Deep Decarbonization of Industry Through Electrification of Process Heating

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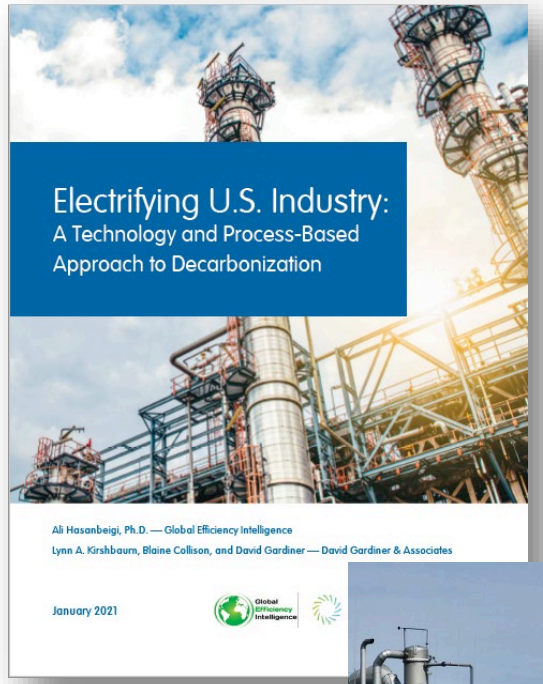

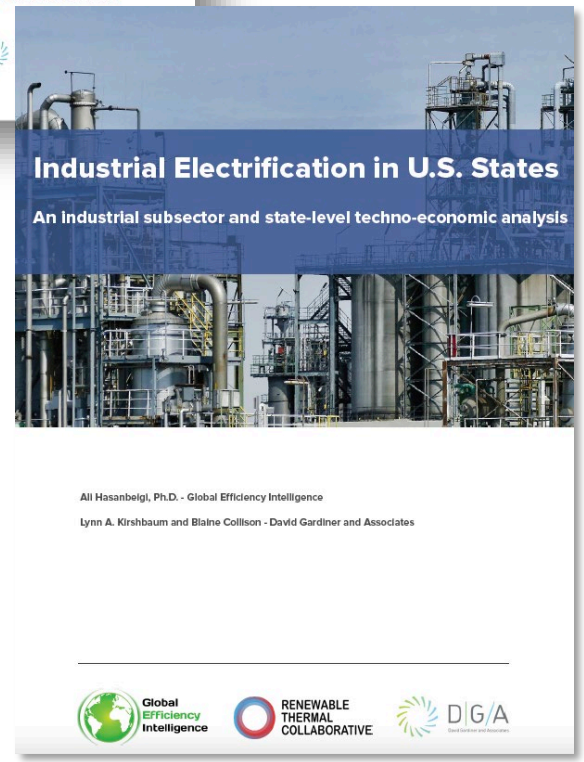

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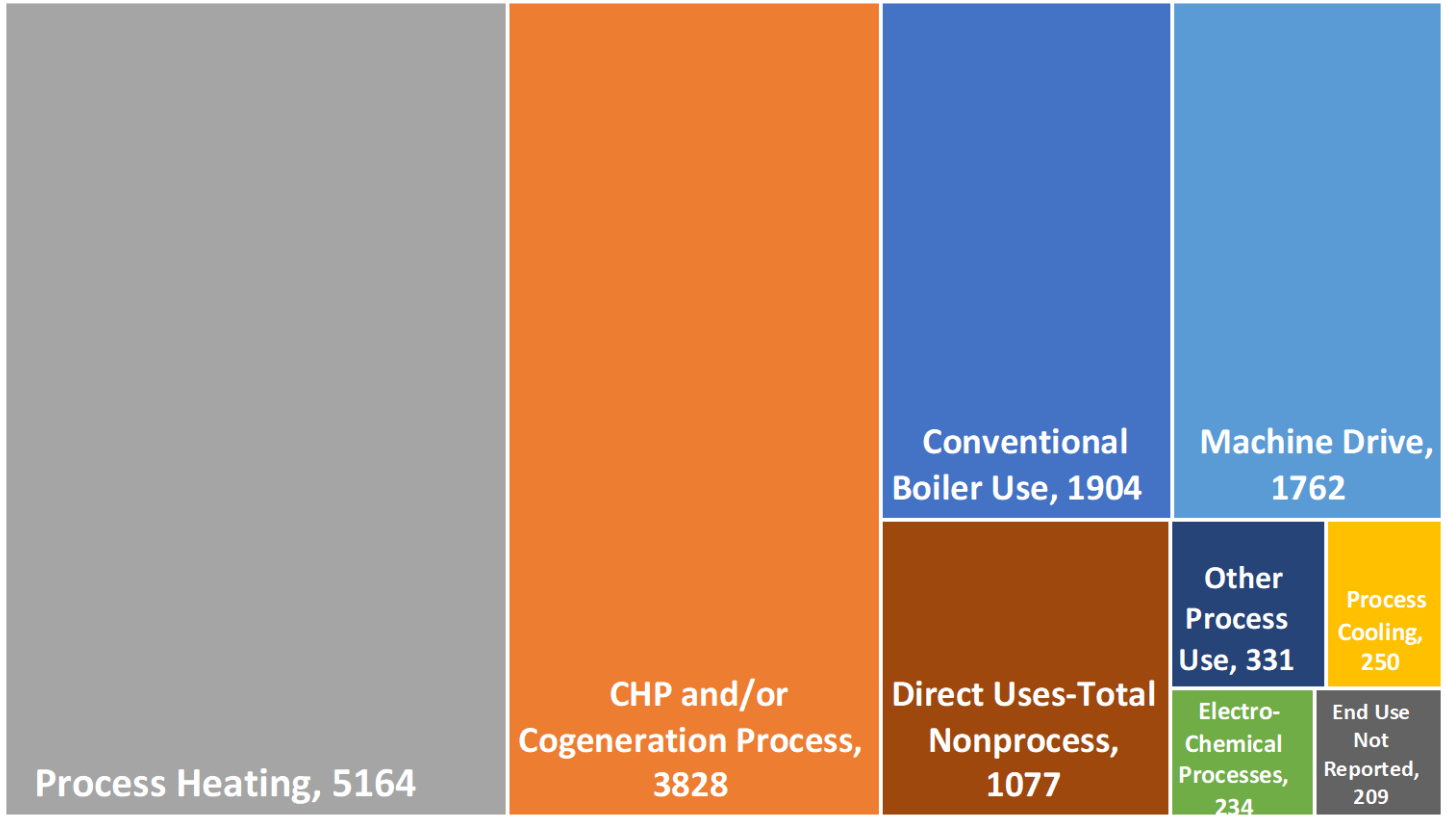
U.S. Manufacturing Energy Use by End Uses in 2018 (Trillion Btu)



