Rate Design to Unlock Industrial Electrification

Summary Presentation

January 2026

Prepared for the Center for Applied Environmental Law and Policy by Synapse Energy Economics

Note: this is a summary presentation - for further detail and citations, see the full report

Outline

- Introduction and Study Scope
- Industrial Energy Use in Colorado and Illinois
- Current and Alternative Rate Structures
- Study Approach
- Economic, Energy, and Emissions Impacts of Industrial Electrification Under Alternative Rate Structures
- Conclusion: Enabling the Economics of Industrial Electrification

Introduction and Study Scope

Introduction

- Industrial electrification: replacing fossil fuel-based process heating at industrial facilities with more efficient electric heating technologies
- Economic opportunity: electrification technologies have the potential to reduce operating costs over time by leveraging mechanisms to access low-cost electricity
- Key economic barriers to industrial electrification:
  - Spark gap: the ratio of electricity prices to fossil fuel prices
  - Upfront costs

Study Scope

- Four utility territories in two states: ComEd and Ameren (Illinois), Xcel and Black Hills (Colorado)
- Two electrification technologies: industrial heat pumps and thermal batteries
  - Industrial heat pumps key advantage: Extremely high efficiency due to transferring rather than generating heat; can utilize waste heat sources; output steam at temperatures up to 200°C
  - Thermal batteries key advantage: electricity price arbitrage from charging when electricity prices are low; output steam at temperatures up to 400°C
- Two electric rate structures: 1) current rates and 2) alternative rates that have the potential to improve the economics of industrial electrification through incentivizing load shifting
- Incumbent heating technologies cover a wide range of equipment types using different kinds of fuel, with the majority of electrifiable fuel use being consumed in natural gas-fired boilers

Industrial Energy Use in Colorado and Illinois

Colorado – Industrial Energy Use Profile

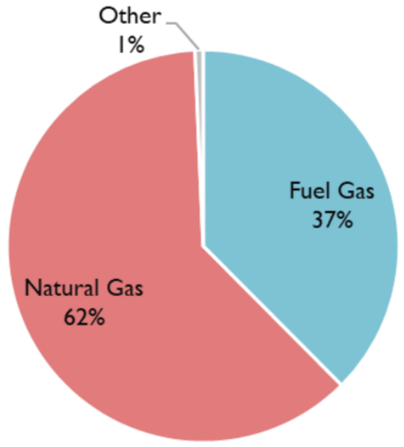
- 28th largest state by industrial sector energy consumption
- The industrial sector is the second largest sector by energy consumption in Colorado
- The petroleum and coal products manufacturing sector has the largest demand for fossil fuels for process heating in Colorado (Suncor Refinery)*

Table 1. Summary of industrial facilities in Colorado

NAICS Code	NAICS Description	Large Facility Count	Estimated Fuel Use for Heating, 2022 (MMBtu)
324	Petroleum and Coal Products Manufacturing	1	15,016,667
311	Food Manufacturing	4	5,231,905
325	Chemicals Manufacturing	7	5,043,333
312	Beverage and Tobacco Product Manufacturing	2	4,773,333
327	Nonmetallic Mineral Product Manufacturing	6	3,870,000
331	Primary Metal Manufacturing	2	3,790,000
334	Computer and Electronic Product Manufacturing	2	600,000

Source: Synapse TIDE tool.

Figure: Share of fuel use for heating by fuel type in the Colorado industrial sector



* The electrification technologies considered in this analysis can electrify low-to-medium temperature heat, and sectors with lower-temperature heating profiles, such as food or beverages, stand to have better technical and economic potential for electrification

Illinois – Industrial Energy Use Profile

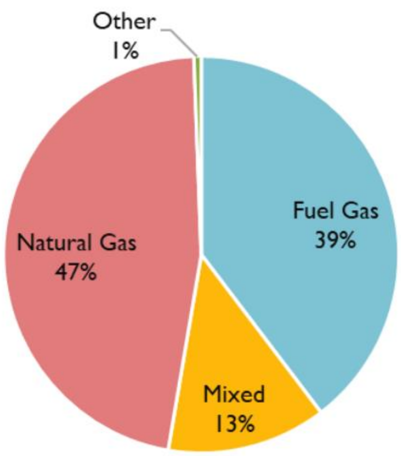
- 7th largest state by industrial sector energy consumption
- The industrial sector is the largest sector by energy consumption in Illinois
- The petroleum and coal products manufacturing sector has the largest demand for fossil fuels for process heating in Illinois*

Table 2. Summary of industrial facilities in Illinois

NAICS Code	NAICS Description	Large Facility Count	Estimated Fuel Use for Heating, 2022 (MMBtu)
324	Petroleum and Coal Products Manufacturing	7	114,515,952
311	Food Manufacturing	11	71,935,615
325	Chemicals Manufacturing	28	68,599,452
331	Primary Metal Manufacturing	12	18,256,250
312	Beverage and Tobacco Product Manufacturing	2	9,440,952
327	Nonmetallic Mineral Product Manufacturing	9	8,280,000
336	Transportation Equipment Manufacturing	3	2,083,333
326	Plastics and Rubber Products Manufacturing	2	2,070,000
334	Computer and Electronic Product Manufacturing	1	1,150,000
333	Machinery Manufacturing	1	1,086,667
332	Fabricated Metal Product Manufacturing	2	851,667
322	Paper Manufacturing	1	300,000
335	Electrical Equipment, Appliance, and Component Manufacturing	2	160,000

Source: Synapse TIDE tool.

Figure: Share of fuel use for heating by fuel type in the Illinois industrial sector



* The electrification technologies considered in this analysis can electrify low-to-medium temperature heat, and sectors with lower-temperature heating profiles, such as food or beverages, stand to have better technical and economic potential for electrification

Current and Alternative Rate Structures

Rate Design Principles

The alternative rate structures modeled in this analysis follow these rate design principles, which are also practical guidelines for utilities:

- **Sufficiency**: Rates should be designed to yield revenues sufficient to recover utility costs
- **Fairness**: Rates should be designed to fairly apportion costs among different customers and avoid "undue discrimination"
- **Efficiency**: Rates should discourage wasteful usage and provide efficient price signals that reflect the costs of providing electricity at different times
- **Customer Acceptability**: Rates should be relatively stable, predictable, simple, and easily understandable

