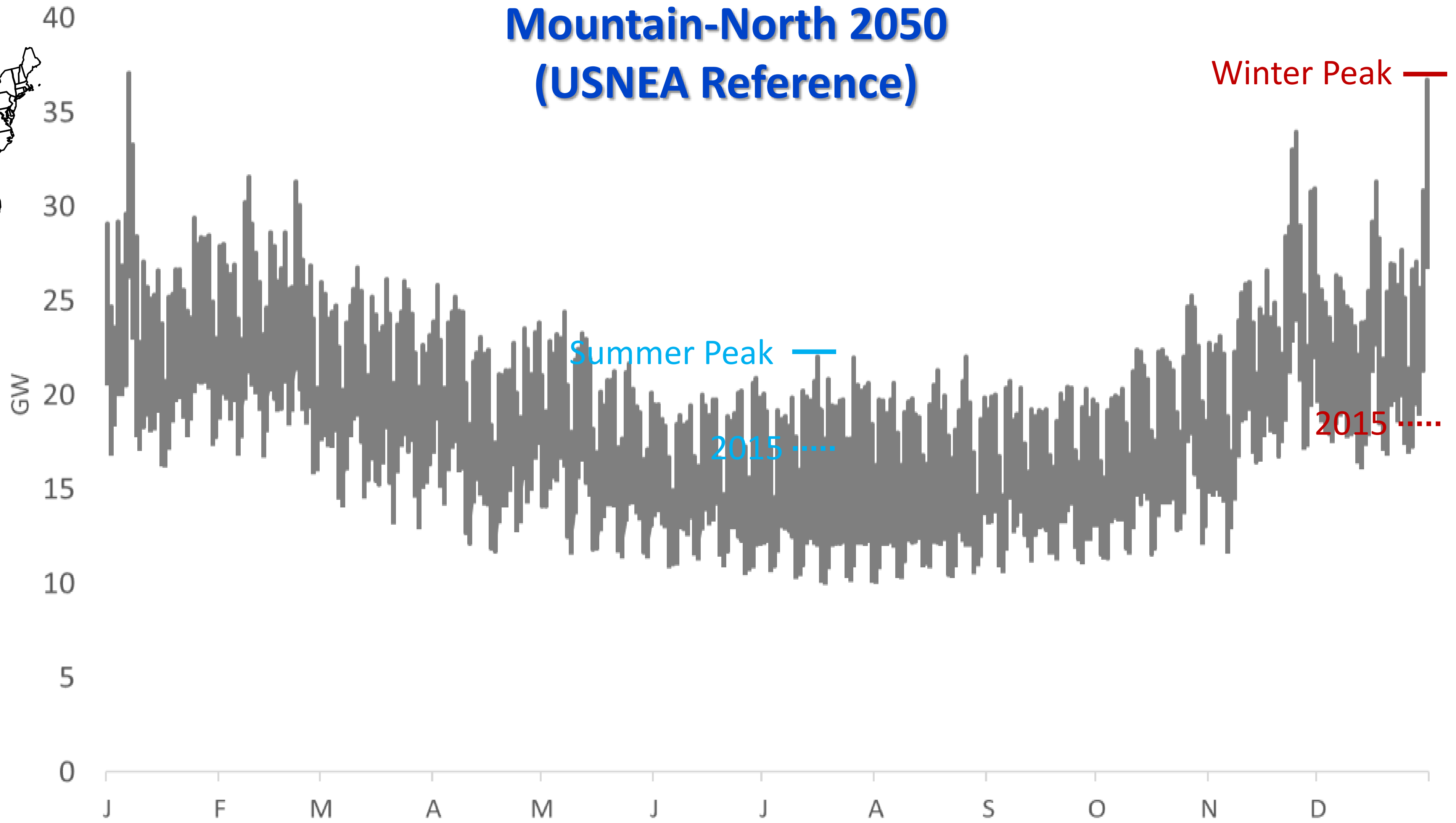
# Current Aggregate Load Shape




**How Stable Are These System Dynamics?**

# Projected Aggregate Load Shape



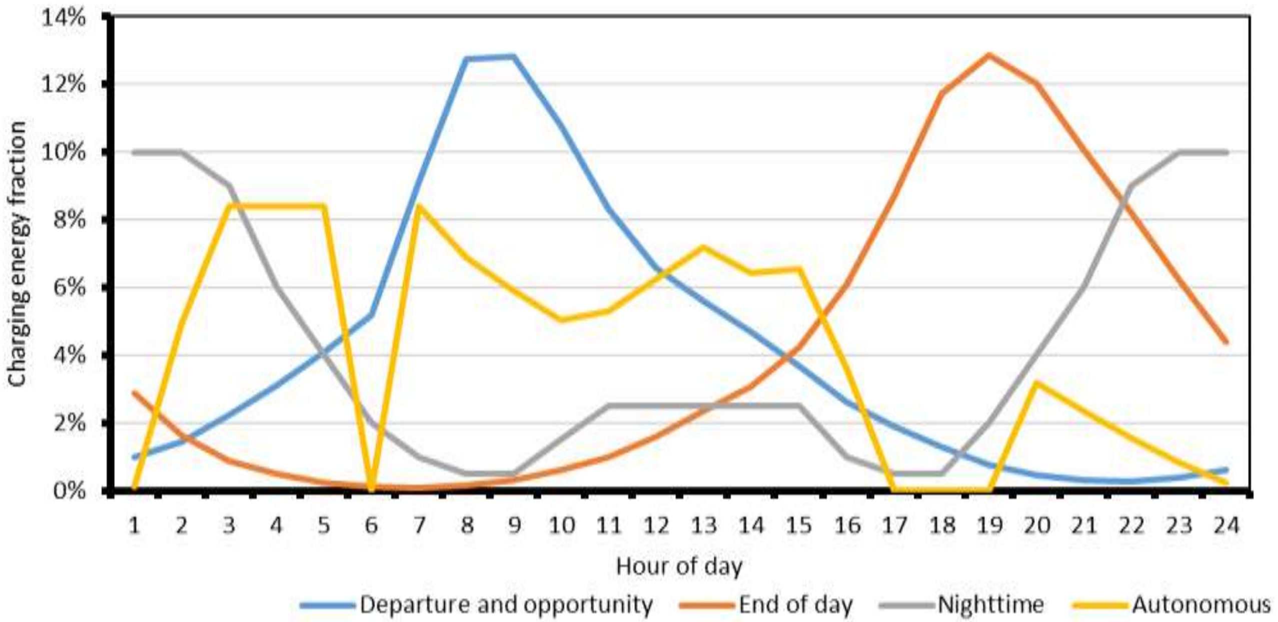


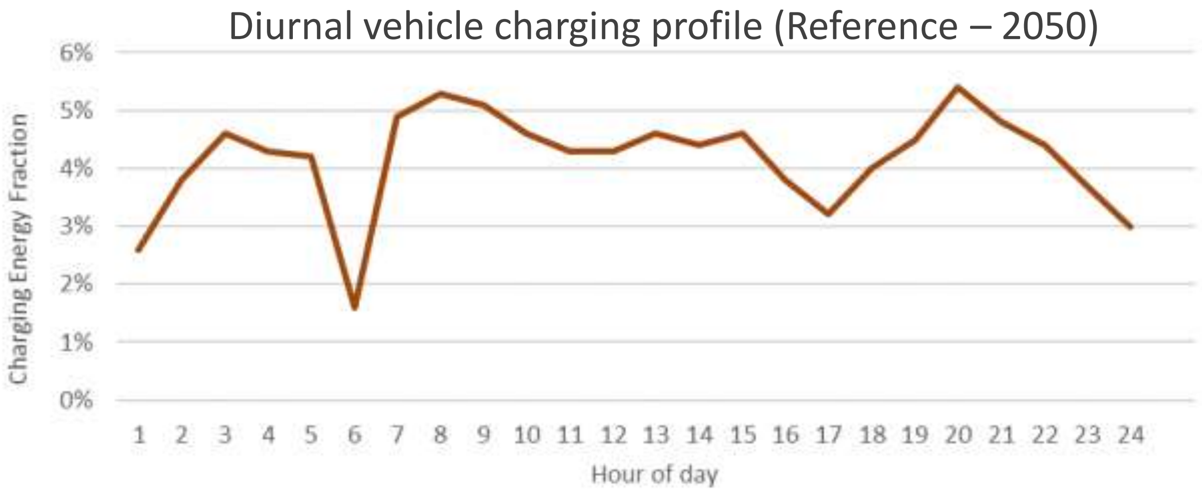

**Electrification Could Impact Resource Planning and Market Design**

# USNEA Assumed Exogenous Charging Profiles (i.e., uncoordinated)

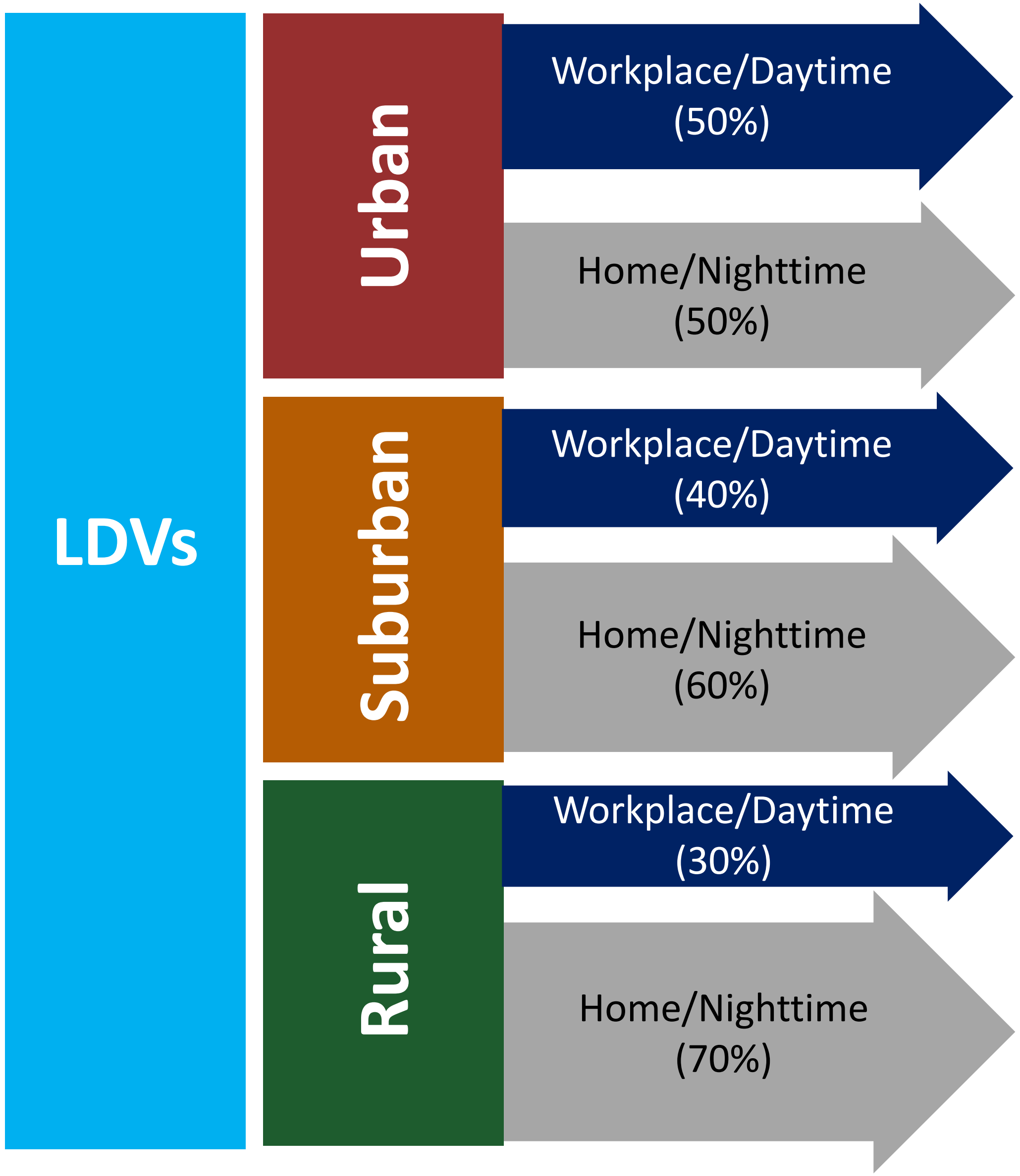
