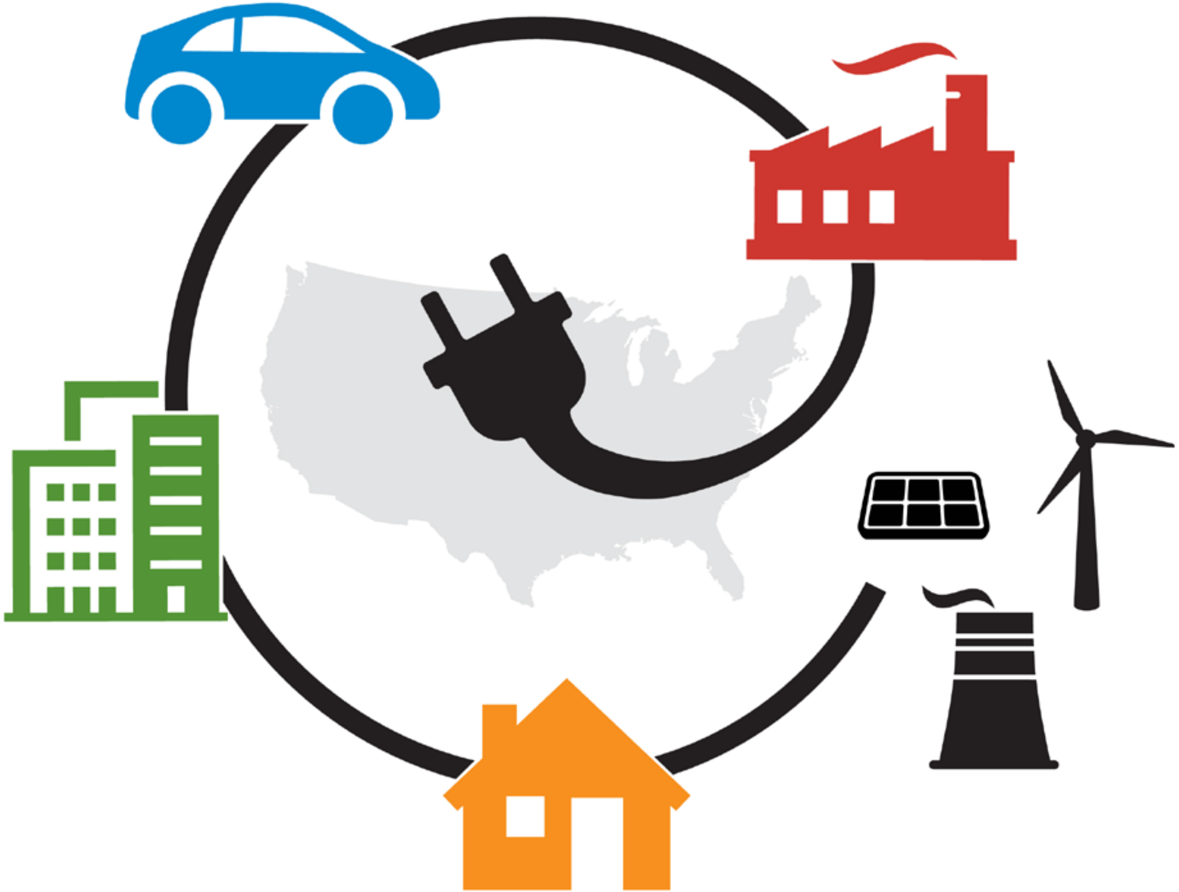
The Electrification Futures Study: **Demand-Side Scenarios**

Webinar
July 26, 2018

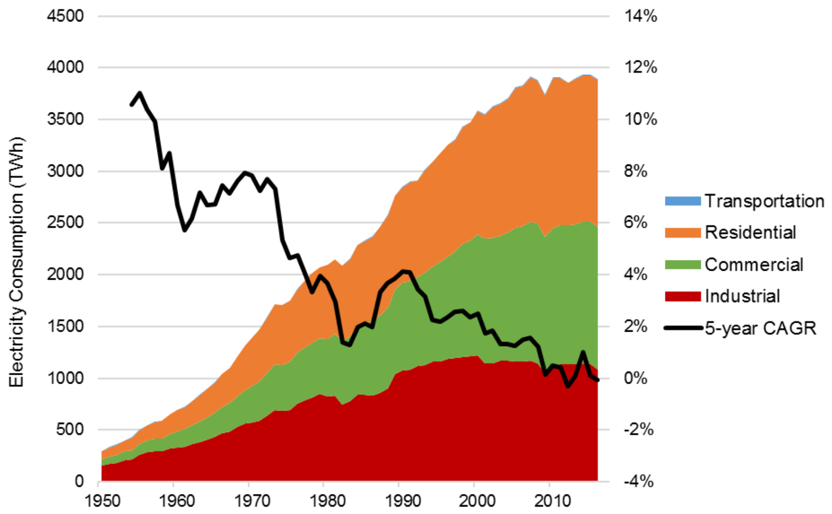
NREL/PR-6A20-72096

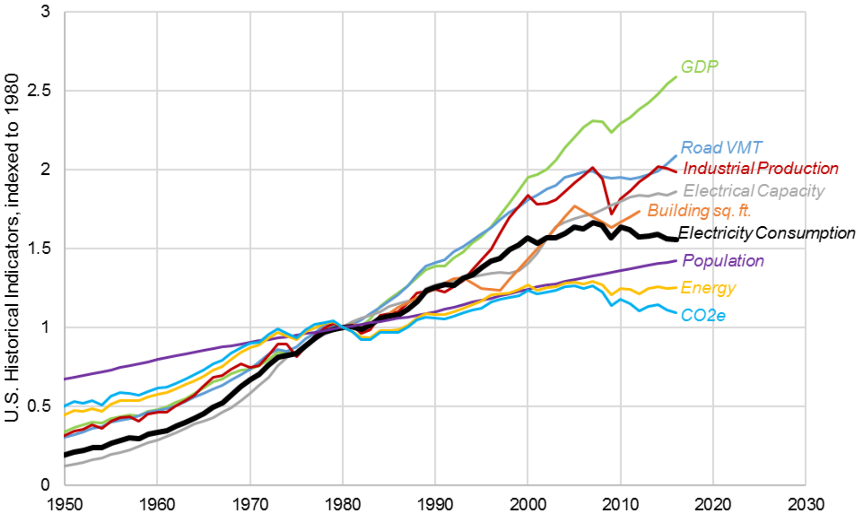


nrel.gov/EFS


Electricity is **integral** to our daily lives—
and increasingly so

Yet total growth in electricity demand has **slowed**



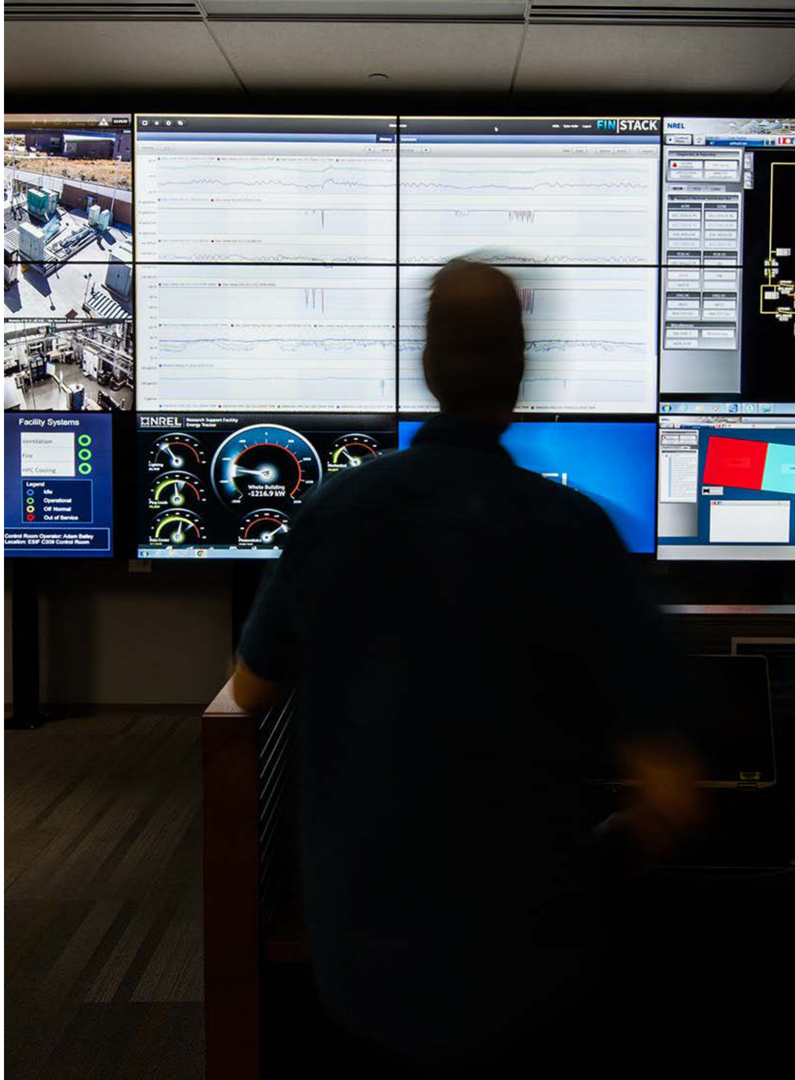


While U.S. population, GDP, and end-use services have all **increased** and changed in complex ways