Source: US DOE 2019- manufacturing energy footprints

Industrial Heat Demand Profile

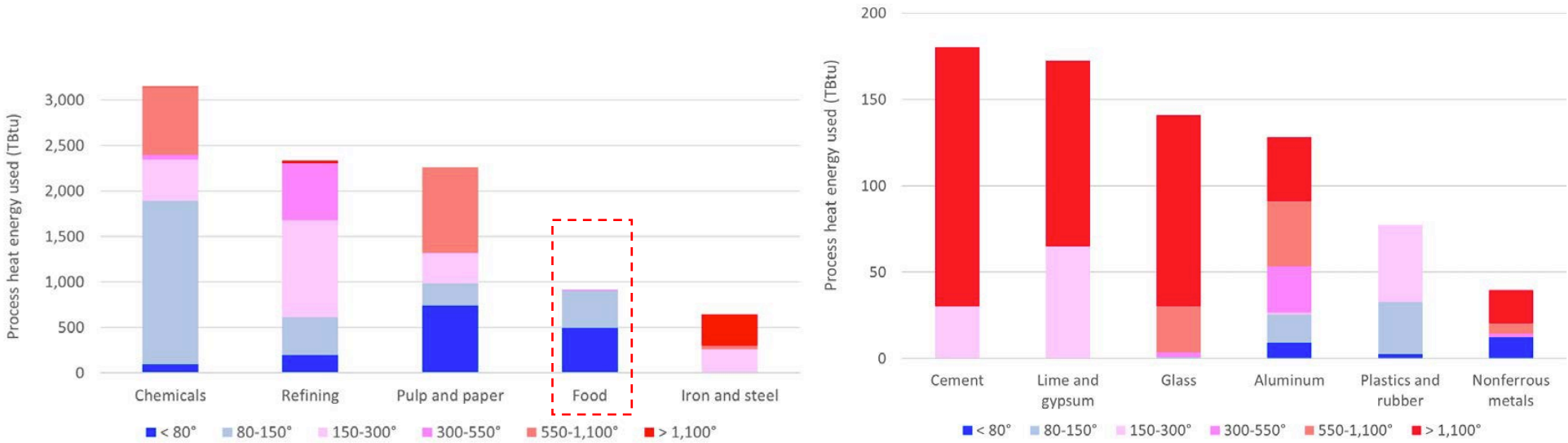


Figure. Segmentation of energy use across temperature levels by industry

Two-thirds of process heat is used in the U.S. industry is for applications below 300°C (572°F)

Source: Rightor et al. 2020; McMillan, 2019

Scope of Work

1	Alabama
2	California
3	Colorado
4	Florida
5	Georgia
6	Illinois
7	Indiana
8	Iowa
9	Kentucky
10	Louisiana
11	Michigan
12	Minnesota
13	North Carolina
14	Ohio
15	Oklahoma
16	Oregon
17	Pennsylvania
18	Texas
19	Washington
20	Wisconsin