**LDVs**

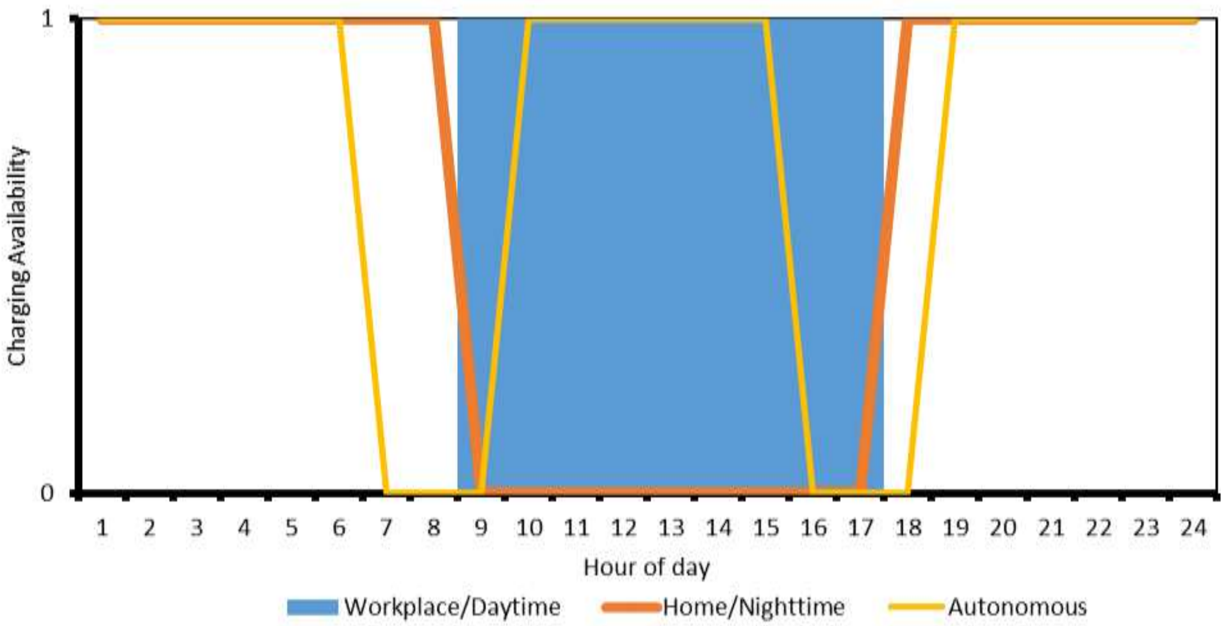
- **Urban**
  - Departure & Opportunity (50%)
  - End of day (30%)
  - Nighttime (20%)
- **Suburban**
  - Departure & Opportunity (40%)
  - End of day (20%)
  - Nighttime (40%)
- **Rural**
  - Departure & Opportunity (30%)
  - End of day (50%)
  - Nighttime (20%)



