Illinois Clean Manufacturing Roadmap

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About RMI

Rocky Mountain Institute (RMI) is an independent, nonpartisan nonprofit founded in 1982 that transforms global energy systems through market driven solutions to secure a prosperous, resilient, clean energy future for all. In collaboration with businesses, policymakers, funders, communities, and other partners, RMI drives investment to scale clean energy solutions, reduce energy waste, and boost access to affordable clean energy in ways that enhance security, strengthen the economy, and improve people's livelihoods. RMI is active in over 60 countries.

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Executive Summary

Though the industrial sector has historically been deemed hard to abate, many of Illinois's industrial emissions — about 8.7 million tons (Mt) of CO_2[1] — come from burning natural gas in low- and medium-temperature ranges for which low-emissions technologies like industrial heat pumps, electric boilers, and thermal energy storage have already proven viable.[2] As these next-generation technologies continue down the cost curve and improve in performance, this roadmap provides a plan for Illinois policymakers to ease the transition to clean manufacturing and production methods.

Manufacturing is a driving force of the Illinois economy. Across the state, approximately 580,000 Illinoisans are employed in manufacturing, specializing in products ranging from food and beverage to biofuel inputs.[3] The state was the nation's fifth largest exporter of goods in 2024, and goods exports accounted for 7.4% of state gross domestic product in the same year.[4] In addition to advancing the economy, the industrial sector is a significant source of climate pollution in the state, comprising 18% of Illinois's total emissions (or 45 Mt of CO_2e).[5] Modern manufacturing also benefits public health, with new analysis estimating that replacing boilers with low-emissions equipment could help avoid 1.7 million asthma attacks by 2050 in Illinois alone.[6] To meet the climate and health targets mandated by the Climate and Equitable Jobs Act while maintaining Illinois's manufacturing might, the state must work to reduce emissions from its industrial sector in a way that allows businesses to stay regionally and globally competitive.[7] The near-, mid-, and long-term actions contained within this roadmap are designed to achieve these dual ambitions.

Technical solutions

In this roadmap we focus on solutions that are technologically and commercially ready (technology readiness level of 9 or higher, meaning the technology has successful full-scale deployment in an operational environment[8]) can be deployed in the near term, and fall into three main categories: energy efficiency, electrification, and geothermal heat.

- **Energy efficiency:** Many assume industrial facilities have already maximized energy efficiency, but a study from ENERGY STAR finds that energy efficiency still represents 34% of feasible carbon emissions reductions in U.S. manufacturing by 2050.[9] This leaves a major opportunity for cost savings and emissions reductions, especially as technologies' efficiency improves. Illinois facilities can implement solutions like industrial heat pumps, low-carbon or geothermal combined heat and power, and energy management systems, which reduce waste without disrupting production.

- **Electrification:** Electrification is a key strategy for reducing emissions in low- and medium-temperature industrial processes. Facilities like those in the food and beverage and chemical sectors can adopt electric resistance heating and thermal energy storage to replace fossil-fueled systems. These technologies are reliable and can be tailored to specific heat and power needs.

- **Geothermal heat:** Advanced geothermal systems now allow heat extraction in regions without geologic activity, making them viable across Illinois. Geothermal heat is ideal for industrial use because it provides direct heat without needing conversion to electricity. Though still emerging, it is already being implemented in similar contexts to Illinois and offers strong potential for demonstration projects.[10]

Barriers to adoption

Despite the maturity of many of these technologies, nearly every facility in Illinois remains reliant on natural gas to fuel operations. Where facilities consider adopting lower-emissions equipment, they face barriers including technology integration, equipment financing, and system-level capabilities. The following barriers were surfaced through informational interviews with facility owners and managers:

- **No one-size-fits-all solution:** Each facility has unique energy needs, making it difficult to apply a universal electrified heating solution. Long equipment lead times and potential production disruptions are major deterrents.
- **Limited capacity among smaller manufacturers:** Small and medium-sized manufacturers often lack the resources to conduct energy audits or evaluate alternative equipment investments.
- **High up-front and operating costs:** Efficient and electrified systems are more expensive than traditional gas boilers. In Illinois, industrial electricity is about 2.4 times more costly than gas.[11]
- **Grid and infrastructure constraints:** Facilities need reliable, affordable electricity, but grid capacity and transmission planning are still catching up. Long deployment cycles and a lack of commercial-scale demonstrations also slow adoption.

Enabling policies

To overcome these barriers and unlock the clean manufacturing potential, Illinois can enact targeted policies and programs. We focus on eight key strategies, many with specific subpolicies, discussed in detail in the ***State Interventions*** section of the report:

1. Support the adoption of emissions-reducing technologies financially
2. Improve efficiency requirements
3. Increase grid clean capacity
4. Incentivize flexible industrial electricity demand
5. Streamline permitting processes for emissions reduction projects
6. Improve emissions standards
7. Leverage state buying power
8. Understand the opportunity and build information bases to support modernizing industrial technology deployment

There is no silver bullet to achieve low-emissions industry, so the state should consider its funding resources, administrative capacity, and input from industrials to unlock the greatest emissions reduction potential. In concert, a number of these strategies (depicted in Exhibit ES1) can be powerful levers to change Illinois's industrial emissions landscape and drive private investment in clean technology.

Exhibit ES1 Timeline of policy interventions to aid industrial emissions reductions

NEAR TERM (0–3 YEARS)

Understand the opportunity and build information bases to support modernizing industrial technology deployment

Decision makers
Legislature, SEO, EDO, climate office, DOT

Description
Foundational training, research, and technical assistance efforts to build the industrial emissions reduction knowledge base. Some of these policies are already in force.

Provide financial support for the adoption of emissions-reducing technologies

Decision makers
Legislature, utility, climate office, EDO, SEO

Description
Tax credits and other incentives to promote technology deployment. Most impactful when introduced early to support rapid deployment.

Standards and **requirements** can be introduced in the near- to mid-term and designed to become more stringent over time.

Improve emissions standards

Decision makers
Legislature, climate office, PUC, SEO

Description
Emissions standards to reduce long-term emissions. These policies should be introduced in the near- to mid-term to maximize impact and can be designed so they become more stringent over time.

Improve efficiency requirements

Decision makers
Legislature, governor's office, climate office, SEO, EDO, PUC, building code council

Description
Efficiency standards, targets, and other efforts. These policies should be introduced in the near- to mid-term to maximize impact and can be designed so they become more stringent over time.

Accelerate permitting processes for emissions-reduction projects

Decision makers
Legislature, climate office, DOT, governor's office, other agency

Description
Accelerate approval processes for emissions-reduction projects. Requires time for policy design, but foundational for electrification upgrades.

Incentivize flexible industrial electricity demand

Decision makers
Legislature, PUC, utility

Description
Policies to support use of affordable, clean electricity by industrial facilities to ensure substantial emissions reductions from electrification. Co-located with increased grid capacity so that sites have adequate clean energy supplies to draw from.

Leverage state buying power

Decision makers
Legislature, governor's office, climate office, EDO

Description
State "buy clean" programs to support use of and create a market for clean industrial materials, particularly in construction projects. Requires deployment of efficiency and electrification improvements so that such products are available.

LONG TERM (10+ YEARS)

RMI Graphic. Source RMI analysis

How will the people of Illinois benefit?

Improving efficiency and electrifying operations in the industrial sector create ripple effects beyond the borders of the facilities.

First, there are tangible air quality benefits to industrial electrification, especially to communities near the facilities. A new report from the American Lung Association found that "the transition to zero-emission technology for low- and mid-temperature industrial boilers would generate substantial reductions in both climate-forcing emissions and local air pollutants that threaten public health."[12] In Illinois specifically, the report estimates the cumulative health benefits of switching low- and medium-temperature boilers to heat pumps to be $61.6 billion.[13] The analysis uses the Environmental Protection Agency's Co-Benefits Risk Analysis (COBRA) tool to assess the frequency of health incidents like asthma and premature mortality caused by industrial pollutant emissions and evaluates the monetary benefit of avoiding them.

Beyond the state's stated ambition to reduce emissions and the obligation to deliver clean air to its residents, Illinois has the opportunity to lead the U.S. towards low-emissions industry and export goods produced to global markets, which are increasingly willing to pay premiums for green products. Given that $12.6 billion of goods produced in the state were exported to the European Union in 2024,[14] the state can consider tightening regulations and supporting Illinois businesses to compete in low-carbon global markets with a carbon border adjustment mechanism.[15]

Overview of Industrial Emissions in Illinois

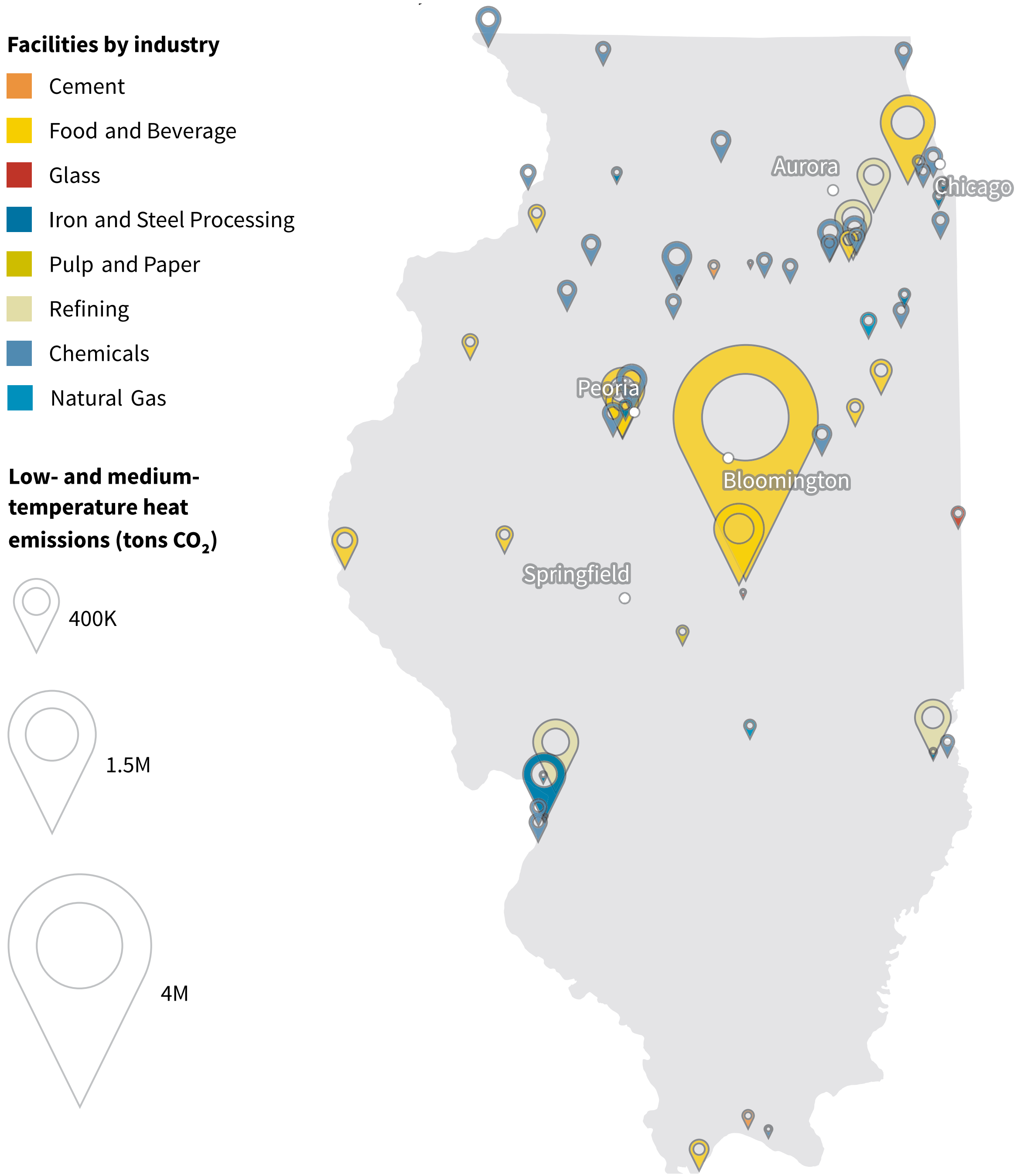
Methodology

An open-source public dataset on industrial combustion emissions called the US Industrial Sector Heat Emissions and Temperature Dataset (HEATset) was used for this analysis.[16] HEATset V1.0 utilizes facility-reported emissions data for reporting year 2022 from the US Environmental Protection Agency's (EPA's) Greenhouse Gas Reporting Program (GHGRP). The data covers industrial facilities with annual Scope 1 CO_2 emissions greater than 25,000 tons. Scope 2 and Scope 3 emissions are not within the purview of this analysis.[i]

This analysis focused on manufacturing facilities in eight high-level industrial sectors: food and beverage, refining, chemicals, iron and steel, glass, cement, natural gas processing, and pulp and paper manufacturing (see Exhibit 1).

i Scope 1 emissions are direct greenhouse gas emissions from sources owned or controlled by a company such as fuel combustion in company-owned boilers. Scope 2 emissions are indirect greenhouse gas emissions from purchased energy such as purchased electricity. Scope 3 emissions are all other indirect emissions that occur in a company's value chain, both upstream and downstream, that are not included in Scope 2. Scope 3 emissions include purchased goods and services and end-of-life treatment of sold products.