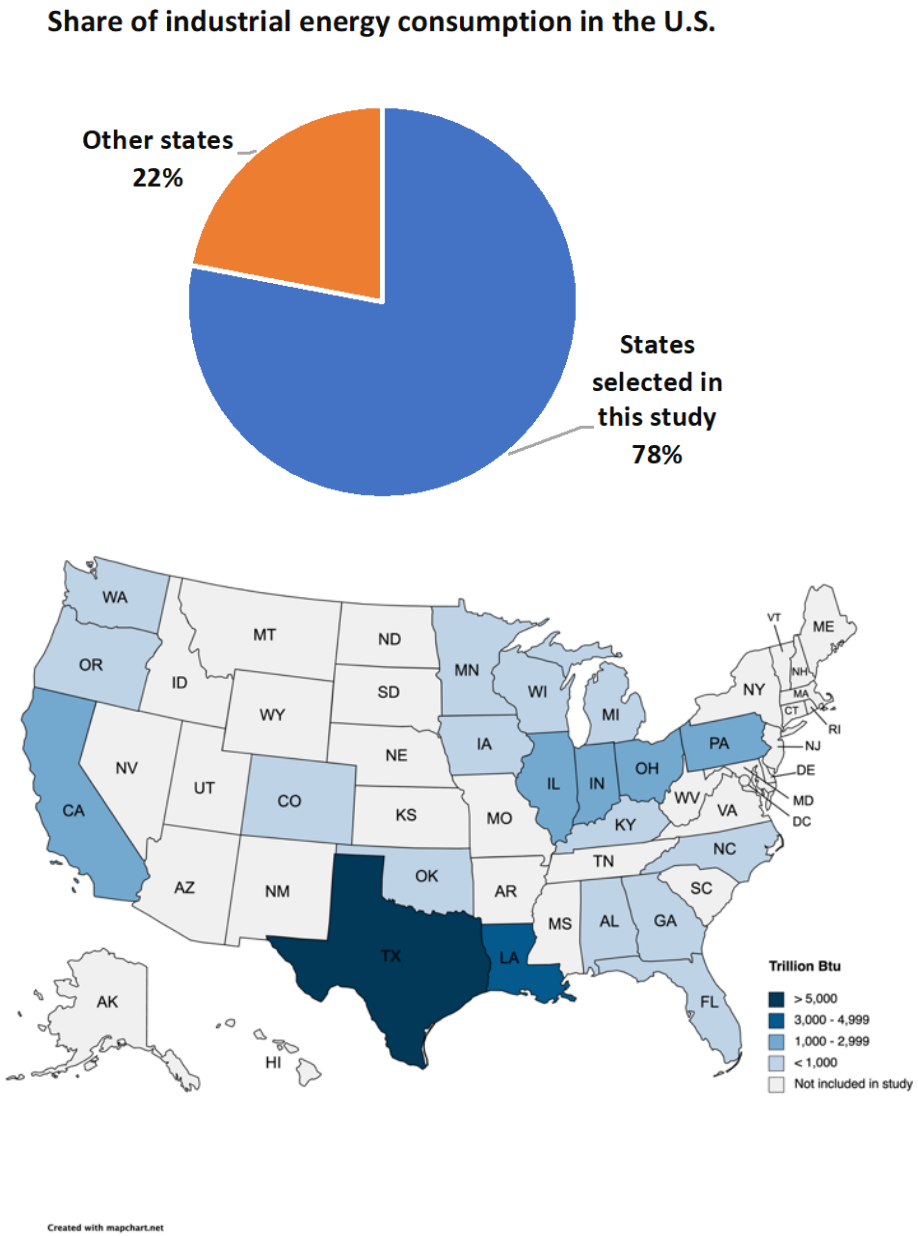
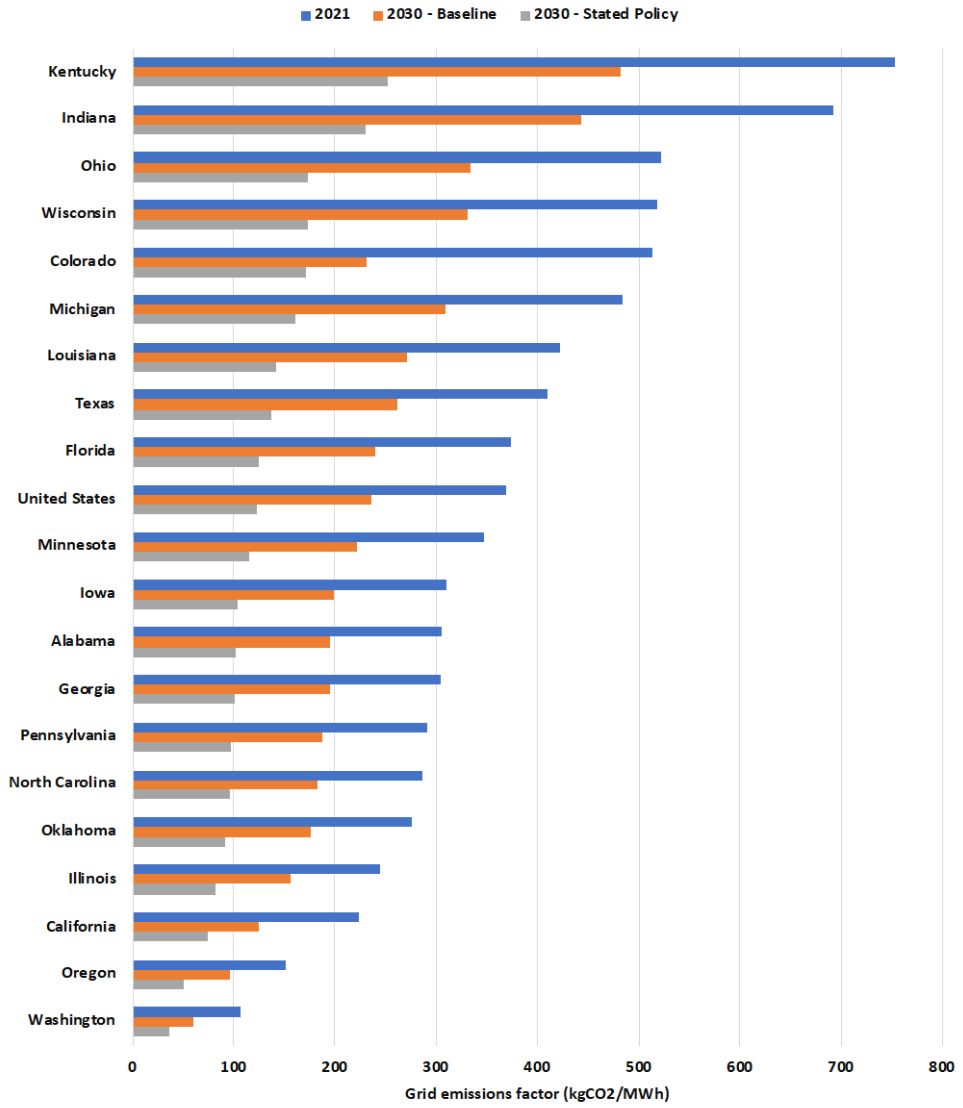


Figure. Industrial energy use in 2019 (trillion Btu)

Why State-level analysis?

Electricity grid emissions factors

- Grid emissions factor varies significantly across states. Some states' grids are clean enough for electrification today!



The United States has set a goal to reach 100% carbon emissions-free electricity by 2035.

Figure. Electricity grid emissions factors in 2021 and 2030 ($kgCO_2/MWh$)

Why State-level analysis?