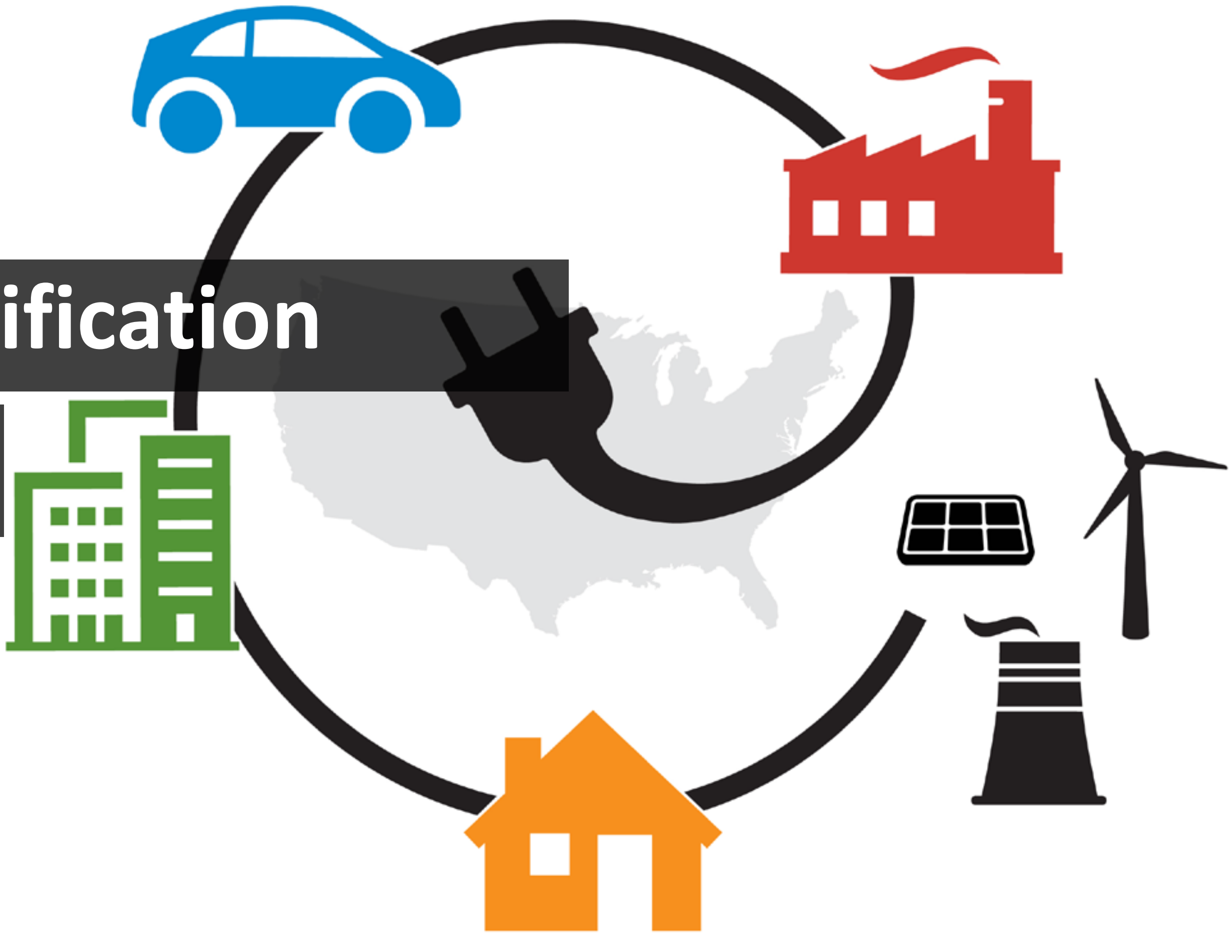
But **greater** electrification may be on the horizon

- Development of **advanced electric technologies** has driven adoption in key sectors—especially in vehicles, but also for businesses and homes
- Local policies and economic incentives support electrification to **reduce emissions**, **improve air quality**, and **increase energy security**
- Electric utilities are carefully watching to see if electrification has the potential to **increase sales and revenues**

So how do we plan for **widespread electrification?**



EFS: The Electrification Futures Study



nrel.gov/EFS

NREL-led collaboration, multi-year study

Collaborators from:

- EPRI
- Evolved Energy Research
- Northern Arizona University
- Oak Ridge National Laboratory
- Lawrence Berkeley National Laboratory
- U.S. Department of Energy

NATIONAL RENEWABLE ENERGY LABORATORY

- Strategic Energy Analysis
- Transportation and Hydrogen Systems
- Buildings and Thermal Systems

+ **Technical Review Committee** of 19 experts from industry and consultants, labs, government, NGOs

Study sponsored by U.S. DOE-EERE Office of Strategic Programs

Answering **crucial questions** about:

Technologies

What electric technologies are available now, and how might they **advance**?

Consumption

How might electrification impact electricity **demand** and **use patterns**?

System Change

How would the electricity system need to **transform** to meet changes in demand?

Flexibility

What role might **demand-side flexibility** play to support reliable operations?

Impacts

What are the potential **costs, benefits, and impacts** of widespread electrification?

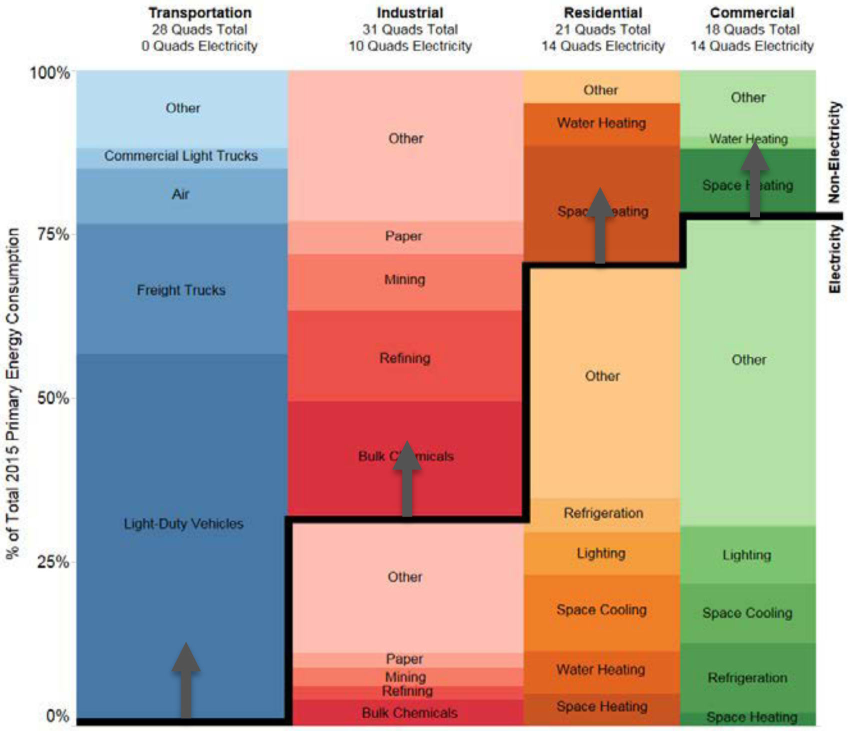
Progress to date

- Technology cost and performance (December 2017)
- Demand-side adoption scenarios (June 2018)
- dsgrid model documentation (coming soon)
- Supply-side evolution scenarios (2019)
- Impacts of electrification (2019)
- Electricity system operations (~2020)
- Value of demand-side flexibility (~2020)