Rate Design Options to Support Industrial Electrification

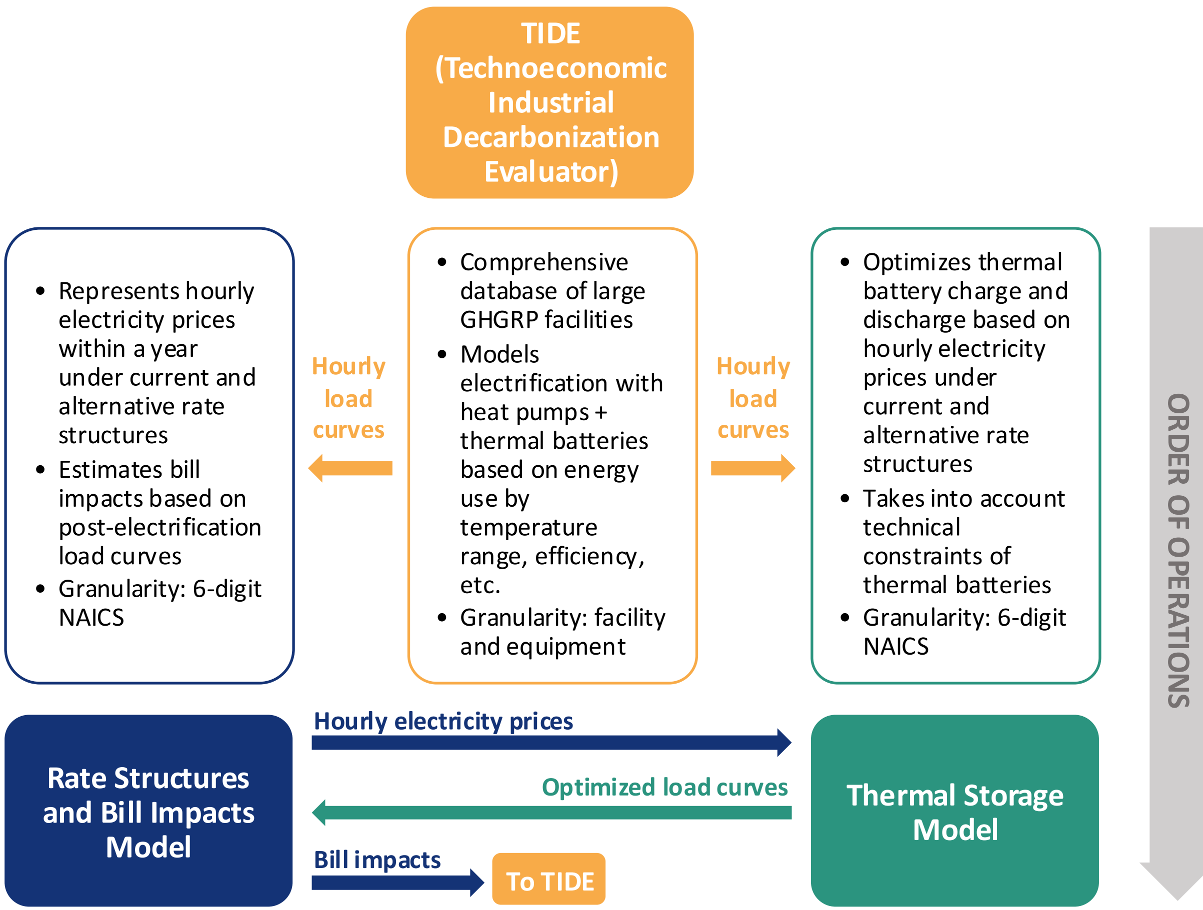
- **Time-Differentiated Rates**
  - Time-of-Use Rates – time blocks within a day (or a season) with peak and off-peak pricing; relatively simple structure for incentivizing load shifting
  - Critical Peak Pricing – occasional events called by the utility with very high pricing
  - Real-Time Pricing – energy charges fluctuate hourly (or sub-hourly), either based on wholesale prices or hourly marginal generation costs (usually applies to generation costs but can also be designed to incorporate transmission and distribution costs)
- **Demand-Charge Alternatives**
  - Coincident Demand Charges – only apply to a customer's demand during peak periods
  - Volumetric Rates – rates with higher energy charges and lower demand charges; can enhance the economics of on-site distributed energy resources
- **Special Electrification Tariffs** – incentives to attract or retain industrial customers; can take many forms

Current Rate Structures and Proposed Alternative Rates

	Xcel	Black Hills	ComEd	Ameren
Current Rates – barriers to incentivizing industrial electrification	Distribution demand charge is non-coincident; energy charges are not time-differentiated	Distribution demand charge is non-coincident; energy charges are not time-differentiated	Minimal - Rates are already time-differentiated and have a coincident demand charge	Includes a non-coincident distribution demand charge
Alternative Rate Structure	Coincident demand charges; TOU energy charges	Coincident demand charges; TOU energy charges	Rate discount	Coincident distribution demand charge

Study Approach

Modeling Workflow



NOx Emissions Modeling Approach

- We quantify NOx emissions reductions from electrification (not facility total NOx emissions – only emissions associated with energy use for heating)
- Incumbent technologies – we assigned EPA AP-42 emissions factors to equipment in our database, based on equipment type, capacity, and fuel used
  - For natural gas boilers, we did a sensitivity analysis using AP-42 emissions factors for controlled and uncontrolled boilers
- Electrification technologies – we used the 20-year average of long-range marginal emissions rates for NOx from grid electricity in each utility territory
  - For thermal batteries, we adjusted emissions factors for NOx (and CO_2) downwards based on a utility-specific estimated discount factor meant to simulate thermal batteries charging during low-price, low-emissions times

Analyzed Facilities

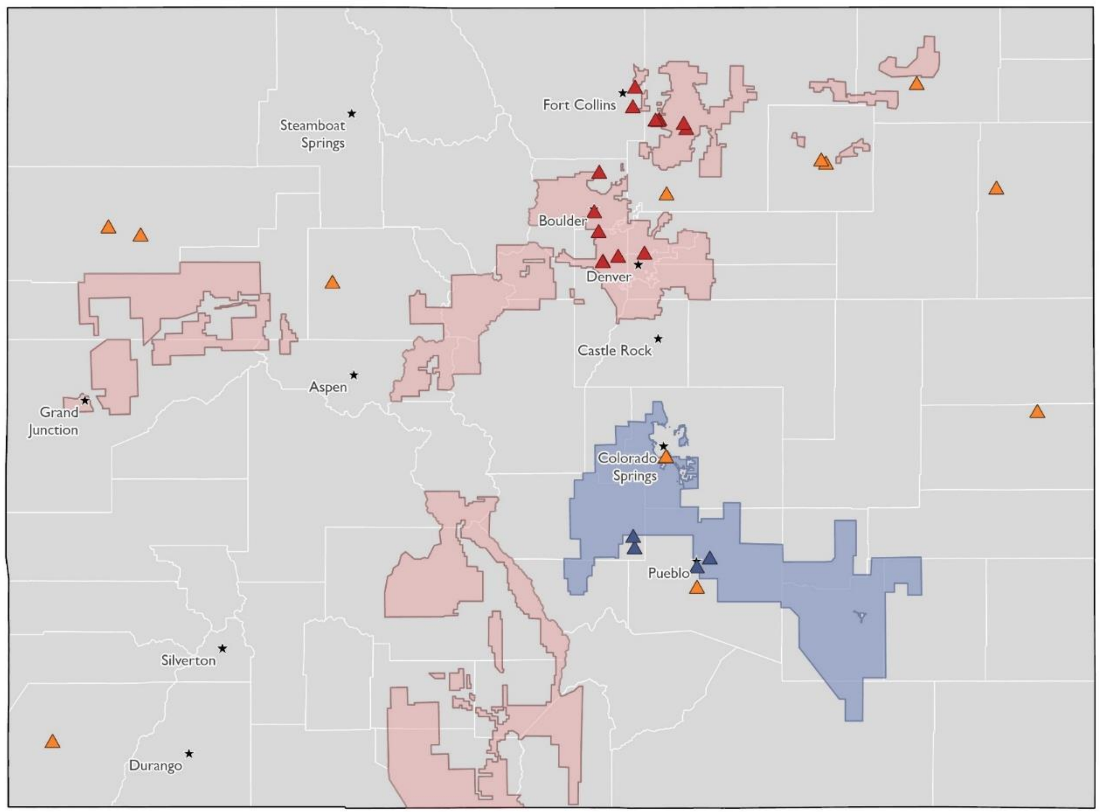
- Synapse identified 95 industrial facilities that are in the ComEd, Ameren, Xcel, and Black Hills utility territories
- The facilities in ComEd/Ameren territories account for 98% of fuel use for heating across all manufacturing facilities in Illinois tracked in our tool
- The facilities in Xcel/Black Hills territories account for 78% of fuel use for heating across all manufacturing facilities in Colorado tracked in our tool