# In a State-Level Study, Examined Impact of Coordinated Charging




**Optimization Model**

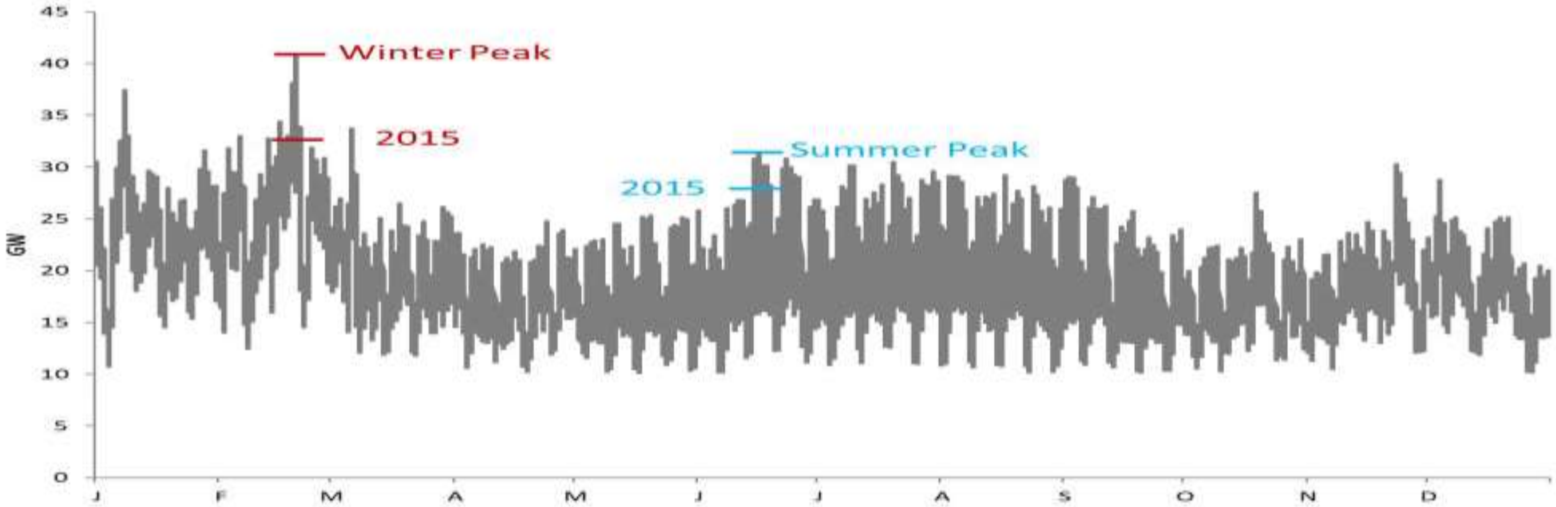
**Minimize** cost of charging where total hourly load is proxy for hourly price

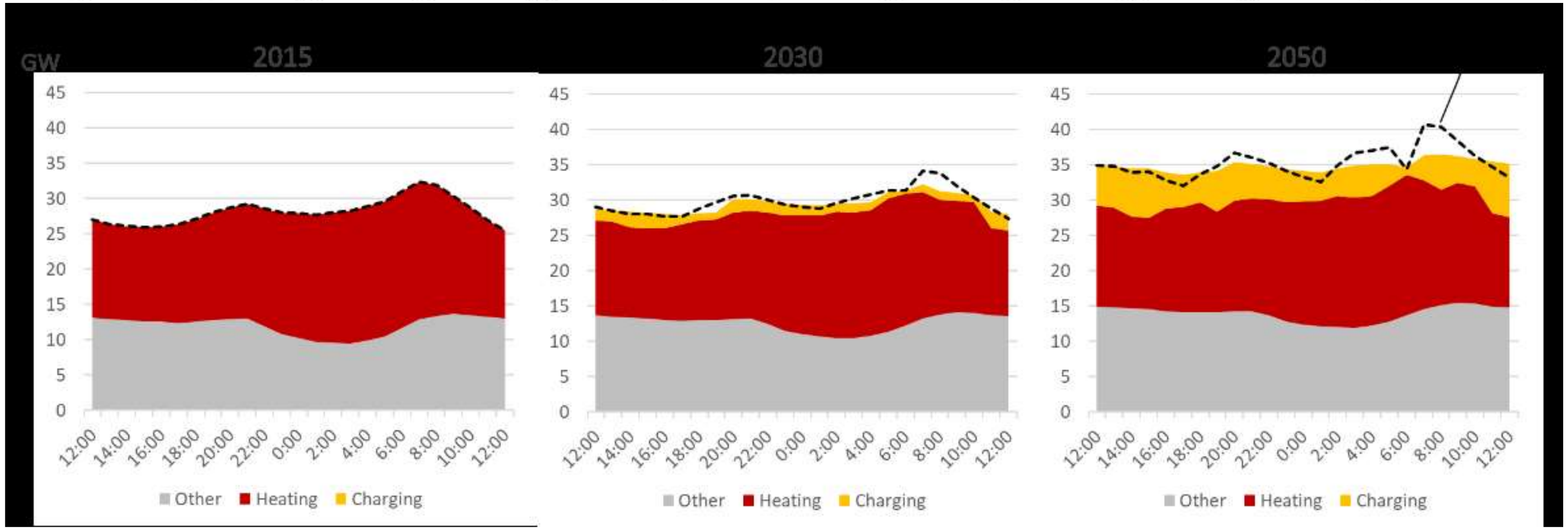
**Subject to:**

(1) Daily vehicle energy requirement for each profile must be met in the available hours

(2) Charge in each hour is limited by available capacity (specified as capacity per vehicle; e.g., 7 kW per vehicle)

# Load Shaping Can Reduce Peak Demand Issues




Electrification of heating and load suggests potential peak demand challenge

Impact of 50% participation in load management program – reduce peak by ~5GW

- Lowers heating peak
- Limits EV charging during heating peak

# Key Take Away Messages from National Electrification Assessment

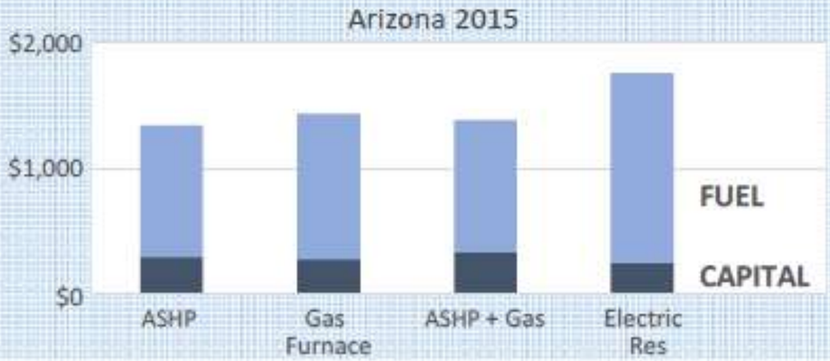
| | |
|---|---|
| **Electrification Trend Continues** | Driven by technological change and consumer choice, further bolstered by policy |
| **Efficiency Increases Emissions Decrease** | Efficient electrification + end-use efficiency lead to falling final energy use |
| **Natural Gas Use Grows** | Remains a key fuel for end-use and electric generation |
| **System Impacts** | Changing load shapes and new flexible loads create challenges and opportunities |