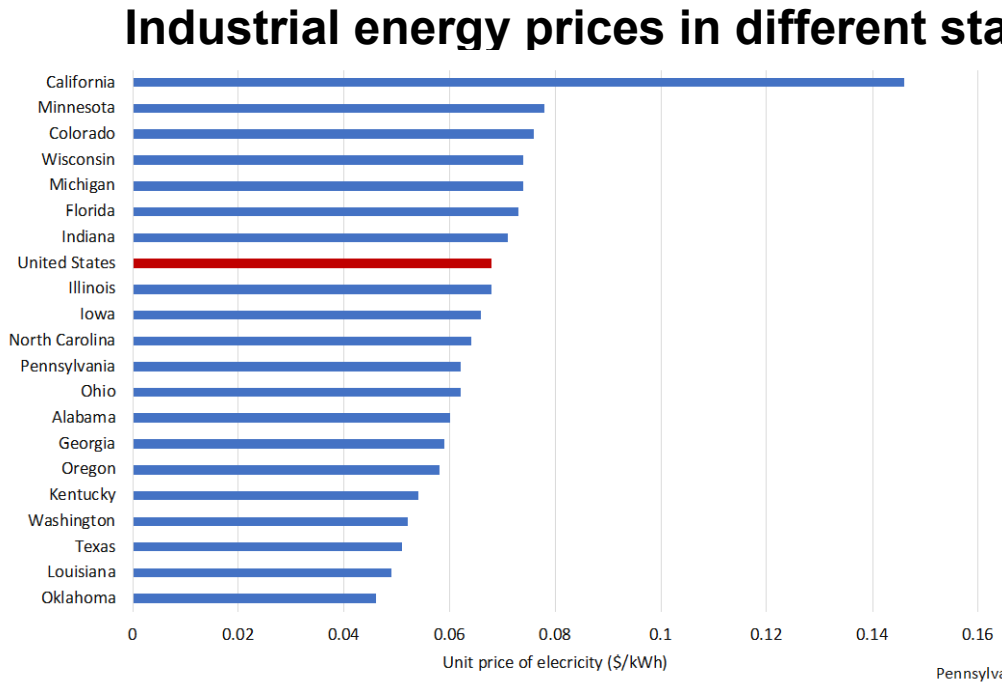


Figure A. Industrial electricity unit price in 2021 ($/kWh)

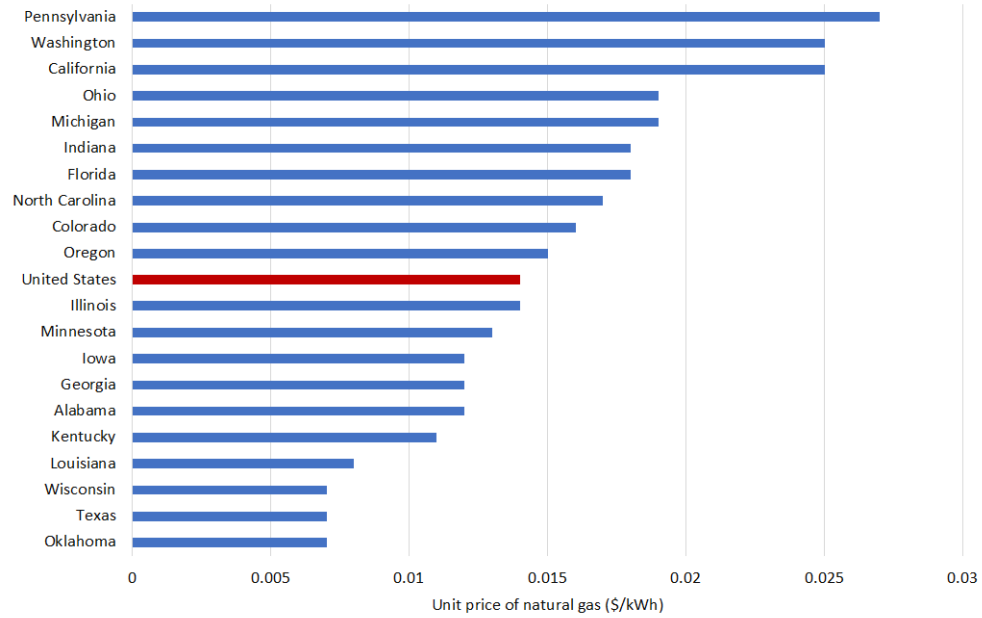


Figure B. Industrial natural gas unit price in 2021 ($/kWh)

Source: Adapted based on US DOE/EIA 2021

The ratio of industrial electricity to natural gas prices is more important than absolute energy prices. **The lower the ratio, the more attractive is industrial electrification**.

