

INDUSTRIAL TRANSFORMATION IN MICHIGAN

A POLICY ROADMAP FOR A COMPETITIVE, DECARBONIZED MANUFACTURING SECTOR

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5 lakes energy

EGLE
MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY

Prepared for the **Michigan Department of Environment, Great Lakes, and Energy (EGLE)**

Prepared by **5 Lakes Energy**

About This Project

Michigan's 2022 MI Healthy Climate Plan established the state's overarching climate goals, including achieving carbon neutrality by 2050. Building on this foundation, the Office of Climate and Energy (OCE) in Michigan's Department of Environment, Great Lakes, and Energy (EGLE) issued the state's Comprehensive Climate Action Plan in 2025, which outlines sector specific greenhouse gas emissions reduction targets. For the state's industrial sector and roughly 12,000 manufacturing firms, many barriers have the potential to impede progress towards these goals – at the same time that many of the state's manufacturers face increasing pressures related to competition in the global marketplace.

With the right support from the state, however, Michigan's manufacturers can achieve the state's long-term climate goals while increasing their competitiveness. The objective of this report, therefore, is to provide Michigan policymakers and high-level decision makers with the right foundations to develop and implement a successful policy agenda to ensure the state's industrial sector charts the right course towards 2050.

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About 5 Lakes Energy

5 Lakes Energy is a Michigan-based consultancy supporting nonprofits, businesses, and government agencies in their pursuit of clean energy goals, design and implementation of climate solutions, and delivery of economic, public health, and other benefits to the people they serve.

Acknowledgements

The findings and recommendations presented in this report incorporate the perspectives of a tremendous number of Michigan-based stakeholders and rightsholders – manufacturers, technology OEMs, energy solution providers, utilities, environmental justice representatives, clean energy and environmental advocates and NGOs, labor representatives, state agencies, and more – who offered 5 Lakes Energy their valuable time and honest opinions over the course of multiple months of outreach and engagement efforts. We wish to extend our most heartfelt gratitude and appreciation to these individuals and their organizations' commitment to supporting Michigan in the state's effort to strengthen its manufacturing sector while pursuing a climate-aligned economy, and a better future for all Michiganders. We also wish to thank our colleague Graham Woolley for his work conducting the Energy Policy Simulator (EPS) modeling and supporting the analysis presented in this report.

Executive Summary

Michigan's industrial sector is central to the state's economy, supporting more than 600,000 manufacturing jobs across roughly 12,000 companies and contributing approximately $100 billion to the state's gross domestic product annually. Industry is also responsible for approximately 17.5% of Michigan's greenhouse gas (GHG) emissions. Achieving the state's clean energy goals, including economy-wide carbon neutrality by 2050, will require significant reductions in industrial emissions.

This roadmap provides an implementation-focused strategy for industrial decarbonization in Michigan. Building on the MI Healthy Climate Plan, Michigan's Comprehensive Climate Action Plan, existing state initiatives, and stakeholder engagement, it identifies priority policies, implementation responsibilities, and sequencing to support industrial emissions reductions through 2050. Its emphasis is on the policies, market conditions, and resources needed to move projects from planning to implementation.

The purpose of this roadmap is to help preserve and strengthen Michigan's position as a leading manufacturing state. Putting resources into industrial decarbonization now is an investment in Michigan's economic future, as well as its climate goals. Decisions made today about industrial revitalization, energy infrastructure, and public policy will shape Michigan's manufacturing competitiveness and emissions trajectory for decades to come. Industrial decarbonization can also deliver community benefits, including improved air quality and new employment opportunities. Updating facilities will position businesses to respond to growing demand for lower-carbon products. Many industrial decarbonization technologies are available today, offering opportunities to modernize facilities, improve productivity, and reduce emissions, while managing energy costs.

Progress, however, will require coordinated action to overcome significant economic, technical, regulatory, and institutional barriers.

INDUSTRIAL DECARBONIZATION OPPORTUNITIES AND CHALLENGES

Michigan's industrial sector includes manufacturers of different sizes, production processes, and energy needs. Targeted investments at major industrial facilities will offer a major step forward, but supporting the state's thousands of small and mid-sized manufacturers will require more accessible technical assistance, financing, and implementation support.

This roadmap identifies energy efficiency, electrification, lower-carbon fuels, and carbon capture as primary technical pathways. No single approach fits every industry. Many emissions-reducing technologies are commercially available today, but high upfront costs, energy prices, and production risks remain major barriers to adoption.

POLICY RECOMMENDATIONS

The roadmap recommends both direct support for industrial projects and policies that address broader barriers to investment. These recommendations include improved industrial energy planning and coordination among state agencies and utilities to address barriers to technology adoption. The roadmap also recommends common carbon accounting and project evaluation metrics to standardize processes across industries. It proposes establishing an integrated

system connecting manufacturers with technical assistance, financing, permitting, and project development resources. Building on existing state and federal resources, this system would help manufacturers move from initial assessments to completed projects while improving coordination across state programs.