**BUT…**

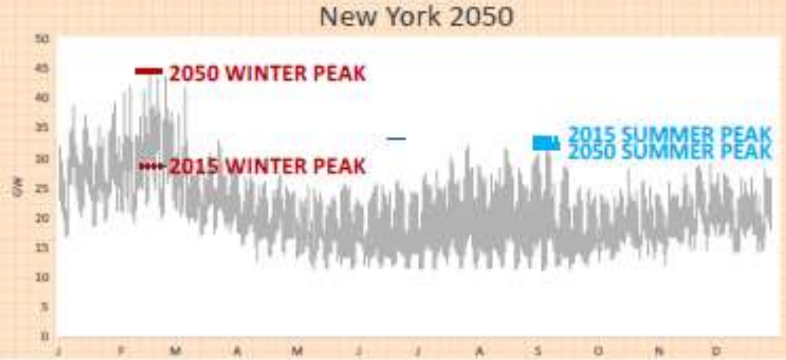
The full potential may not be realized without deliberate and integrated decisions

# U.S. National Assessment is a Beginning… Many Potential Implications to Understand

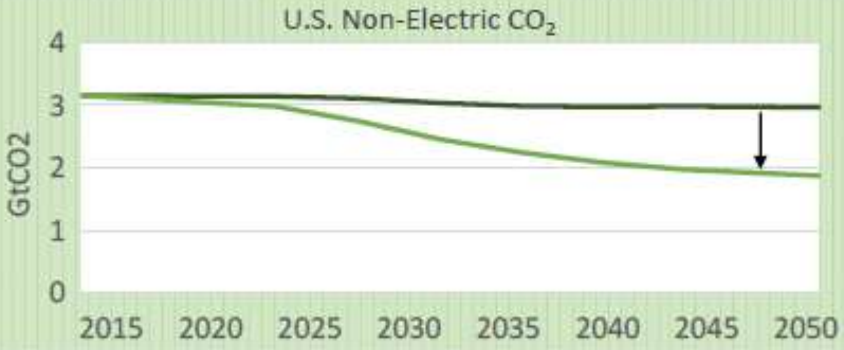
## End-user costs/benefits
- Capital vs. operating costs
- Service/product quality and productivity




## System costs/benefits
- Generation, T&D capacity requirements
- Grid flexibility




## Environmental costs/benefits
- $CO_2$, criteria pollutant emissions
- Water resources, quality

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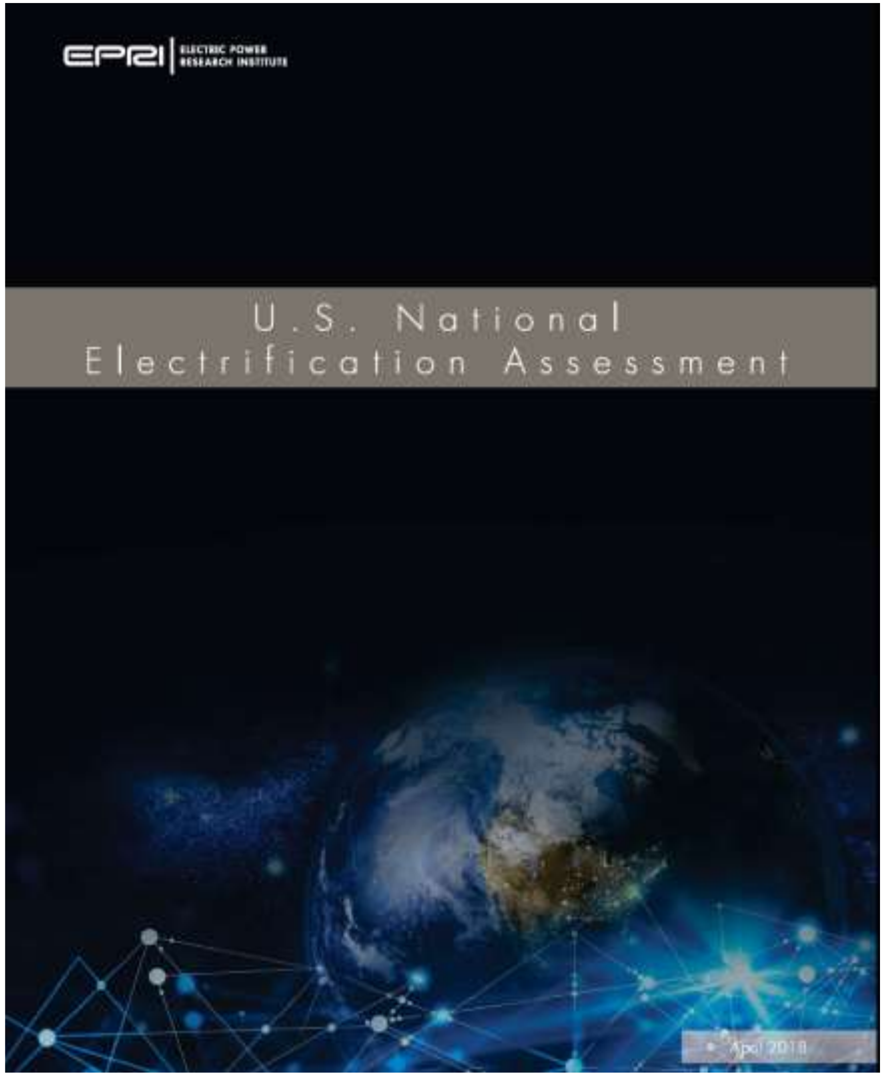
# Emerging Analytical Debate on Electrification


**Despite lots of modeling detail, different messages driven primarily by questions asked**

# Important Perspectives When You Review a Report

- Purpose
  - Many explore possible futures
  - Others assess specific policies
- Scope
  - Economy-wide vs one sector vs one end-use.
    - Narrow focus can allow more detail, but can miss the big picture
- Assumptions about future electricity
- Technology availability, cost and performance
- Consumer's circumstance and options