*based on GHGRP reporting of facilities emitting >25,000 MT CO_2/year

Analyzed Facilities: Colorado

GHGRP Facilities in Colorado

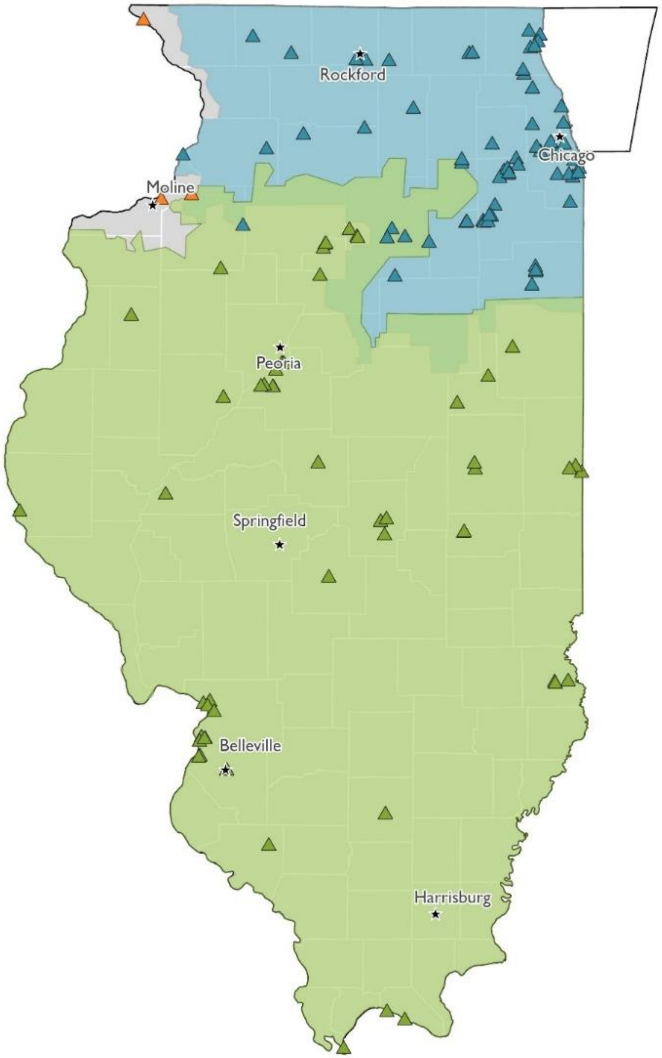
- Xcel Energy (Colorado DOT def.)
- Black Hills Energy (HILFD def.)
- Other utility
- Facility in Xcel Energy service territory
- Facility in Black Hills service territory
- Facility in other utility service territory
- Major city or town



Analyzed Facilities: Illinois

GHGRP Facilities in Illinois

- Ameren Illinois Company (Ameren)
- Commonwealth Edison (ComEd)
- Other utility
- Facility in Ameren service territory
- Facility in ComEd service territory
- Facility in other utility service territory
- Major city or town



Economic, Energy, and Emissions Impacts of Industrial Electrification Under Alternative Rate Structures

Xcel

Colorado

Electricity Bill Impacts from Electrification

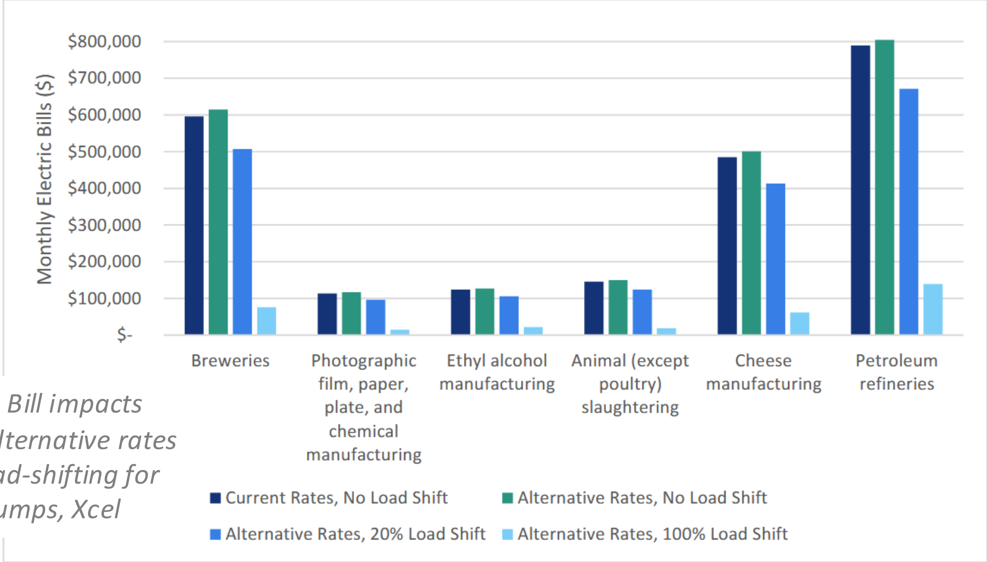


Figure: Bill impacts from alternative rates and load-shifting for heat pumps, Xcel

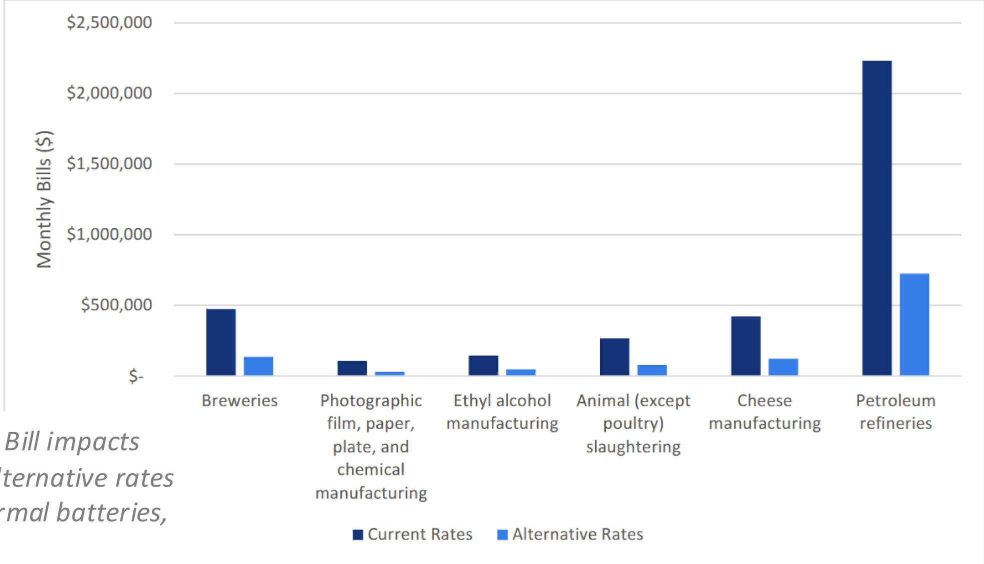
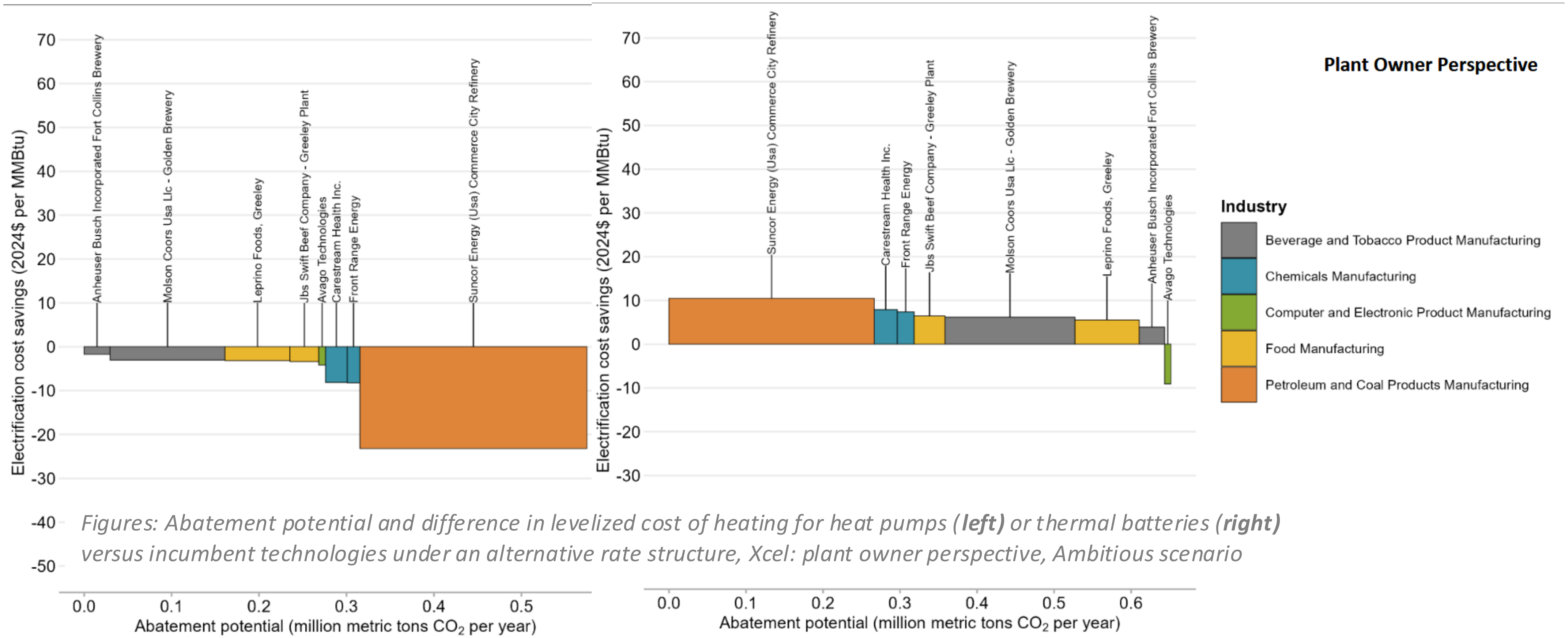