To address financial barriers, the roadmap recommends a recurring industrial modernization and decarbonization grant program, complementary financing mechanisms, and a clean heat production tax credit. These policies would help manufacturers manage upfront investment costs and the ongoing operating costs of adopting lower-carbon technologies, with targeted support for small and mid-sized manufacturers. Industrial electricity rate reforms and improved utility planning would support electrification while managing infrastructure needs and ratepayer impacts. Expanded energy waste reduction and efficient electrification programs would provide additional support for industrial efficiency improvements and fuel switching.

Additional recommendations include a phased 'Buy Clean, Buy Michigan' procurement program to strengthen markets for lower-carbon materials, as well as expanded markets and infrastructure for recycled and circular materials to increase the use of recovered feedstocks and reduce demand for virgin materials. The roadmap also recommends evaluating a Great Lakes region cap-and-invest program for major industrial emitters.

The roadmap calls for streamlined permitting for industrial decarbonization projects, reducing delays and uncertainty associated with implementing emissions-reducing technologies. It also calls for establishing innovation hubs and industrial clusters to support technology deployment and shared infrastructure. The roadmap outlines a framework for responsible carbon capture, utilization, and storage where other emissions-reduction approaches are infeasible. Finally, workforce development initiatives that build on existing training programs will prepare workers for new technologies and support manufacturers' changing skill needs.

IMPACTS OF DECARBONIZATION POLICIES

To assess the potential impacts of these policies, the roadmap uses the Energy Policy Simulator (EPS) to evaluate four scenarios representing progressively greater levels of policy intervention and technology deployment. The results illustrate potential outcomes. Under business-as-usual (BAU) conditions, annual industrial GHG emissions remain relatively stable through 2050, reaching approximately 42 million metric tons of carbon dioxide equivalent (MMT CO_2e). Under the foundational, accelerated, and transformational policy scenarios, annual emissions decline to approximately 35, 32, and 29 MMT CO_2e, respectively, representing reductions of 15%, 23%, and 31% by 2050 relative to the BAU modeled policy scenario. Remaining emissions even in the transformational scenario underscore the need for continued technology development, commercialization, and deployment to address hard-to-abate industrial processes. The modeling also indicates potential employment and public health benefits, including reduced air pollution and improved public health outcomes.

SEQUENCING AND IMPLEMENTATION

Successful implementation will depend on sequencing policies to address immediate barriers, support deployment, and lay the groundwork for deeper emissions reductions over time. From 2027 to 2030, Michigan should prioritize foundational programs, technical assistance, commercially available technologies, and a pipeline of viable projects. Between 2030 and 2035, the state should scale successful programs, expand technology deployment, and strengthen financing and market mechanisms that increasingly leverage private investment. From 2035 to 2050, efforts should focus on deeper emissions reductions, including emerging technologies and strategies for industrial processes that cannot be fully decarbonized using existing solutions. While these activities will overlap, early investments will be critical to enabling later deployment.

Industrial decarbonization should be a central part of Michigan's manufacturing and economic development strategy. The priority now is to translate these recommendations into sustained programs, coordinated planning, and investments that help Michigan's manufacturers to remain competitive while reducing their emissions.

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Introduction and Roadmap Purpose

Michigan has committed to economy-wide carbon neutrality by 2050, including an interim goal of reducing greenhouse gas (GHG) emissions by 52% below 2005 levels by 2030.[1] These targets, which were established through the MI Healthy Climate Plan in 2022 and reinforced through the state's broader climate and energy planning and other programs, are intended not only to reduce GHG emissions but also to improve:

- Air quality
- Public health
- Manufacturing competitiveness
- Clean energy job creation

Industry in Michigan is both a major source of GHG emissions[2] and a driving force of the state's economy.[3] Decarbonizing the industrial sector will, therefore, be paramount to Michigan's success in both climate and economic development priorities. Investments in industrial decarbonization can also strengthen manufacturing competitiveness by improving energy efficiency, reducing exposure to energy price volatility, and positioning Michigan manufacturers to meet increasing demand for lower-carbon products. However, doing so will require significant policy support, investment, and coordination across government agencies, utilities, and the private sector to offset the current trajectory of growth and fuel use. Additionally, if industrial decarbonization proceeds without deliberate planning, especially among utilities, regulators, and financing partners, the result could be a disparate, delayed transition that strains the electric grid, and increases costs for both manufacturers and other ratepayers.

This roadmap defines how Michigan can reduce industrial GHG emissions while strengthening manufacturing competitiveness, supporting workers and communities, improving air quality, and positioning the state as a national leader in clean industry. It is intended as an implementation focused document for state leaders, agencies, utilities, policymakers, manufacturers, and others. Industrial decarbonization efforts should strengthen Michigan's economy and ensure that the state's goals are translated into scalable projects, enabling infrastructure, and a lasting policy landscape. To accomplish this, the roadmap addresses both the policy and market conditions needed to enable industrial decarbonization and the support needed to advance individual projects. This roadmap builds on existing work, including policy mechanisms previously recommended in other relevant studies, by suggesting definitive actors for the different measures proposed herein and explicit next steps.

GUIDING PRINCIPLES AND STRATEGIC PILLARS

The recommendations laid out in this roadmap are linked by a shared set of policy principles. These are intended to help Michigan prioritize actions that reduce emissions, while also serving to focus the state on economical, equitable, and practical considerations.