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US Regional Perspectives

Regulation -- Updated measures of costs and benefits

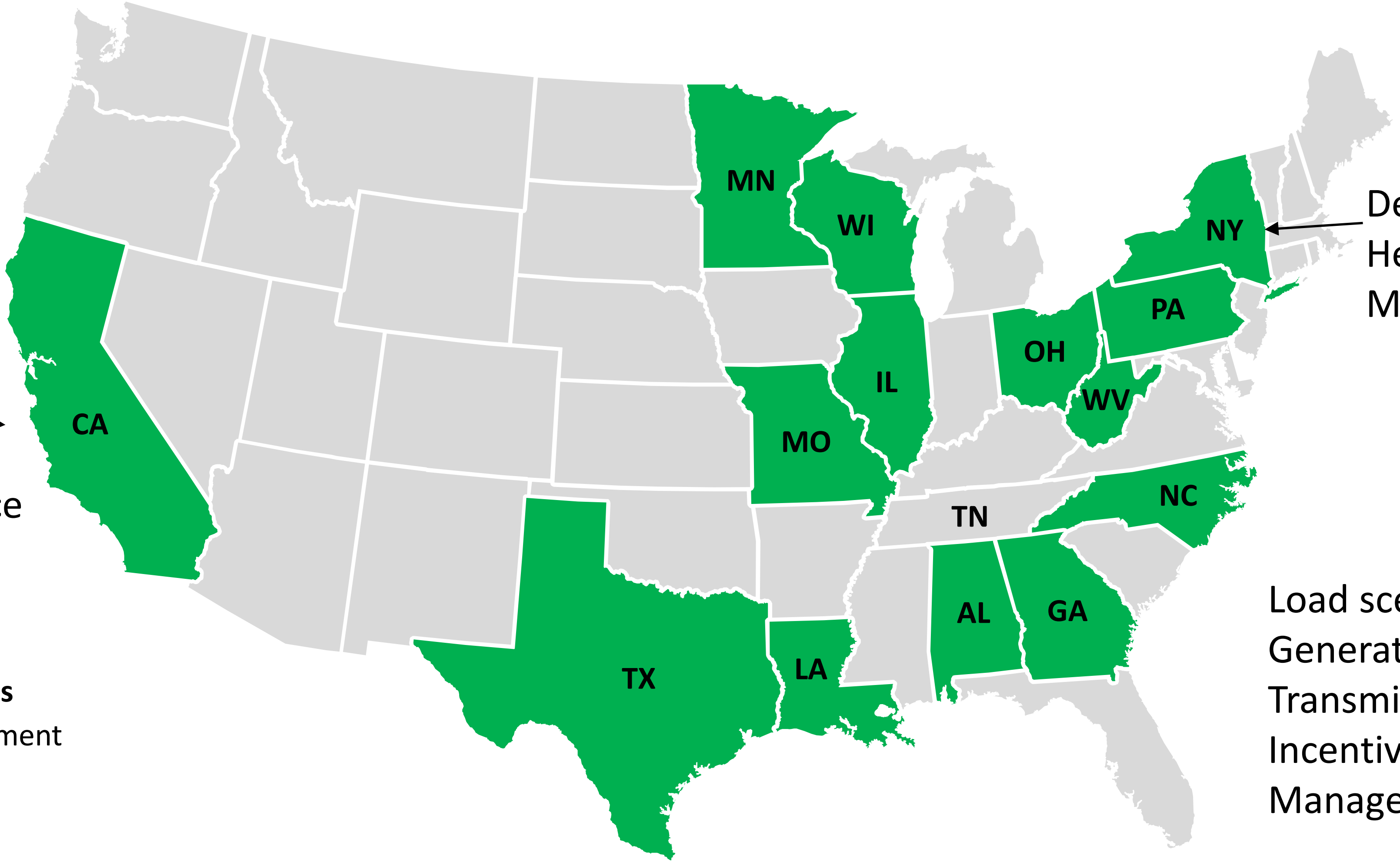
Minnesota Perspectives

Concluding Remarks

# U.S. State & Utility Electrification Assessment Projects:

## Opportunities and Challenges Differ by Energy Infrastructure, Economy, Policy, Climate…

Air Quality
Net-zero Electricity
Environmental Justice




Decarbonization
Heating Technologies
Medium Transport

Load scenarios
Generation mix
Transmission needs
Incentives/strategies
Managed heat and EV charging