Figure: Bill impacts from alternative rates for thermal batteries, Xcel

- For heat pumps, even a small amount of load shifting enables bill savings
- For heat pumps without load shifting, alternative rates result in minor bill increases due to a coincident distribution demand charge under alternative rates that is slightly higher than the noncoincident charge under current rates
- Thermal batteries under alternative rates can avoid coincident demand charges and dramatically lower bills (noting that electrification with thermal batteries under current rates is not a realistic option)

Levelized Cost of Heating Comparison

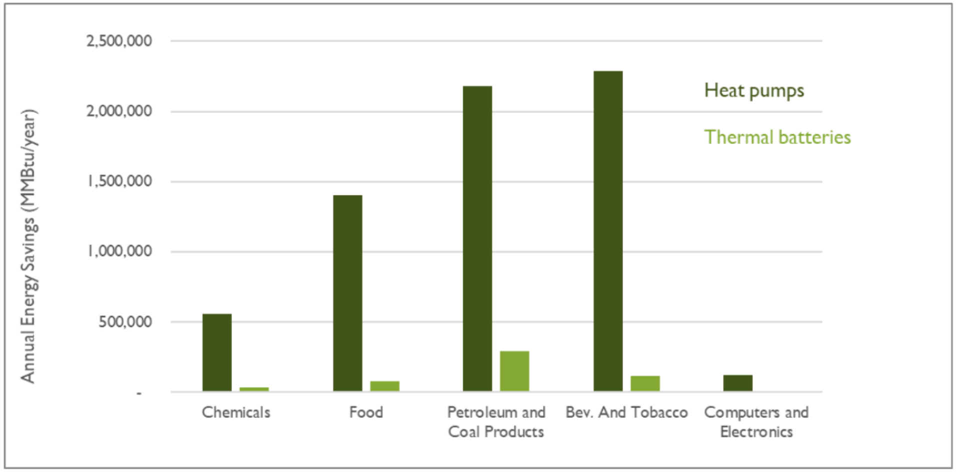
- Alternative rates structures reduce the LCOH for heat pumps, but do not fully close the gap with incumbent technologies
- For thermal batteries, the ability to charge during low-price hours under alternative rate structures enables a lower LCOH than incumbent technologies for most facilities
- Considering the LCOH from a societal perspective that accounts for the social cost of carbon makes electrification favorable for all facilities and electrification technologies



*Figures: Abatement potential and difference in levelized cost of heating for heat pumps (**left**) or thermal batteries (**right**) versus incumbent technologies under an alternative rate structure, Xcel: plant owner perspective, Ambitious scenario*

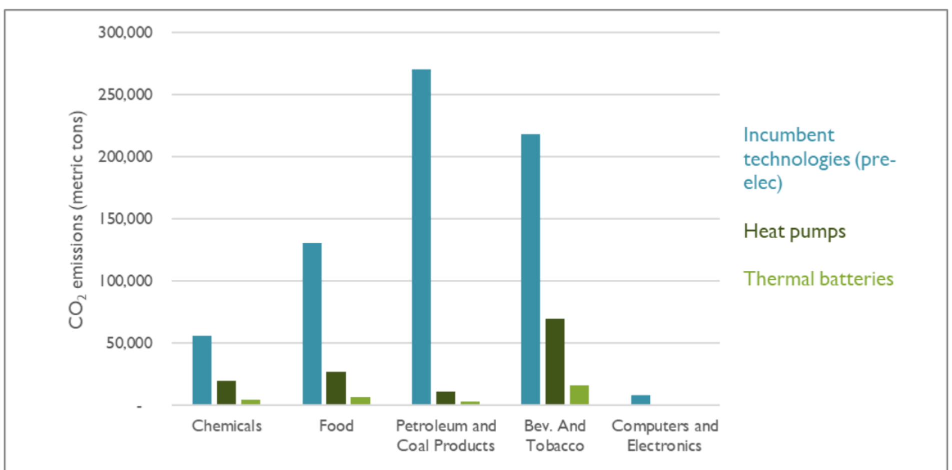
Energy and Emissions Impacts

Figure: Annual energy savings by sector from electrification with heat pumps and thermal batteries, Xcel



- Heat pumps can save more energy than thermal batteries, with the beverage and tobacco industry having the greatest energy savings potential
- Heat pumps reduce CO_2 emissions by 64 to 96 percent across subsectors, and thermal batteries 91 to 99 percent based on the average long-run marginal emissions rate (LRMER) for grid electricity in Colorado
- NO_X has large abatement potential across all sectors

Figure: CO_2 emissions for incumbent and electrified technologies by sector, Xcel



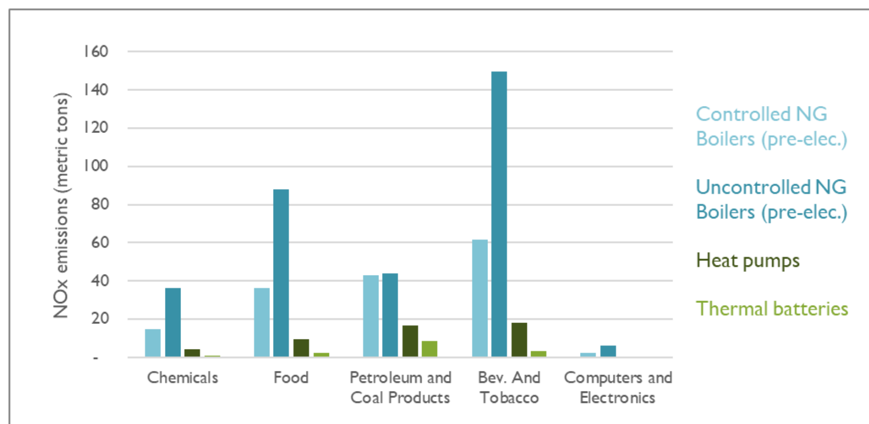


Figure: NOx emissions for incumbent and electrified technologies by sector, Xcel

Black Hills

Colorado

Electricity Bill Impacts from Electrification

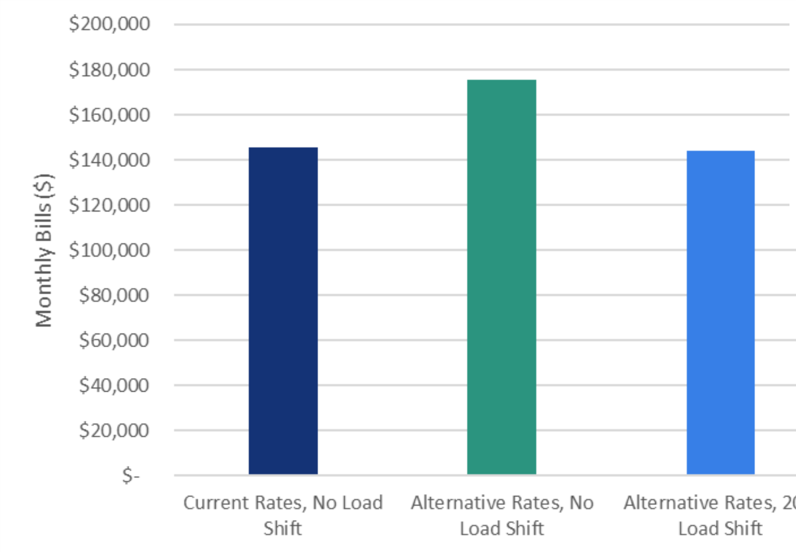


Figure: Bill impacts from alternative rates and load-shifting for heat pumps, Black Hills