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[1] "MI Healthy Climate Plan," Michigan Department of Environment, Great Lakes, and Energy, April 2022.

[2] "MI Healthy Climate Plan," Michigan Department of Environment, Great Lakes, and Energy, April 2022.

[3] "Manufacturing Powerhouse at the Heart of American Innovation," Manufacturing Michigan, accessed September 2026.

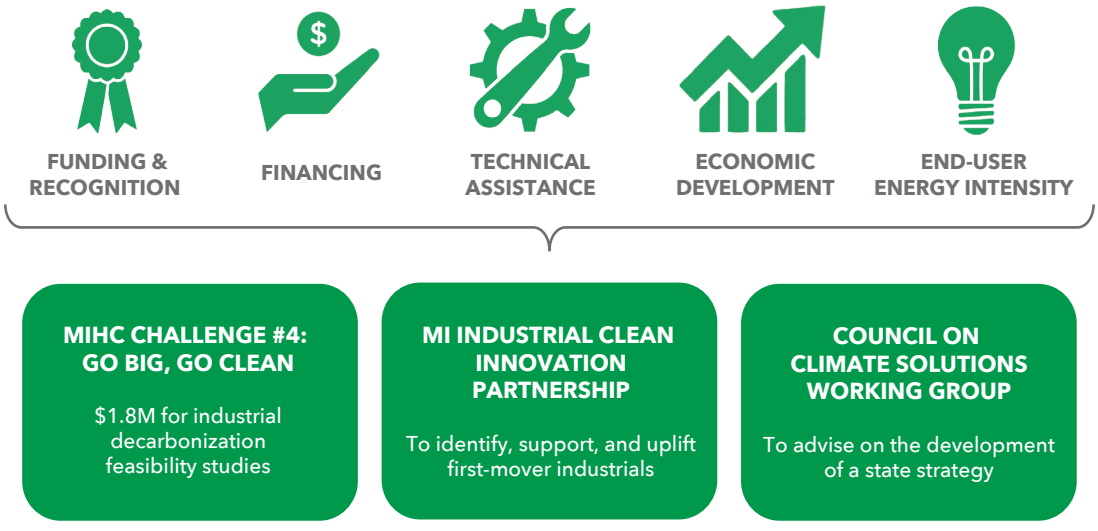
1. **Ground the work in the MI Healthy Climate Plan (MIHCP).** Recommendations should be centered on the goals of the MIHCP.
2. **Focus on implementation-oriented recommendations.** Recommendations should prioritize practical, actionable policy options. Recommendations should distinguish between near-term actions, longer-term strategies, and actions requiring additional authority, funding, utility engagement, or federal support. They should identify sequencing and which actors are best positioned to lead or support implementation.
3. **Advance emissions reductions while supporting competitiveness.** Industrial decarbonization should be framed as both a climate strategy and an economic strategy. Policies should prioritize helping Michigan industries reduce emissions, lower energy costs where possible, improve operational resilience, and remain competitive in a changing economy.
4. **Address barriers directly.** Policies should address the cost, financing, risk and other barriers that prevent industrial facilities from adopting cleaner technologies and processes.
5. **Recognize the diversity of Michigan's industrial sector.** The roadmap should reflect that industrial decarbonization will need to accommodate the different needs and priorities of manufacturing subsectors, including size, geography, trade exposure, hard-to-abate subsectors, and workforce availability.



6. **Support workers and workforce development.** Industrial decarbonization strategies should support the creation and continuation of high-quality jobs.
7. **Support frontline, neighboring,** and Tribal communities. Industrial decarbonization strategies should aim to engage and reduce impacts on frontline communities, Tribes, and other communities historically burdened by pollution.
8. **Use transparent data and shared assumptions** The roadmap should be based on publicly available data on Michigan's industrial emissions profile, major sources of emissions, available technologies, costs, barriers, and opportunities.
9. **Build on existing work.** The roadmap should build on and leverage existing initiatives, completed reports, utility efforts, and private sector activities.

The recommendations also fit under five strategic pillars of implementation that reflect the main functional categories Michigan must strengthen if industrial decarbonization is to progress from isolated projects to a replicable part of the state's manufacturing economy. These pillars are defined as:

- **Funding and recognition** Relevant programs should include grant funding, incentives, and public recognition that reward early action, de-risk, and send market signals. Recognition efforts should elevate successful projects, disseminate lessons, and create a visible pipeline.
- **Financing** Michigan should develop financing tools for industry to access capital.
- **Technical assistance** Assistance programs should include assessments, audits, and energy management support – especially for small and mid-sized enterprises (SMEs, which are usually defined as companies with fewer than 500 employees and annual receipts less than $7.5 million[4]) – as well as peer groups and information exchange.
- **Economic development** Decarbonization should be seen as a key part of the state's economic development strategy, including modernization and workforce development.
- **End-user energy intensity.** Michigan's industrial decarbonization strategy should focus on technologies that reduce the most significant costs and largest emissions sources.



[4] "SBA Get Started with Contracting," U.S. Small Business Administration, Basic Requirements, 2026.