Exhibit 1 Map of Illinois facilities with CO_2 emissions from low- and medium-temperature heat



RMI Graphic. Source: Center for Applied Environmental Law and Policy (CAELP) HEATset

Emissions by temperature grade

Low-temperature (0°C–200°C) and medium-temperature (200°C–400°C) heat account for approximately 50% of combustion CO_2 emissions from industry in Illinois, or 8.7 of 17.6 million tons (Mt) total in 2022. Of these sub-400°C temperature heat emissions, 90% can be attributed to low-temperature heat and the remaining 10% to medium-temperature heat (see Exhibit 2).

Emissions by industrial subsector

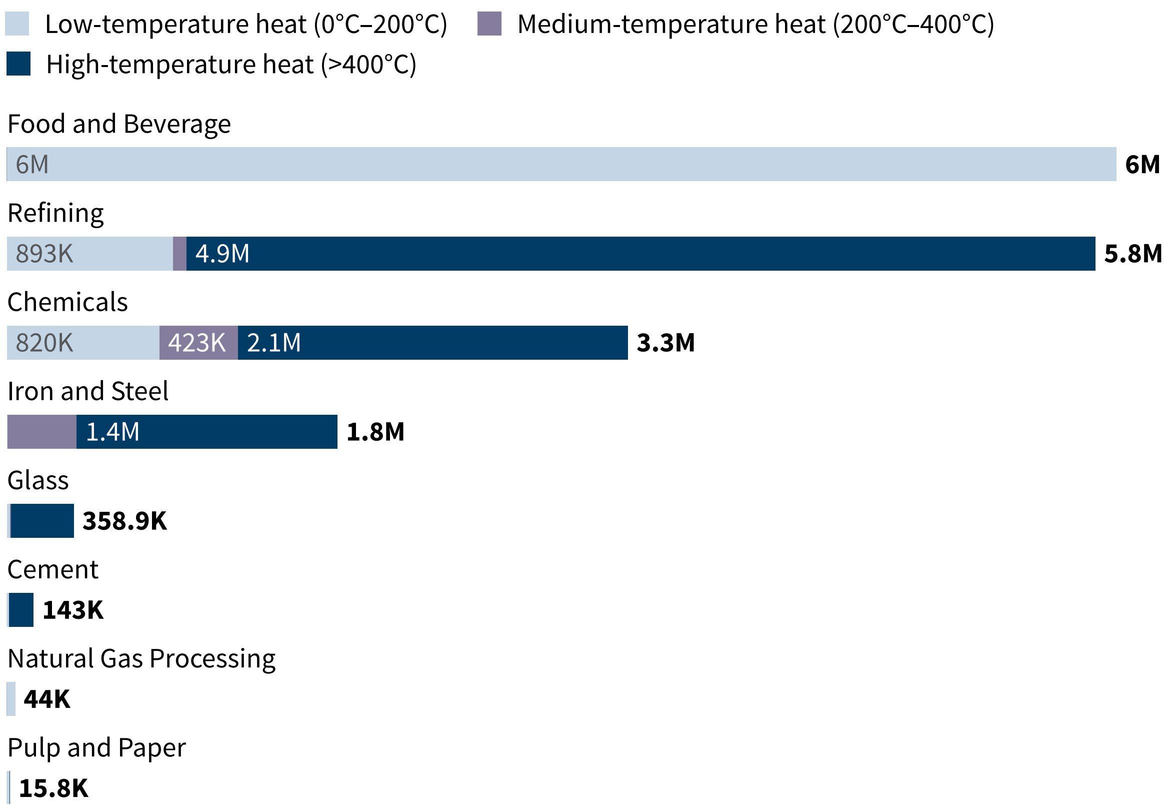
The food and beverage subsector accounts for most emissions from low- and medium-temperature heat (approximately 69%), followed by the chemicals sector (approximately14%), and the refining sector (approximately 11%).

The chemicals and refining sectors also have substantial emissions from high-temperature heat (above 400°C). Iron and steel, glass, and cement manufacturing emissions are all primarily associated with high-temperature heat.

Exhibit 2

Annual emissions by industrial subsector (2022)

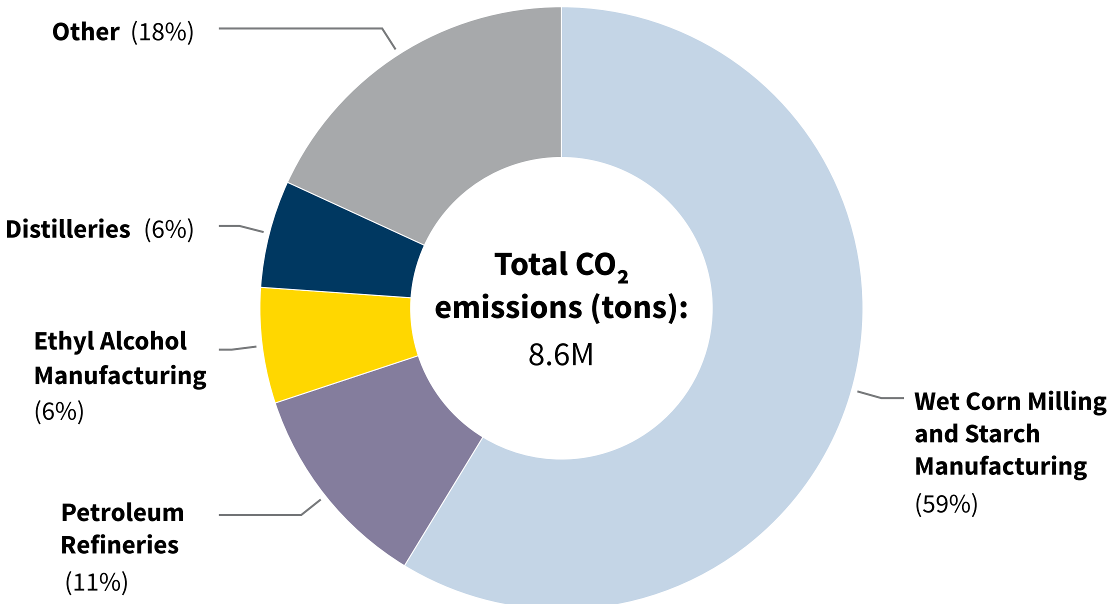
2022 estimated CO_2 emissions from on-site combustion of fuels for process heating (tons)



RMI Graphic. Source: CAELP HEATset

Wet corn milling accounts for approximately 59% of low- and medium-temperature heat emissions. Petroleum refiners, ethyl alcohol manufacturing, and distilleries account for 11%, 6%, and 6% of emissions, respectively (see Exhibit 3).

Exhibit 3 Annual low- and medium-temperature heat emissions by specific manufacturing process (2022)



RMI Graphic. Source: CAELP HEATset

Emissions by facility

Manufacturers using low- and medium-temperature heat in the state include ADM (wet corn milling), Ingredion Inc. (wet corn milling), Alto Ingredients Inc. (wet corn milling), Tate & Lyle Ingredients Americas LLC (wet corn milling), and Phillips 66 (petroleum refinery). Their respective subsectors combined are responsible for 70% of emissions from low- and medium-temperature heat (see Exhibit 4).

Exhibit 4 Emissions from low- and medium-temperature heat manufacturing

Parent company name	Industrial subsector	Low- and medium-temperature heat emissions (tons)
ADM	Wet corn milling	4,197,530
Ingredion Inc.	Wet corn milling	531,039
Alto Ingredients Inc.	Wet corn milling	496,988
Tate and Lyle Ingredients Americas LLC	Wet corn milling	440,813
Phillips 66	Petroleum refinery	355,454

RMI Graphic. Source: CAELP HEATset

Emissions by fuel type

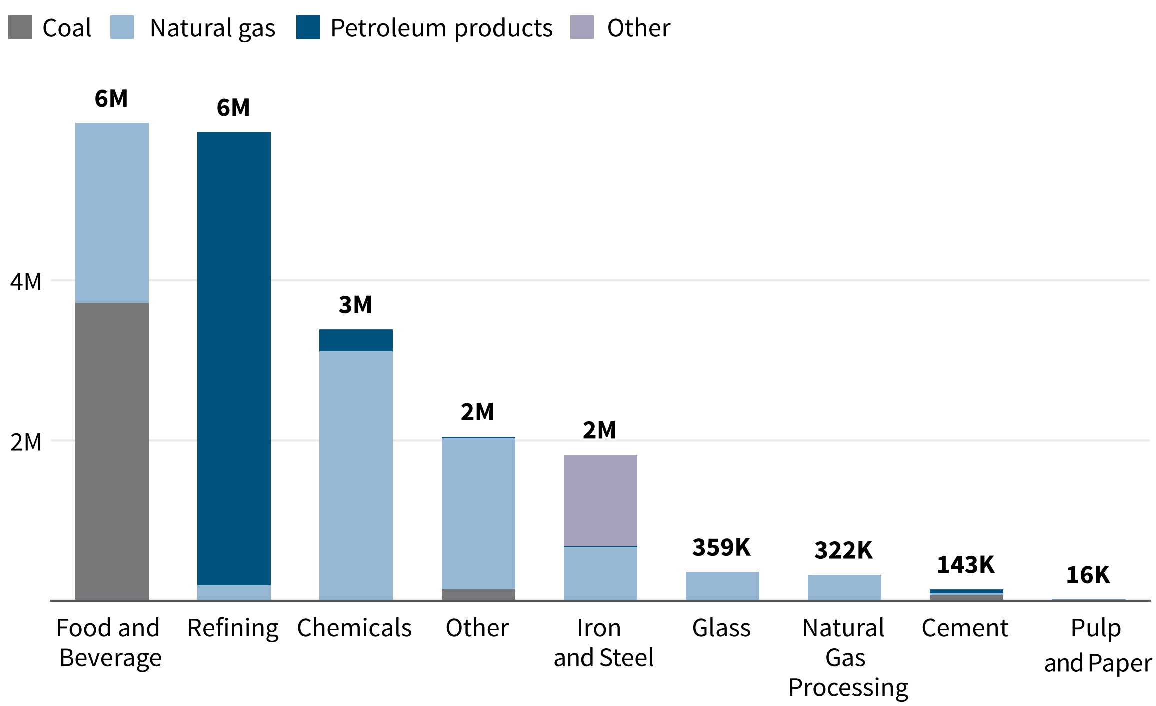
As illustrated in Exhibit 5, combustion of natural gas and coal account for most of the combustion emissions in the state, at 57% and 20%, respectively. Most of the coal combustion emissions are from the ADM facility in Decatur.

The primary fuel used in refineries is fuel gas, a gas produced as a by-product of the refining process that is combusted as fuel on-site. The primary fuel used in iron and steel manufacturing is blast furnace gas, a by-product of the process.

Exhibit 5

Emissions by fuel type

2022 estimated CO_2 emissions from combustion of fuel for process heating at all temperature ranges (tons)



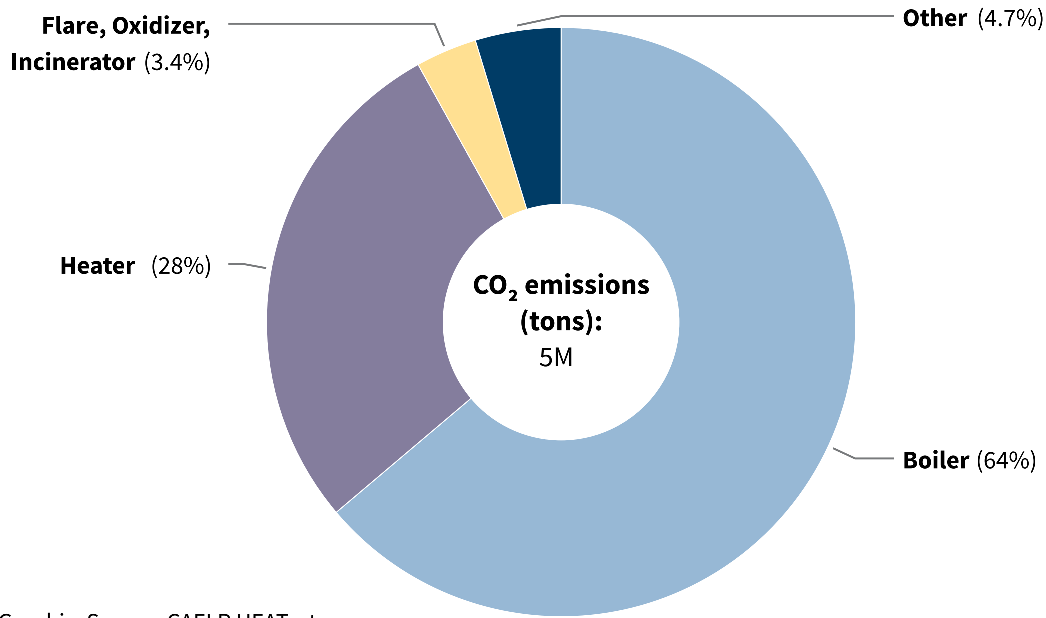
RMI Graphic. Source: CAELP HEATset

Emissions by equipment type

Based on the GHGRP dataset of large emitting facilities, boilers account for approximately 64% of combustion emissions from industry.[ii] Other key users of heat are heaters, furnaces, and dryers (see Exhibit 6).

ii This is based on individually reported units in the US EPA GHGRP in 2022, representing approximately 30% of Illinois's 2022 industrial CO_2 emissions across all temperatures. At least 108 unclassified units are not included. Unit count also excludes generators, units without reported emissions, and units from facilities without reported emissions.