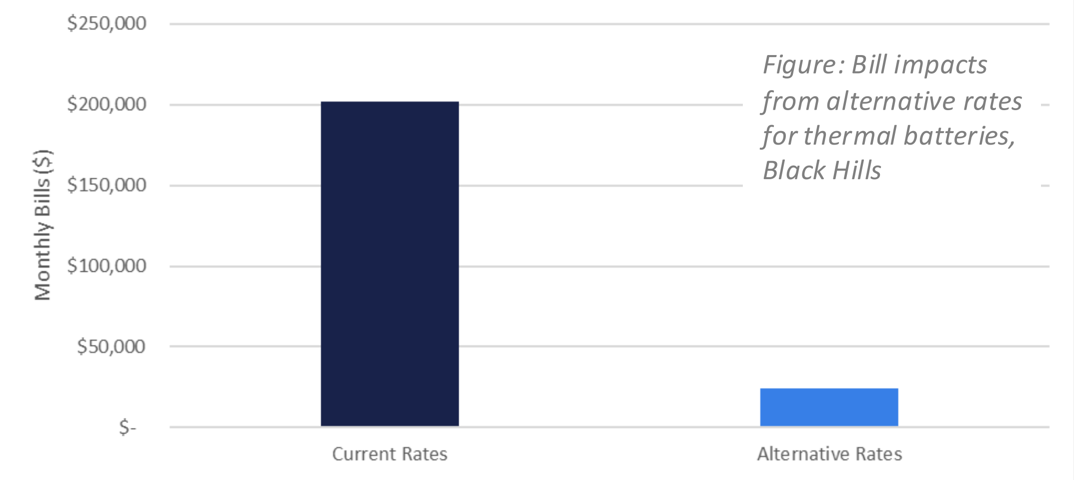


Figure: Bill impacts from alternative rates for thermal batteries, Black Hills

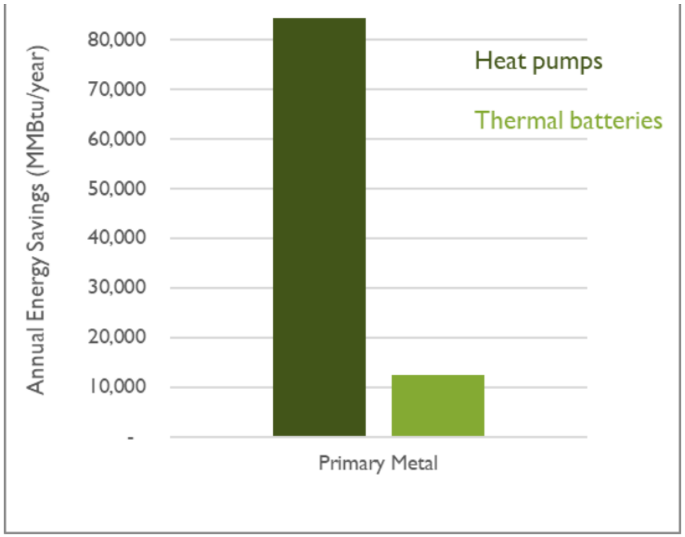
- In our analysis, Synapse concluded that only one industrial facility in Black Hills service territory has electrification potential: the Rocky Mountain Steel mill in Pueblo (and even then, overall electrification potential is small since iron and steel largely requires high-temperature process heating)
- Even a small amount of load shifting enables bill savings with heat pumps
- For heat pumps without load shifting, alternative rates result in minor bill increases, similar to Xcel
- Thermal batteries under alternative rates can avoid coincident demand charges and dramatically lower bills (noting that electrification with thermal batteries under current rates is not a realistic option)

Levelized Cost of Heating Comparison

- Electrification of Rocky Mountain Steel in Black Hills with heat pumps is not economical under any of the studied scenarios
  - This is driven by the relatively high temperatures used in the combustion units recorded in TIDE
  - Our database records two small combustion units with a small amount of heating provided at just under 200°C that could be electrified
  - In addition, these units represent a very small portion of onsite energy use. The Rocky Mountain Steel mill produces steel via a scrap-based electric arc furnace, an already-electrified process that accounts for the vast majority of onsite energy use
- The LCOH for thermal batteries is lower than for the incumbent technologies at the Rocky Mountain Steel mill

Energy and Emissions Impacts

Figure: Annual energy savings from electrification with heat pumps and thermal batteries at the studied steel mill, Black Hills



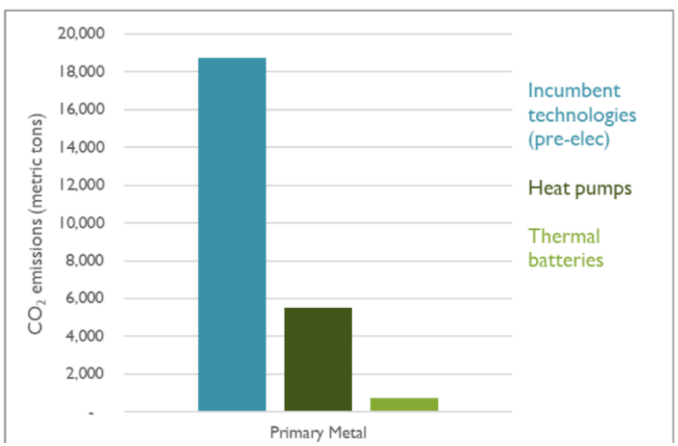


Figure: CO_2 emissions for incumbent and electrified technologies for the studied steel mill, Black Hills

- Heat pumps can save more energy than thermal batteries at the studied site, although overall energy savings are small relative to other sectors in other territories
- Heat pumps reduce CO_2 emissions by 71 percent across subsectors, and thermal batteries by 96 percent
- NO_X has large abatement potential, but single-facility results have high uncertainty based on the underlying emissions factor data source

Figure: NOx emissions for incumbent and electrified technologies by sector, Xcel

ComEd

Illinois

Electricity Bill Impacts from Electrification

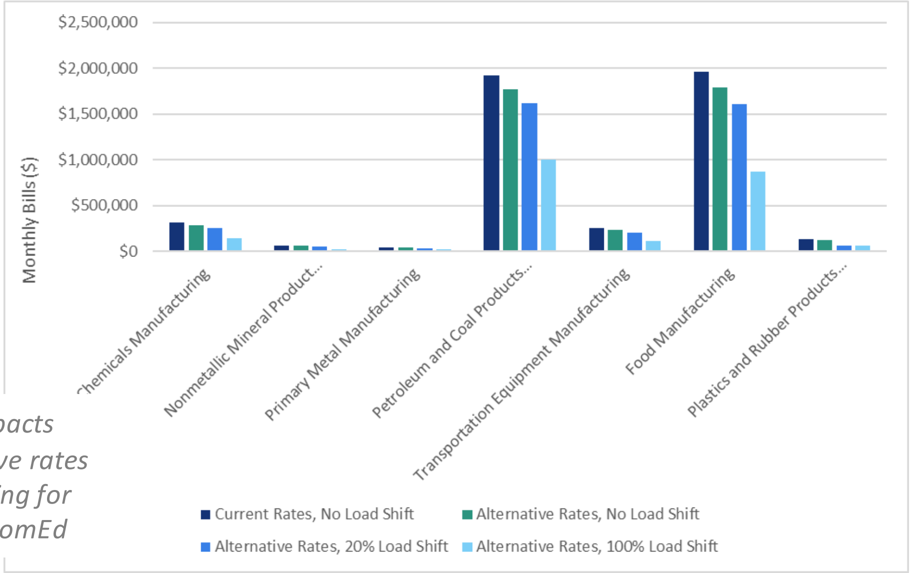


Figure: Bill impacts from alternative rates and load-shifting for heat pumps, ComEd