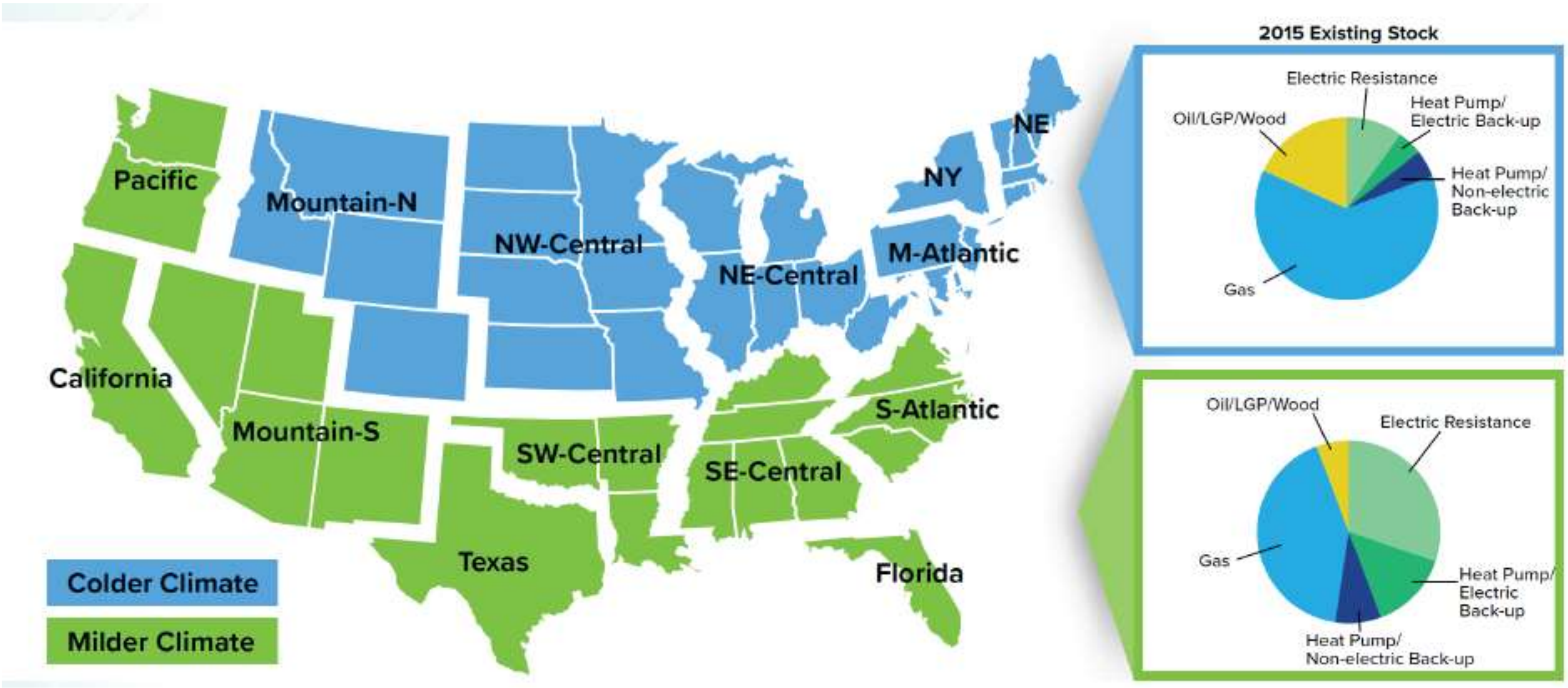
**Key – State Project Status**

- Funding Commitment

**Current U.S. Participation: 14 States with 17 Members … plus Ontario and South Korea**

Update: June 13, 2019

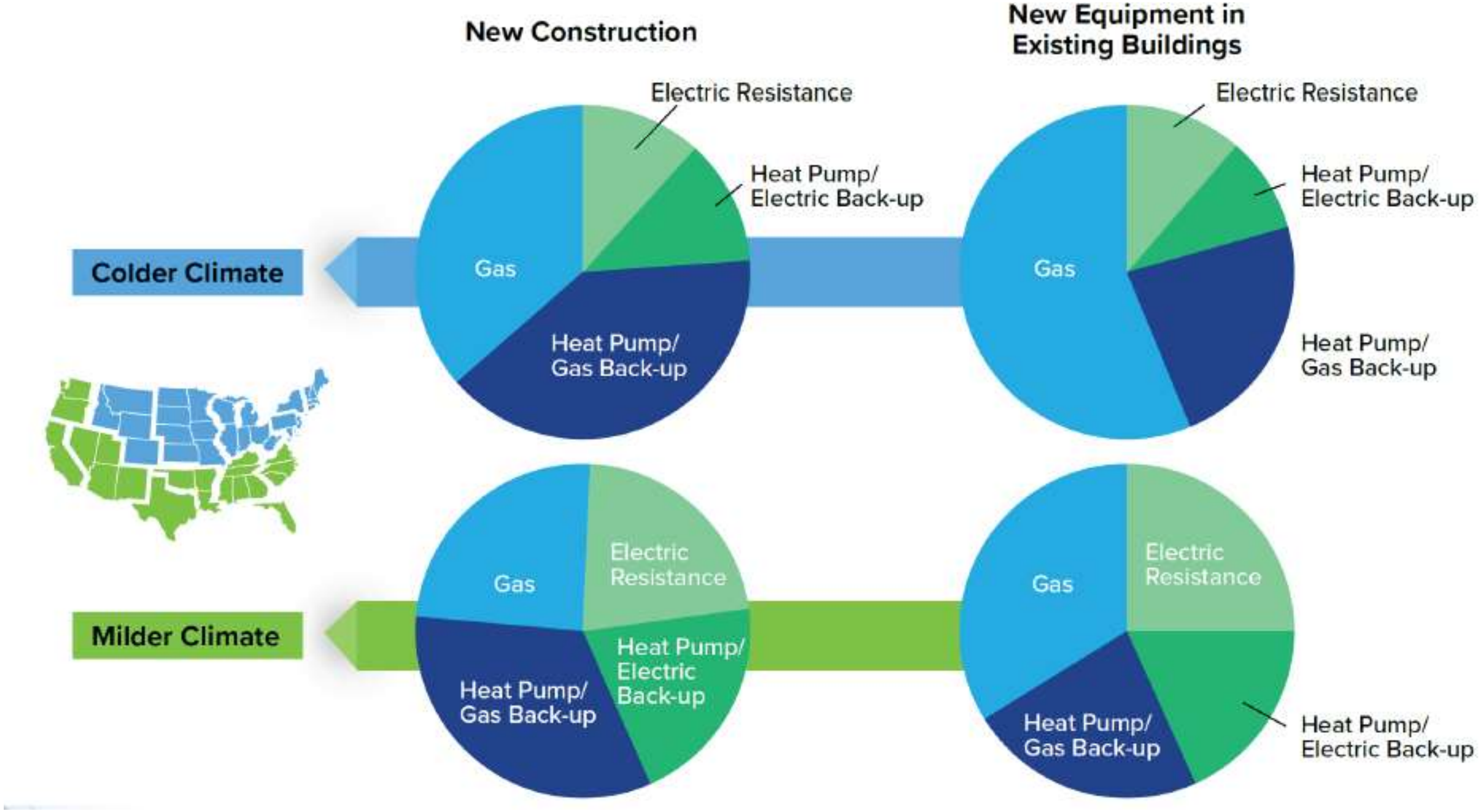
# Space Heating in 2015 – Colder vs. Milder Climates




**80% fossil**
**10% heat pump**

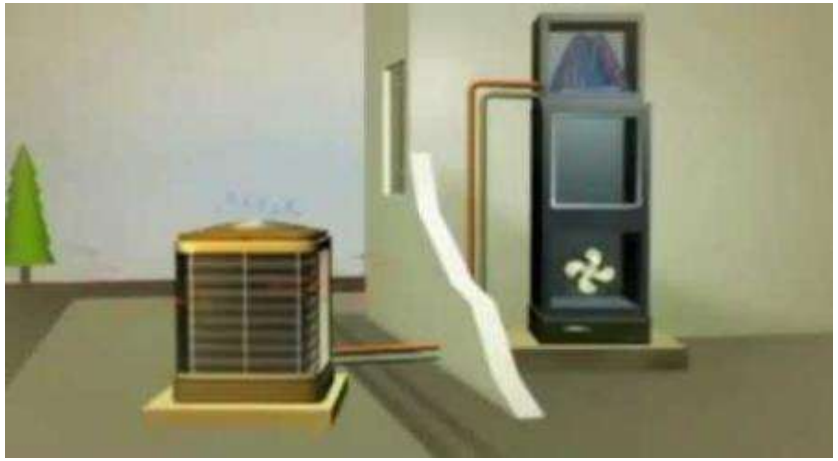
**< 50% fossil**
**23% heat pump**

# Projected Space Heating in 2030 – Colder vs. Milder Hard to Beat the Incumbent Technology



# Although “Mature”, Heat Pump Technology Poised for Dramatic Improvements

US National Electrification Assessment assumed current technologies.  Near-term advances reduce cost and grid impacts and can improve resiliency



- Next Generation Variable Capacity Heat Pumps (VCHP)
  - Operate effectively to 5F and below (versus 30F typical today)
- Advanced Residential Heating Systems
  - Integrated operation of heat pump and backup
  - Smart-grid capabilities
    - With fossil backup and non-electric operation, can provide flexibility and resiliency

Source: Extreme Cold Weather and Heat Pumps (2019).EPRI Quick Insights 3002016792.

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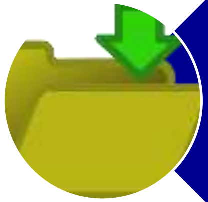
# Objectives for Cost-Effectiveness Framework

**Defensible**

Rooted in standard energy efficiency tests widely accepted by regulators

**Rigorous**

Comprehensive costs and benefits, e.g. societal impacts, grid impacts, and avoided costs beyond power sector



**Applicable**

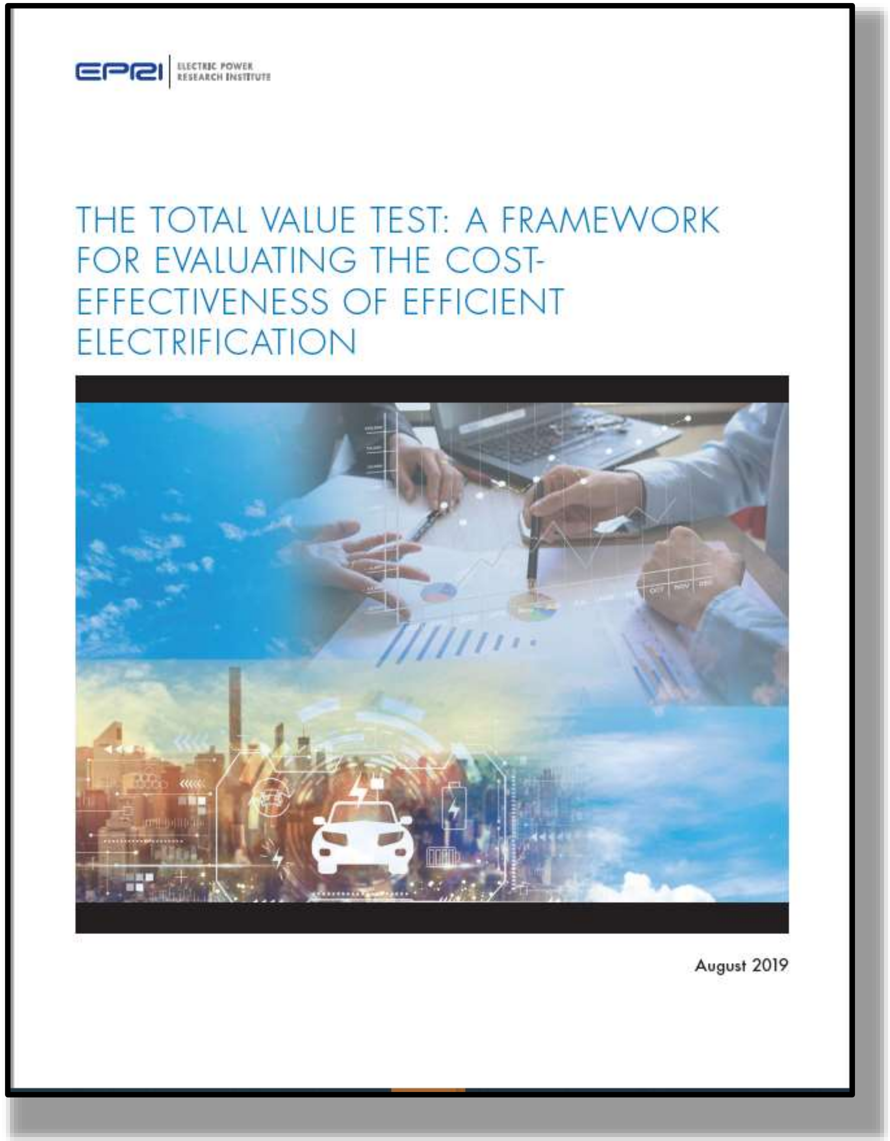
Usable by utilities in regulatory filings to justify electrification programs

