NREL
Transforming ENERGY

Electrification of Industry

Summary of Electrification Futures Study
Industrial Sector Analysis

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September 2018

Summary

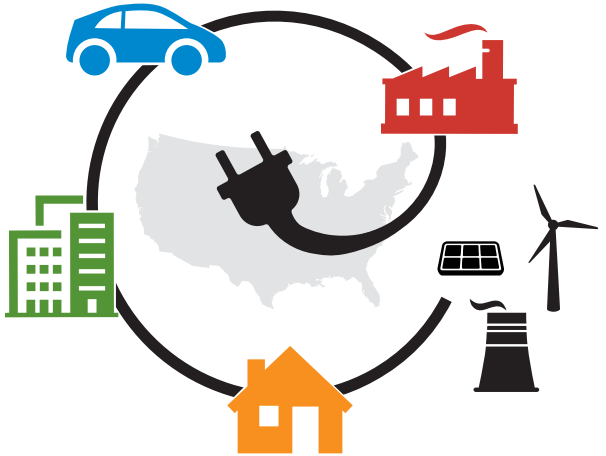
- Limited policies exist to motivate industry to electrify; this is unlike buildings and transportation.
- Industrial electric technologies lack the public profile of electric vehicles and consumer-focused technologies for buildings.
- Industry has unique barriers that deter adoption *and* unique opportunities that may accelerate adoption.
- Researchers and policymakers face significant gaps in data (e.g., energy use, cost) and analysis tools.

Electrification Futures Study (EFS) Overview

- Multiyear collaborative study exploring the potential effects of **electric technology adoption** on:
  - Demand and use patterns
  - Electricity system transformation
  - Need for flexibility/demand side management
  - Costs, benefits, and impacts.

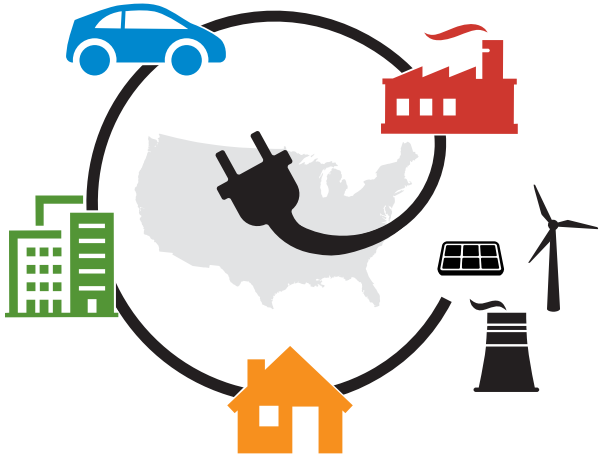
www.nrel.gov/efs

EFS Overview



- **Electrification:** the shift from any non-electric source of energy to electricity at the point of final consumption
- Contiguous U.S. energy system, including transportation, residential and commercial buildings, and industry
- Focus on 2050, but transition modeled as well