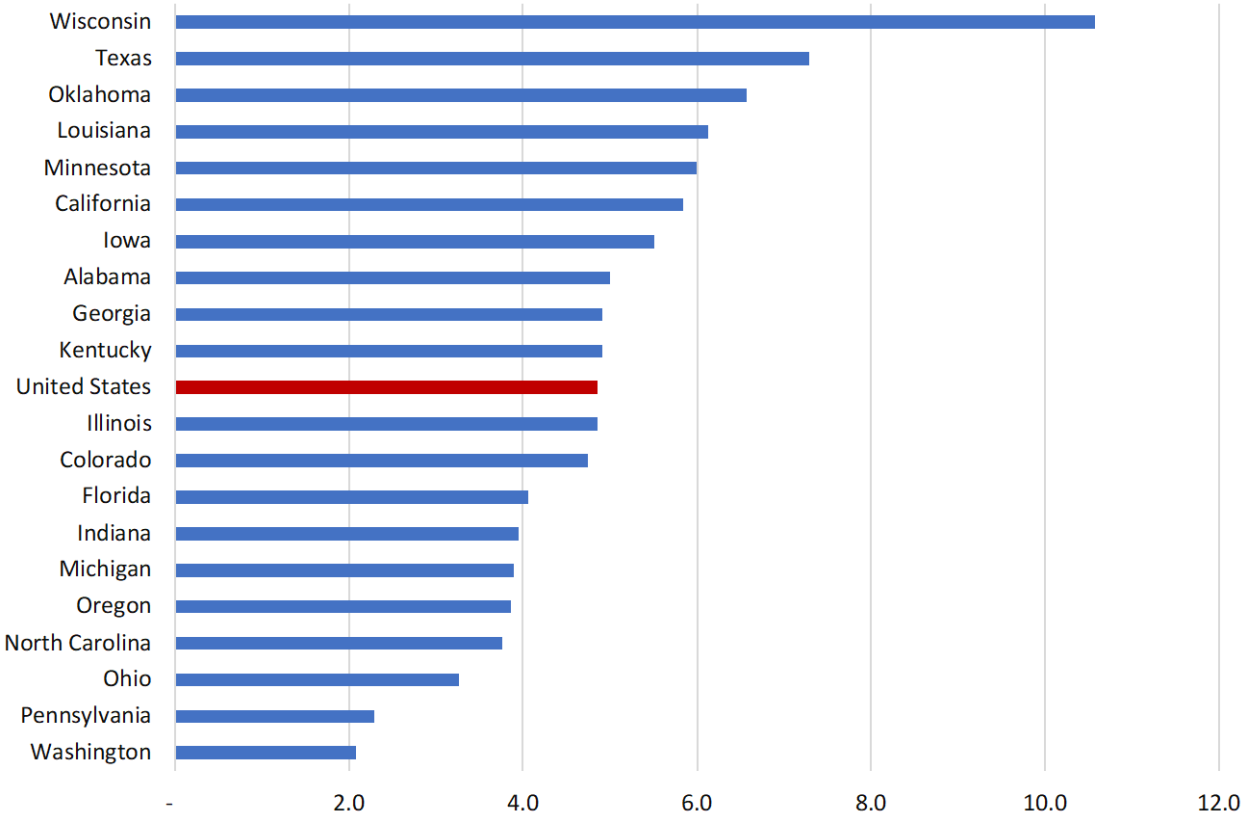


Figure. The ratio of the industrial unit price of electricity to natural gas in 2021

Bottom-up Analysis Method

Step1
- Detailed analysis of existing heating system

Step2
- Selection of suitable electrification technology

Step3
- Process integration assessment with new electrified heating technology

Step 4
- Calculation of changes in energy use and GHG emissions, cost implications, grid impact

	Industry
1	Aluminum casting
2	Ammonia
3	Methanol
4	Recycled plastic
5	Pulp and paper
6	Container Glass
7	Steel
8	Beer
9	Beet Sugar
10	Milk powder
11	Wet corn milling
12	Soybean oil

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Electrification of the **beer production** industry

Conventional System Process		Process steps	All Electric Process	
Heating Equipment	Thermal Demand (kWh/Hectoliter)		Electrical Demand (kWh/Hectoliter)	Heating Equipment *
Centralized Gas Boiler System	2.9	Mashing	0.6	Heat Pump 4
Centralized Gas Boiler System	12.9	Boiling	6.1	Heat Pump 1&2
Centralized Gas Boiler System	5.2	Pasteurization	0.9	Heat Pump 3
Centralized Gas Boiler System	12.0	Cleaning & Production Support	2.6	Heat Pump 4
	33.0	**Subtotal**	**10.2**	
33.0		**Total Energy**	**10.2**	

Electrification of the **beer production** industry– Energy Saving

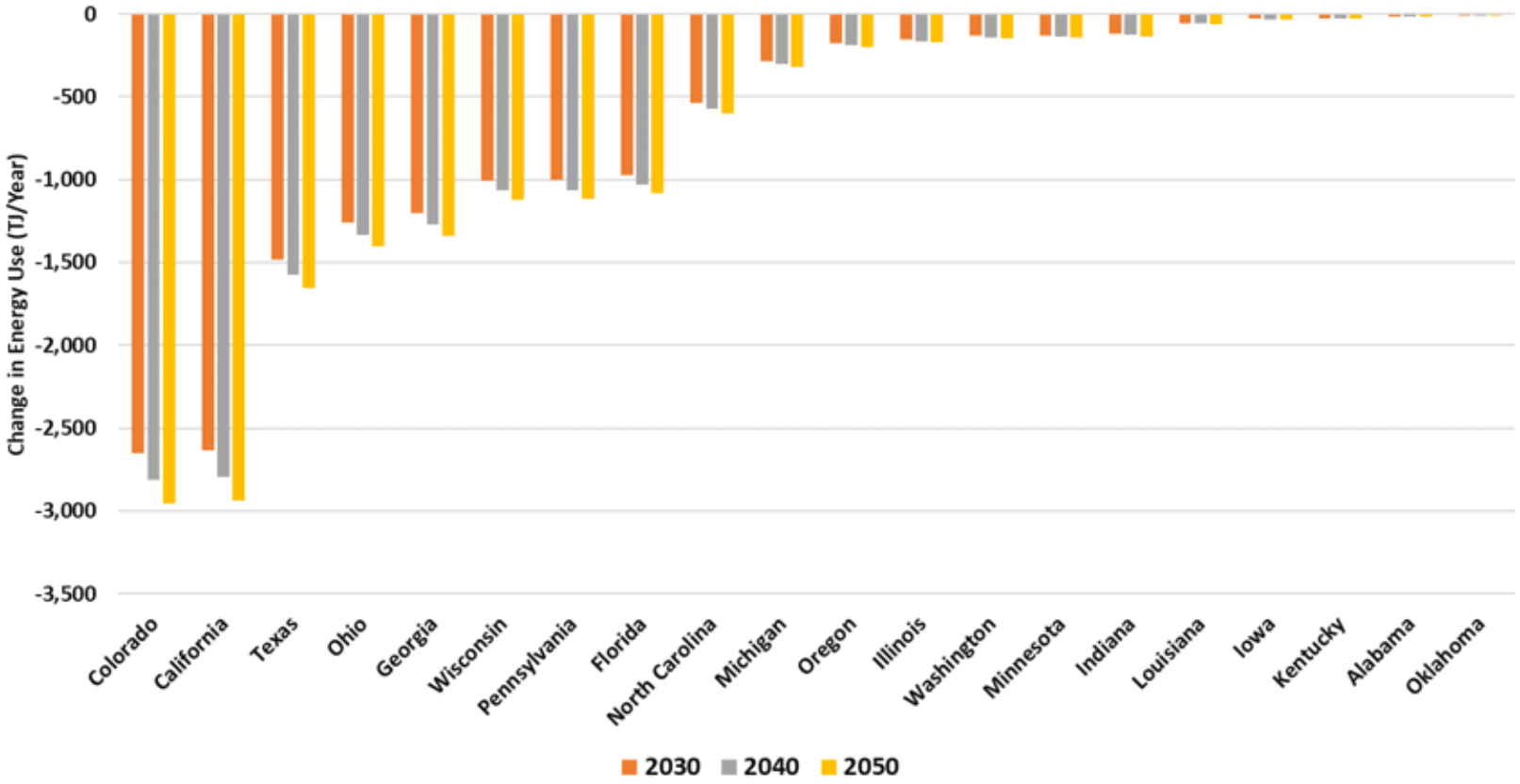


Figure. Change in the beer production industry's total final energy use after electrification (Technical potential assuming 100% adoption rate)