Note: Future work scope is tentative

Scope and definitions

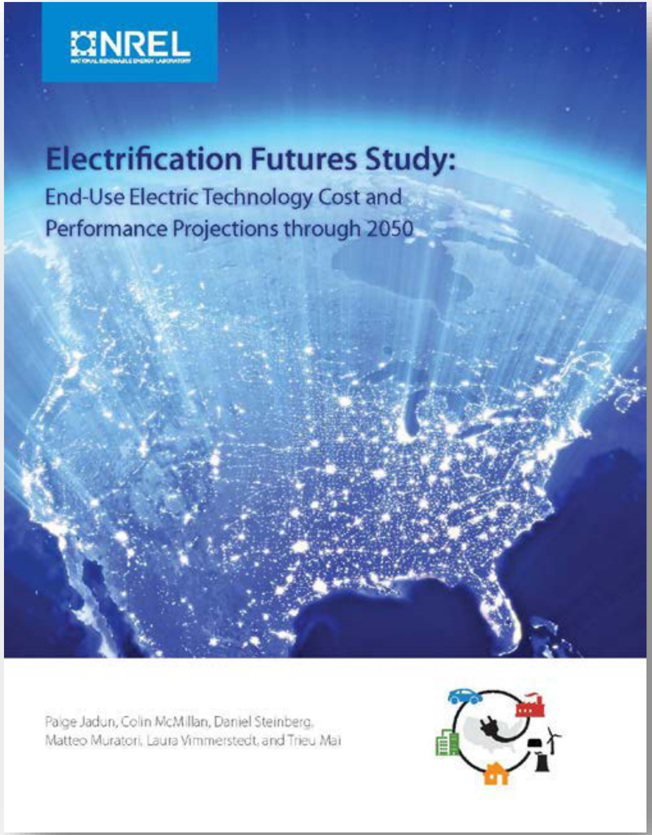
- **Electrification**: the shift from any non-electric source of energy to electricity at the point of final consumption
  - Direct electric technologies only
  - Not exploring new sources of demand
  - Isolating electrification from other changes
- **Contiguous U.S. energy system**, including transportation, residential and commercial buildings, industry
  - Sectors cover **74% of primary energy in 2015** (79% of energy-related CO_2)
  - Excludes air, petroleum refining and mining, CHP, outdoor cooking
- **Focus on 2050**, but transition modeled as well



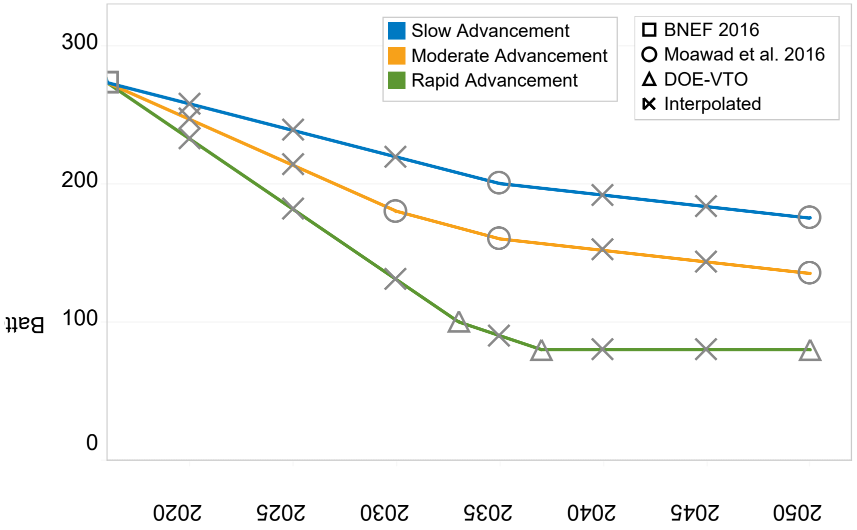
Technology Cost and Performance Data Report

(December 2017)

https://www.nrel.gov/docs/fy18osti/70485.pdf



Foundational technology data

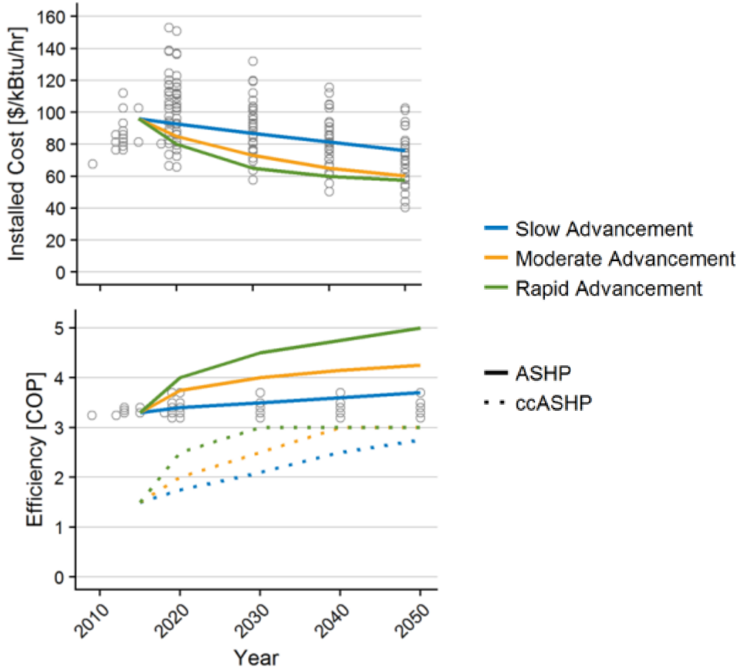


- Three technology advancement trajectories (slow, moderate, rapid) for **buildings** and **transportation** technologies
- Literature-based summary of **industrial** electrotechnologies

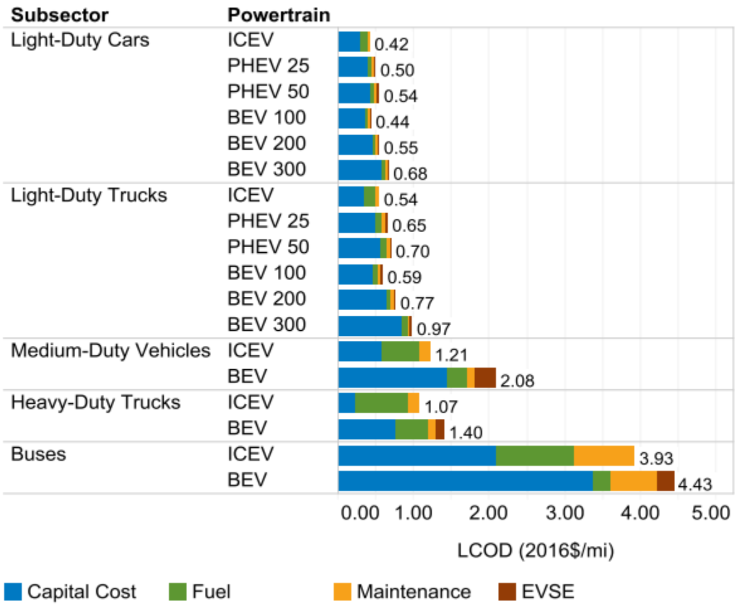
Key Technologies:

- Light-duty and heavy-duty vehicles, buses (multiple range PHEVs and BEVs)
- Air-source heat pumps (including cold-climate ASHPs)
- Heat pump water heaters

Used in EFS modeling and **available for download**



Commercial ASHPs
installed cost and efficiency projections

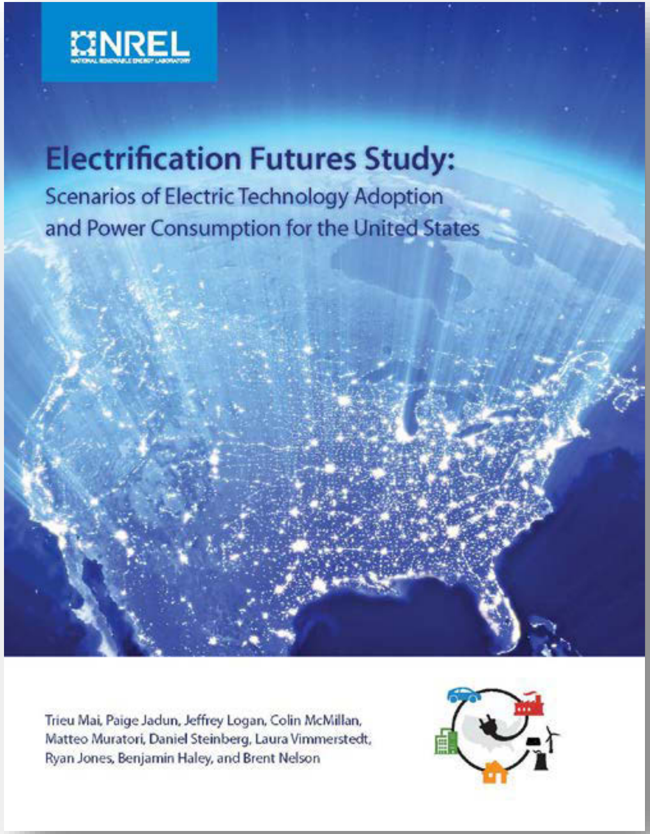


Levelized cost of driving (2020 Moderate)

Demand-Side Scenarios Report

(June 2018)

https://www.nrel.gov/docs/fy18osti/71500.pdf



Looking at the **demand side**

OBJECTIVES

Characterize **changes to end-use sectors** under futures with increasing levels of electrification

Quantify how electrification impacts **total electricity demand** and **consumption profiles**