EFS Overview

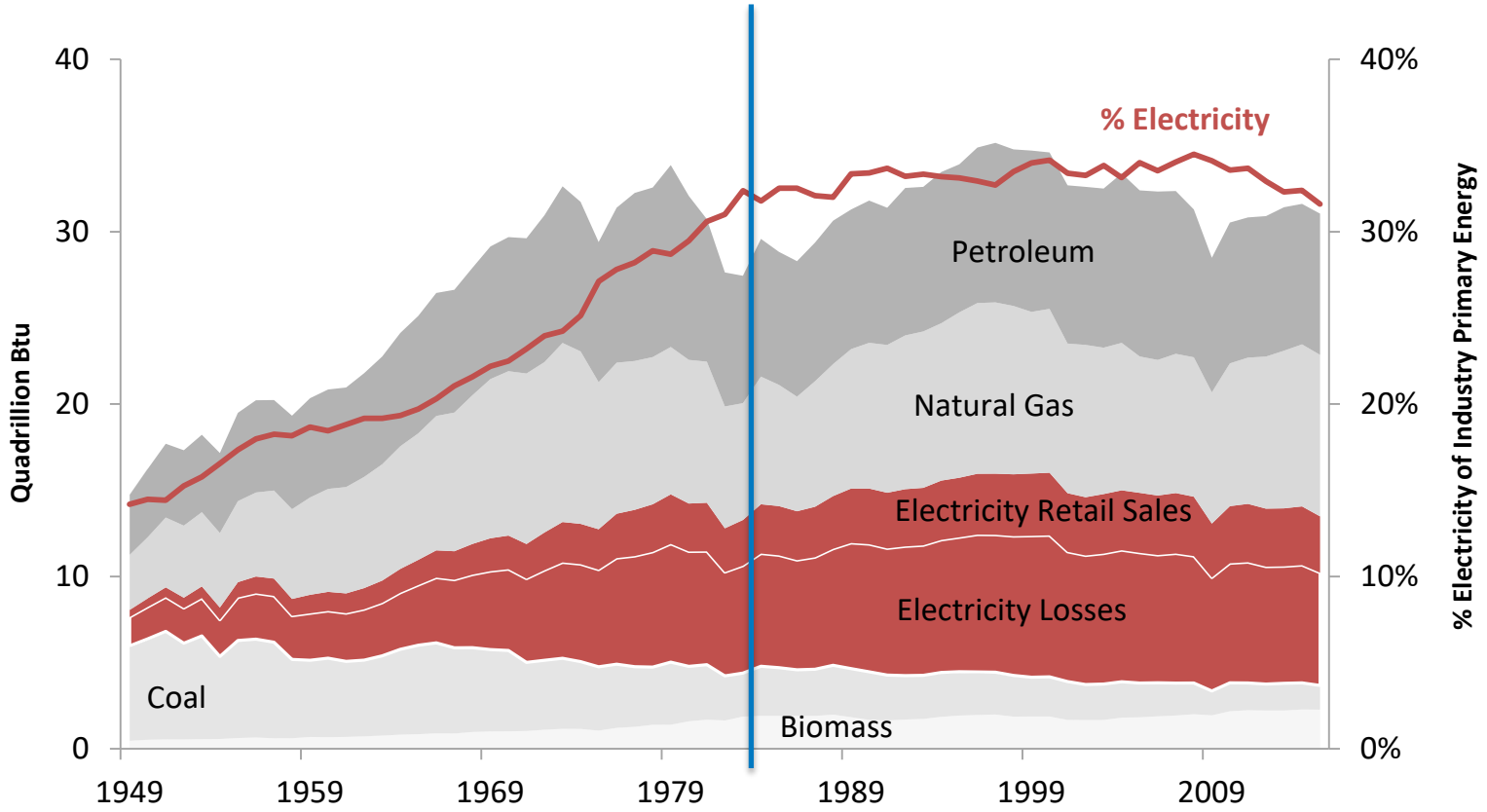


- Phased research and reporting approach
  - Year 1: electric **technology cost and performance** assessment
  - Year 2: demand-side **technology adoption** scenarios
  - Year 3+: supply-side **evolution and operation**, electrification **impacts**, and demand-side flexibility