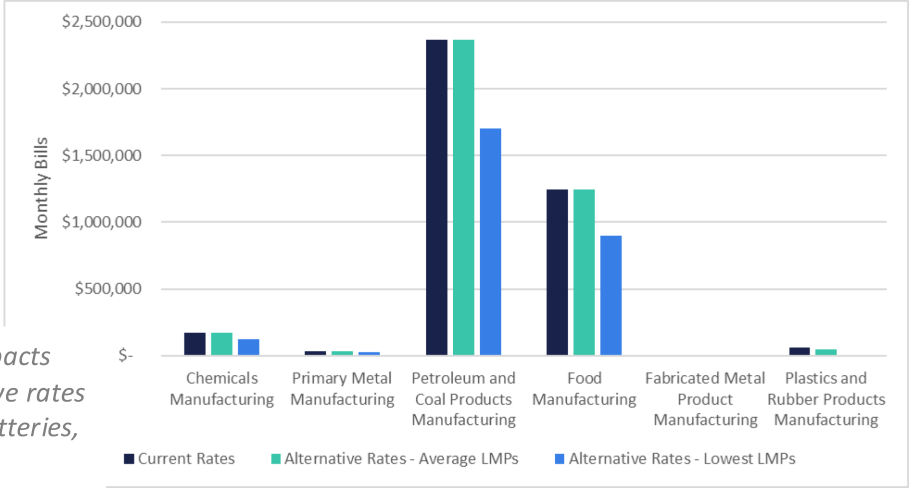
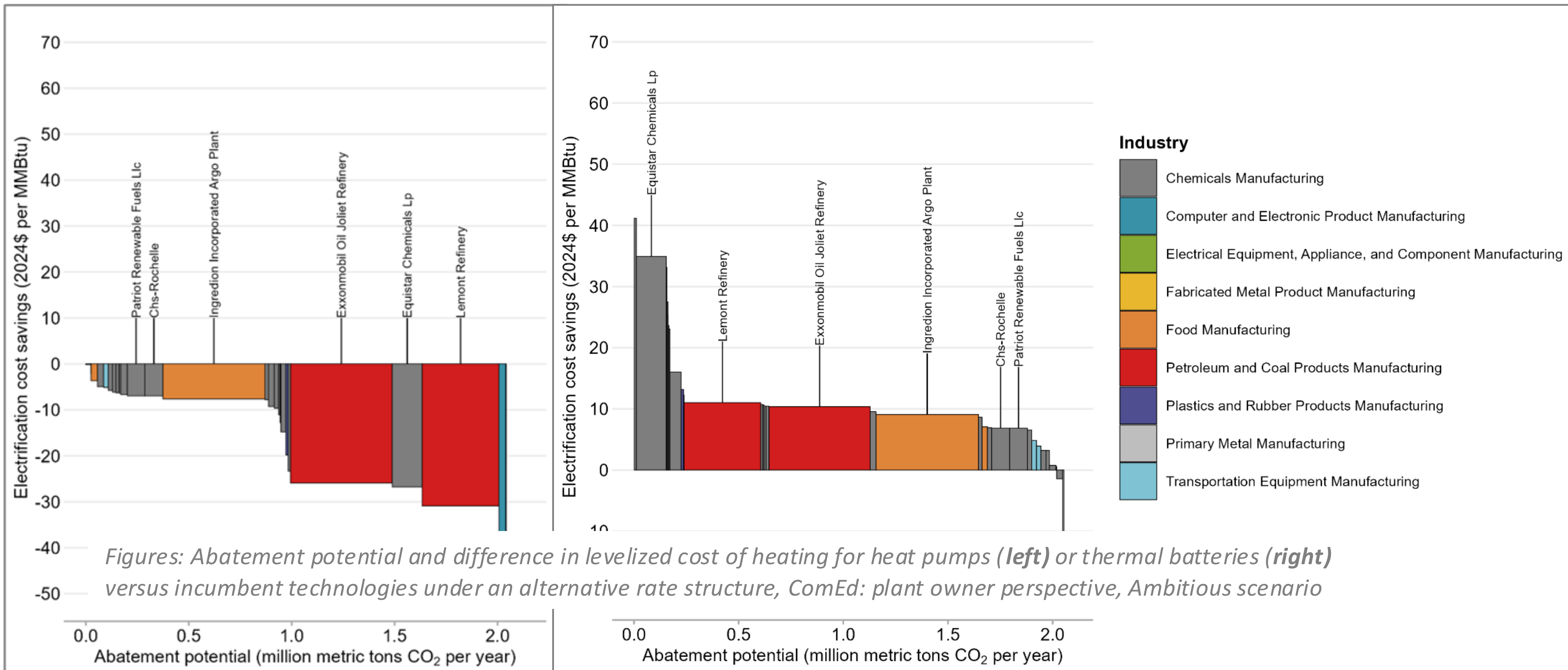


Figure: Bill impacts from alternative rates for thermal batteries, ComEd

- The alternative rates for ComEd only differ from current rates in offering a discount on distribution charges, so monthly bills are lower with heat pumps even without load shifting
- Thermal batteries do not have savings under alternative rates because they already avoid coincident demand charges under current rates
- However, customers connected at PJM nodes with lower LMPs can access lower electricity costs post-electrification

Levelized Cost of Heating Comparison

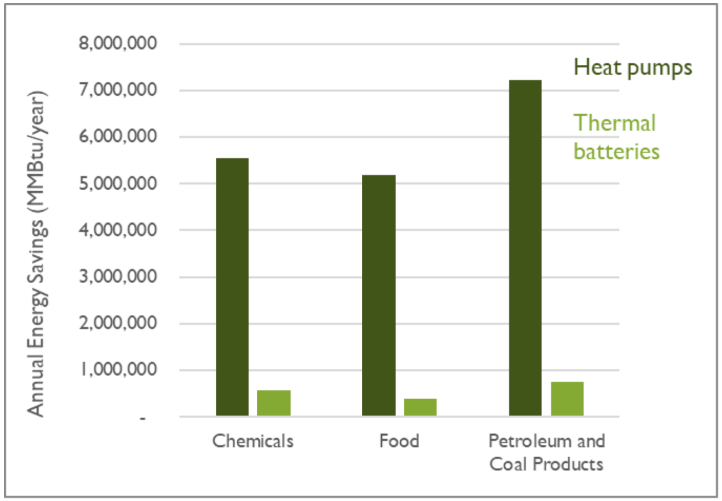
- Alternative rates structures reduce the LCOH for heat pumps, but do not fully close the gap with incumbent technologies
- For thermal batteries, most facilities can electrify economically, assuming these facilities can access average LMPs under alternative rate structures
- Considering the LCOH from a societal perspective that accounts for the social cost of carbon makes electrification favorable for all facilities for thermal batteries, and most facilities for heat pumps



*Figures: Abatement potential and difference in levelized cost of heating for heat pumps (**left**) or thermal batteries (**right**) versus incumbent technologies under an alternative rate structure, ComEd: plant owner perspective, Ambitious scenario*