**Flexible**

Adaptable to any electrification program or locale

# EPRI "Total Value Test"

- Energy efficiency cost-effectiveness metric, inclusive of electrification
- Amalgam of best attributes of standard energy efficiency tests implemented for decades
- Adapted and refined for more comprehensive benefits and costs characteristic of electrification, including environmental and grid impacts
- Objectively compares cost-effectiveness of electric, natural gas, and other options
- NOT pre-disposed to any particular fuel choice
- Published August 2019, available on EPRI.com





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# Standard energy efficiency cost-effectiveness tests do not adequately capture value of Electrification

**Energy Efficiency Cost-Effectiveness Tests**

Participant Cost

Total Resource Cost (TRC)

Ratepayer Impact Measure (RIM)

Utility / Program Administrator Cost

Societal Cost

Originally developed in California in 1980s

Periodically tweaked but never overhauled

Applied (unevenly) across states for decades

Each test assumes a different point of view

Incomplete treatment of utility system impacts

Asymmetrical application of costs and benefits

**Electrification requires more robust treatment**

# Electrification encompasses more benefit and cost categories

### ENVIRONMENTAL IMPACTS

- GHG Emissions
- Air Quality
- Water
- Land
- Other Resources


### ECONOMIC IMPACTS

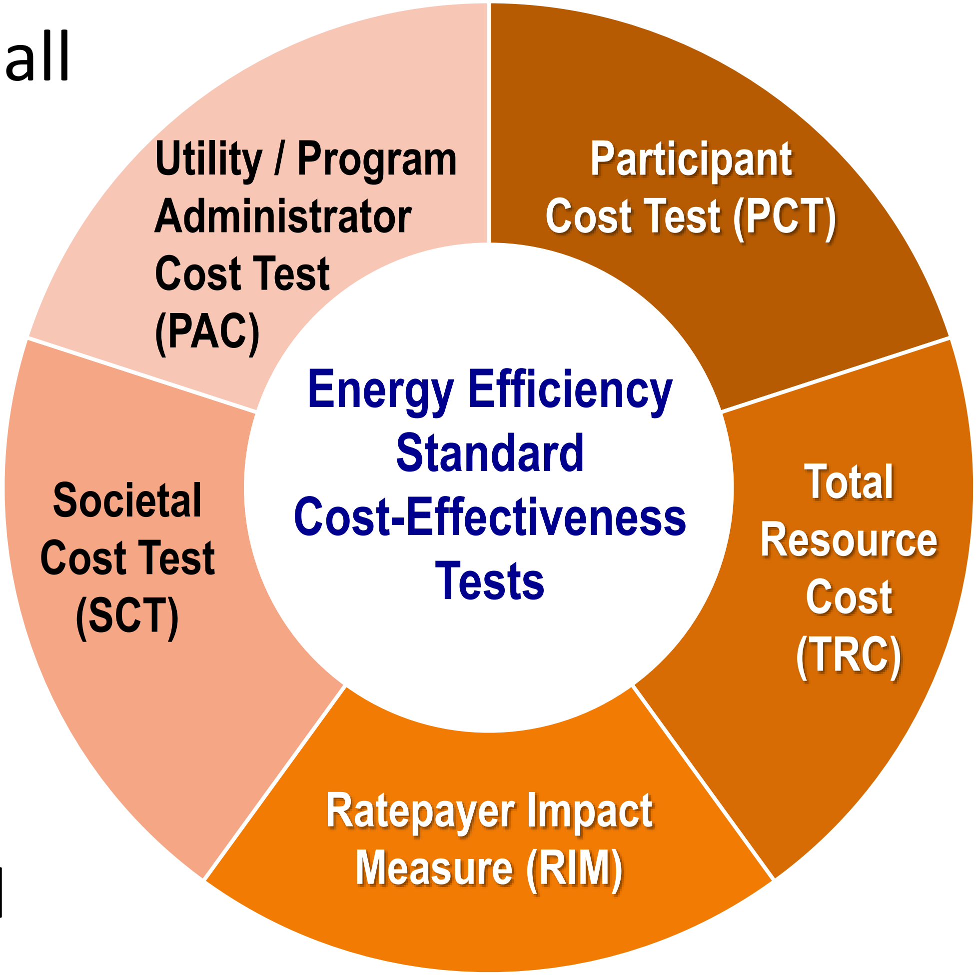
- Productivity
- Product Quality
- Worker Health and Safety
- Occupant Comfort
- Cost of Service

### ENERGY INFRASTRUCTURE

- Avoided Costs
- Grid Flexibility
- Reliability

# Leveraging and Extending Energy Efficiency Tests

- Comprehensive view of benefits & costs from all perspectives (societal + customer + utility)
- Applicable for electrification and energy efficiency, whether electric or non-electric
- Quantifies environmental and grid flexibility impacts, using EPRI best practices
- Extends Total Resource Cost (TRC): cross-fuel comparison; non-energy impacts
- Refines Societal Cost Test (SCT): customer and utility impacts; more realistic discount rate