EFS: Industry

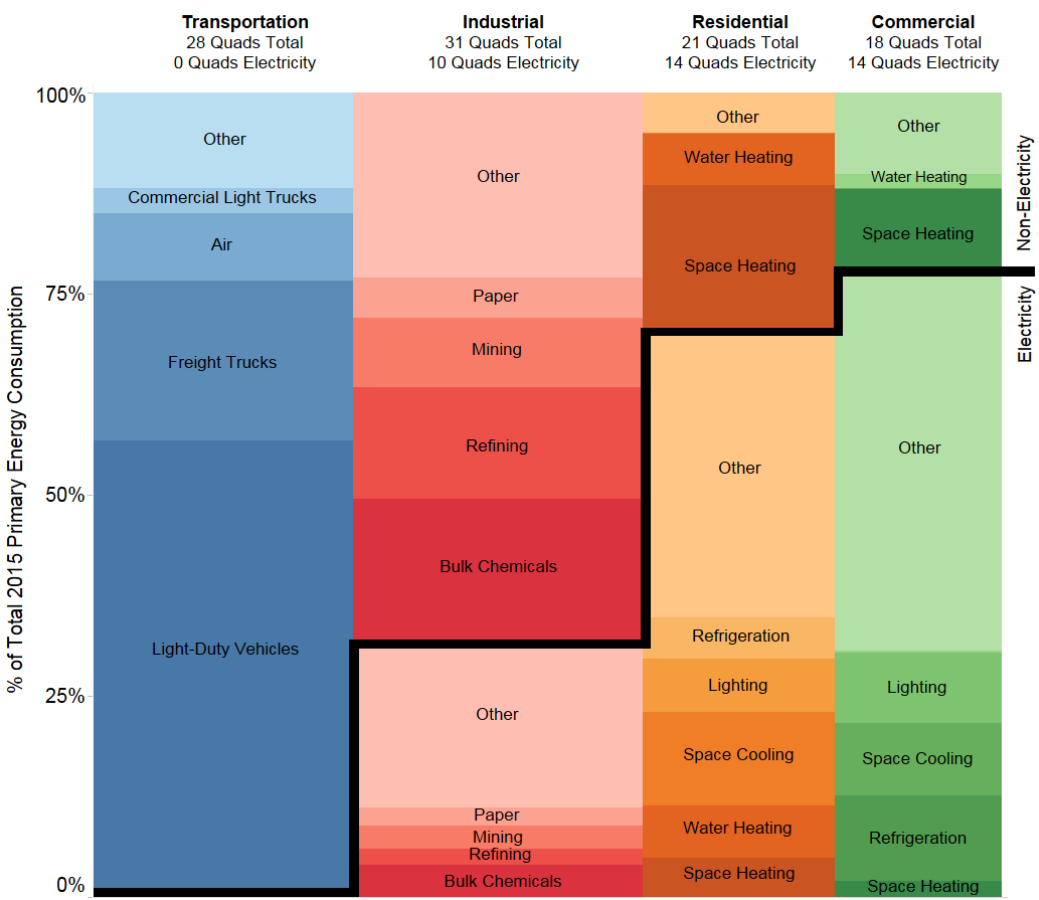
Energy Use

Industry Primary Energy Use: 1949–2015



Data from EIA "Monthly Energy Review" (https://www.eia.gov/totalenergy/data/monthly/index.php)

Electricity by End Use Sector



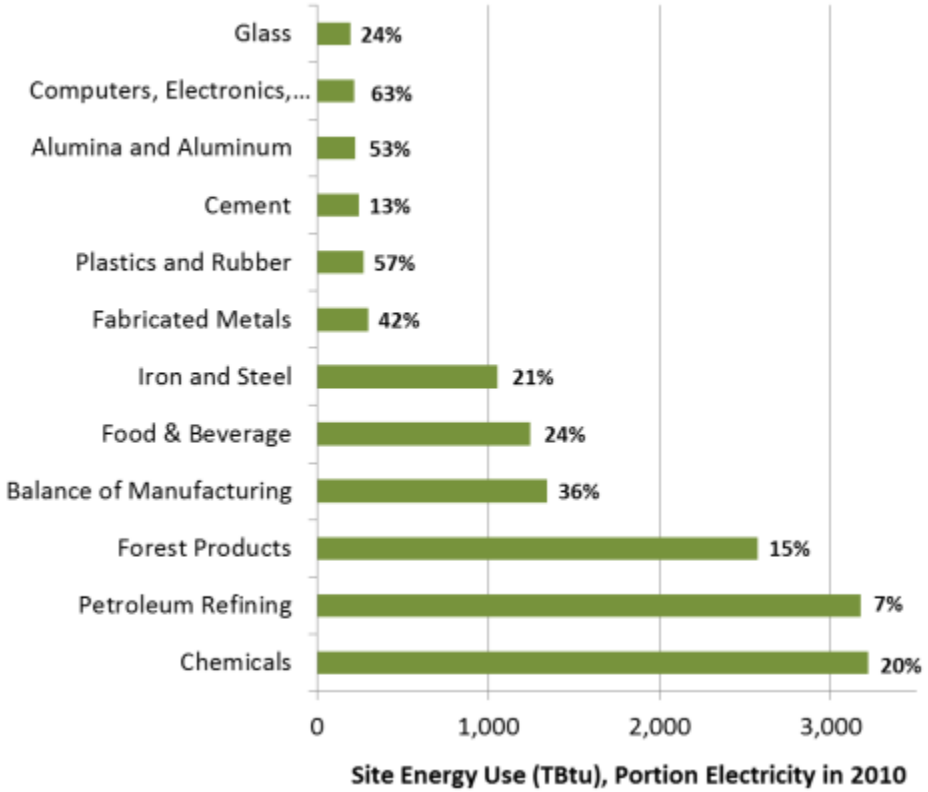
Jadun, Paige, Colin McMillan, Daniel Steinberg, Matteo Muratori, Laura Vimmerstedt, and Trieu Mai. 2017. *Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-70485. https://www.nrel.gov/docs/fy18osti/70485.pdf

Electricity Use by Industry Subsector

Manufacturing: Large variation in the amount of electricity used:

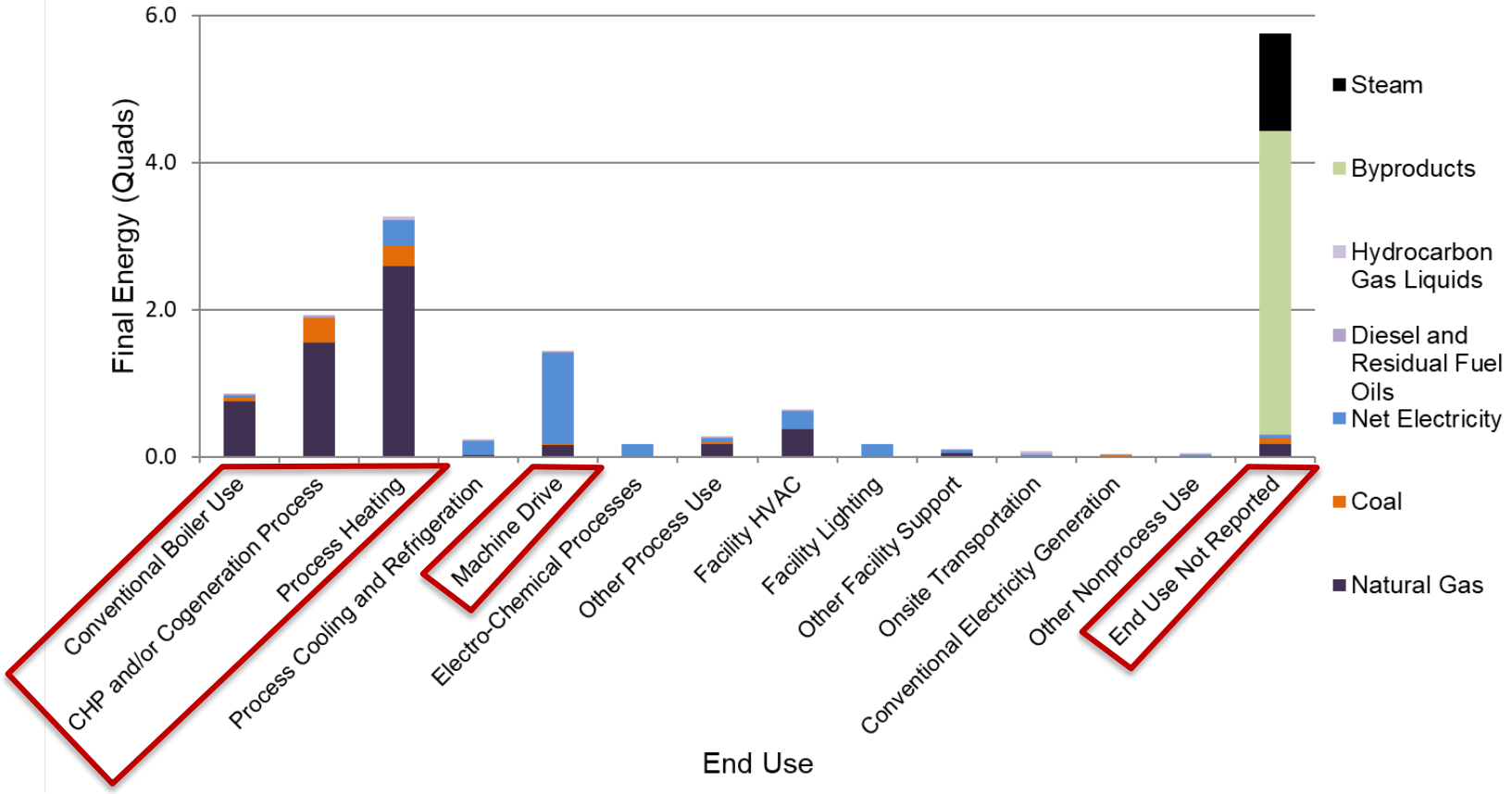
- 7% of site energy use in petroleum refining is electricity
- 63% of site energy use in computers, electronics and equipment is electricity

Non-Manufacturing: Lower-quality data are available for non-manufacturing industries (agriculture, mining, and construction), but electricity is generally <10% of site energy