Electrification of the **beer production** industry - CO_2 Emissions Reduction

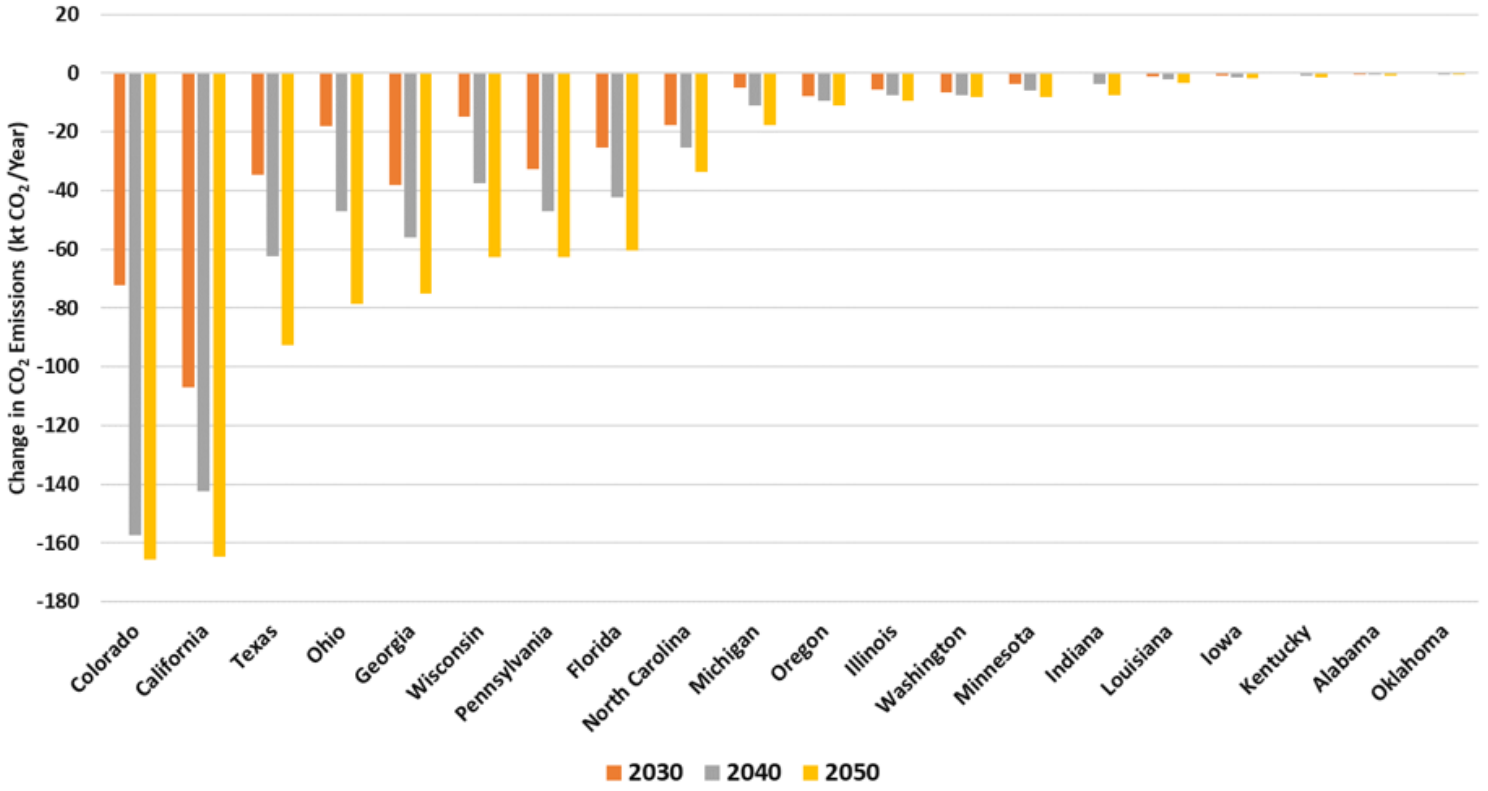
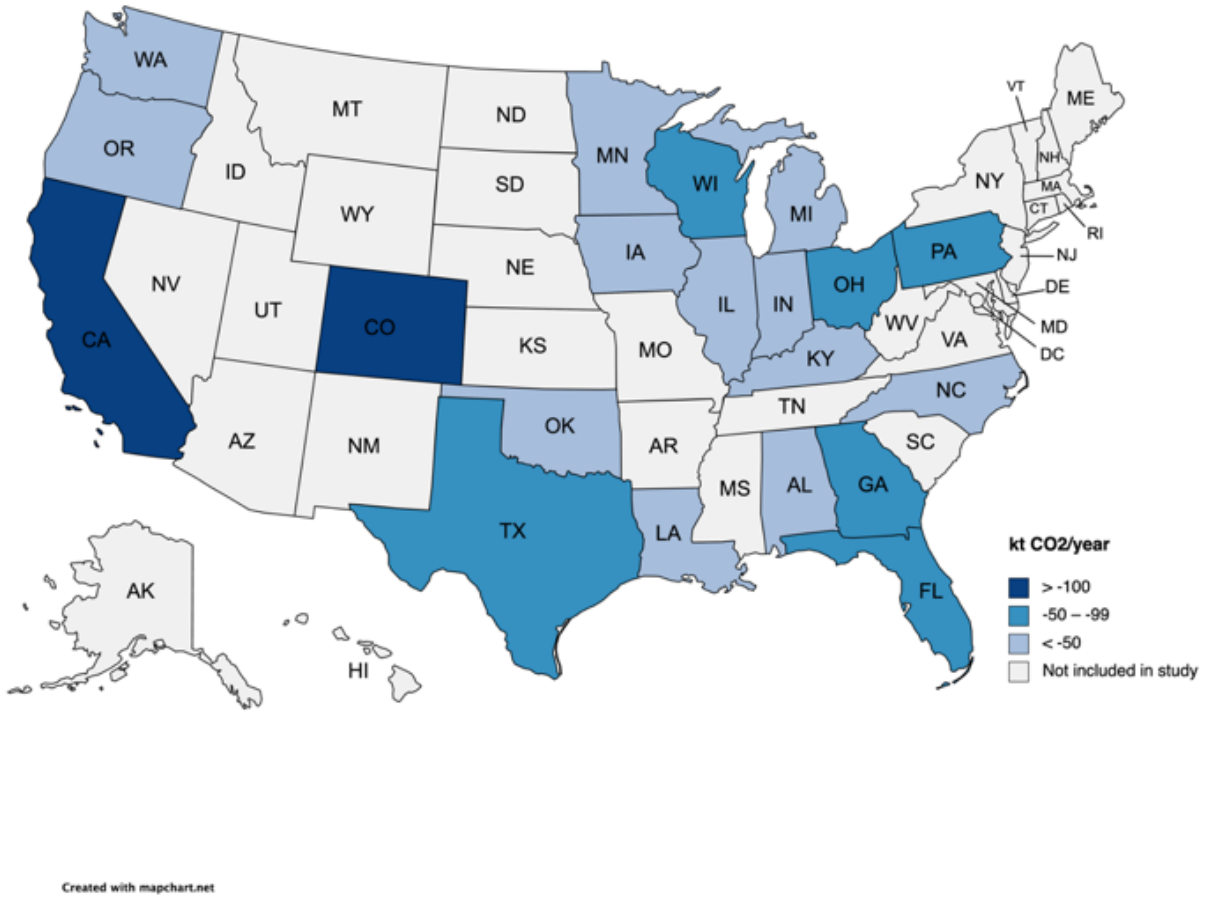