Exhibit 6 Emissions by equipment type



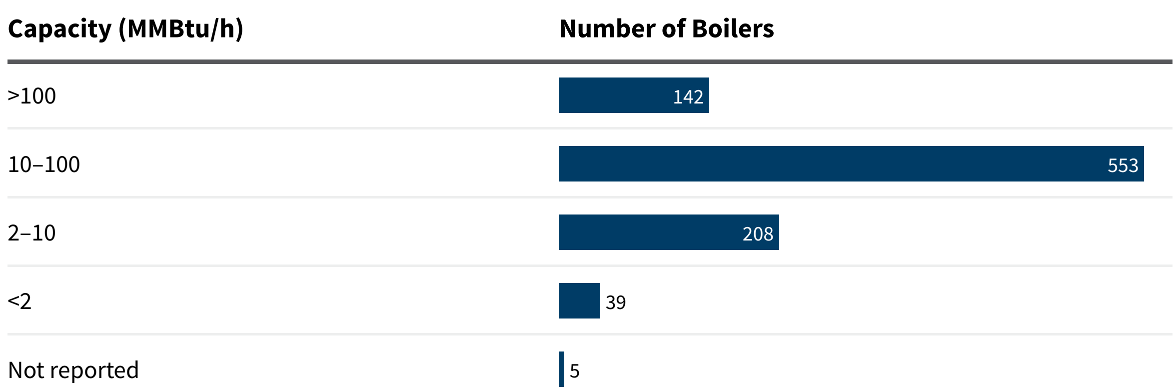
RMI Graphic. Source: CAELP HEATset

Boilers deep dive

Because the GHGRP dataset is limited in its coverage, and given the significant impact of boilers on industrial emissions, a more detailed assessment of boiler emissions in Illinois was conducted using the National Map of Industrial Boilers, which utilizes the 2020 National Emissions Inventory data from the US EPA.[17]

Based on the data, there were 947 boilers in Illinois that emit approximately 5,400 tons of nitrous oxide annually (see Exhibit 7). Some 51.2% of boilers are in ozone nonattainment areas. And 142 boilers have a capacity of more than 100 million British thermal units per hour (MMBtu/h). Given the size, most are believed to be operating in industry use cases. The sectors with the most boilers are food and beverage (236) and chemicals (189).

Exhibit 7 Boiler count by heating capacity



RMI Graphic. Source: Evergreen Action (National Map of Industrial Boilers)

Illinois's Opportunity: Low-Emissions Industry, Heat, and Power

Industry today

The transition of manufacturing from high- to low-emissions heat will fundamentally change industry's heat and power use patterns.

Today, approximately 80% of energy use in industry comes from combustion of fuels and about 20% comes from electricity. Electricity is primarily used to power mechanical equipment like pumps and compressors, whereas fuels are used to provide heat for boilers, furnaces, kilns, dryers, and other heaters.

Most industrial facilities generate heat on-site through the combustion of fuels like natural gas, petroleum products (liquid fuel), and coal (solid fuel). Some facilities purchase heat, typically in the form of steam, from adjacent facilities that generate excess heat or from colocated combined heat and power (CHP) facilities. Yet others, such as waste incinerators and cement kilns, utilize waste streams from other industries as fuel.

Transformation within and without

The transition to low-emissions industry will mean change inside and outside the site limits of industrial facilities. Managed correctly, this change can deliver more reliable, resilient, and efficient energy systems for industrial facilities and for Illinois.

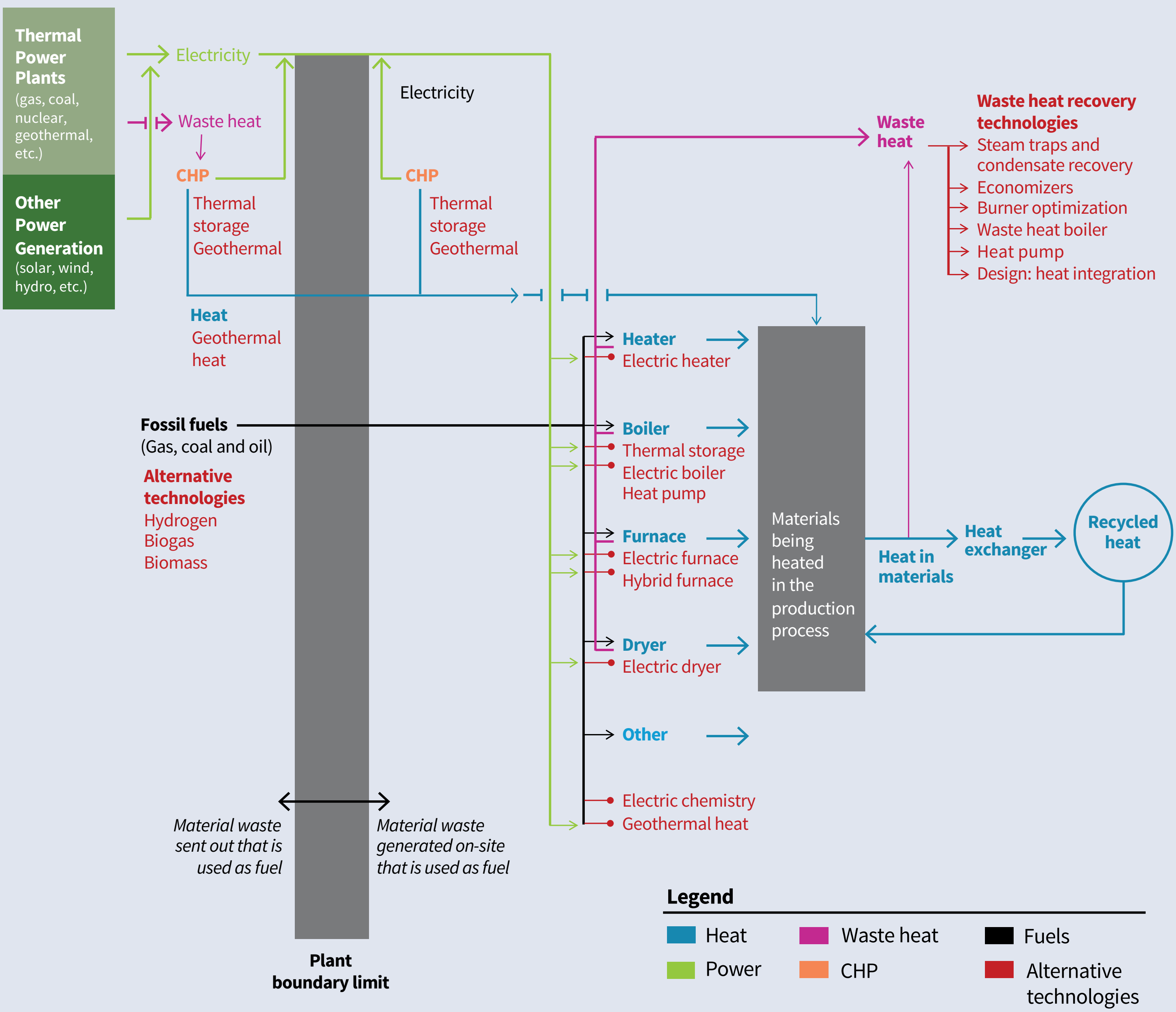
The energy mix for low-emissions industry in 2050 will look very different from today's. Many factors, from policy and market forces to technological breakthroughs, will determine the eventual mix. Yet, it is certain that to meet the state's climate pollution reduction targets, fossil fuel–fired heating will need to be minimized.

To that end, energy efficiency could significantly reduce the demand for energy. Electricity could make up a significantly larger share of industrial energy use as facilities shift to electrified heating through technologies like electric boilers, thermal energy storage (TES), and electrified furnaces. CHP from low-carbon fuels and geothermal energy may play a more significant role, and on-site combustion of low-carbon fuels may be pivotal for high-temperature heat processes. On the horizon, breakthrough technologies currently in lab or pilot scale could transform the equation.

Exhibit 8 is a diagram of a facility's transition to low-emissions operations and the interconnection to external fuel and power. This diagram shows how numerous low-emissions technologies, in red and orange, can be implemented within and outside facility boundaries. Though not a complete diagram of all possible facility connections and processes, it illustrates the general interconnectedness of a representative industrial facility and the suite of options available for a low-emissions future.

In practice, each industrial facility is unique in its on-site processes and its connection with adjacent industry, the power grid, and local communities. As a result, every facility's transition to a low-carbon future will also be unique and dependent on factors like current processes, proximity to fuel and power sources, and age of existing equipment.

Exhibit 8 **Heat and power map of industry**



RMI Graphic.

From facility assessments to a statewide strategy

A meaningful roadmap for low-emissions industry must be built on a foundation of high-quality facility-level engineering assessments that create facility-level roadmaps by answering the questions: which technological interventions, where, why, how, and when?

These facility-level assessments could feed into a system-level engineering assessment for Illinois that considers the interplay between industrial electrification, gas distribution, low-carbon fuels availability, geothermal energy potential, and untapped CHP, among other variables deemed pertinent to create a cohesive system-level roadmap.

Illinois's industrial concierge service can be leveraged to achieve this goal. Collaboration with The 2035 Initiative at the University of California Santa Barbara — which has developed open-source energy models for archetype facilities in key industrial subsectors — can give state officials and industry players an empirically grounded blueprint to accelerate the transition to low-emissions industry.[18]

Finally, Illinois's roadmap to low-emissions industry will need to evolve to respond to changes in the technology, economic, and policy landscapes. Therefore, the state must implement a system for continuous review, revision, and evolution of the roadmap to sustain the present and future needs of the people of Illinois.

Facility Emissions-Reduction Strategies

There is a suite of technical options available for facility owners to reduce emissions from their operations, especially within low- and medium-temperature process heating applications. Broadly, emissions-reduction strategies for industry include energy efficiency improvements, electrification, geothermal heat, switching to low-carbon fuels, and carbon capture and storage (CCS).[19] Implementing these emissions-reduction strategies could reduce annual emissions in Illinois by nearly 8.7 Mt if facilities transition to 100% zero-emissions low- and medium-temperature heat.

Commercially available technologies: In this report, we focus on near-term technologies that are technically and commercially feasible today (technology readiness level [TRL] 9 and higher, meaning a full-scale system has been proven in an operational environment) for low- and medium-temperature process heating. These technologies fall into three main categories: efficiency, electrification, and geothermal heat. Within these categories we highlight the strategies that are readily available and have the broadest applicability across the industrial sector, rather than presenting an exhaustive list of possible options. For each technology we provide a technical overview, identify low- and medium-temperature heating applications, and highlight some of the key deployment considerations — such as advantages and challenges — for real-world implementation of these technologies at facilities.

Emerging technologies: There are also other new and emerging technologies that have the potential to transform the heat and power landscape, but due to their low TRL are not near-term solutions. One example is natural, or geologic, hydrogen where companies like Koloma and HyTerra are exploring options to drill natural hydrogen wells in the United States.[20] Though natural hydrogen is projected to have production costs of less than $1/kg at optimal sites and could be used to generate low-cost, low-emissions electricity, this technology has not been proven commercially at scale and is not considered in this roadmap.[21]

Limited opportunities: Fuel switching and CCS are commercially available today, but these emissions-reduction strategies are best reserved for hard-to-electrify applications, like high-temperature process heating or manufacturing with high process emissions, due to the limited quantities of available alternative fuels and the low CO_2 concentration of combustion streams.

Facility-specific opportunity assessments: Overall, selecting the most impactful and cost-effective emissions-reduction strategy is highly specific to each facility's processes and needs. Generalizing the best solution for a manufacturing process or equipment type is difficult without detailed information on a facility. Facilities will ultimately need energy and opportunity assessments specific to their site to evaluate and act on the most appropriate solutions. Some resources for facilities exist, like the Industrial Assessment Centers and the Department of Energy's (DOE's) Better Plants program.[22] The Illinois EPA also received funding through the Carbon Pollution Reduction Grant program to develop a pilot clean industry concierge, similar to its program for buildings, that will support low-carbon retrofitting for 10 industrial facilities.[23] Despite these existing resources, there remains a need for programs with additional scope and capacity to address deeper emissions reduction of industrial combustion processes.

Energy efficiency

Energy efficiency is the most cost-effective and proven tool for cutting industrial emissions; simply by reducing energy consumption, facilities can reduce emissions from fossil fuel combustion.[24] These efficiency solutions are readily available and include, but are not limited to, heat pumps, economizers, heat exchangers, burner optimization, advanced process controls, advanced heat integration design, steam system optimization, waste heat boilers, and CHP.

Below we highlight heat pumps, CHP, and efficiency management systems because these are the broadly applicable strategies across industrial processes and heating equipment.

One study published in 2022 by the *Journal of Cleaner Production* suggests that energy efficiency measures could achieve roughly 30% emissions reductions across all manufacturing sectors.[25] In Illinois, these energy efficiency savings are equivalent to around 2.6 Mt of annual CO_2 emissions from low- and medium-temperature heat and 5.1 Mt of annual CO_2 emissions when considering all temperature grades.

Heat pumps

Overview

As is done in the residential and commercial buildings sector, heat pumps can be implemented in the industry to reduce combustion emissions through increased efficiency and lowered fossil fuel consumption. The most common heat pumps — mechanical vapor compression and mechanical vapor recompression — use electricity to increase the temperature of heat from the surrounding air or waste heat sources to a higher, usable target temperature that can be further applied in heating processes. Other types like adsorption and thermocompression heat pumps rely on thermal energy to upgrade and transfer heat.[26]

The TRLs of heat pump technologies depend on the technology type and temperature range. Generally, low-temperature heat pumps that supply output temperatures below 100°C are at TRL 9 and commercially available, but do not have widespread deployment in industrial applications in the United States. Heat pumps that have output temperatures greater than 100°C mainly range from pilot and demonstration testing to TRL 9 with several models that are market ready.[27]

Application

Most industrial heat pumps currently deployed are in the food and beverage sector for pasteurizing, sterilizing, and washing.[28] Heat pumps have higher deployment in the residential and commercial buildings sector for space and water heating due to the small demands and lower temperatures compared with industrial applications.