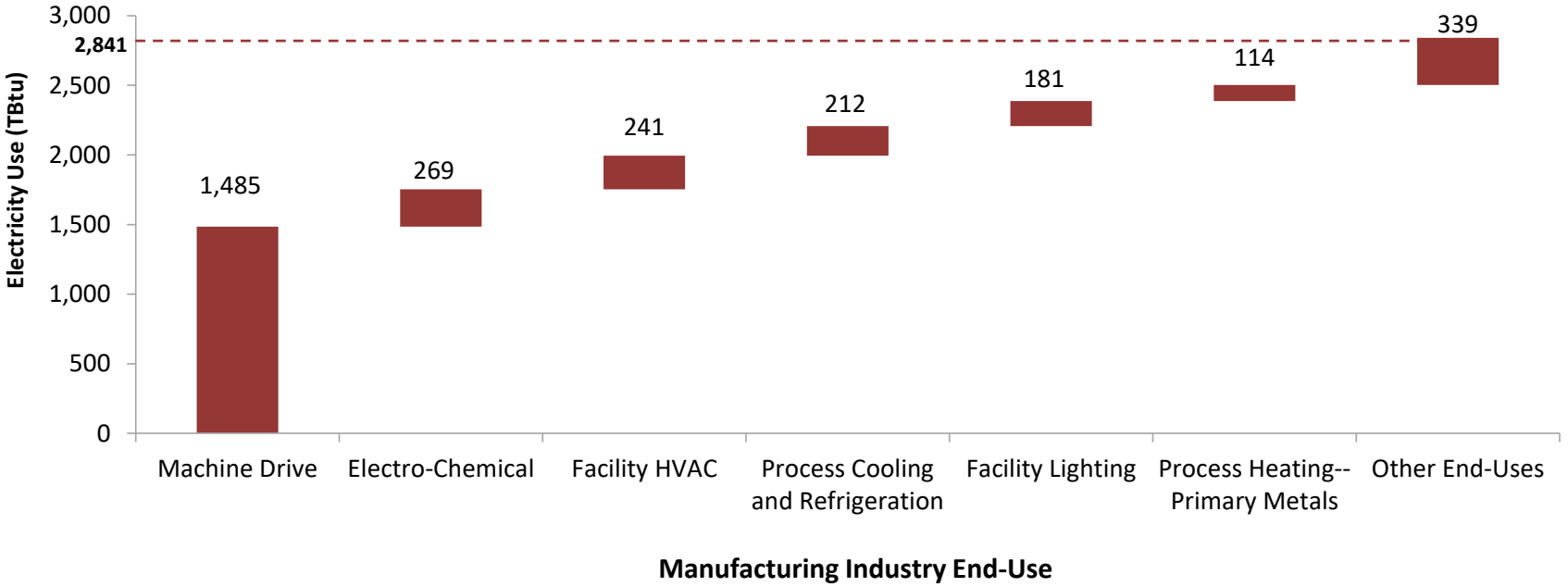
Data from DOE "Manufacturing Energy and Carbon Footprints: 2010 MECS" (https://energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2010-mecs)

Manufacturing Energy by End Use (2014)



Data from DOE "Manufacturing Energy and Carbon Footprints: 2010 MECS" (https://energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2010-mecs)

Electricity Use by Manufacturing End Use



Process heating is ~ 50% of manufacturing energy use, but only 5% of process heating is electrified.

Data from DOE "Manufacturing Energy and Carbon Footprints: 2010 MECS" (https://energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2010-mecs)

EFS: Industry

Electrification

EFS Questions for Industry

- Year 1: Technology cost and performance projections
  - *Which industries and end uses could be electrified? Which electrotechnologies are relevant?*
  - *How might the cost and performance evolve?*
- Year 2: Electric technology adoption scenarios
  - *How quickly and extensively would the relevant electrotechnologies be adopted?*

Our efforts were limited to using existing data and tools

EFS Scenarios

		Technology Advancement (Jadun et al. 2017)		
		Slow	**Moderate**	**Rapid**
Technology Adoption (this report)	**Reference**	Slow Advancement, Reference Adoption	Moderate Advancement, Reference Adoption	Rapid Advancement, Reference Adoption
	Medium	Slow Advancement, Medium Adoption	Moderate Advancement, Medium Adoption	Rapid Advancement, Medium Adoption
	High	Slow Advancement, High Adoption	Moderate Advancement, High Adoption	Rapid Advancement, High Adoption

Mai, Trieu, Paige Jadun, Jeffrey Logan, Colin McMillan, Matteo Muratori, Daniel Steinberg, Laura Vimmerstedt, Ryan Jones, Benjamin Haley, and Brent Nelson. 2018. *Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71500. https://www.nrel.gov/docs/fy18osti/71500.pdf

EFS Approach for Industry

Which industries and end uses could be electrified?
Which electrotechnologies would be chosen?

How might the cost and performance evolve?

- Literature search
- EPRI consultation
- Payback and fuel cost analysis

Literature is old (20+ years), largely anecdotal, and difficult to generalize for existing energy analysis tools.

EFS Approach for Industry

How quickly and extensively would the relevant electrotechnologies be adopted?

- Literature search

Literature is old (20+ years), largely anecdotal, and difficult to generalize for existing energy analysis tools.