APPROACH

Expert judgment **adoption projections** and **consumer choice modeling**

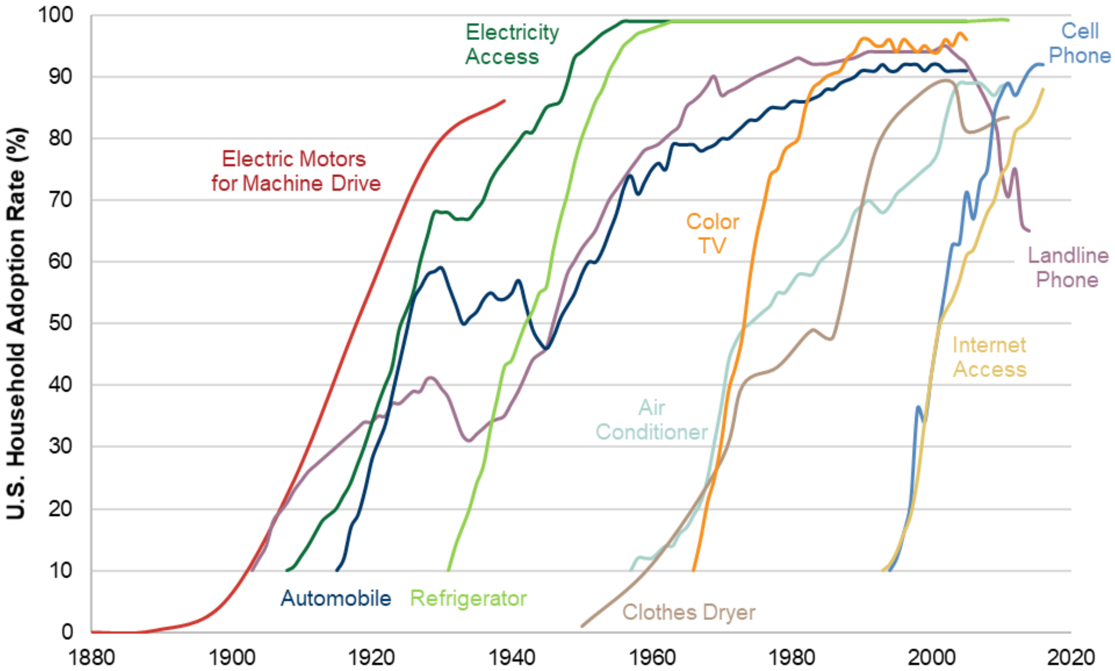
Bottom-up **stock and energy accounting model** (EnergyPATHWAYS)

USES

Provides data for evaluating **future electricity supply scenarios**

Gives researchers and decision-makers **data and context** to plan for an electrified energy system

Technology adoption and energy transitions generally follow characteristic **S-curve shape**

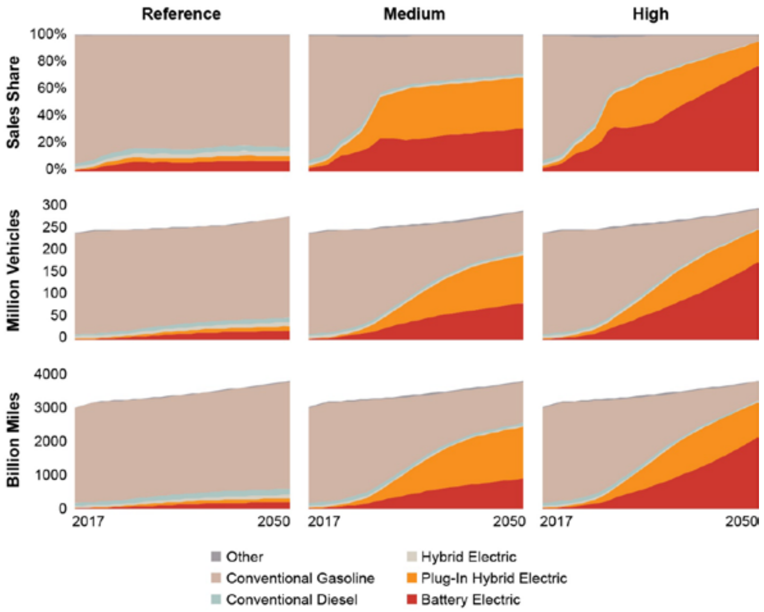


invention → innovation → niche market → pervasive diffusion → saturation → senescence

Method in brief:

Electrification follows a similar trend

Example for light-duty vehicles



Sales shares determined from a combination of expert judgment based on current trends & consumer choice models (e.g., NREL ADOPT model for LDVs)

EnergyPATHWAYS model used for stock rollover and detailed energy accounting

Principles: technology-rich assessment, bottom-up accounting, cross-sectoral breadth, national scope with state-level detail

Scenarios

- **Reference**: Least incremental change (~AEO2017)
- **Medium**: Widespread electrification among low-hanging fruit opportunities
- **High**: Transformational electrification
  - *focus of this presentation*
- + end-use technology advancement sensitivities

Scenarios designed for assessment of isolated impacts of electrification
Scenarios are not forecasts or predictions

What we found:

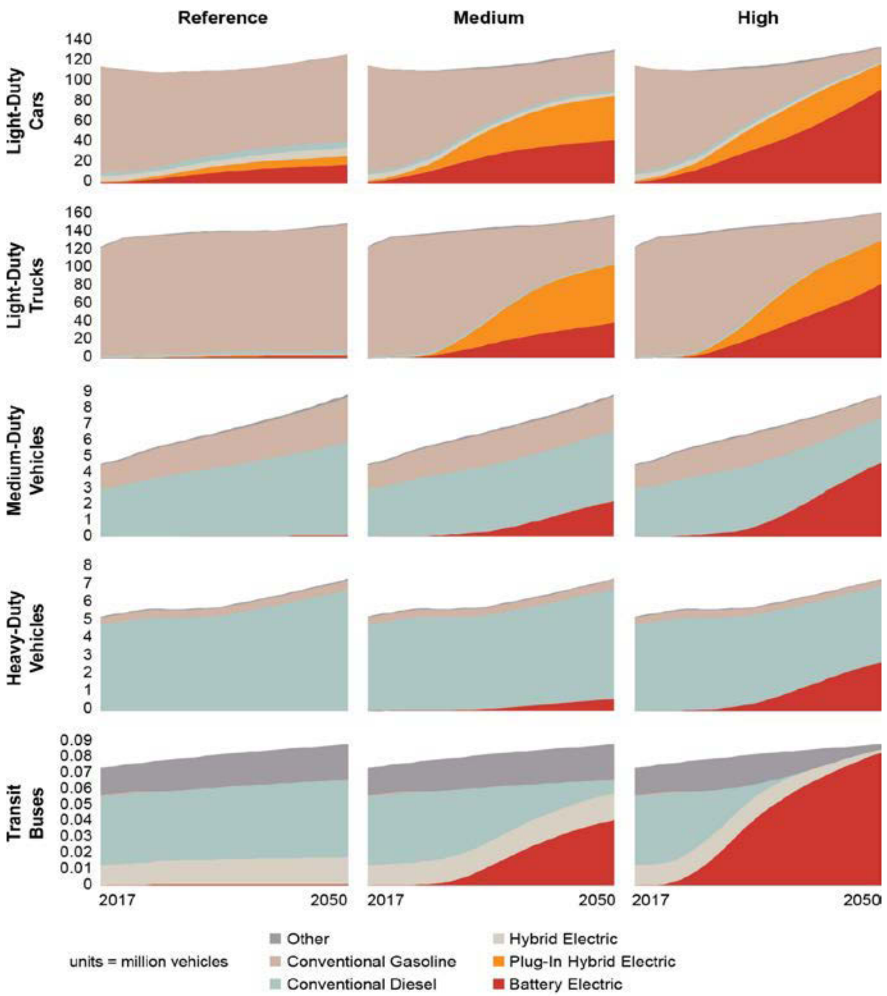
Key takeaways by sector

Transportation sector

- Significant opportunities exist for electric vehicles, in part because electricity currently provides <1% of total transportation energy needs
- **Light-duty plug-in electric cars and trucks** drive the greatest overall electrification impact in all scenarios
- But **electric freight trucks** can play a major role, particularly for short-haul applications and in more transformational scenarios
- **Transit buses** are prime candidates for electrification

Transportation sector **details**

- 2050 U.S. transportation fleet (High scenario):
  - **240 million** light-duty plug-in electric vehicles
  - **7 million** medium- and heavy-duty plug-in electric trucks
  - **80 thousand** battery electric transit buses
- Together these deliver up to **76%** of miles traveled from electricity in 2050
- 138,000 DCFC stations (447,000 plugs) and 10 million non-residential L2 plugs for light-duty vehicles