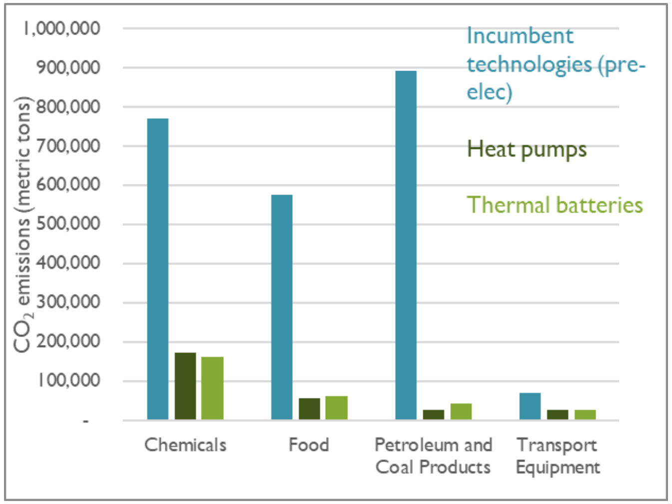
Energy and Emissions Impacts

Figure: Annual energy savings by sector from electrification with heat pumps and thermal batteries, ComEd



- Heat pumps can save more energy than thermal batteries, with the petroleum and coal products industry having the greatest energy savings potential
- Heat pumps reduce CO_2 emissions by 61 to 97 percent across subsectors, and thermal batteries 60 to 98 percent based on the average LRMER for grid electricity in Illinois
- NO_X has large abatement potential across all sectors (only largest sectors presented here – see report for full details)

Figure: CO_2 emissions for incumbent and electrified technologies by sector, ComEd



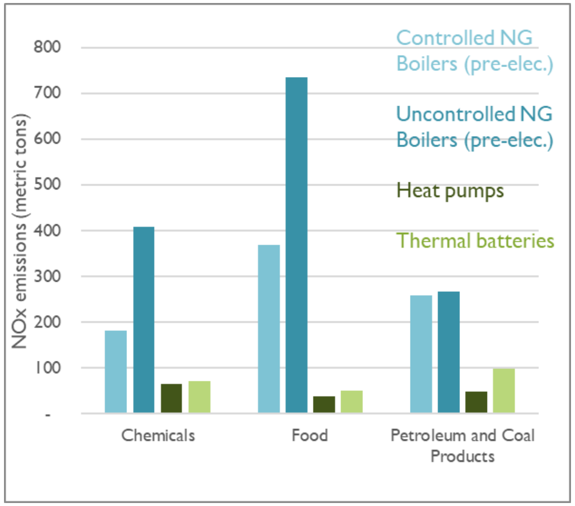
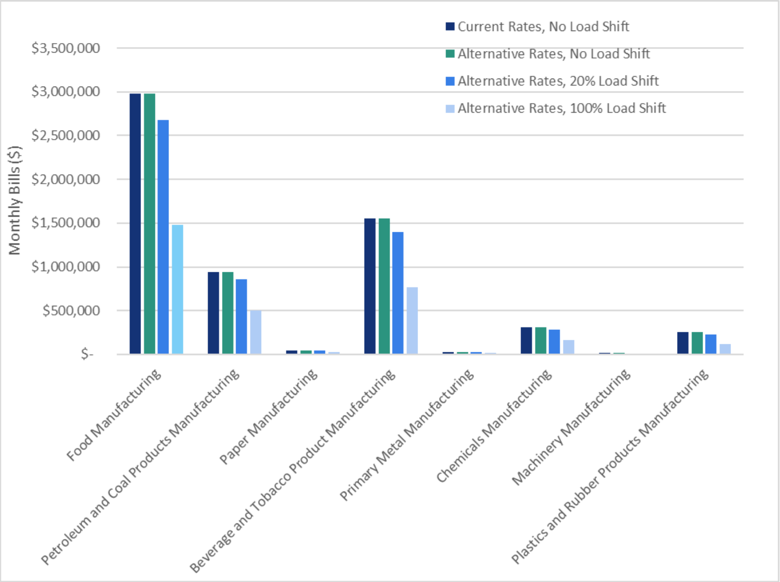


Figure: NOx emissions for incumbent and electrified technologies by sector, ComEd

Ameren

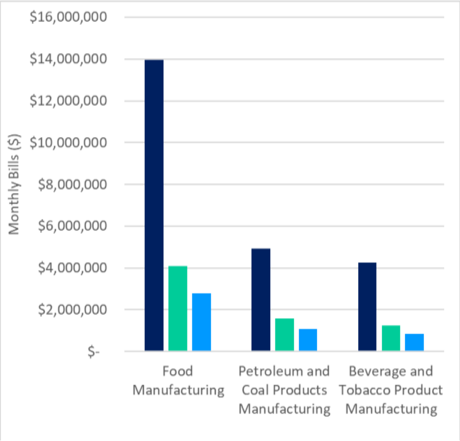
Illinois

Electricity Bill Impacts from Electrification



- Customers who adopt heat pumps and shift 100 percent of their load to off-peak hours could achieve a bill reduction of between 46 and 53 percent compared to alternative rates without load-shifting
- Thermal batteries can also save money on electricity bills, especially if they are located at MISO nodes with lower LMPs than the rest of Ameren's territory

Figure: Bill impacts from alternative rates and load-shifting for heat pumps, Ameren



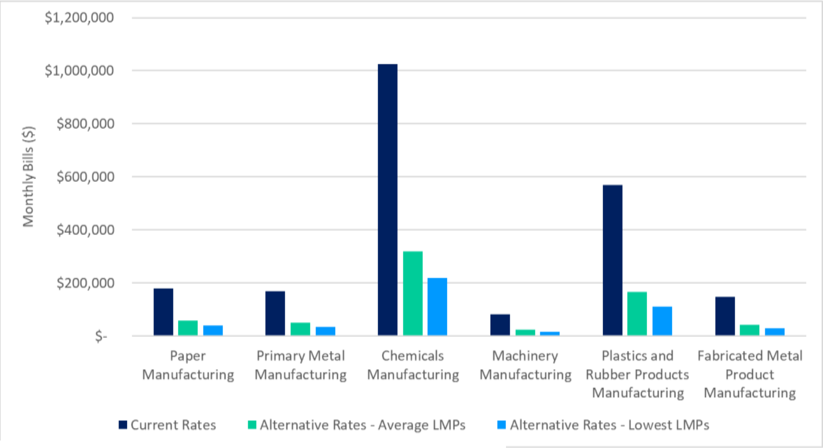
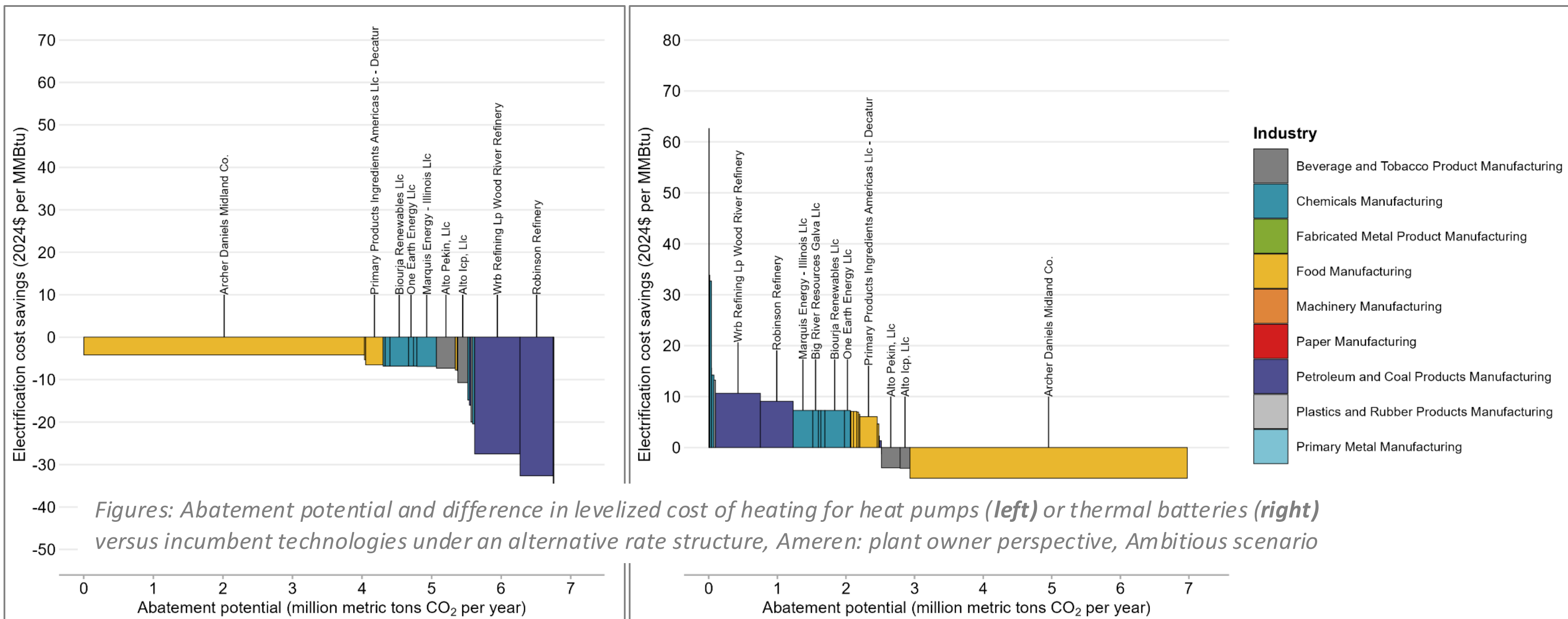