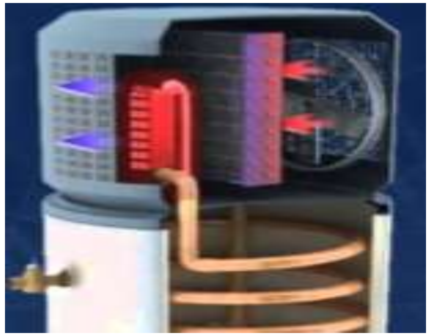

***Total Value Test (TVT)***

# Total Value Test Case Studies

Battery Electric vs. Diesel City Buses


Indoor Agriculture

Residential Water Heating



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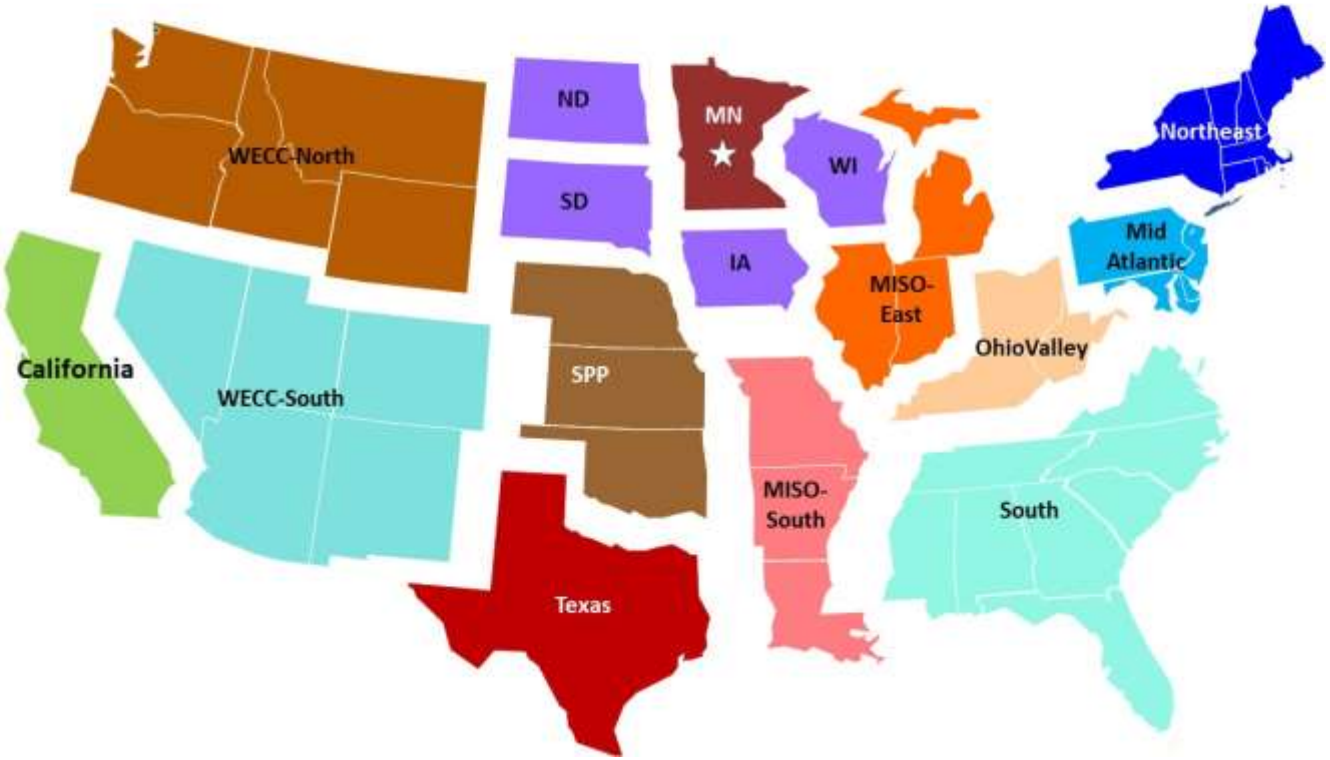
# Minnesota Electrification Study with Great River Energy Underway


Scenarios include:

- Reference (with variations on imported power, natural gas price, and end-use technologies)
- Zero-carbon electricity
- 80% economy-wide reduction

Preliminary results directionally consistent with US results, but point out the issues with state-level (rather than national) action.

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# Electrification Appears an Effective (Likely Necessary) Means to Many Goals … But is Not a Given

Technology Improvement: Cost + Performance

Policy and Market Design: An Economy-wide View

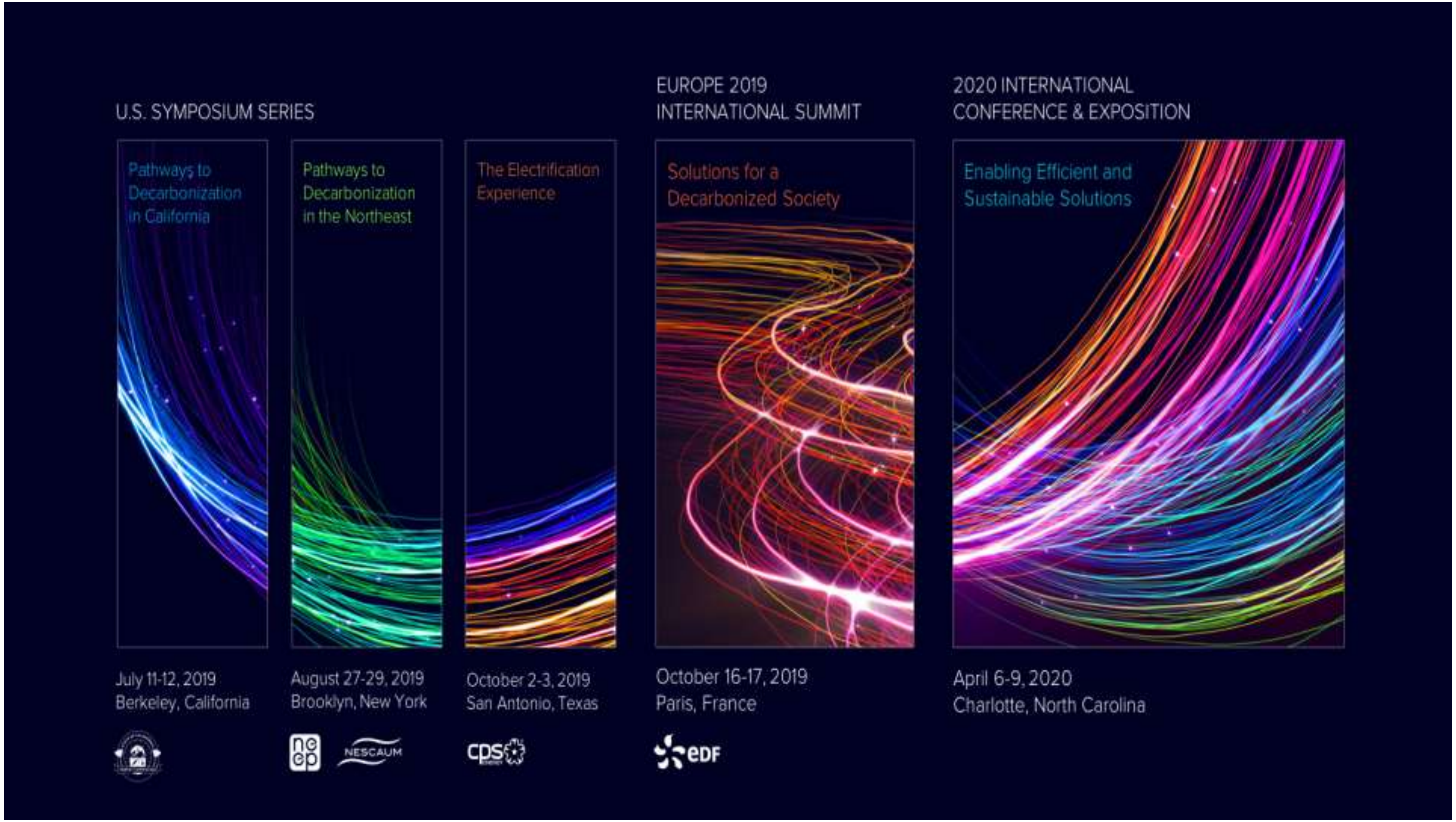
Infrastructure Investment

Analyzing Customer Choice

Encouraging Proactive Consumer Behavior

Fundamentally New Options: Autonomous/Shared Mobility

# Communication: Sharing Information and Experience



# Together…Shaping the Future of Electricity

**Tom Wilson**
650-855-7928
twilson@epri.com