Key questions in transportation electrification

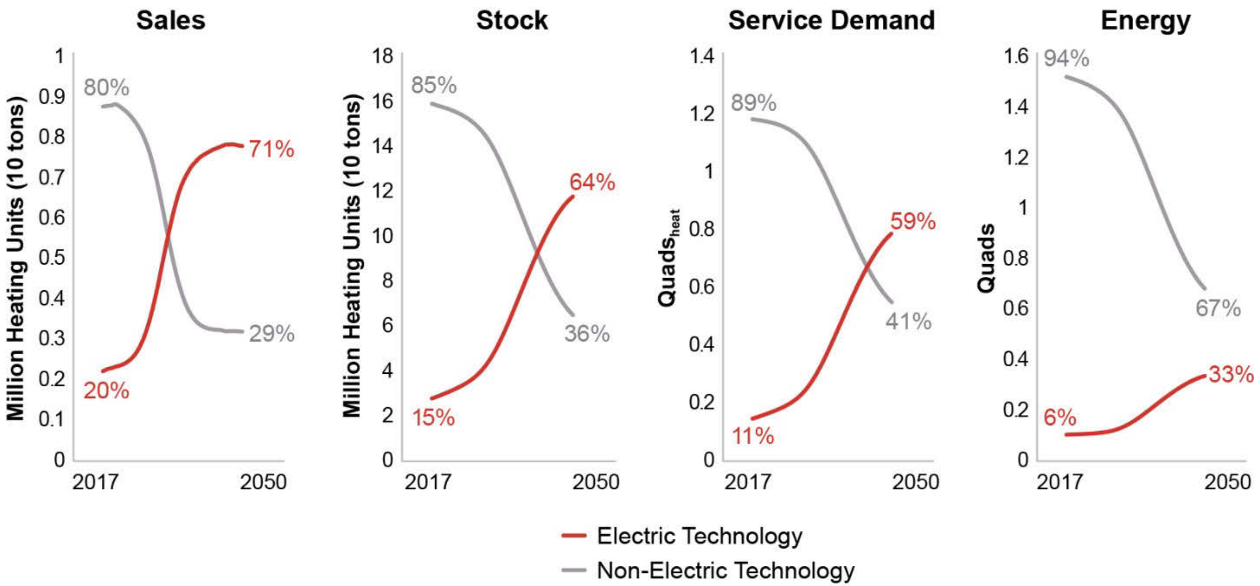
- Will **battery costs** continue to decline, and will battery **performance** continue to improve?
- How might **consumer preference**—range anxiety, acceleration, automation—and technology development evolve?
- Will **EVSE infrastructure** enable or impede electrification?
- How will **ownership models**—for vehicles and chargers—evolve and impact utility planning? How might **utility-controlled charging** and **vehicle-to-grid services** affect energy use and adoption?

Buildings sector

- Electricity already powers a significant share of buildings end-use services
- Electrification opportunities in buildings are most significant for **space and water heating**
- Air-source **heat pumps** are the key buildings electrification technologies

Buildings sector **details**

Commercial space heating (High scenario)



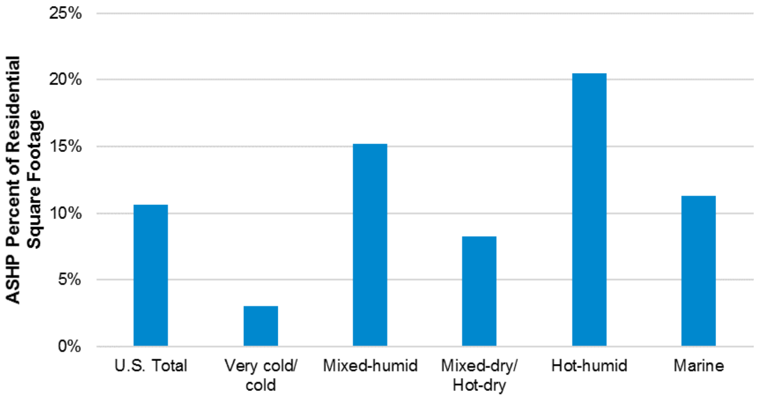
- Electric equipment provides up to **61% of space heating**, **52% of water heating**, and **94% of cooking services** in the combined commercial and residential building sectors by 2050 (High scenario)
- Would require dramatic change in **appliance manufacturing** and **installations** (170 million heat pumps in 2050*)

*Heat pumps include ASHPs and geothermal heat pumps (sales shares of geothermal heat pumps reach 3% by 2050 for commercial space heating in the High scenario)

Key questions in buildings electrification

- Will advancements in **cold-climate** heat pumps be sufficient to enable widespread adoption?
- Will new technologies facilitate electrification in **retrofits** and new buildings?
- How might **challenges** to buildings electrification—cultural acceptance, familiarity, landlord-tenant issues—be overcome?
- How might **value streams** through “smart” and “grid-connected” appliances affect consumer adoption?

Non-uniform adoption of ASHPs in commercial buildings (2012)

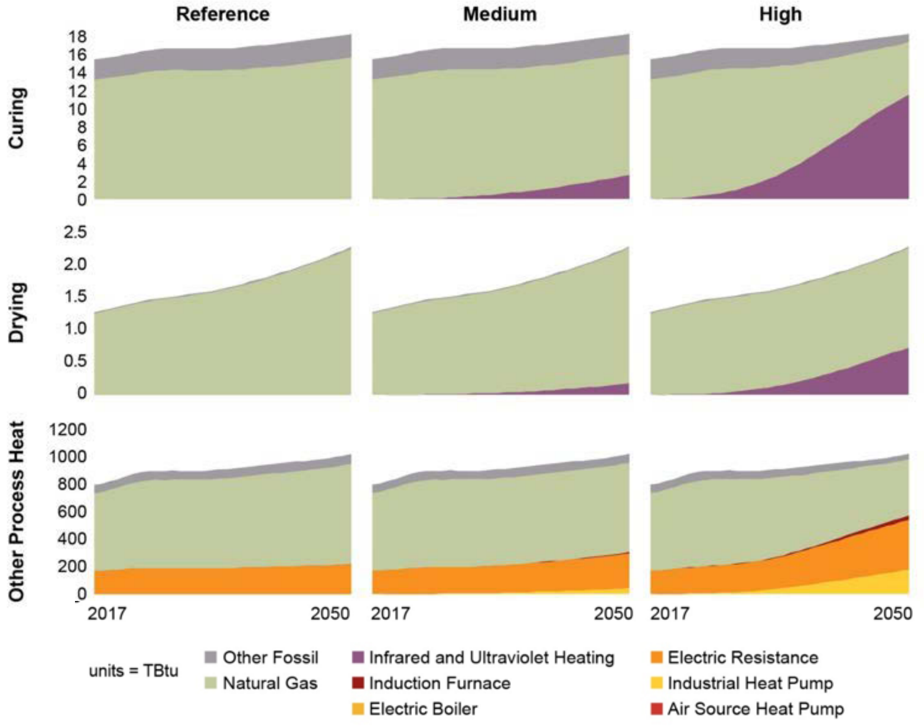


Industrial sector

- Industry experienced early electrification and sustained growth, but electricity consumption has been flat since ~1990
- **Heterogeneity of industries** prevents broad generalizations
- **Limited industrial data** create challenges for assessing electrification opportunities
- We focus on industrial **process heating**

Industrial sector **details**

- Industrial electrification is more muted compared to other sectors
- Most-significant growth for electrotechnologies with **productivity benefits:** improved product quality, higher throughput, reduced scrap and labor costs
- In the High scenario, electrotechnologies provide **63% of curing** needs, **32% of drying** services, **56% of other process heating**