EFS Approach for Industry: Sector and Tech Selection

Table 13. Industrial Subsectors and End Uses Relevant to Electrification Scenarios

Industrial Subsector	End Use	Representative Electrotechnology
All manufacturing industries and agriculture	Building HVAC	Industrial heat pump
	Machine drive	Electric machine drive
Food, chemicals, transportation equipment, plastics, and other manufacturing	Process heat	Electric boiler
Food	Process heat	Industrial heat pump
Chemicals	Process heat	Resistance heating
		Industrial heat pump
Glass and glass products	Process heat	Direct resistance melting (electric glass melt furnace)
Primary metals	Process heat	Induction furnace
Transportation equipment	Process heat	Induction furnace
Plastic and rubber products	Process heat	Resistance heating
	Process heat	Infrared processing
Other manufacturing	Process heat	Resistance heating
Other wood products and printing and related support	Process heat: curing	Ultraviolet curing

Table from Jadun et al. 2017 (Jadun https://www.nrel.gov/docs/fy18osti/70485.pdf)

Industry Scope

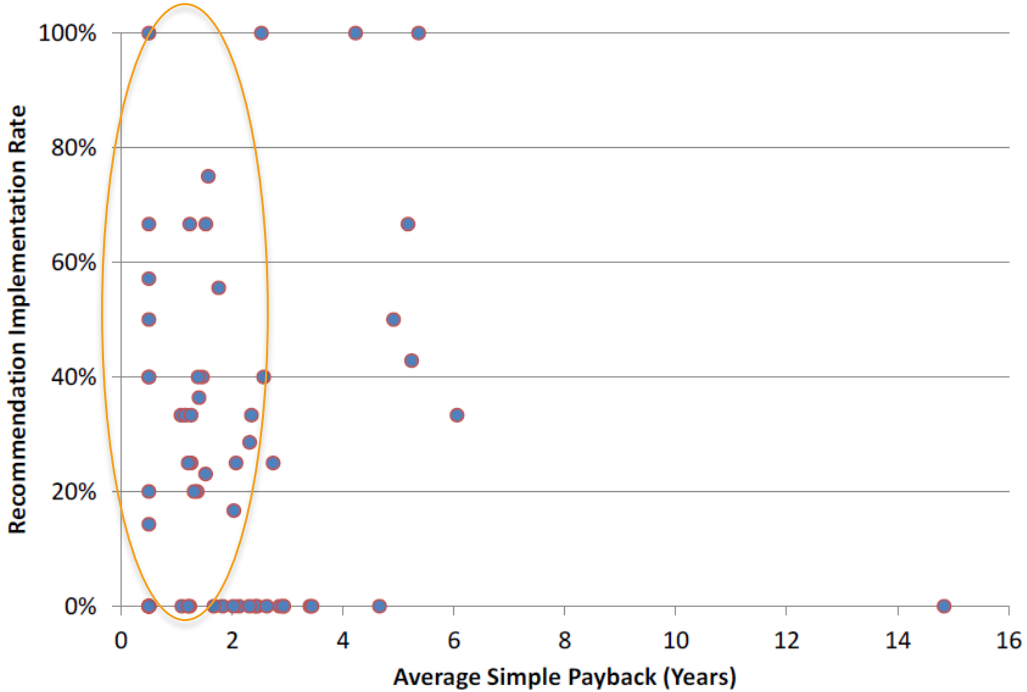
- **Excluded:** iron and steel processes, cement, lime, petroleum refining, and pulp and paper processes
- Included industries and end uses account for 43% of industry fuel energy use.
- Extent of electrification ultimately depends on **stock turnover** and **adoption** assumptions.

EFS Approach for Industry: Payback Analysis

Analysis of DOE Industrial Assessment Center (IAC) data

- DOE-sponsored program that recommends energy-related improvements to small manufacturers
- Analyzed electrification recommendations and their implementation