ROADMAP APPROACH AND DISTINGUISHING FEATURES

Various important and publicly available resources already identify industrial decarbonization opportunities in Michigan and nationally, including a collection of Michigan-specific analyses and roadmaps. Those resources help establish the technical case for industrial decarbonization and identify technologies, barriers, and high-level policy ideas. These reports provide a foundation of research and analysis that informs the recommendations presented in this roadmap.

This roadmap focuses on implementation – the resources, institutions, authorities, and policy structures needed to move industrial decarbonization projects from concept to deployment at scale in Michigan, and the significance of technology deployment and commercialization in terms of the state's ability to reach its broader goals. This roadmap includes the criteria by which the recommended policies were selected, potential packaging options for different outcomes, and sequencing recommendations.

Key questions explored in this roadmap include:

- How should Michigan prioritize industrial facilities and subsectors for decarbonization efforts?
- Which actions can or should Michigan take immediately, and which will require legislative, regulatory, or institutional changes?
- What are the guiding principles of the recommended policy options? How should the recommendations be sequenced? For example, the roadmap lays out near-term opportunities to support the state's early movers. How do the policy options presented differ from establishing a supportive landscape and an economy of scale for decarbonized technologies?
- What does a project pipeline look like? How can a pipeline function across the state's industrial sector to help scale decarbonized solutions?

This roadmap covers emissions from Michigan's industrial sector, including direct fuel combustion, purchased electricity, process emissions, and infrastructure needs. It addresses both large and small-sized facilities, and considers a range of decarbonization strategies and technologies at various points of commercialization. This roadmap considers the cross-cutting institutions needed to support implementation.

Table 1 presents a summary of the relationship between existing resources, what this roadmap addresses, and what the combination of existing resources and this roadmap is intended to enable.

Table 1

EXISTING RESOURCES ESTABLISH:	THIS ROADMAP ADDRESSES:	TO ENABLE:
Technical opportunities	Policy selection criteria	Project deployment
Technology pathways	Resources and institutions	Technology commercialization
Barriers to greater deployment	Authorities and implementation roles	Industrial modernization
Policy options	Policy packages and impact scenarios	GHG reductions
Michigan industrial context	Sequencing and dependencies	Economic, health, and system benefits

Michigan Industrial Sector Profile

Manufacturing in Michigan is a cornerstone of the state's economy, employing more than 600,000 workers (an estimated 20% of jobs; see Figure 1(a)) at an average salary of $71,700 across roughly 12,000 firms.[5,6] Combined, the sector contributes roughly $100 billion to the state's gross domestic product (GDP) each year, including nearly $60 billion in exports.[7] Because many of the state's core manufacturing facilities rely on energy-intensive processes, the sector is directly responsible for 17.5% of Michigan's GHG emissions (i.e., scope 1 emissions; Figure 1(b)).[8] The sector also buys about one-third of the state's electricity to drive its operations,[9] with that electricity supplying about 15% of all on-site industrial energy consumption in Michigan.[10]

Direct emissions (i.e., scope 1; see Figure 2) from the state's manufacturers have decreased by about 18% since 2005, with almost half of those reductions stemming from the broad push to move the state's economy off coal. More recently, the main driver has been a contraction of the state's primary steel sector, which is also a major consumer of coal products.[11] Despite these shifts, about 6% of industrial fuel emissions in Michigan can still be attributed to coal products[12] – and the sector's technical complexity not only explains its distinct and complex fuel mix (Figure 1(d)), but also underscores why the state's emissions reduction goals for its manufacturing sector are comparatively modest relative to those for other economic sectors (Figure 1(c)).[13]

Of the state's roughly 12,000 manufacturing facilities, just 80 high-emitting sites were responsible for an estimated 94% of industrial emissions in 2023, with most of those emissions arising from a complex fuel mix and the use of GHG-emitting chemical processes in core production activities (Figure 2). Those roughly 80 high-emitting sites belong to about 37 distinct industrial subsectors. In contrast, the state's thousands of remaining small and mid-size manufacturers span a broader range of subsectors, capture a larger share of manufacturing employment, and in general rely on natural gas as a fuel where process heat is supplied through combustion, not electrified technologies.

Despite the diversity of Michigan's manufacturing sector, emissions remain concentrated in only a handful of industries, among a small number of sites. Records show that in 2023, roughly 86% of industrial emissions derived from about 40 facilities in just 10 subsectors – iron ore mining and pelleting (1 facility), beet sugar manufacturing (4), paper and paperboard mills (10), petroleum refining (1), ethyl alcohol (ethanol) manufacturing (5), iron and steel (3),[14]

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[5] "Michigan Manufacturing Industry Cluster Workforce Analysis," Michigan Department of Technology, Management, and Budget, Center for Data and Analytics, 2023.

[6] "Manufacturing Powerhouse at the Heart of American Innovation," Manufacturing Michigan, accessed September 2026.

[7] "Manufacturing Powerhouse at the Heart of American Innovation," Manufacturing Michigan, accessed September 2026.

[8] "Michigan's Comprehensive Climate Action Plan," Michigan Department of Environment, Great Lakes, and Energy (EGLE), December 2025.