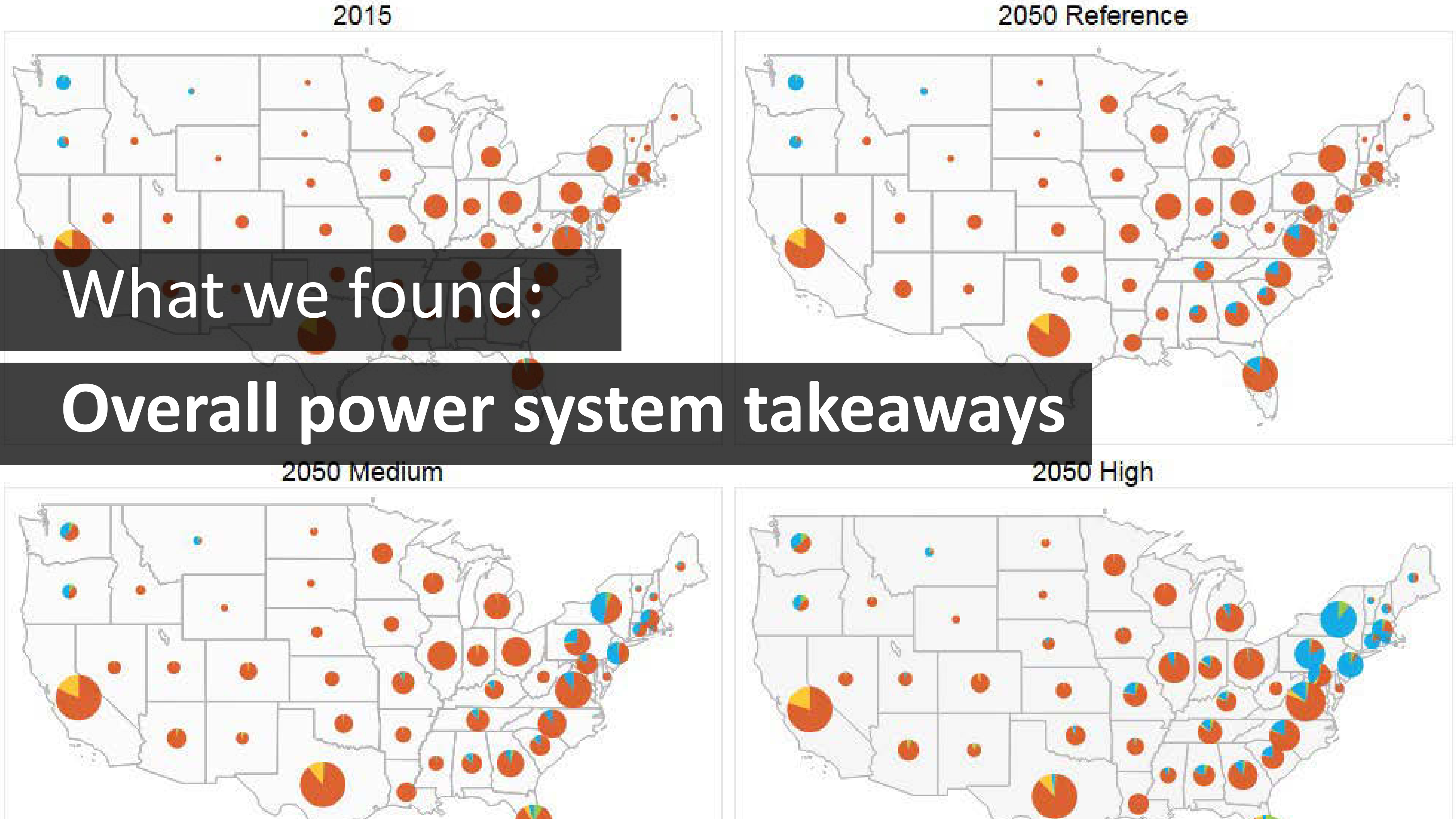
Key questions in industrial electrification

- Will **productivity benefits** from electrotechnologies overcome potentially higher costs and other adoption barriers, especially when energy costs comprise a small share of total costs?
- Can cost-effective technologies for **high-temperature** applications be developed?
- How might the interplay between **long equipment lifetimes** and manufacturers' profit-driven decisions impact the technology transition rate?

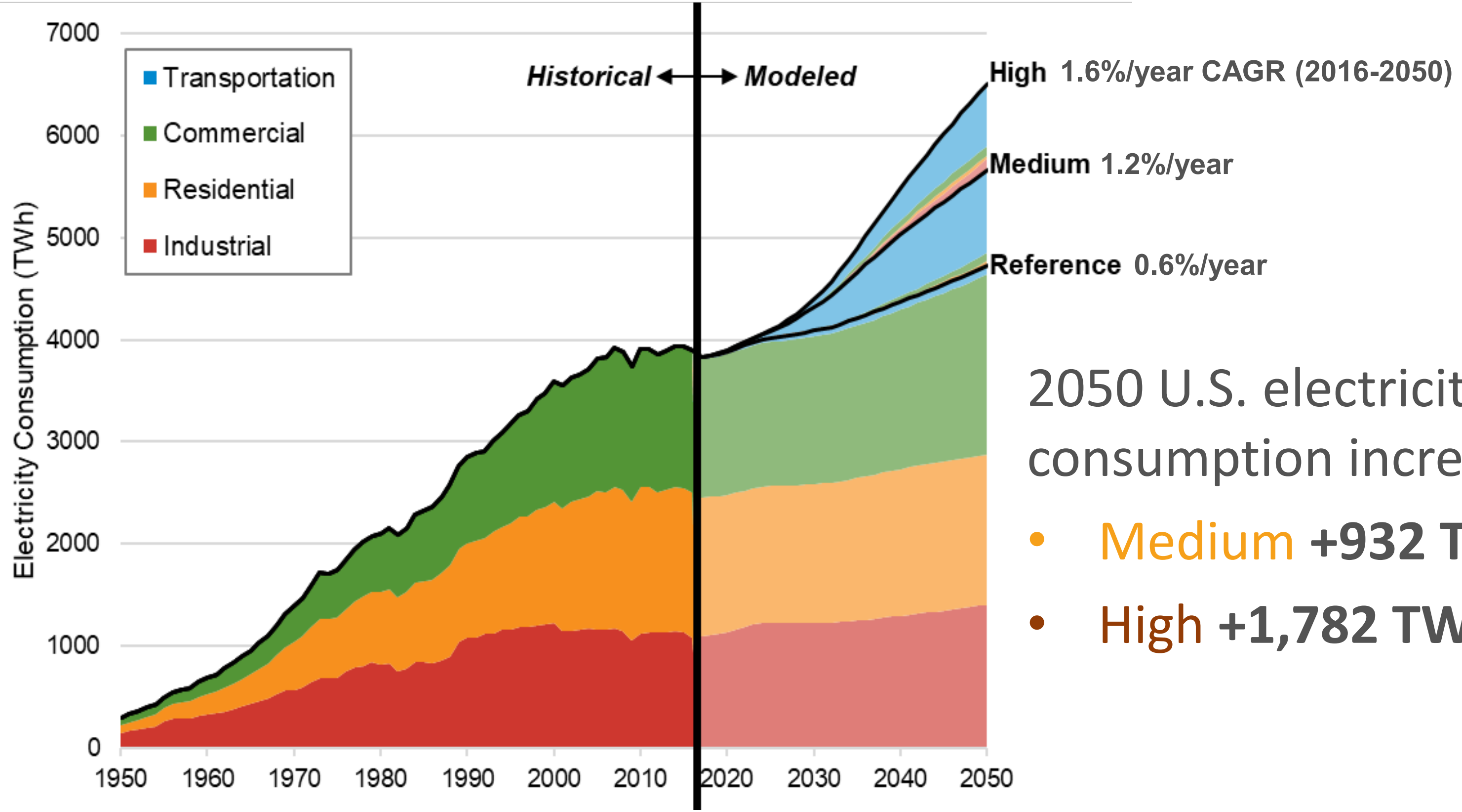
More data and research are needed!

What we found:

Overall power system takeaways



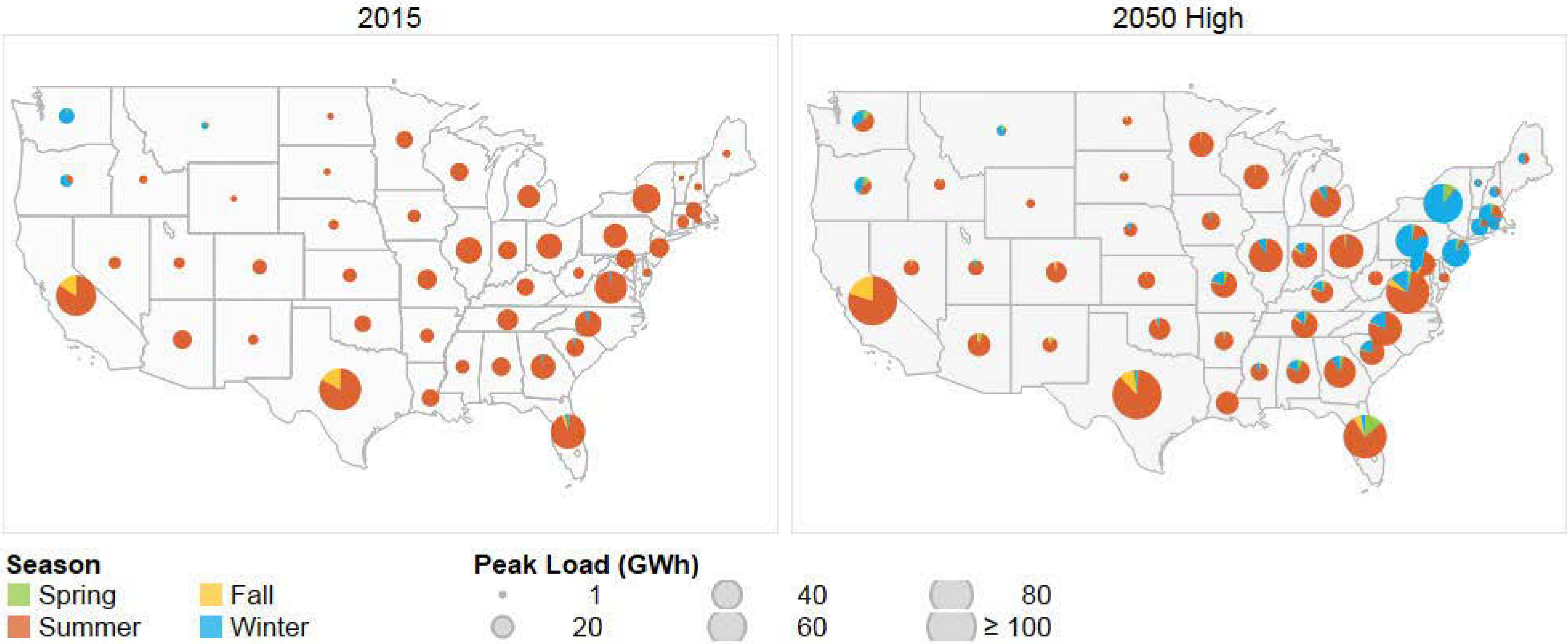
Vehicle electrification dominates incremental growth in **annual** consumption