Deployment considerations

Typically, the usable energy upgraded by the heat pump is greater than the electricity consumed by the heat pump. This ratio of usable output heat supplied by the heat pump and the input electrical energy is known as the coefficient of performance (COP). The higher the COP, the more efficient the heat pump is at upgrading heat to the target temperature and the cheaper its operating cost. Heat pump COPs vary depending on type of heat pump, system design, temperature lift from input temperature to output temperature, and environmental conditions. An analysis of commercially available industrial heat pumps from the Institute of Energy Economics and Financial Analysis found that COPs ranged widely from 1.7 to 10.3, but were typically between 2.5 and 4.0 depending on waste heat availability.[29]

Air-sourced heat pumps that upgrade the heat of the surrounding air to generate steam can replace fossil-fired industrial boilers, particularly for the food and beverage industry, but are newer to the market for industrial applications. One example is AtmosZero's first Boiler 2.0 heat pump, which was installed in New Belgium Brewing's flagship brewery in Colorado earlier this year and can reach output temperatures of nearly 155°C.[30]

Heat pumps that depend on waste heat from other parts of the process cannot replace fossil-fired boilers because their operation is linked to waste heat originally generated by said boilers. This category of heat pump is best implemented as an efficiency solution to reduce the energy demand of fossil-fired heating technology or coupled with other electrified heating technologies like TES and electric boilers.

Combined heat and power

Overview

According to the EPA, CHP generation (also referred to as co-generation) is up to 30% more efficient than generating heat or power alone. In traditional power generation facilities, two-thirds of the useful energy in the fuel (coal, gas, or other) is wasted in the form of heat released to the atmosphere.[31] CHP facilities have additional infrastructure to capture this waste heat and supply it in the form of hot water or steam to meet adjacent residential, commercial, and industrial demand. To maximize the benefits of CHP in a transition to low-emissions industry, CHP systems must use low-carbon fuels or geothermal energy.

Application

There are two types of CHP generation facilities that can be used in industry. They are differentiated by the order in which they generate heat and electricity. In a topping cycle CHP, fuel is combusted to generate electricity first and the waste heat is captured and utilized for industrial heating. In a bottoming cycle CHP, fuel is combusted to generate the heat for industrial heat first and the waste heat is captured to generate electricity. The electricity generated by both types of CHP may be used on-site, sold back to the grid, or both.

Deployment considerations

CHP is a mature technology with 82 gigawatts (GW) of total operational capacity across every state. Some 78% of this capacity is utilized for steam and power generation within the industrial sector.

Per EPA estimates from 2016, there were 149 GW of untapped potential for CHP in the United States. Illinois alone has 7.5 GW of technical potential, including 3.7 GW of potential in industrial use cases.[32]

Increasing CHP in industrial applications will improve the efficiency of heat and power use, but the emissions reduction potential is limited to 30% — the efficiency benefits of CHP generation. This is because CHP facilities largely depend on fossil fuels as the primary source of energy. To maximize the benefits of CHP in a transition to low-emissions industry, CHP systems must use low-carbon fuels or geothermal energy.

Efficiency management systems

Overview and application

Like energy-reducing equipment, established best practices for managing energy efficiency at industrial facilities are underutilized. For example, strategic energy management (SEM) is a process that was developed more than 15 years ago to help industrial facilities more efficiently use energy resources through continuous improvement.[33] Although SEM programs have proven cost-effectiveness among facilities, these programs are not widely adopted within US industries. In addition to SEM programs, ISO 50001 is a voluntary international standard that provides a framework for implementing an energy management system (EnMS). Industrial facilities can use an EnMS to better manage energy consumption and achieve savings by establishing policies and procedures to track, analyze, and improve energy efficiency.[34] However, not all industrial facilities leverage an EnMS to improve efficiency.

Deployment considerations

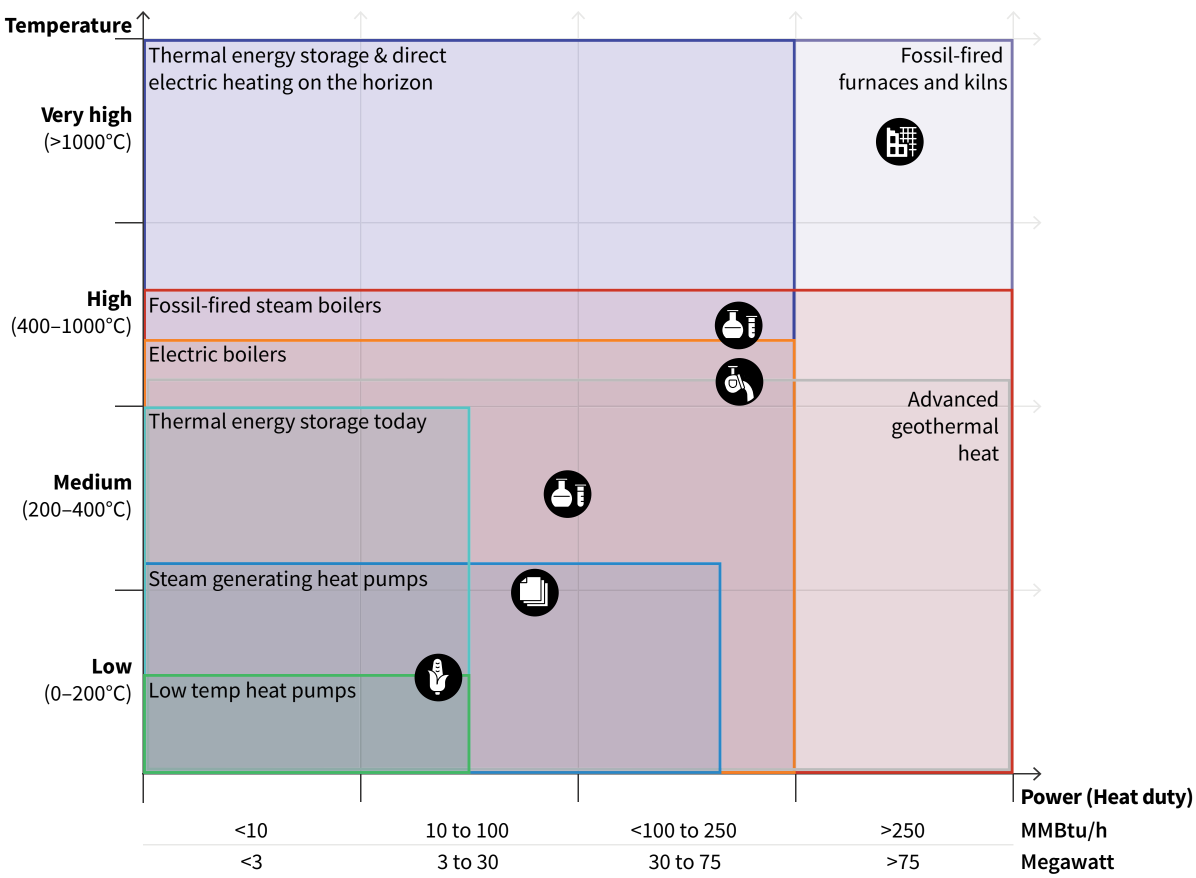
Alliances and federal programs also work to disseminate tools and resources for industrial facilities to improve energy efficiency. The DOE Better Plants program works with manufacturers to set ambitious energy, water, waste, and emissions reductions goals. To achieve this mission, the Better Plants program creates educational resources geared toward facilities.[35] On a regional level, the Midwest Energy Efficiency Alliance (MEEA) promotes energy efficiency to optimize energy generation, reduce consumption, create jobs, and decrease carbon emissions. Though not solely focused on the industrial sector, MEEA includes industrial facilities in its building efficiency work and provides broader information and resources to help support facilities improve energy efficiency.

Electrification

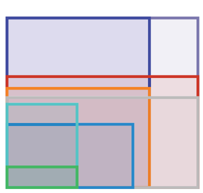
Electrified heating technology options vary by heating temperature and power requirements. Exhibit 9 shows the heat and power capabilities of several commercially available fossil and electrified heating technologies. The general heat and power requirements of industrial subsectors are overlaid on the matrix to represent where technologies are best applied. There are several electrified technologies that meet the heat requirements of the food and beverage, pulp and paper, and chemicals industries due to the processes' lower heating and power requirements.

Exhibit 9 Temperature and power capabilities of heating technologies compared with the requirements of industrial sectors

This map is a simplified representation of a complex industry. Its purpose is to help a general audience understand the main factors shaping pathways to low-emission industrial heating.



Industrial heat technologies



The values represent the capability of a single unit of each technology. In practice, multiple units can be combined—for example, stacking several thermal energy storage units—to increase overall power delivery.

Note: Illustrative and non-exhaustive

Key industrial subsectors

- Food & beverage
- Pulp and paper
- Chemicals
- Refining
- Iron & steel, cement

The values represent the an approximate overlay of the average energy needs for typical heating applications in key industrial subsectors.

Most subsectors require heat across multiple temperature ranges, and equipment size varies depending on the application and facility scale.

RMI Graphic. Source: RMI analysis

Electric resistance heating

Overview

Electric resistance heating, also called joule heating or ohmic heating, uses an electric current to directly or indirectly produce heat at a target temperature. In direct heating, the electric current is applied directly to the material being heated. With indirect heating, the current runs through a resistor and heats up surrounding materials through convection, conduction, or radiation.

Application

Resistance heating is a proven technology in industry with a TRL of 9 and is most commonly applied as indirect heating. Resistance heating is mainly deployed in the food and beverage sector in drying, pasteurizing, cooking, and other processes. Resistance heating is applicable across all other industrial sectors to replace fossil-fired equipment like boilers, ovens, furnaces, and air heaters without major system changes.[36]

Deployment considerations

Electrified equipment with resistance heating has several advantages. Uniform heating can be achieved by strategically positioning heating elements to ensure that heat is evenly controlled and consistently applied. Resistance heating also allows for precise temperature controls, making it a suitable alternative for any process heating that requires specific thermal conditions. The precise temperature controls also reduce the risk of overheating the equipment. Finally, resistance heating equipment can have much faster startup and shutdown times compared to fossil-fired equipment, allowing for more flexible production and implementation in facilities with batch productions.[37]

Thermal energy storage

Overview

TES, or thermal batteries, is a storage solution that converts electricity into heat. The heat is stored for a time depending on the material used and then released by the unit when heat is needed. Like other storage solutions, TES can heat its materials using low-cost, intermittent electricity from sources like wind or solar to minimize expense while still supplying manufacturing processes with heat on demand.

There are several types of TES, which can be divided into three categories: thermochemical, latent, and sensible. Thermochemical and latent TES technologies are lower than TRL 9 and still in the research and testing phases. Sensible TES technologies are the most technically proven at TRL 9 and store energy through heating either liquid or solid materials, like graphite, rocks, ceramics, molten salts, or water.[38]

Application

TES can be used to replace fossil-fired equipment or be paired with other electrification technologies to improve efficiency and reliability when using intermittent renewable power sources. TES technologies can meet customized thermal energy needs depending on facility requirements, providing on-demand heat at a wide range of temperatures to provide steam, process air, and hot water for different industrial processes.

Deployment considerations

TES bridges the gap between renewable energy supply and regular baseload industrial requirements. Electrification of heating that still meets the reliability criteria of industrials will likely require TES, especially in the near and medium term as renewable capacity is still growing. In addition to TES's reliability improvements, its ability to consume energy during off-peak hours and the use of low-cost storage mediums like rocks or bricks makes it economically competitive compared with fossil-fired equipment.[39]

Next-generation geothermal heating

Overview

According to The 2035 Initiative, geothermal energy is currently utilized in 40 countries for applications ranging from electricity generation to industrial heating, including a milk pasteurization facility in Klamath Falls, Oregon, and a pulp and paper processing facility in Kawerau, New Zealand.[40] Though conventional geothermal systems have historically been limited by geographic constraints, next-generation geothermal technologies overcome this barrier by enabling access to subsurface heat nearly anywhere.

These advanced systems involve drilling deep boreholes to circulate fluid underground, where it absorbs geothermal heat before being pumped back to the surface for use. There are two primary types: enhanced geothermal systems, which use a single-pass fluid flow, and advanced geothermal systems, which operate in a closed-loop configuration.

Application

Next-generation geothermal heating can provide continuous, low-emissions heat, typically in the form of steam, suitable for all low- and medium-temperature industrial processes; has low operating costs; and can be used for CHP generation. Geothermal energy can also be coupled with heat pumps to boost the efficiency of energy use.

Deployment considerations

Capital costs are the main challenge for next-generation geothermal energy — each well costs approximately $4.8 million, and a minimum of two wells is required per system. As a result, these systems may be most viable when colocated within industrial parks, where infrastructure costs and maintenance responsibilities can be shared across multiple facilities. The heat-as-a-service model, where a developer finances, constructs, and maintains the geothermal system and charges industrial customers for delivered heat and power via a monthly utility bill, for example, may also be particularly suitable for this technology.[41]

Next-generation geothermal energy systems also come with some geothermal resource risk. Resource availability can be unpredictable, and wells require active oversight and specialized expertise for monitoring and maintenance.