[9] "Michigan: Michigan Electricity Data," U.S. Energy Information Administration (EIA), accessed September 2026.

[10] "Michigan: Michigan Total Energy Data," U.S. Energy Information Administration (EIA), accessed September 2026.

[11] "Michigan's Comprehensive Climate Action Plan," Michigan Department of Environment, Great Lakes, and Energy (EGLE), December 2025.

[12] Based on 2023 U.S. Environmental Protection Agency greenhouse gas emissions data, as reported in the Facility Level Information on GreenHouse gases Tool.

[13] "Michigan's Comprehensive Climate Action Plan," Michigan Department of Environment, Great Lakes, and Energy (EGLE), December 2025.

[14] This tally includes Dearborn Works, which was a fully operational integrated steel mill in 2023. In 2025, new steel production at the mill was indefinitely idled, leaving only a portion of the facility still in operation. As of the date of publication, this fact remains true.

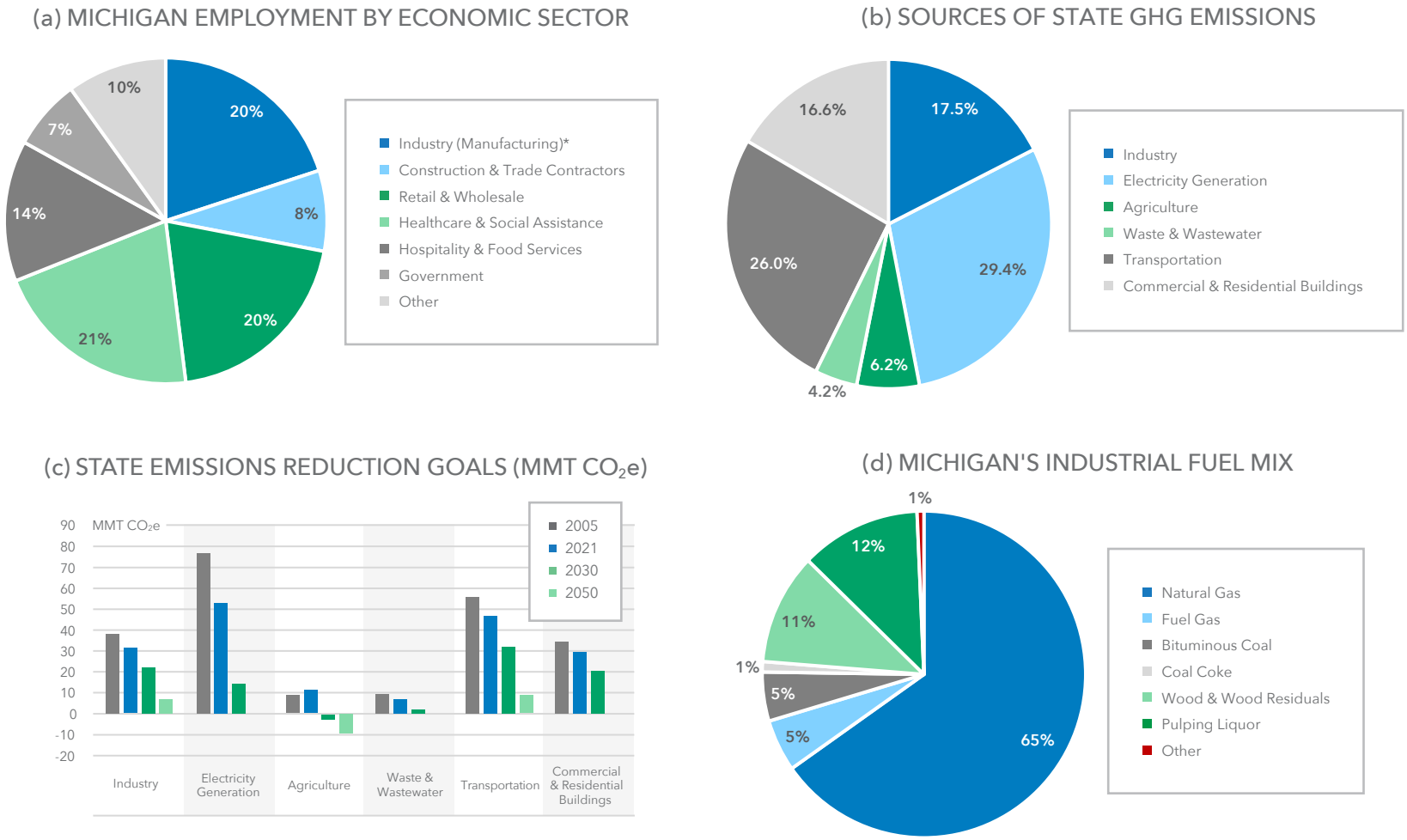


Figure 1 *(a) Michigan employment data reveals that industry (including manufacturing) is one of the state's top three economic sectors. (b) As an energy-intensive sector, industry is directly responsible for roughly 17.5% of state GHG emissions, with an additional share of electricity generation emissions attributable to industry consumption. (c) Due to the complexity of decarbonizing the industrial sector, existing state goals for emissions reduction are comparatively shallow for the next two decades. (d) A large share of Michigan's manufacturing emissions can be traced to fuel combustion, where the sector's fuel mix is highly diverse — a fact that contributes to the complexity of decarbonizing this economic sector.*