2050 U.S. electricity consumption increases

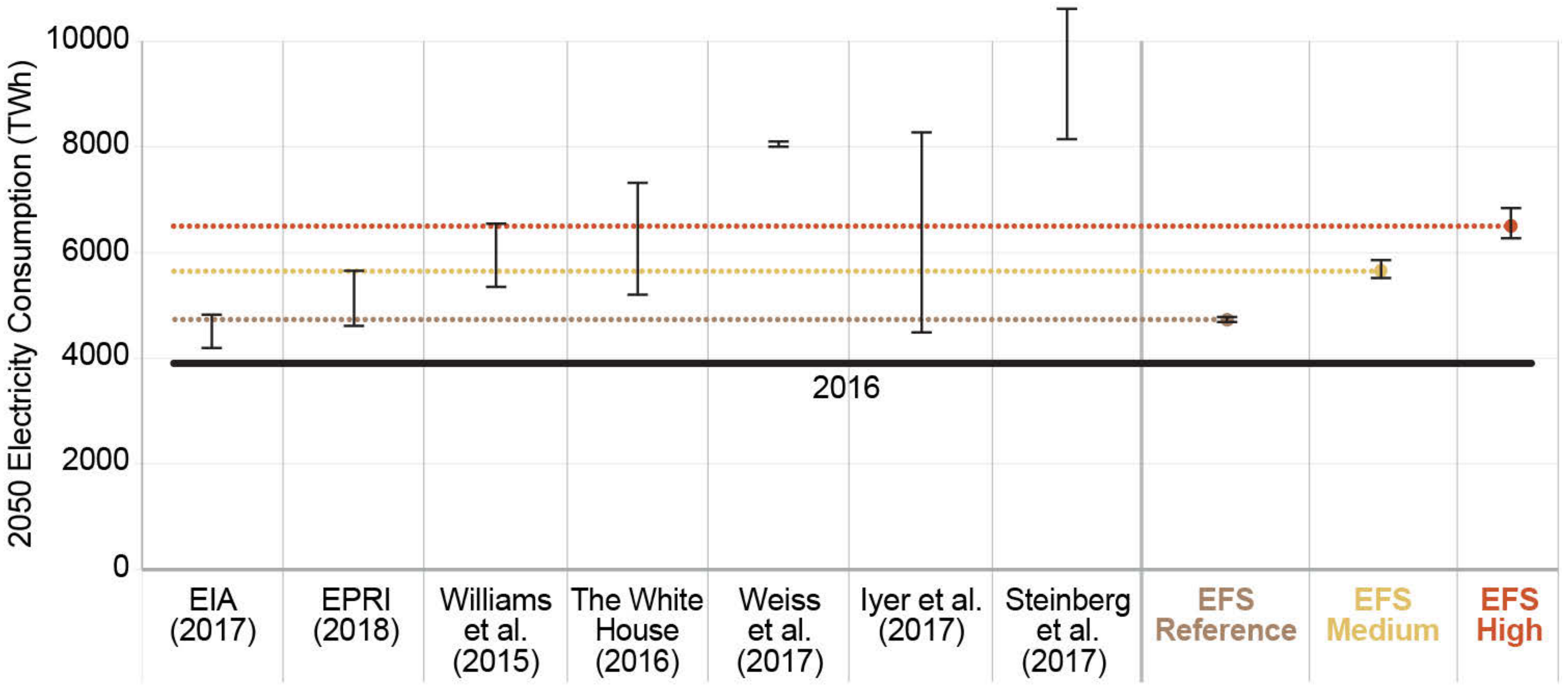
- Medium **+932 TWh (20%)**
- High **+1,782 TWh (38%)**

However, electric space heating more significantly changes the timing and magnitude of **peak demand**

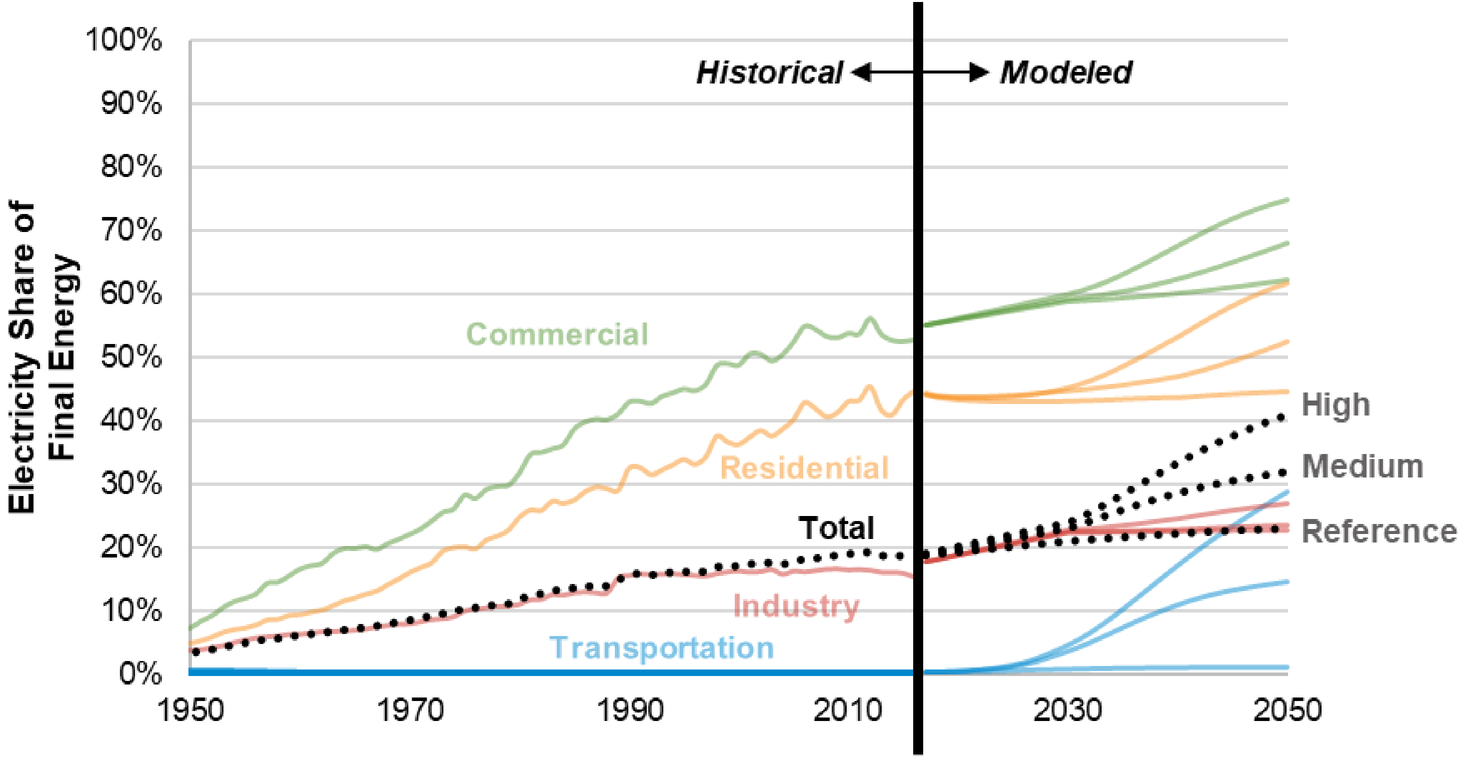


Note: Summer = June-August, Fall = September-November, Winter = December-February, Spring = March-May

Electrification in **Medium** scenario is loosely consistent with that from favorable “economic” conditions; **High** is closer to transformational scenarios