For Illinois-specific planning, geothermal resource mapping is available through Project Innerspace.[42]

Fuel switching and CCS

Other emissions-reduction strategies fall into two broad categories: fuel switching and CCS. Though these emissions-reduction strategies are commercially available, they are less effective for low- and medium-temperature process heat. For fuel switching strategies, these are best reserved for applications such as high-temperature process heat or feedstock replacement in the chemicals industry, where emissions cannot be easily abated with efficiency or low-carbon electrification technologies. Currently, CCS is most impactful and economical for process emissions where CO_2 streams are more concentrated compared with post-combustion streams with dilute concentrations.[43] Because these technical interventions are more strategically reserved for high-heat- and -process-related needs, they are therefore out of scope for this roadmap. There are a few cases where individual facilities could consider fuel switching or CCS as a emissions-reduction lever for low- and medium-temperature heating applications; these are described briefly below.

Fuel switching

Fuel switching is the broad category of emissions-reduction strategies in which facilities transition to combustion fuels with lower emissions. This includes switching from fossil fuels to nonfossil sources like e-fuels or biofuels or to lower-emitting fossils fuels such as when switching from coal to certified low-emissions natural gas. Cleaner fuels like low-emissions hydrogen and biofuel still offer very limited production capacities in the United States. Due to the limited availability and the complexities of transporting hydrogen over long distances, industrial applications should be reserved for hard-to-electrify applications such as high-temperature heating for steel production, heavy transportation, and some chemicals production routes.[44]

However, there are a few cases where industrial facilities could consider switching to biofuels for low- and medium-temperature applications. The first is if waste biomass streams such as agricultural wastes, forest residues, or biogas from sources like landfills are readily available near a facility. The second is if there are natural synergies between the manufacturing process and its use of biomass, such as combusting black liquor (the liquid left over after wood chips are pulped) to fuel recovery boilers in the pulp and paper manufacturing process.

In some cases, facilities with large volumes of coal combustion could consider fuel switching to natural gas if other technologies are not technically or economically feasible for the site. However, due to system inefficiencies upstream, methane leakage often reduces the emissions reduction impact of switching to natural gas.[45] To guarantee emissions reductions, it is critical to reduce fugitive and flaring emissions across gas transport, oil refining, and chemicals equipment through enhanced leak detection.

Carbon capture and storage

CCS technologies capture stationary process and combustion CO_2 emissions from industry and transport it for long-term storage. Two primary drivers for CCS viability are CO_2 concentration and distance to storage location. CCS is more efficient and cost-effective when capturing emissions streams with high CO_2 concentrations. Today, CCS is best implemented on process emissions streams because industrial combustion flue gas streams typically have lower concentrations of less than 10% CO_2.[46] The saline aquifers in Illinois and surrounding states could be potential local storage sites, making CCS more viable for facilities in the state with high process and combustion emissions. However, without any currently operational or planned CO_2 pipelines in Illinois facilities would likely need to be colocated with storage sites for CCS to be feasible.[47]

Barriers to Low Emissions Industry

Though the emissions-reduction technologies and strategies referenced above are largely commercially available, industrial facility managers face uniquely complex barriers preventing implementation. These challenges fall into three broad categories. First, **individual facility and technology constraints** reflect site-specific challenges that make it difficult for plants to adopt new solutions. Second, **financial barriers** like high energy costs, capital requirements, and restrictive investment norms can limit the business case for cleaner technologies. Finally, **system-level barriers** such as grid capacity, long equipment lifespans, and slow permitting processes create broader structural obstacles that affect the entire industrial sector. Together, these factors shape the pace and feasibility of emissions reduction across Illinois industry, and understanding their role is essential to designing effective policy interventions to accelerate industrial emissions reductions.

Individual facility barriers and technology constraints

Unique facility needs and integration levels

Industrial facilities are highly customized environments, with equipment often tailored to specific process needs.[48] Even when technologies are designed to be cross-sector and "plug-and-play," integrating them into existing systems requires detailed engineering and planning.

In addition to customized needs, many industrial facilities also have highly integrated heat and material flows, which can complicate efforts to electrify individual components without disrupting the entire system. Upgrades and retrofits must be considered at the facility level, which increases complexity and reduces scalability.

Dilemma of choice

Industrial facilities face a complex landscape of efficiency and electrification upgrade and retrofit options, ranging from more mature technologies like electric boilers and heat pumps to emerging solutions such as thermal batteries.[49] This abundance of options can create decision paralysis, especially when TRLs, policy incentives, and energy prices are in flux.[50] A lack of clear guidance on sequencing amid this uncertainly can stall progress, including for deployment of technologies like low- and medium-temperature electric heating that are especially valuable for their ability to be deployed across sectors.[51] As a result, companies may benefit from structured technical assistance and planning support to navigate this complexity.

Capacity constraints

Some industrial facilities, especially smaller ones, may lack the internal capacity or technical expertise to evaluate emissions reduction opportunities and determine what options might be best suited to their unique needs. These restrictions include limited awareness of available technologies, insufficient site-specific data, and a shortage of qualified assessors or consultants.[52] Workforce development and technical assistance efforts — like Illinois's proposed Clean Industry Concierge — can help support adoption of emissions reduction technologies and build internal capacity.[53]

Financial barriers

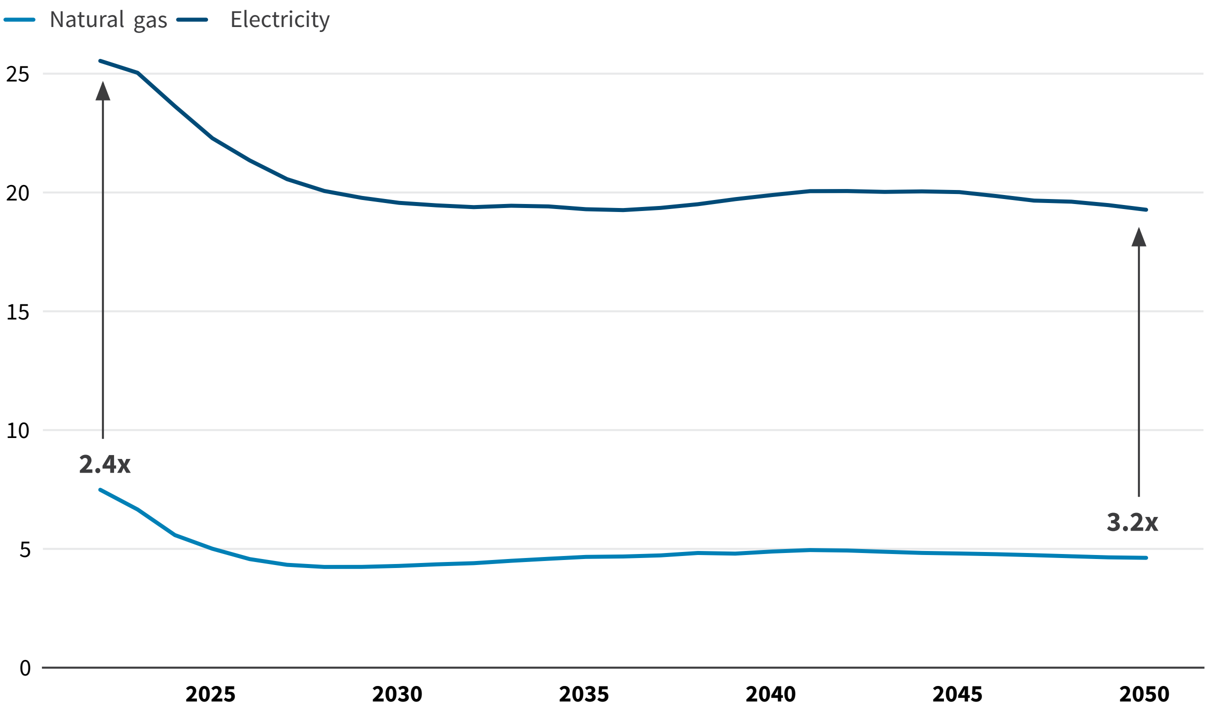
Electricity vs. gas costs and operational expenditures

The rate and scale of industrial heat electrification will depend on energy prices. Under current conditions, industrial electricity prices in the East North Central region as defined by the US Energy Information Administration (a region that includes Illinois) are forecast to remain above industrial natural gas prices, with cost parity between the two not expected by 2050 (see Exhibit 10).[54]

Exhibit 10

Industrial energy prices in the East North Central region (2022 $ /MMBtu)

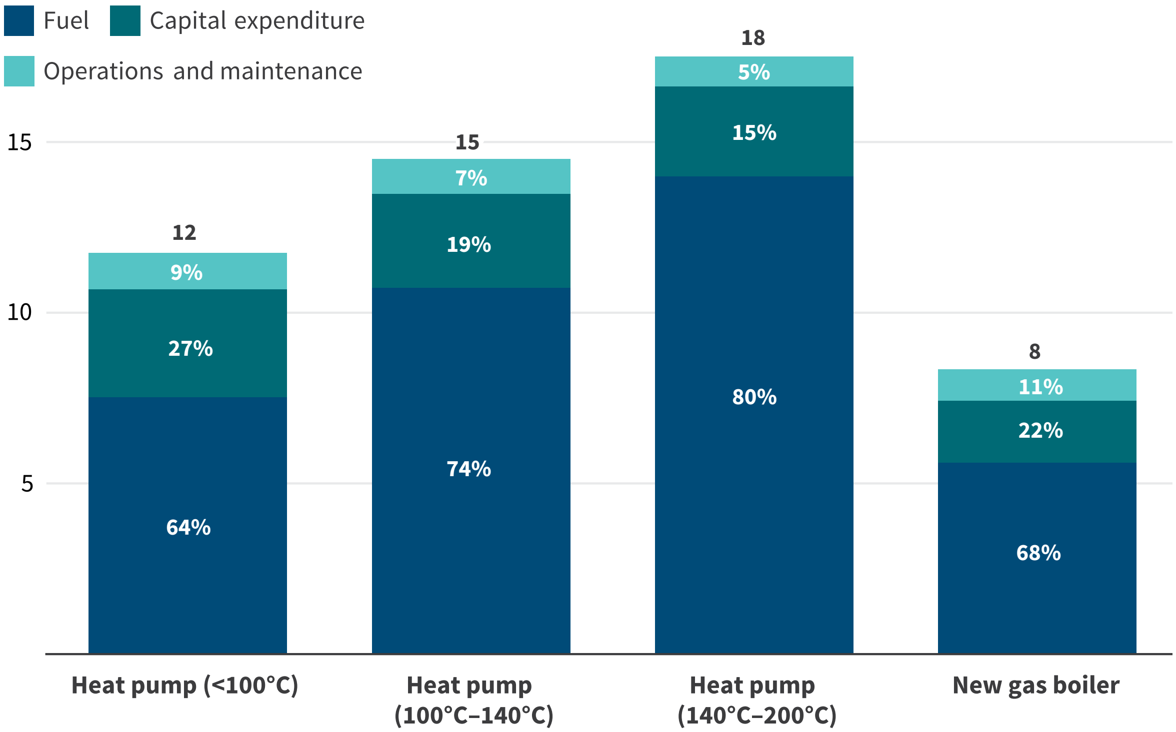
Industrial electricity prices (2022 $ / MMBtu) in the East North Central region, which includes Illinois, were 2.4 times higher than natural gas prices in 2022 and are forecast to be 3.2 times higher in 2050.



RMI Graphic. Source: US Energy Information Administration

Higher electricity costs will increase operational expenditures for facilities when switching to electrification technologies because the majority of the levelized cost of heat is predominantly due to fuel costs, rather than capital expenditure needs.

Exhibit 11 **Levelized cost of heat in industrial heating equipment ($/MMBtu-thermal)**



RMI Graphic. Source: Energy and Environmental Economics, Inc.

As a result of these operational expenditure considerations, the competitiveness of certain electrification technologies is sensitive to electricity prices. For example, heat pumps could theoretically competitively replace a portion of industrial natural gas demand in states with lower electricity costs, but this may require policy intervention in high-cost states to aid adoption.[55]

High and fluctuating energy costs can complicate operational plans, including emissions reductions efforts. In 2022, for example, Century Aluminum Company announced it would temporarily idle its Hawesville, Kentucky, aluminum smelter in response to high energy costs.[56]

Efficiency gains from electric technologies can offset some operational expenditure needs. A 2023 analysis found, for example, that thermal batteries have a smaller efficiency loss as they charge and store heat than the loss associated with combusting natural gas to produce heat, contributing to the technology's cost-competitiveness in certain regions.[57] The report also concluded this competitiveness is improved when paired with real-time pricing (RTP) or access to wholesale power markets.

Up-front capital costs

High up-front capital expenditure needs are a significant barrier to scaling industrial emissions reduction technologies. Facilities must carefully evaluate the highest and best uses of capital by weighing decarbonization investments against other priorities like production expansion, reliability and safety upgrades, or compliance needs.[58] Facilities can also consider the cost-benefit ratio of replacing equipment for emissions reduction earlier than replacement cycles would otherwise dictate. Policy interventions, particularly financial incentives, can help overcome any cost-benefit gaps related to this decision.

The DOE forecasts that, nationwide, industrial sectors could need between roughly $700 billion and $1.1 trillion in capital expenditure to deploy decarbonization technologies to reach net zero by 2050.[59] In Illinois, an RMI analysis found that switching all fossil-based heating to electrified heating could require approximately $840 million in capital expenditure.

Short payback periods and financial model capital restrictions

Manufacturing companies often require short payback periods — frequently three years or less — for capital investments, which limits the adoption of lower-emissions technologies that may have longer-term returns.[60] This approach can be driven by factors like risk aversion, shareholder expectations, and the need to maintain competitiveness in low-margin markets.