Figure A. Change in the beer production industry's net CO_2 emissions after electrification - **baseline scenario** (technical potential assuming 100% adoption rate)

- **Baseline Scenario**: Zero Carbon Grid in 2050 or as Stated in Each State's Target.
- **Stated Policy Scenario**: Zero Carbon Grid in 2035 in All States

Electrification of the **beer production** industry - CO_2 Emissions Reduction



- CO_2 emissions reductions can be achieved even **today** using grid electricity in **most states studied.**

- **Plant-level** CO_2 emissions reductions can be achieved **today** in **any state** through electrification projects that are **tied with sufficient renewable electricity** supply.

Figure. Change in CO_2 emissions in the container glass industry in 2050

Electrification of the **beer production** industry – Energy Cost

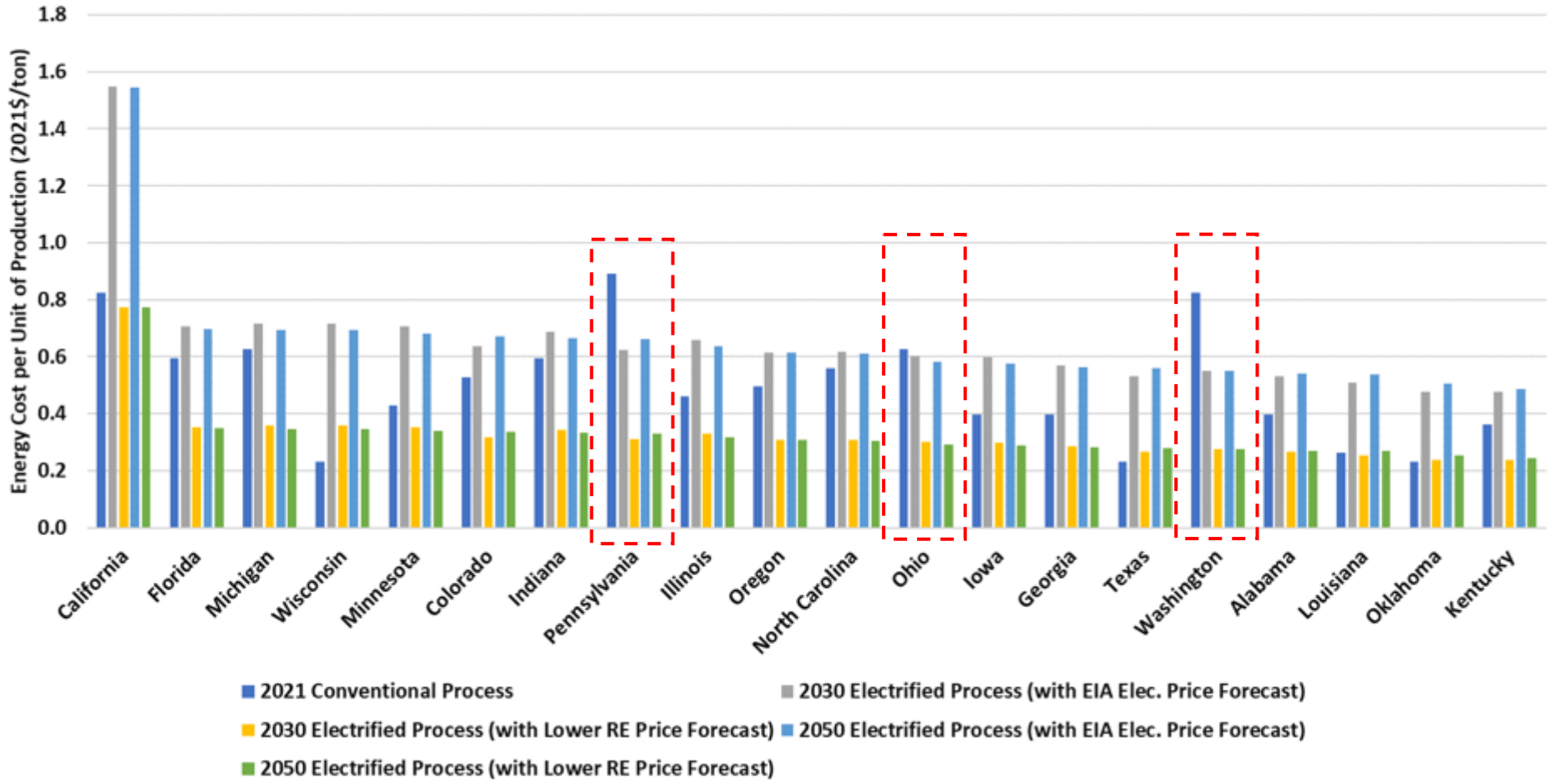


Figure. Energy cost per unit of production in the beer production industry

Energy cost is only a small portion of total manufacturing cost for many industrial subsectors. Therefore, a moderate increase in energy cost per unit of product resulting from electrification will have a minimal impact on the price of final product and final consumers.