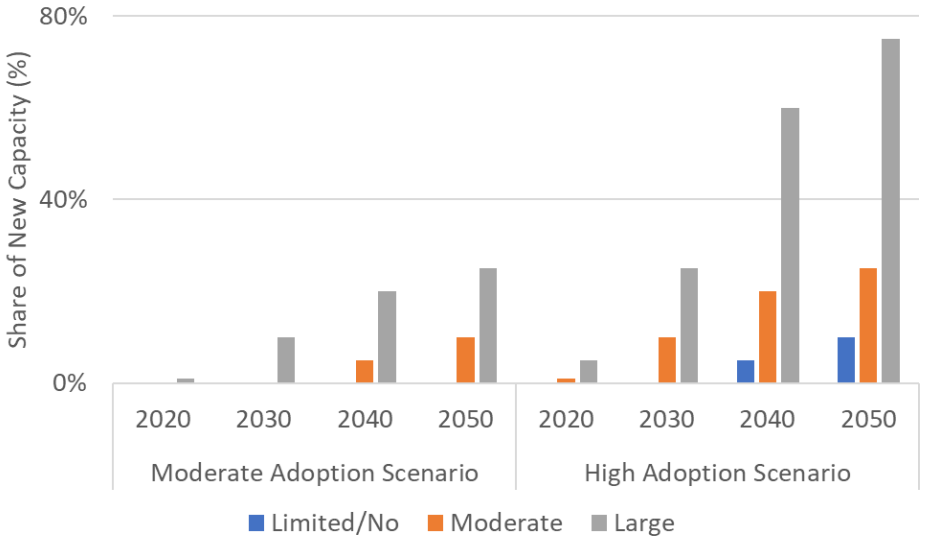
Simple payback is not enough to describe behavior.



Jadun et al. 2017 (Jadun https://www.nrel.gov/docs/fy18osti/70485.pdf)

EFS Approach for Industry: Adoption Heuristic

- Literature and anecdotal evidence point to **productivity or profitability** benefits as the primary drivers of new technology adoption: improved product quality, higher throughput, reduced scrap and labor costs
- Created an adoption heuristic to approximate this behavior
  - Limited or no benefits (e.g., electric boilers)
  - moderate benefits (e.g., resistance heating)
  - large benefits (e.g., induction melting)



Note: Effects also depend on stock turnover.

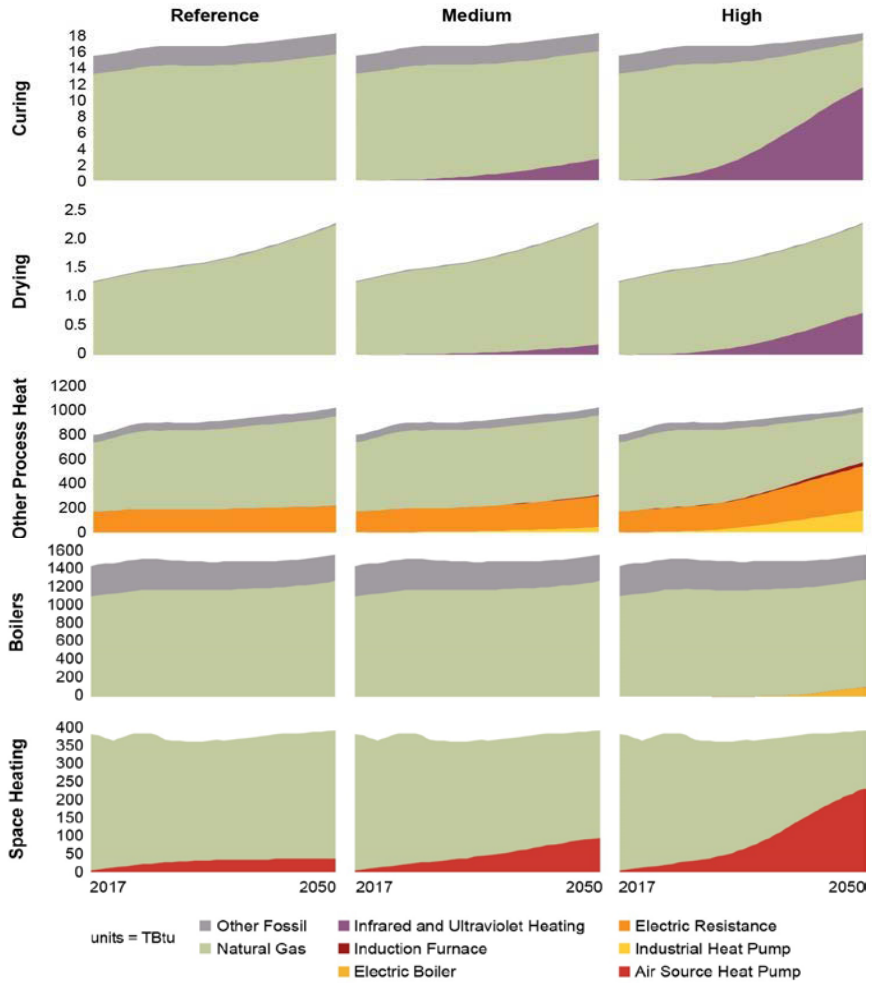
EFS Approach for Industry: EnergyPATHWAYS