This prioritization of short-term returns and internal rate of return found in these traditional financial models can also be shaped by limited access to or awareness of innovative financing mechanisms like carbon contracts for differences (CCfDs) or energy-as-a-service models.[61]

System-level barriers

Electricity demand

Large-scale electrification of industrial heat will drive increased industrial electricity demand and a need for new electricity supplies across Illinois, including in utility service areas for both ComEd and Ameren, the two major utilities operating in the state.[62] In some cases, however, holdups like grid congestion, limited interconnection capacity, and aging transmission infrastructure may constrain the grid's ability to meet that demand and delay the deployment of some electrification technologies.

If 100% of the fuel consumed for energy at industrial facilities in Illinois — excluding fuel used as a chemical feedstock, biomass, and purchased heat, and absent any other changes — was shifted to electricity by 2050, annual industrial electricity demand in the state would increase 183% from 42.4 terawatt-hours (TWh) in 2024 to 120.1 TWh by 2050, according to the Energy Policy Simulator model.[63] As of December 2024, the transmission system operator Midcontinent Independent System Operator (MISO) had approximately 56 GW, most of which is solar and battery storage capacity, in interconnection agreements projected to come online in the near term.[64] In the Pennsylvania-New Jersey-Maryland Interconnection's (PJM) service area at the same time, generator retirements were outpacing new generation.[65] Just within Illinois as of August 2025, there were approximately 90 GW of electricity generation capacity active in state interconnection queues.[66]

These needs are not insurmountable, but they require proactive planning and investment in grid technologies and capacities. While this report is not focused on electricity sector interventions to increase grid capacity, measures taken by state decisionmakers to that effect can be an important enabler of industrial electrification. In particular, integrating flexible industrial loads into the grid can help manage load growth while enhancing the value proposition of clean energy investments by aligning demand with variable supply.

Asset lives and capital improvement cycles

Boilers and other traditional industrial heating equipment typically have long asset lives —sometimes up to 40 years and beyond — and therefore long depreciation periods, which can discourage early replacement.[67] In Illinois, a 2025 analysis by the Environmental Integrity Project of 35 industrial plants across multiple sectors found that 31, or 89% of the plants, had at least one outdated heater or boiler. This makes timing critical because policies must align with capital improvement cycles to be effective.[68]

High bar for proof of concept

Manufacturers can be hesitant to adopt new technologies without proven performance in similar settings. This risk aversion is especially strong in sectors with tight margins or high reliability requirements, like the cement sector, where end products used in construction must meet performance standards that may limit room for deployment of emissions-reducing supplementary cementitious materials.[69]

Pilot projects and first commercial deployments are essential to build confidence. State support for demonstration grants and research, development, and demonstration (RD&D) can help de-risk these technologies and accelerate deployment.

Long deployment cycles

Deploying low-emissions upgrades and retrofits can involve lengthy planning, permitting, and execution cycles. These extended timelines are driven by several factors: the complexity of integrating new technologies into existing industrial systems, the need for detailed engineering and feasibility studies, and the time required for state and federal permitting procedures, where necessary.[70] An analysis from consulting firm McKinsey & Company, for example, found that the average proposed manufacturing project takes two to three years to proceed through the federal permitting process.[71]

State Interventions

Targeted state policy interventions are essential to overcoming economic, regulatory, and infrastructure barriers to industrial emissions reductions in Illinois. These interventions can help lower costs, reduce uncertainty, and accelerate deployment of clean technologies across the state's industrial sectors. State action can manifest in a variety of policy strategies that Illinois can adopt or expand on, including those presented in the *Policy interventions menu* section of this report.

Although state policy plays a pivotal role in enabling the deployment of energy efficiency and electrification technologies, these efforts must also align with Illinois's and the federal government's existing air quality and emissions regulations, which shape the compliance landscape for industrial decarbonization, and should consider Illinois's unique characteristics, like the composition of its electricity generation sources.

Current landscape

Illinois has several existing and upcoming policies and programs to address industrial emissions. In the next year, the state will be implementing its Climate Pollution Reduction Grants, including $2.6 million to set up a clean industrial concierge service.[72] That service will connect small and medium-sized manufacturers with technical assistance and technology providers that will conduct facility energy assessments and install low-emissions technologies.

Illinois also won a $15 million federal grant to seed an energy efficiency revolving loan fund, which primarily issues bridge and participation loans to efficiency and clean energy projects awaiting disbursement of a federal or state incentive. However, neither of the loan products are designed to support low-emissions industry directly, and the bridge loan is targeted to projects already receiving tax benefits created by the Inflation Reduction Act.[73] The state also has energy efficiency regulations in place for buildings, though these are primarily targeted at residential and commercial facilities, with a loophole for industrial energy customers of a certain size.[74]

ComEd and Ameren offer some flexible demand rates for electricity pricing, but most of these programs are designed to target residential and commercial sectors.

Overall, the state has some of the key ingredients needed to encourage low-emissions industry: appropriate regulatory authority, various state financing tools for efficiency and clean energy projects, and the political tailwinds to address climate issues, both through the executive and legislative branches. However, to directly encourage industrial emissions reductions, the state can consider expanding programs in some places, increasing public funding availability in others, and creating new incentives to enable industrial emissions reductions across the state. Illinois decision makers can also consider how best to incorporate industrial emissions reductions goals into planning efforts like state implementation plans, which are developed by state and local governments and outline strategies for local actors to limit climate pollution and meet National Ambient Air Quality Standards (NAAQS) set by the EPA.

Policy intervention mechanisms and authorities

To effectively support industrial emissions reductions in Illinois, state policymakers must consider not only what interventions to pursue, but also how and when those interventions can be implemented — and by whom. The mechanisms through which policies are deployed vary widely, from setting long-term standards to offering direct financial support or improving planning and permitting processes. These mechanisms fall into three broad categories:

- **Management,** which includes data collection and planning;
- **Certainty,** which involves mandates, standards, and long-term goals; and
- **Support,** which encompasses programs and policies that provide funding, incentives, workforce development, and technical assistance.

Each intervention can also involve action from one or more state decision-making bodies, including the Illinois legislature, governor's office, climate office, energy office, economic development office, public utility commission (PUC), utilities, and other agencies such as the Department of Transportation or relevant building code councils. Understanding which entities hold authority, and what level of funding or regulatory change may be needed, can help prioritize near-term opportunities and guide long-term planning.

Interventions can also be stacked and sequenced. Near-term interventions are those that would likely (1) be relatively easy to implement, including those that can build on existing programs, and/or (2) relate to feasible infrastructure deployment that would have the greatest potential for long-term impact if implemented today. Midterm interventions are those that might (1) face more hurdles to pass or authorize, and/or (2) have complex design features that require time to develop. Long-term interventions are those that (1) might have the greatest impact as TRLs of various low-emissions technologies improve, and/or (2) could be implemented in the near term but strengthened over time, like efficiency requirements.

The interventions in the following sections are included to show a variety of options but do not constitute specific recommendations.

Mapping policy solutions to barriers

To accelerate industrial emissions reductions in Illinois, it is critical to align policy interventions with the specific barriers they are designed to address. This helps identify high-impact opportunities, supports strategic planning, and ensures that state action is responsive and effective.

Exhibit 12 maps potential policy strategies to the barriers they help confront. Many interventions can address multiple barriers simultaneously, such as technical assistance programs that help facilities navigate both technology complexity and internal capacity gaps. Others can be more targeted, like interconnection reforms aimed at reducing grid bottlenecks.

Exhibit 12 Mapping policy interventions to industrial emissions reduction barriers

Barrier	Policy Strategy	Benefits
Unique facility needs and integration levels	Technical assistance initiatives for facility-level technology and electricity assessments	Provide site-specific guidance to help facilities integrate new technologies into unique, complex systems
	State-mandated facility-level assessments	Ensure tailored solutions by requiring facilities to identify their own emissions-reduction opportunities
	Clean heat emissions standards	Encourage whole-facility planning and integration by setting performance expectations
Dilemma of choice	Technical assistance programs for facility-level technology and electricity assessments	Help facilities evaluate and prioritize among many technology options
	Grant programs for industrial electrification and/or efficiency projects	Reduce risk and complexity by supporting a range of technology choices, helping direct facilities toward certain available technology options
	Encouraged participation efforts for certification programs and alliances	Help facilities identify vetted technologies and best practices, reducing uncertainty
	Equipment requirements set through air quality regulations	Set clear standards for facilities to adhere to as they navigate equipment choices
Capacity constraints	Technical assistance programs for facility-level technology and electricity assessments	Address gaps in internal expertise and awareness of available solutions
	Workforce education and training programs	Build the skilled workforce needed to assess and implement new technologies
	Binding targets for sector-wide industrial energy efficiency	Create a clear mandate that drives investment in capacity-building and efficiency upgrades
	Material efficiency standards	Reduce the need for complex retrofits by encouraging simpler, less resource-intensive production
Electricity vs. gas costs and operational expenditures	Alternative electricity pricing paths for industrial consumers	Allow facilities to optimize energy use and reduce costs
	Large-load electricity tariff reforms	Can make electricity pricing more favorable to incentivize electrification
	Utility exit fee reforms	Reduce or remove financial penalties for leaving gas service, lowering the effective cost of switching to electric heat and improving the economics of electrification
	Incentives and support for clean electricity generation	Support development of lower-cost clean electricity, improving affordability for industrial users
	Clean heat production tax credits	Provide financial incentives for early adoption of clean heat solutions
	Tax credits for clean manufacturing production	Reduce financial burden for facilities investing in clean production technologies
	Local or regional cap-and-invest or carbon pricing mechanisms	Place a price on carbon emissions and improve the relative economics of low-carbon technologies

Exhibit 12 Mapping policy interventions to industrial emissions reduction barriers, continued

Barrier	Policy Strategy	Benefits
Up-front capital costs	Grant programs for industrial electrification and/or efficiency projects	Reduce the initial investment required for new equipment
	Incentives for emissions-reducing equipment	Lower capital costs for purchasing clean technologies
Short payback periods and financial model capital restrictions	Grant programs for industrial electrification and/or efficiency projects	Make projects more attractive by improving payback periods
	Incentives for emissions-reducing equipment	Enhance financial returns, helping projects meet internal investment criteria
	State “buy clean” initiatives	Create market demand for low-carbon products, improving investment returns
	Local or regional cap-and-invest or carbon pricing mechanisms	Create a predictable carbon price and generate revenue that can be reinvested into clean technology deployment for long-term value
Electricity demand	Renewable portfolio standards that include renewable thermal power/waste heat	Reduce grid strain by promoting non-electric clean heat sources
Asset lives and capital improvement cycles	Clean heat production tax credits	Incentivize early replacement of long-lived fossil equipment
	Incentives for emissions-reducing equipment	Make retrofits more financially attractive before end of life
	Grant programs for industrial electrification and/or efficiency projects	Support upgrades outside normal capital cycles
	Efficiency requirements for new-build facilities	Ensure new facilities adopt efficient technologies from the outset, avoiding long-lived fossil systems
	Energy efficiency standards for industrial equipment	Encourage replacement of outdated equipment with more efficient alternatives
	Equipment requirements set through air quality regulations	Encourage replacement of high-emissions equipment that does not meet minimum performance or emissions standards
High bar for proof of concept	RD&D grants or incentives	Fund demonstration projects to prove new technologies in real-world settings
Long deployment cycles	Alternate approval processes for emissions reduction projects at existing sites	Shorten permitting and implementation timelines and streamline regulatory processes for faster project delivery

RMI Graphic.

Policy interventions menu

Though adequately mapping policy interventions to major decarbonization barriers is essential to support industrial emissions reductions, so too is robust design of those interventions.

Generally, the best-practice design principles for state policy interventions ensure the policies are:

- Rooted in evidence and data
- Clear and adaptable
- Effective and efficient
- Equitable and inclusive
- Focused on the long term
- Transparent and enforceable

Interventions can be sequenced to match time-based considerations like the TRLs of emissions reduction technologies and the feasibility of deployment in the near through long term. They can also be arranged so enabling policies, like financial supports to boost rapid deployment, and foundational policies, like those that advance grid-scale clean energy to support electrification, are implemented in the near to midterm, with other policies like emissions standards being implemented in the near term but made more stringent over time.

The interventions outlined in this section span a range of mechanisms and include some best-practice guidance. An intervention's inclusion does not constitute a recommendation, but is intended to show a variety of options available to state decision makers.

Notably, the cleanness of Illinois's grid — and therefore the electricity received by grid-connected facilities — differs by provider, making electricity-related interventions more pivotal for some facilities than others. In 2024, Ameren, whose service area extends across much of the southern portion of the state, sourced 40% of its supplied electricity from natural gas, 27% from coal, 14% from nuclear, and 19% from combined renewables.[75] For PJM, whose service area is in the ComEd service zone in the northern part of the state, approximately 45% of existing installed capacity in Illinois as of December 2024 was natural gas, 39% nuclear, 10% coal, and 6% wind and solar.[76] Across the state's service areas in 2023, approximately 55% of electricity generation came from nuclear, 14% from renewables, and 32% from fossil fuels.[77]

STRATEGY 1

Support the adoption of emissions-reducing technologies financially

(1.1) Tax credits for clean manufacturing production

To help address cost barriers, Illinois can consider tax credits for clean manufacturing production, which provide financial incentives to industrial facilities that produce low-carbon goods. These credits can be structured to reward manufacturers based on the carbon intensity of their products, with tiered benefits for commodities such as steel, cement, and chemicals. The policy could also be designed to make credits refundable or transferable, ensuring accessibility for firms without tax liability as well as incorporate robust emissions tracking systems to verify performance.[78]

Exact emissions reductions from this policy depend on uptake and product mix, but targeting high-emissions materials could yield substantial benefits. Costs would primarily fall on the state budget through forgone tax revenue, with administrative costs for verification and compilation of accurate and updated emissions data, as well as reporting enforcement.