Figure: Bill impacts from alternative rates for thermal batteries, Ameren

Levelized Cost of Heating Comparison

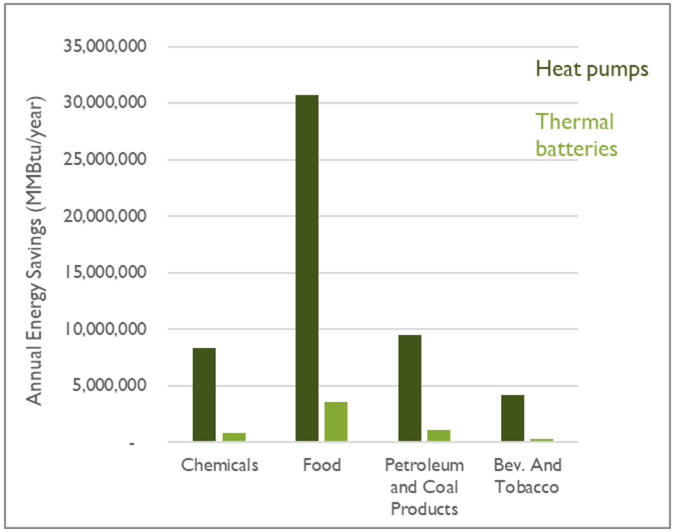
- Alternative rates structures reduce the LCOH for heat pumps, but do not fully close the gap with incumbent technologies
- For thermal batteries, most facilities can electrify economically, assuming these facilities can access average LMPs under alternative rate structures
- Considering the LCOH from a societal perspective that accounts for the social cost of carbon makes electrification favorable for all facilities for thermal batteries, and most facilities for heat pumps



*Figures: Abatement potential and difference in levelized cost of heating for heat pumps (**left**) or thermal batteries (**right**) versus incumbent technologies under an alternative rate structure, Ameren: plant owner perspective, Ambitious scenario*

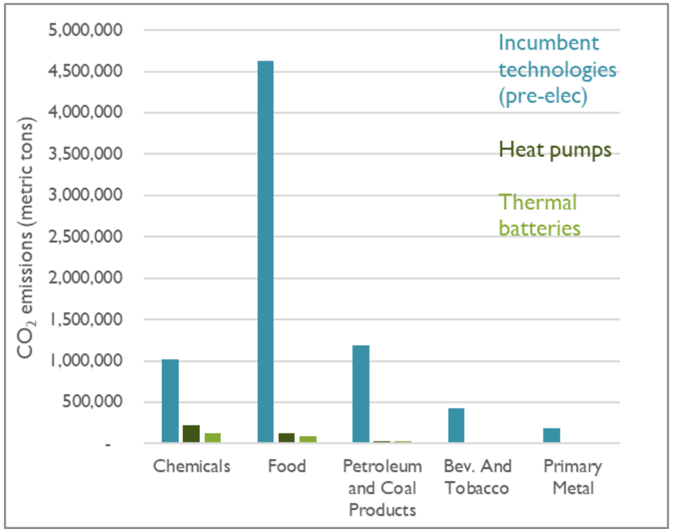
Energy and Emissions Impacts

Figure: Annual energy savings by sector from electrification with heat pumps and thermal batteries, Ameren



- Heat pumps can save more energy than thermal batteries, with the food industry having the greatest energy savings potential
- Heat pumps reduce CO_2 emissions by 65 to 97 percent across subsectors, and thermal batteries 80 to 98 percent based on the average LRMER for grid electricity in Illinois
- In total across sectors, there is large NOx abatement potential, however, in some sectors there is a risk of NOx emissions increasing if marginal electricity demand is met with old gas peaker plants in MISO

Figure: CO_2 emissions for incumbent and electrified technologies by sector, Ameren



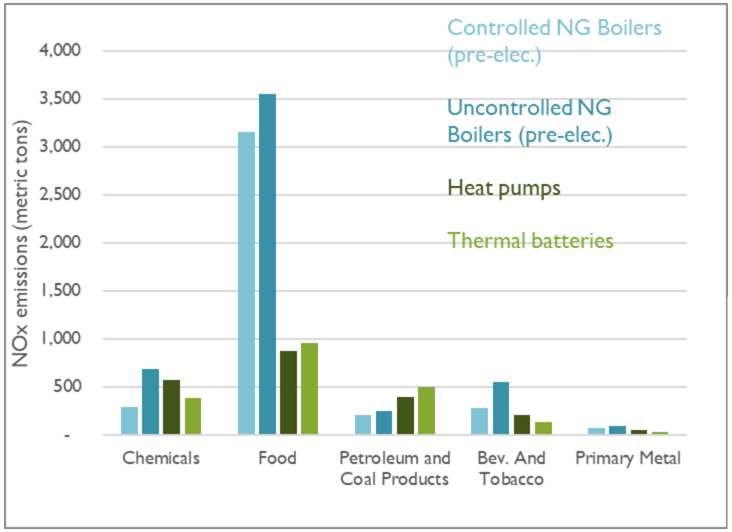


Figure: NOx emissions for incumbent and electrified technologies by sector, ComEd

Conclusion: Enabling the Economics of Industrial Electrification

Key Findings

- **Load-shifting to reduce electricity bills:** Alternative rate structures have considerable potential to reduce electricity bills compared to electrification under current rate structures, with load-shifting as a key strategy to capture these bill reductions
- **Thermal battery price arbitrage:** Thermal batteries that can take advantage of alternative rate structures to charge during low-price hours enable some facilities in each territory to lower heating costs relative to incumbent technology
- **Heat pumps' cost-competitiveness:** Alternative rates paired with load shifting reduce the LCOH for electrification technologies but are generally not enough to make heat pumps cost-competitive with incumbent technologies, though in practice results will be highly specific to a facility's waste heat availability

Recommendations

- **Load flexibility:** Enable load flexibility (especially for heat pumps) with mechanisms such as retaining existing heating equipment as backup, combining heat pump and thermal battery systems, installing steam accumulators, etc.
- **Capital and installation cost support:** Deploy targeted financial and programmatic support for heat pumps and thermal batteries, such as grants, investment tax credits, production-based incentives, etc.
- **Incentives for on-site DERs:** Incentives for on-site DERs can complement rate design to help unlock industrial facilities' load flexibility potential, enabling industrial customers to take advantage of lower electricity prices that help make projects viable
- **Support for grid upgrade costs:** Cost-sharing mechanisms and incentive programs to help improve the economics of industrial electrification projects