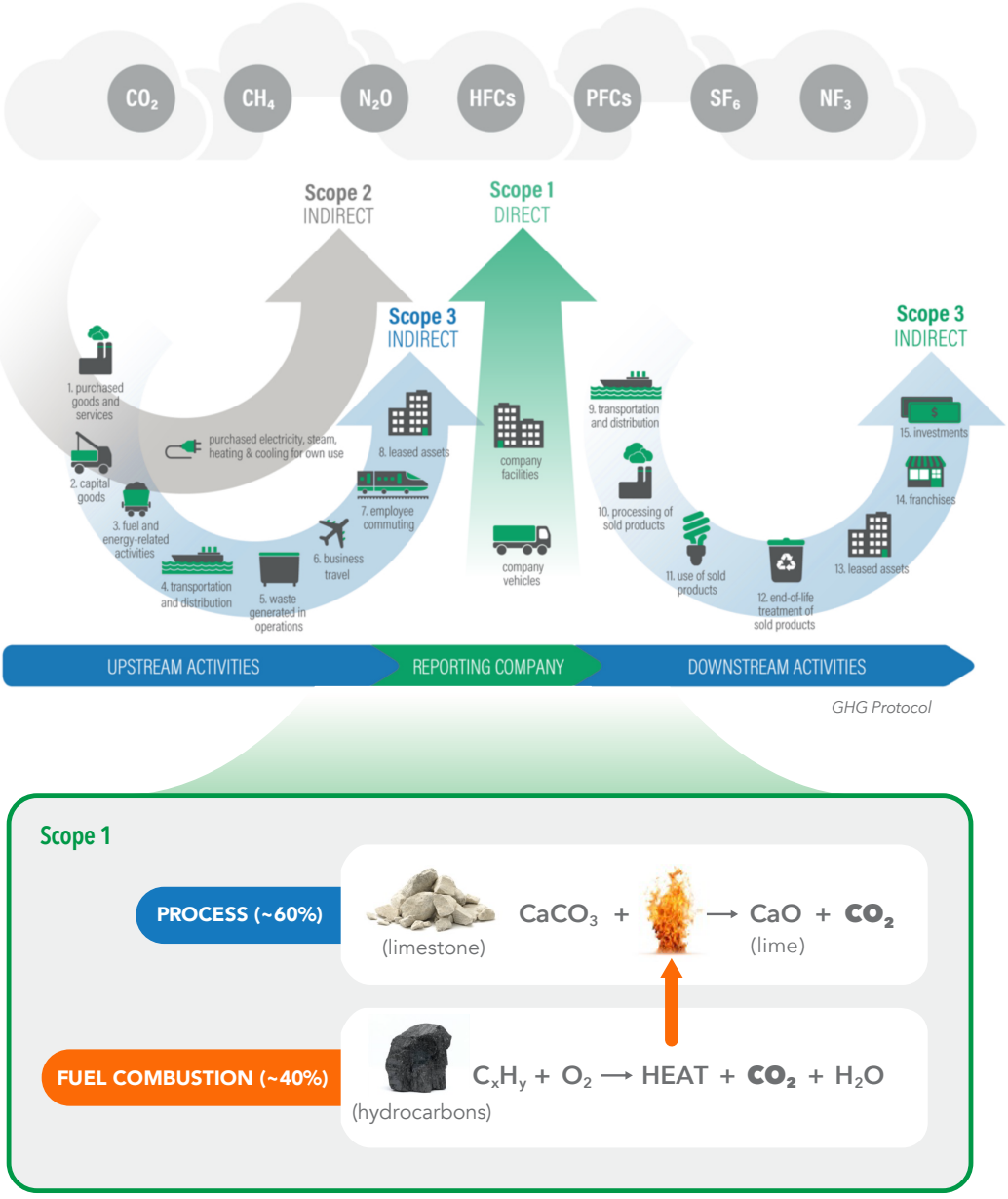


Figure 2 *Different categories of GHG emissions associated with manufacturing. Scope 1 emissions originate at the manufacturing facility and are the focus of this paper. Scope 1 emissions are composed primarily of fuel and process emissions. Fuel emissions are produced during combustion of fossil fuels, like coal or natural gas. Process emissions are generated as a chemical byproduct during the manufacturing process, regardless of the heating source. Lime production from limestone, which is a major source of process emissions in Michigan, is shown as an example. For some facilities, scope 1 emissions also include those derived from wastewater treatment or the landfilling of waste. Scope 2 emissions are produced primarily from off-site electricity generation to power industrial equipment and facilities. Scope 3 emissions are generated during upstream and downstream activities, associated with the products manufactured at the facility. Upper image in the figure was reprinted, with permission, from "Technical Guidance for Calculating Scope 3 Emissions," p. 6, GHG Protocol, 2013.*

cement and lime (4), and automotive and light duty vehicle manufacturing (12).[15] Among these high-emitters, a handful stand out as true super-emitters, with just 7 facilities giving rise to nearly 80% of industrial emissions in Michigan, which underscores the degree to which Michigan must work with its largest industrial firms to secure deep decarbonization of the sector.