Though Illinois does not have a similar tax credit in place, the state does have a framework for this type of incentive within its competitive incentive program under the Reimagining Energy and Vehicles in Illinois Act for qualifying companies within the electric vehicle and renewables supply chains.[79] Policy designers could also draw from language of the federal Advanced Manufacturing Production Credit (known as 45X) established by the 2022 Inflation Reduction Act.[80] Some efforts to establish international standards for carbon intensity of heavy industry goods like steel also outline metrics and thresholds that could inform any standards set by the state for the credit.[81]

(1.2) Clean heat production tax credits

A clean heat production tax credit (PTC) incentivizes the generation of low-carbon heat from electricity for industrial processes and reduces operational costs for sectors otherwise reliant on fossil-fueled heat.[82] As with a clean manufacturing tax credit, the PTC should be refundable and transferable, allowing firms without tax liability to benefit directly without relying on tax equity investors, who typically capture a significant portion of the credit's value.[83] The PTC should also be designed to decrease in value as TRLs improve, and can be calculated based on the temperature range and emissions profile of the heat source and the temperatures required for specific industrial processes. Emissions reduction potential is significant, particularly in sectors reliant on fossil-fueled heat. Costs would be borne by the state through tax expenditures, and enforcement would require emissions data collection and verification systems. Illinois does not currently have a clean heat PTC in effect.

STRATEGY 1, CONTINUED

Support the adoption of emissions-reducing technologies financially

(1.3) Grant programs for industrial electrification and/or efficiency projects

Grant programs for industrial electrification and/or efficiency projects provide direct financial support for facilities to adopt clean technologies, addressing financial barriers and the dilemma of choice by enabling facilities to act on emissions-reduction opportunities. Grants can apply to both new construction and retrofits and may include transparency stipulations or cost-sharing requirements. Programs should prioritize projects with high emissions reduction potential and be flexible enough to accommodate diverse facility needs.

Illinois has some basis for such a program in the competitive grants and revolving loans for energy efficiency and clean energy projects offered by the Illinois EPA Office of Energy with funding facilitated by federal money.[84] The emissions reduction potential of grants depends on project scope, and long-term grant project success relies on electricity prices, with uptake potentially limited if significantly higher annual energy costs would make electrification financially infeasible despite deferred up-front costs. Costs are borne by the state or federal government, although there is potential for leveraging private capital. Grant programs can also be reauthorized to support long-term emissions reduction planning.

(1.4) Incentives for emissions-reducing equipment

Incentives for emissions-reducing equipment, such as utility rebates or tax credits, can support the purchase and installation of lower-emissions technologies by addressing up-front capital costs and short payback period barriers. These incentives can be scaled based on the margin by which equipment outperforms emissions intensity thresholds. Incentives can be tailored to different facility sizes and technology types and can be particularly impactful when paired with performance standards. These incentives should be designed to ensure real emissions benefits to avoid by buyers who would have purchased emissions-reducing equipment even without the incentive. Emissions reductions will vary by equipment type. Costs are borne by utilities or the state, and continued funding and reauthorization of the incentives would be needed.

Utilities around the country have a variety of efficiency incentive programs.[85] Illinois does not have a direct incentive for deployment of specific industrial or commercial technologies like heat pumps, but some utilities that operate in the state like ComEd and Ameren offer their own incentives.[86]

STRATEGY 2

Improve efficiency requirements

(2.1) Efficiency requirements for new-build facilities

Efficiency requirements for new-build industrial facilities mandate that newly constructed plants meet minimum energy performance standards. These requirements can be embedded in building codes or sector-specific regulations and are designed to lock in long-term energy savings and avoid future retrofit needs. In Illinois, the Energy Conservation Code (ECC) and Energy Efficient Building Act already apply to new commercial construction, renovations, and upgrades.[87] The Illinois Stretch Energy Code allows certain municipalities and state-funded projects to exceed base ECC efficiency standards.[88]

Because this policy has the potential to raise upfront investment costs, pairing it with financial supports will increase its efficacy. Although emissions reductions depend on facility type and energy use, early adoption of electric boilers or heat pumps in new facilities can significantly reduce long-term fossil fuel reliance. Costs are borne by developers, but can be mitigated through incentives, and assistance can be tailored to small and medium-sized manufacturers that may face the largest proportional up-front cost burden.

(2.2) Renewable portfolio standards that include renewable thermal power/waste heat

Expanding Illinois's Renewable Portfolio Standard (RPS) to include renewable thermal energy — like solar thermal, biomass, and geothermal technologies — and waste heat recovery would recognize nonelectric clean heat sources as eligible for renewable energy credits (RECs).[89] This policy would entail tracking thermal heat output across industrial facilities, setting a portfolio standard for the share coming from clean heat, creating a market for clean heat credits, and assessing compliance costs for facilities that fall short of the standard.

This policy supports emissions reduction in sectors where electrification is challenging and can be adjusted to match regional resource availability. Because most RPS structures are designed around electrical, not heat, output, this change would require careful design, including new tracking and crediting systems for thermal energy, legislative updates to the RPS framework, and clear definitions of eligible technologies.

This intervention would broaden the scope of Illinois's existing clean energy policy to align it with the new maturity of lower-emissions technology in the industrial space and directly addresses system-level barriers related to electricity demand. It targets potentially underutilized heat sources and can be inclusive if designed to support smaller facilities and diverse technologies. Emissions reductions depend on uptake and technology mix. Costs would likely be primarily administrative and borne by the state, with potential for long-term savings through reduced grid strain.

Case Study: Massachusetts's Alternative Energy Portfolio Standard

Massachusetts's RPS and Alternative Energy Portfolio Standard (APS) provide an example of how renewable thermal energy can be integrated into state-level clean energy standards. Established under the Green Communities Act of 2008, the APS was designed to complement the state's RPS — established by the Massachusetts Electric Utility Restructuring Act of 1997 and amended by the 2008 law — by recognizing technologies that improve energy efficiency and reduce climate pollution outside of renewable energy systems.[90] In December 2017, the Massachusetts Department of Energy Resources concluded rulemaking to expand the APS to include renewable thermal technologies, fuel cells, and waste-to-energy thermal systems as eligible sources.[91]

Under the APS, eligible renewable thermal technologies include CHP, air- and ground-source heat pumps, geothermal heat exchange, solar thermal, woody biomass, biogas, liquid biofuels, and compost heat exchange systems, all subject to specifications.[92] These systems must deliver useful thermal energy to facilities in Massachusetts and have an operational start date of January 1, 2015, or later. Facilities that qualify generate alternative energy certificates (AECs) per every megawatt-hour equivalent of thermal energy generated.[93] These AECs, like RECs under the RPS, can be bought by utilities to comply with state clean energy standards, creating a financial incentive for clean thermal energy deployment.[94]

Massachusetts's APS design has design features that could be emulated in other states' policies. For example, the program uses multipliers to reward technologies based on their emissions reduction potential and application type. Ground-source heat pumps and solar hot water systems used for domestic purposes receive higher multipliers, increasing their financial attractiveness.[95] The APS minimum standard indefinitely increases by 0.25% annually to promote steady growth in clean thermal energy adoption.[96] This incremental approach aims to help Massachusetts build a diverse portfolio of clean thermal technologies while reducing reliance on fossil fuels for heating.

STRATEGY 2, CONTINUED

Improve efficiency requirements

(2.3) Energy efficiency standards for industrial equipment

Energy efficiency standards for industrial equipment set minimum performance thresholds for technologies such as motors and boilers. These standards can be phased in over time and designed to become more stringent, encouraging continuous improvement.[97] In Illinois, the ECC (which adopts the 2021 International Energy Conservation Code) and the *Illinois Statewide Technical Reference Manual for Energy Efficiency* provide frameworks for calculating energy savings and compliance in the industrial and commercial sectors.[98]

This policy, which addresses barriers related to outdated equipment and long asset lives, is most impactful when paired with state incentives and utility programs that support efficiency upgrades. This is in part to encourage manufacturers to outperform the standard's cutoffs, where possible. It can also be paired with "no-regrets" policies for end-of-life boiler replacement along with financial supports to cover the cost differential between a traditional replacement boiler and an electric boiler or heat pump for small and medium-sized manufacturers. The Illinois administrative code already contains rules governing boiler repairs.[99] Costs are borne by manufacturers and facility owners, with enforcement costs borne by the state.

(2.4) Binding targets for sector-wide industrial energy efficiency

Binding energy efficiency targets establish mandatory goals for energy savings across the industrial sector. These targets can be aligned with utility programs and state climate goals and may be implemented through legislation or regulatory mandates. Though Illinois does not currently have sector-specific efficiency targets, it does have an energy efficiency portfolio standard for utilities and guiding principles for electric and gas efficiency programs published by the Illinois Commerce Commission (ICC).[100]

This policy can address capacity constraints by setting clear goals for facilities to follow and encourage long-term planning. Emissions reductions depend on the ambition of the targets and compliance rates. Costs include enforcement and program administration, typically borne by the state, with potential for cost savings through reduced energy use. Equity among facilities can be supported by tailoring targets to facility size and sector characteristics.

(2.5) Encouraged participation efforts for certification programs and alliances

Encouraging industrial facilities to participate in voluntary certification programs and alliances — such as ISO 50001 or sector-specific energy management initiatives — can build awareness of best practices and promote recognition for facilities adopting efficiency improvements.[101] This policy is low cost and easy to implement but has limited impact without mandates or incentives. Illinois could also consider creating something akin to California's Heat Pump Partnership, a public–private initiative that aims to rapidly scale the adoption of residential heat pumps across the state through consumer and contractor education and targeted policies.[102] Illinois does not have a direct certification program policy in effect. Emissions reductions are indirect and depend on voluntary uptake. Costs are minimal and are borne by participating firms.

STRATEGY 2, CONTINUED

Improve efficiency requirements

(2.6) Material efficiency standards

Material efficiency standards require manufacturers to reduce the amount of raw material or increase the use of recycled content used in production. By reducing emissions via materials changes and without necessitating complex retrofits, this policy aids efficiency without requiring the specialized knowledge or capacity needed for equipment changes, which some facilities may lack. These standards support circular economy efforts and can drive innovation in product and process design. Implementation would require sector-specific tailoring and robust enforcement mechanisms.[103]

Emissions reductions depend on material type and production volume, though an analysis for the Energy Transitions Commission suggested material efficiency measures could curb global heavy industry emissions by 40% by 2050.[104] Costs include compliance and enforcement, typically borne by manufacturers and the state. Illinois does not have a dedicated material efficiency standard in effect.

(2.7) Equipment requirements set through air quality regulations

Under the federal Clean Air Act, states must develop regulations and documents—collectively referred to as state implementation plans (SIPs)—to implement, maintain, and enforce the NAAQS set by the law for six criteria air pollutants.[105] The Illinois Environmental Protection Agency (IEPA) is the primary agency responsible for developing the state's SIP, while the Illinois Pollution Control Board (PCB) is a separate body that adopts state environmental regulations, including state air quality regulations.[106]

Illinois can leverage air quality regulations to drive industrial decarbonization by setting equipment standards that require the adoption of lower-emissions technologies more stringent than federal rules. This approach has precedent in California's South Coast Air Quality Management District (SCAQMD), which in 2024 passed zero-emission boiler rules designed to limit nitrogen oxide (NOx) emissions from residential and commercial boilers in line with SCAQMD's air quality management plan.[107] The rules set NOx emission limits and a compliance schedule for covered facilities, providing clear compliance pathways for manufacturers.[108]

Adopting similar equipment requirements in Illinois through the SIP process or other IEPA and PCB rulemaking has the potential to lock in long-term emissions reductions, improve local air quality, and create market certainty for manufacturers investing in clean technologies. These standards can be phased in over time, updated to reflect advances in emission control technologies and changes in federal and state air quality regulation, and paired with other supportive policies like technical assistance and financial supports.

STRATEGY 3

Incentivize flexible industrial electricity demand

(3.1) Alternative electricity pricing paths for industrial consumers

Granting industrial consumers access to real-time or wholesale electricity pricing allows facilities to purchase electricity at rates that reflect actual market conditions, rather than fixed tariffs. This can incentivize load shifting to off-peak hours where possible, and support deployment of electrification technologies in concert with thermal batteries.[109] RTP is especially valuable for sophisticated industrial users with predictable energy use or flexible operations. Although Illinois utilities like ComEd and Ameren offer RTP programs, these are primarily targeted at residential and small commercial customers.[110] Large industrial users may negotiate RTP contracts directly, but no dedicated statewide policy exists to support broader industrial access. To maximize effectiveness, RTP programs should be opt-in and paired with advanced metering infrastructure. Policies should be rooted in data, using historical load profiles and price signals to guide design. They should be adaptable to evolving grid conditions and equitable by ensuring smaller facilities are not excluded due to complexity or infrastructure gaps. Emissions reductions are indirect but potentially significant if load shifting enables greater integration of electrification technology. Costs are borne by utilities and participating facilities, with potential savings from reduced peak demand and improved grid stability.