- Industrial scenario modeling was conducted with EnergyPATHWAYS (EP).
  - EP is an open-source energy and carbon planning tool for use in evaluating long-term, economy-wide greenhouse gas mitigation scenarios.
- EP was expanded to include stock turnover behavior and industrial electrotechnology characteristics.
- Limited granularity for processes and technologies due to data and model limitations

github.com/energyPATHWAYS/EnergyPATHWAYS

EFS Industry Results

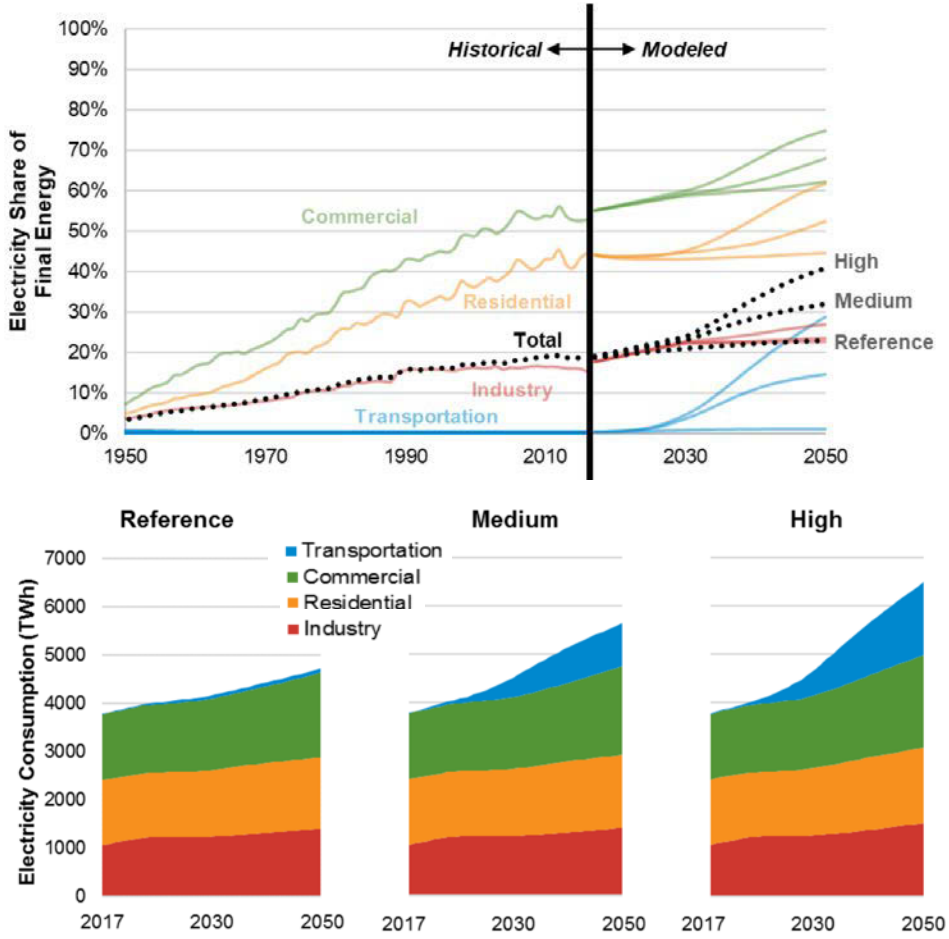
- Most-significant growth for electrotechnologies with **productivity benefits**
- In the **High** scenario, electrotechnologies provide **63% of curing** needs, **32% of drying** services, and **56% of other process heating**
- High scenario driven by a 50% reduction in equipment lifetimes



Mai et al. 2018 (https://www.nrel.gov/docs/fy18osti/71500.pdf)

EFS Industry Results in Context

- Industrial electrification is more muted than other sectors.
- Even in the reference scenario, the structure of the economy—not electrotechnologies—drives changes to electricity share within industry



Mai et al. 2018 (https://www.nrel.gov/docs/fy18osti/71500.pdf)

EFS: Industry

Challenges

Electrification Challenges for Industry

- **For analysts/modelers**: big improvements needed in data and tools to estimate generalized, national results and to identify opportunities for electrification
- **For policymakers**: incomplete picture of opportunities and impacts from analysts/modelers
- **For electrification proponents**: no technological momentum, low natural gas prices, significant aversion to process disruption (process is biggest piece of energy pie), and capital investment decision-making

Thank you

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NREL/PR-6A20-72311

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Office of Strategic Programs. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.