In many cases, these high-emitting industrial subsectors can be found clustered in different geographic regions of the state (Figure 3). For example, about half of Michigan's paper mills are located in the state's forested upper peninsula with ready access to raw material inputs; the state's two cement plants are located in the northern end of the lower peninsula, where the state's geological history offers abundant limestone resources; and food and beverage and ethanol plants are scattered throughout the lower half of Michigan's lower peninsula, in the state's agricultural region. This means that in Michigan, subsector-specific industrial decarbonization strategies will be intrinsically tied to geographic, and thus economic, regions within the state.

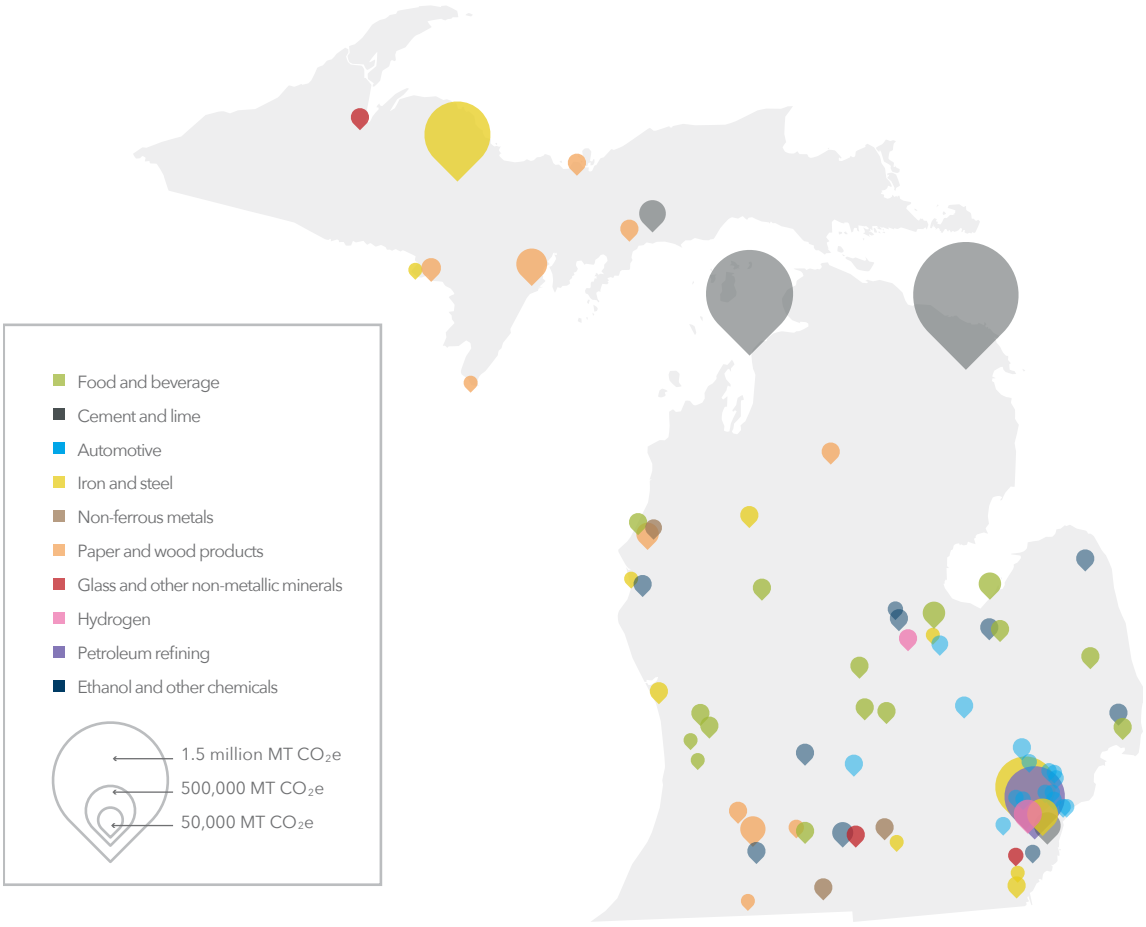


Figure 3 *Map showing relative total annual GHG emissions from Michigan's super-emitting industrial and manufacturing facilities, by subsector. Based on 2023 data from U.S. EPA's FLIGHT resource.*

[15] Based on 2023 U.S. Environmental Protection Agency greenhouse gas emissions data, as reported in the Facility Level Information on GreenHouse gases Tool.

The processes and technologies that Michigan's various high-emitting industrial subsectors rely on are even more distinct than the sector's complex fuel mix or geographic distribution. A previous report estimates that there are nearly 500 operating industrial-scale boilers in Michigan — most of which are located in the state's large and mid-size manufacturing facilities, where they deliver hot water and steam to a range of processes.[16] But industries like iron ore pelleting, sugar manufacturing, paper manufacturing, automotive assembly (especially paint curing activities), primary steel production, lime and cement manufacturing, flat glass and mineral wool production, and other metals and nonmetallic minerals processing plants rely on a variety of specialty furnaces and kilns.