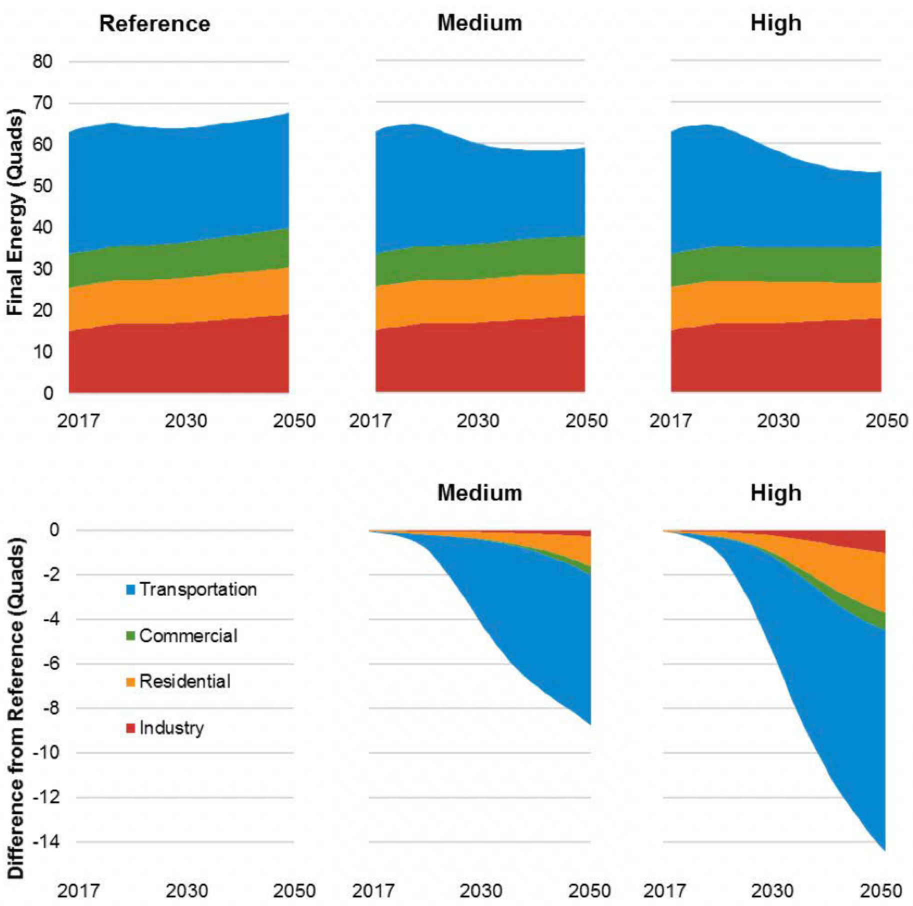
Electricity share of final energy **doubles** from 2016 to 2050 under the High scenario



Note: Sector definitions and scope differ slightly between Historical and Modeled data

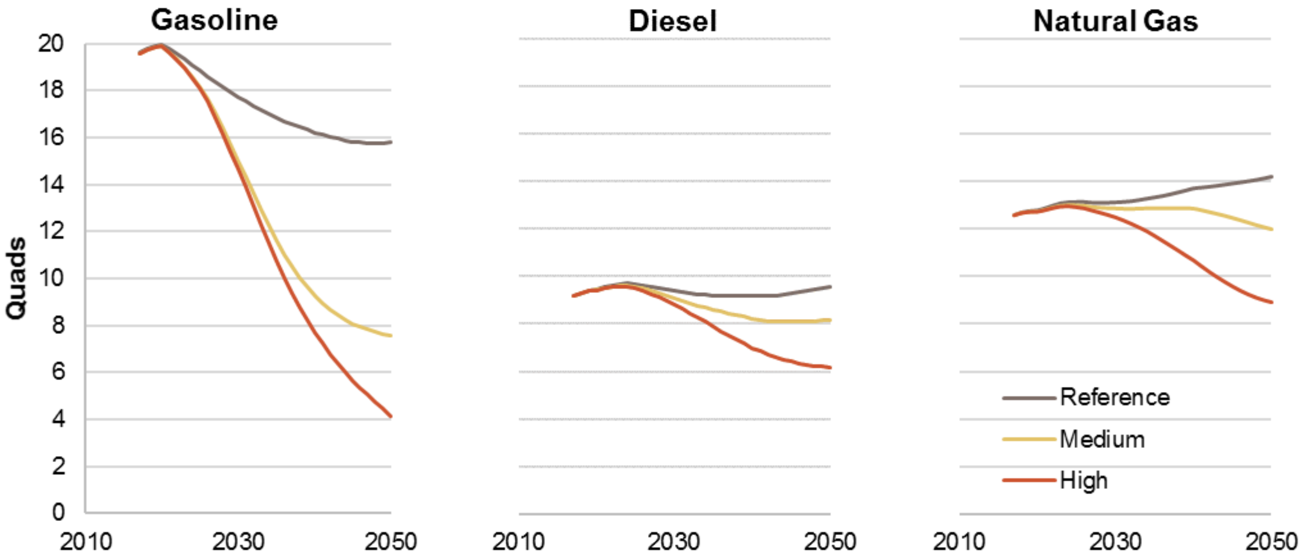
Electrification leads to **energy savings**

- Greater efficiency of electric technologies yields **reductions in final energy consumption** by up to 21% (High scenario), relative to the Reference
- **Technology improvements** could lead to even greater savings
- Impacts to *primary* energy will depend on generation mix



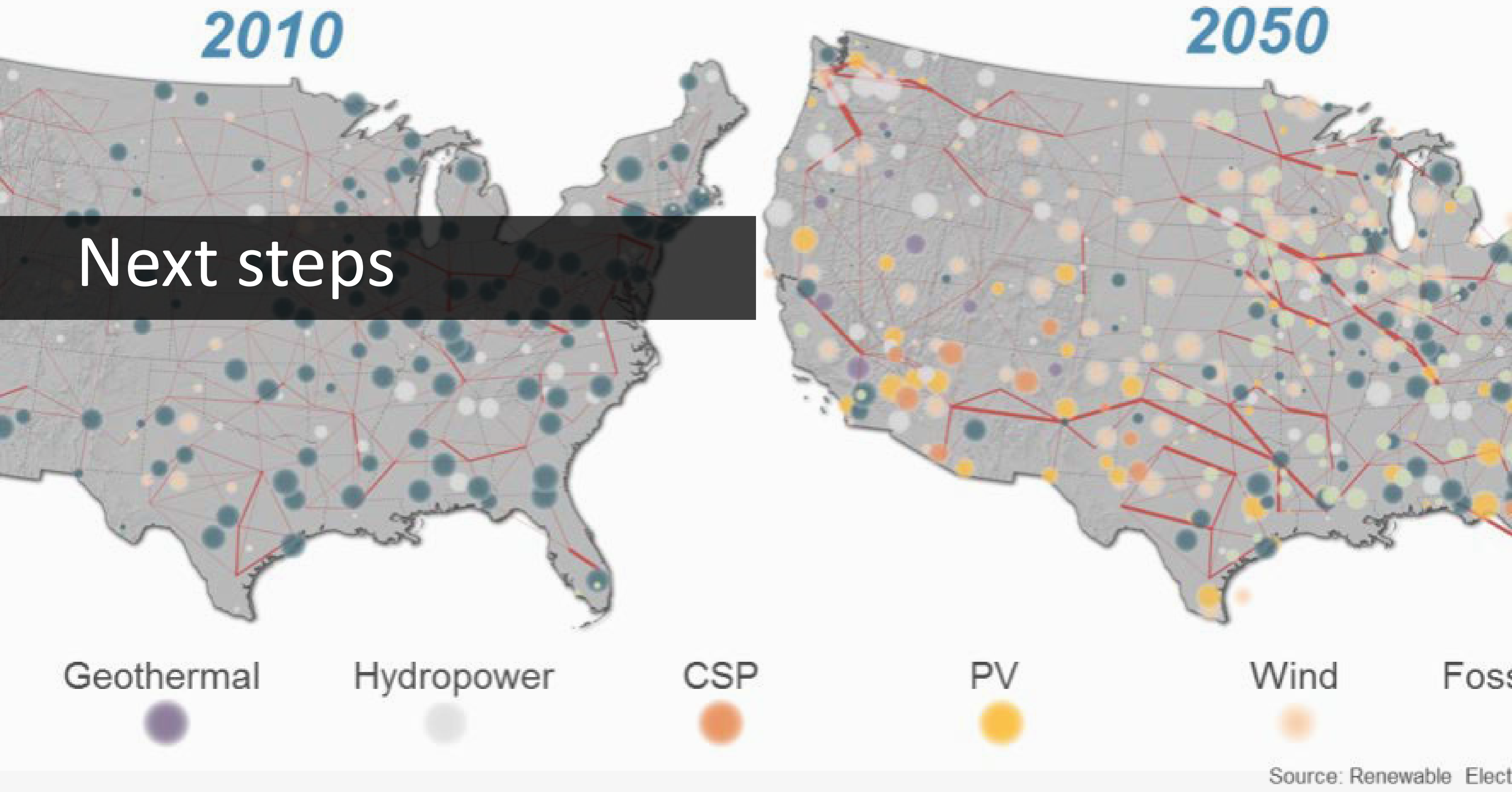
Note: Does not include all activities, e.g., petroleum refining and extraction excluded

Estimated **fuel use** reductions



- Domestic onsite fuel use reductions: **74% gasoline**, **35% diesel**, **37% natural gas** in 2050 (High scenario)
- Expands opportunities for greater fuel use for power generation, fuel exports

Next steps


2010
2050
Geothermal
Hydropower
CSP
PV
Wind
Foss
Source: Renewable Elect

Forthcoming EFS reports

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Thank you

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