Industrial electrification's impacts on electricity grid

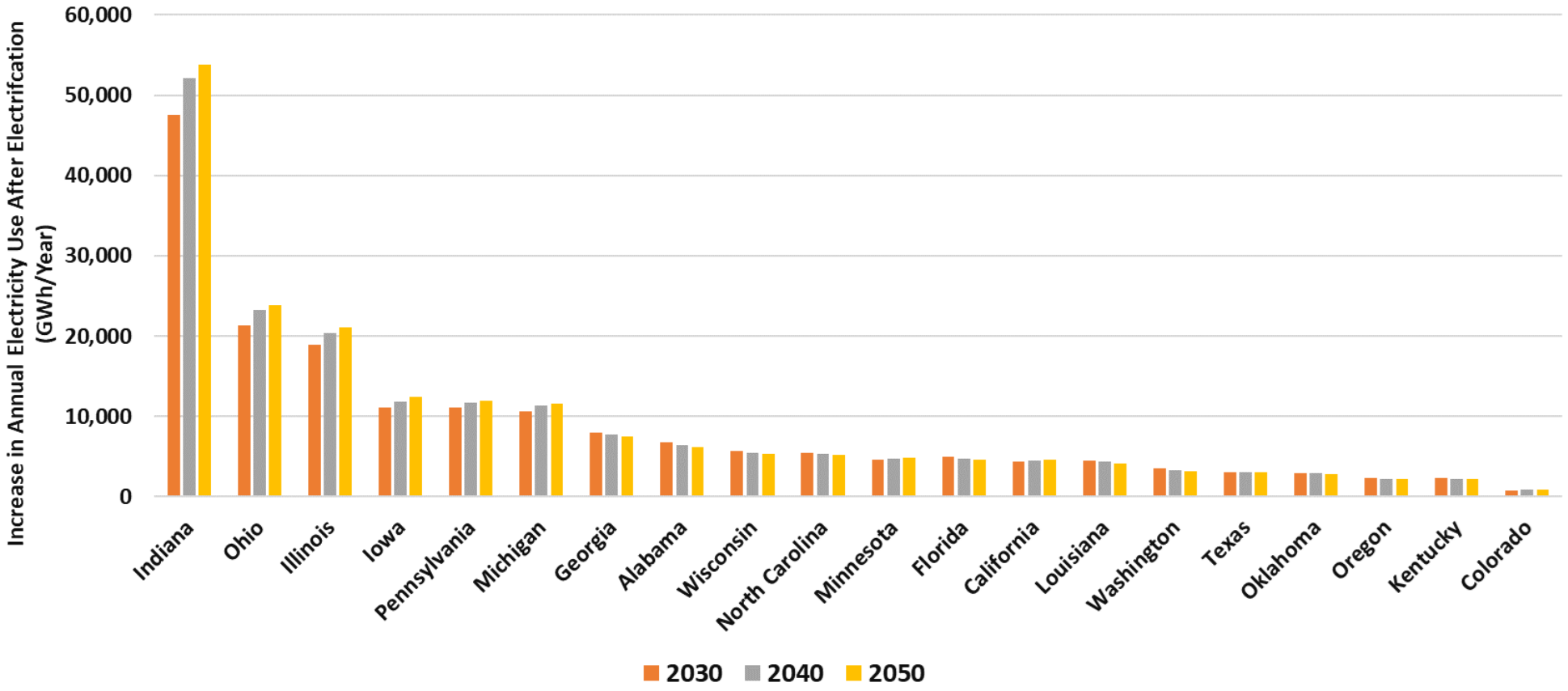


Figure. Increase in annual electricity consumption after industrial electrification in industries studied (GWh/year) (assuming 100% adoption rate)

Key takeaways

- There is **significant potential to decarbonize** the US industry with electrification.
- Using grid electricity, CO_2 emissions reduction from electrification **can be achieved today in some states** with clean electricity supply and **in many more states in 2030**.
- Plant-level CO_2 emissions reductions **can be achieved today** in any state through electrification projects that are tied with sufficient renewable electricity supply (e.g. through PPA).
- **Energy cost per unit of production** for electrified processes is higher but can be competitive with conventional processes if lower price RE electricity is available.
- **Future electricity and fuel prices** and potential carbon price on energy can substantially impact the economics of industrial electrification.
- Industrial electrification provides **co-benefits** (air pollution reduction, health benefits, production cost reduction, O&M cost reduction, etc).

Recommendations

- **Identify the sweet spots and start there**. Start in states with more favorable conditions [e.g., cleaner grid, lower ratio of electricity to natural gas prices, more favorable investment conditions and local incentives, etc.]
- The industry sector should initiate **partnerships** with government, academia, think tanks, and other stakeholders to develop and/or scale electrification technologies.
- **Six impactful actions** that would support increased industrial electrification in US states:
  - 1) Support demonstration of emerging electrification technologies and new applications of existing technologies,
  - 2) Financially incentivize electrification,
  - 3) Increase renewable electricity generation capacity,
  - 4) Enhance the electricity grid,
  - 5) Engage communities,
  - 6) Develop the workforce.
- The **US$369 billion** in climate and clean energy incentives provided by the **Inflation Reduction Act (IRA)** provides powerful tailwinds for industrial electrification.

Thank You!

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