STRATEGY 3, CONTINUED

Incentivize flexible industrial electricity demand

(3.2) Large-load electricity tariff reforms

Large-load tariff reforms aim to restructure electricity pricing for industrial customers to better reflect their actual cost of service and incentivize flexible, low-carbon energy use. This can include changes like creating new rate classes for flexible loads or implementing critical peak pricing.[111] These reforms allow facilities to benefit from lower off-peak prices, especially when paired with on-site storage technologies. Tariff changes should be transparent and aligned with grid-planning processes, and include clear metrics for participation and ratepayer protections, including ensuring industrial users continue to contribute an appropriate share of nonmarginal and customer-specific costs.[112]

Equity considerations are critical to ensure smaller or variable-load facilities are not disadvantaged by tariff changes. Though emissions reductions are indirect, they can be substantial if reforms enable broader electrification and load flexibility. Depending on the structure of the tariff changes and if other ratepayers are implicated, costs are primarily administrative and borne by utilities and regulators, with potential savings for participating facilities. Illinois does not have a direct policy or program in effect.

(3.3) Utility exit fee reforms

Exit fee reforms remove or reduce financial penalties for industrial customers that switch from fossil fuel systems (typically natural gas) to electricity. These fees, often imposed by utilities to recover infrastructure investments, can lock facilities into carbon-intensive systems and discourage electrification.[113] Under Illinois's Home Energy Affordability and Transparency (HEAT) Act, suppliers cannot charge residential and small-business customers exit fees for leaving a contract early.[114]

This policy can be designed to limit exit fees to cases where recent infrastructure investments were made and to establish transparent criteria for fee applicability. Emissions reductions are indirect because removing exit fees can potentially unlock electrification for facilities otherwise deterred by cost. Costs may shift to utilities or be absorbed through rate adjustments, requiring careful stakeholder engagement.

Advancing grid clean capacity for industrial electrification

While this report focuses on ways to directly influence industrial clean energy use, measures to increase clean generation to meet this new industry-driven electricity demand on the grid will be important to emissions reduction efforts by making electricity cheaper, cleaner, and more reliable. State decisionmakers can confront barriers to clean generation like grid congestion, limited interconnection capacity, and aging transmission infrastructure through a variety of mechanisms, including:

- **Improved utility planning procedures:** By aligning long-term utility investment strategies with state decarbonization goals, this approach helps ensure clean grid power is available when facilities look to electrify their processes.

- **Improved utility interconnection procedures:** Slow interconnection procedures can delay new clean generation sources from connecting to the grid. Improving and streamlining these procedures reduces grid bottlenecks and is critical for ensuring that the grid is able to meet industrial electricity demand with clean generation.

- **Siting and permitting reforms for clean energy projects:** Siting and permitting reforms accelerate the development of clean energy infrastructure by reducing soft costs and increasing transparency, addressing system-level barriers to grid expansion.

- **Supported deployments of grid-enhancing technologies (GETs) and advanced conductors:** Supporting deployment of GETs, such as dynamic line ratings, advanced conductors, and topology optimization, can increase grid capacity and flexibility without major infrastructure expansion, mitigating electricity demand concerns.[115][iii] These technologies improve transmission efficiency and resilience, enabling more clean energy to reach industrial loads.

- **Incentives and support for clean electricity generation:** A suite of complementary financial incentives, standards, and financing structures can be deployed to incentivize both grid-scale and on-site clean energy generation and to help industries reliably and affordably access clean electricity. These might include a tax credit for clean electricity generation, clean electricity rebates, incentives for on-site renewables installation, standards for clean generation colocation with new-build industrial facilities, and CCfDs for clean electricity.

- **Reduced or eliminated grid interconnection fees for low-carbon energy:** Reducing or eliminating grid interconnection fees for low-carbon energy projects lowers financial barriers for developers that otherwise act as a barrier to the deployment of clean electricity generation technologies.

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STRATEGY 4

Streamline permitting processes for emissions reduction projects

(4.1) Alternate approval processes for emissions reduction projects at existing sites

To directly address long deployment cycles, the state could consider streamlining permitting for emissions reduction projects at existing facilities. This could include fast-tracking approvals, standardizing documentation, and providing clear eligibility criteria for technologies like electric boilers or heat pumps. Though the Illinois EPA offers expedited permitting for some projects, no dedicated pathway exists for clean industrial upgrades.[116]

To be effective, these processes should prioritize high-impact projects, maintain environmental safeguards, and be accessible to small and medium-sized manufacturers. Emissions reductions depend on project scope, but faster permitting can shorten deployment timelines and thus accelerate emissions reductions. Costs are mainly administrative and would be borne by permitting agencies.

STRATEGY 5

Improve emissions standards

(5.1) Clean heat emissions standards

The state could also consider a clean heat emissions standard, which sets performance benchmarks for industrial thermal energy systems.[117] The standard should be technology-neutral, allowing facilities to choose the most cost-effective compliance pathway, but also have guardrails to ensure only meaningful measures are supported.[118] The standard should apply to new and existing equipment and should be rooted in analysis that aligns the rule with broader state climate goals. Illinois does not have a clean heat emissions standard.

Best practices include using verified emissions data, setting clear thresholds that can be made more stringent in the long term, and ensuring enforcement through transparent reporting.[119] Emissions reductions depend on coverage and stringency, but the policy is foundational for driving long-term electrification and clean heat adoption. Costs include compliance and verification, typically borne by facilities and the state.

(5.2) Local or regional cap-and-invest or carbon pricing mechanism

A cap-and-invest or carbon pricing mechanism sets a price on industrial emissions, creating financial incentives for facilities to reduce their carbon footprint. Revenue from the program can be reinvested in clean technology deployment, workforce training, or community resilience. Illinois does not have a carbon pricing program, and though politically challenging, this policy could offer a powerful market signal and long-term funding source.

Carbon pricing should reflect emissions intensity and be phased in gradually. Equitable outcomes can be supported through specifically allocated revenue investment in disadvantaged communities. Emissions reductions from the program depend on the price level and coverage, and costs are borne predominantly by emitters, with potential economic benefits from reinvestment and innovation.

Case Study: Colorado's Clean Heat Standard

In 2021, Colorado became the first state to adopt a Clean Heat Standard through Senate Bill 21-264, which mandates climate pollution reductions from gas utilities. The law requires gas distribution utilities with more than 90,000 retail customers to submit clean heat plans to the state's PUC demonstrating how they will reduce emissions 4% by 2025 and 22% by 2030, relative to 2015 levels.[120] These plans can include a mix of clean heat resources, including beneficial electrification, energy efficiency, recovered methane, and green hydrogen, and must be implemented at the lowest reasonable cost to customers, with a cost cap of 2.5% of annual gas bills for all full-service customers.[121]

Colorado's largest utility, Xcel Energy, submitted its first clean heat plan in 2023, committing $176 million annually to reduce emissions by 2.2 Mt by 2030 through six strategies.[122] The Colorado PUC approved the plan in June 2024 with modifications, after opposition from nonprofits over the utility's proposed inclusion of certified natural gas and carbon offsets in its initial clean heat portfolio proposal initiated a discussion process.[123]

Colorado includes data gathering and transparency requirements in clean heat plans, like an annual report and a directive for utilities to describe their monitoring and verification methodology.[124]

STRATEGY 6

Leverage state buying power

(6.1) State "buy clean" initiatives

A state or regional "buy clean" initiative uses public procurement to support low-carbon industrwial products — especially construction materials like steel, cement, and asphalt — by prioritizing the procuring of materials with verified lower emissions for state-backed projects. This creates stable demand for cleaner goods and helps manufacturers economically justify investments in emissions-reducing technologies. Illinois has no dedicated buy clean policy but was part of the federal–state Buy Clean Partnership under the Biden administration.[125] Illinois also identified the creation of a buy clean pilot initiative in its Priority Climate Action Plan (PCAP).[126]

Best practices include setting clear emissions thresholds, using standardized product-level carbon intensity metrics, and ensuring verification systems are transparent and enforceable.[127] Costs to the state may be higher for acquisition of low-carbon materials compared with traditional materials.

STRATEGY 7

Understand the opportunity and build information bases to support modernizing industrial technology deployment

(7.1) RD&D grants or incentives

RD&D grants support innovation in industrial decarbonization by funding pilot projects, material development, and process improvements. These programs help de-risk and demonstrate proof of concept for emerging technologies. Illinois already offers RD&D support through its Clean Energy Innovation Fund for the clean technology sector and its Research and Development Tax Credit.[128]

This policy can be targeted at especially carbon-intense industrial process needs and sectors where TRLs are low. Transparent reporting and qualification requirements should be included in the program, which should also be adaptable to evolving TRLs. Emissions reductions are long term and depend on successful commercialization. Costs are borne by the state, which would likely need to continuously reauthorize funding for the program, with potential for private co-investment.

(7.2) Workforce education and training programs

Workforce education and training programs help build the skilled labor needed to deploy and maintain clean industrial technologies. These can include direct job training, curriculum development, and support for access to electrification-related careers. Illinois has or plans to have several clean energy workforce programs under the Climate and Equitable Jobs Act.[129] The state also proposed the creation of a workforce training liaison as part of its PCAP.[130]

Programs should be designed with industry input, prioritize underserved communities, and be flexible to meet changing technology needs. Although emissions reductions are indirect, workforce readiness is essential for long-term decarbonization. Costs are borne by the state and participating institutions, with benefits including job creation and economic resilience.

(7.3) Technical assistance programs for facility-level technology and electricity assessments

Technical assistance programs help industrial facilities evaluate technology options and site-specific opportunities for emissions reductions, addressing the dilemma of choice, unique facility needs, and capacity constraints barriers. Support can include engineering assessments, energy audits, and guidance on electricity pricing models or financing options. Emissions reductions from this policy are indirect and depend on uptake and implementation of projects indirectly enabled by the assistance. Costs are borne by the state, with potential for federal support.

Some Illinois utilities like ComEd may offer facility assessments to identify commercial facility efficiency upgrade opportunities.[131] The University of Illinois System also houses the EnergySense Resilience Center, which provides energy assessments to a variety of clients, and Illinois's PCAP proposes a Clean Industry Concierge to provide this kind of support in the form of contractor and supply chain education and strategic planning support.[132]

STRATEGY 7, CONTINUED

Understand the opportunity and build information bases to support modernizing industrial technology deployment

(7.4) State-mandated facility-level assessments

Mandating facility-level assessments would require industrial sites to evaluate their emissions reduction potential, helping identify opportunities and inform planning. Though Illinois does not currently require these assessments, similar requirements exist for air quality permitting.[133]

To be effective, mandates should include clear guidelines, allow flexibility in methodology, and be paired with technical assistance. They should be enforceable and designed to minimize the burden on small manufacturers. Emissions reductions depend on follow-through, but the policy is foundational for building a statewide low-emissions roadmap for industry. Costs are borne by facilities and the state.

Building the Foundation for a Low-Carbon Industrial Future

There is both a climate and material benefit for Illinois to pursue low-emissions, low- and medium-temperature industrial heat. To meet statewide decarbonization goals, deliver clean air benefits to burdened communities, and prepare Illinois's industry to compete in the low-carbon markets of the future, industrial emissions must be abated. Due to barriers like project economics, technical assistance needs, and grid capacity concerns, companies are not independently pursuing methods to improve their production methods. The interventions outlined in this roadmap can ease the switch for facilities adopting more efficient and electrified technologies.

Though one intervention will not sufficiently address the problem, the state can consider sequencing a number of priority policies to begin to tackle industrial emissions with technology that is already commercially viable.

Appendix: Glossary of Technical Terms

Advanced geothermal systems: Geothermal systems that operate in a closed-loop configuration to extract heat from the earth.

Carbon border adjustment mechanism: A policy tool that imposes a carbon price on imports to equalize the cost of domestic and foreign goods.

Carbon capture and storage (CCS): A technology that captures carbon dioxide emissions from sources like power plants and stores it underground.

Carbon contracts for differences (CCfDs): Financial instruments that provide price certainty for low-carbon technologies by covering cost gaps.

Clean heat standard: A policy that sets emissions performance benchmarks for heating technologies.

Coefficient of performance (COP): A ratio that measures the efficiency of heating technologies, comparing heat output with energy input.

Combined heat and power (CHP): A system that simultaneously generates electricity and useful heat from the same energy source.

Electric boiler: A boiler that uses electricity to generate heat, often used as a cleaner alternative to a fossil-fueled boiler.

Electrification: The process of replacing fossil fuel–based systems with electric-powered alternatives.

Energy management system (EnMS): A framework for managing energy use and improving efficiency in organizations.

Enhanced geothermal systems: Geothermal systems that use fluid injection to enhance heat extraction from underground reservoirs.

Geothermal energy: Energy derived from the heat stored beneath the earth's surface.

Greenhouse Gas Reporting Program (**GHGRP**): A US EPA initiative for tracking industrial emissions.

Heat pump: A device that transfers heat energy from a source to a destination, often used for heating or cooling.

High-temperature heat: Heat delivered to an industrial process above 400°C.

Industrial Assessment Centers: Programs that provide energy assessments to industrial facilities to identify efficiency improvements.

ISO 50001: An international standard for energy management systems to improve energy performance.

Levelized cost of heat: A measure of cost for delivering thermal energy, measured in dollars per MMBtu delivered to an industrial process.

Low-carbon fuels: Fuels that produce fewer carbon emissions compared with traditional fossil fuels.

Low-temperature heat: Heat delivered to an industrial process between 0 and 200°C.

Material efficiency standards: Strategies to reduce the amount of raw materials or increase recycled content used in manufacturing.

Medium-temperature heat: Heat delivered to an industrial process between 200°C and 400°C.

Renewable portfolio standard (RPS): A regulation that requires increased production of energy from renewable sources.

Technology readiness level (TRL): A measure used to assess the maturity of a technology.

Thermal energy storage (TES): A technology that stores thermal energy for later use, improving energy efficiency and flexibility.

Waste heat recovery: The process of capturing and reusing heat that would otherwise be lost in industrial processes.

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