While boilers are generally classified as low- and medium-temperature heating units, furnaces and kilns are all high-temperature units — often operating in excess of 1,800°F (1,000°C). These workhorse heat-supplying units consume an incredible volume of fuel each year, combusted to yield an estimated 21 million metric tons (MMT) of GHGs. In some cases, the processes they drive also emit GHGs: cement clinker production gives rise to process carbon dioxide (CO_2) during limestone calcination (see Figure 2); limestone, lime, and soda are common fluxing agents for impurity removal in the iron, steel, and glass industries — releasing CO_2 as they react; and industries like paper and beet sugar manufacturing process their own lime on site, again giving rise to chemical process CO_2, which in these cases is typically consumed and recycled on site.

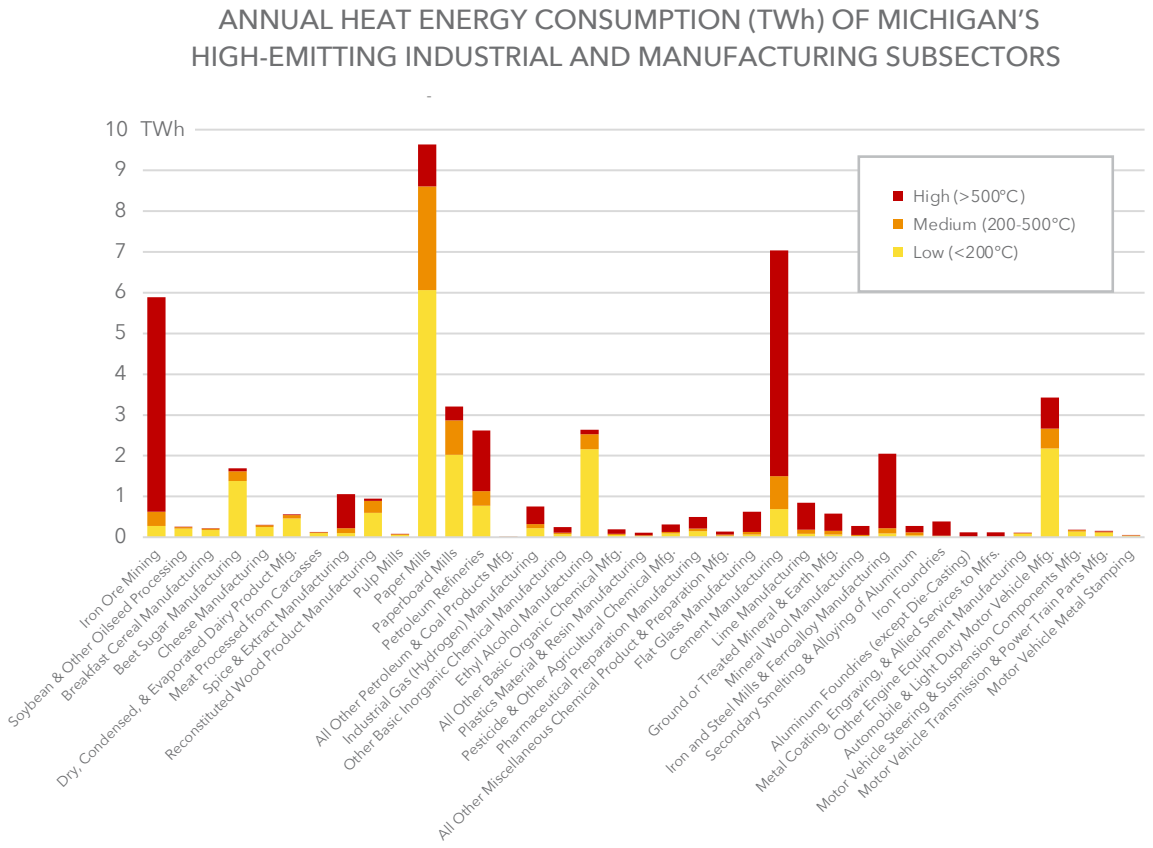


Figure 4 *Total estimated annual heat energy needs of Michigan's super-emitting industrial and manufacturing subsectors, by temperature category (low, medium, high). Derived from U.S. EPA's FLIGHT resource, using 2023 records. Subsectors are plotted in ascending order of corresponding 6-digit NAICS codes.*

[16] T. Dolan, A. Restrepo, et al., "Embracing Clean Heat," Evergreen Collaborative and Sierra Club, May 2025.

These distinctions also explain many differences in the heat energy needs, by temperature, that can be observed across these subsectors. For example, iron ore mines must fire 'green' ore pellets to achieve strength for subsequent handling steps, in a process that requires temperatures on the order of 2,200°F (1,200°C). In contrast, most of the energy consumed in ethanol manufacturing is associated with distillation, evaporation, and drying activities — all classified within the low-temperature (<200°C) industrial heat range. Figure 4 presents the differences in fractions of heat energy required by different Michigan industrial subsectors and their respective processes.

The diversity of Michigan's manufacturing sector is a testament to the state's abundant natural resources and favorable agricultural regions, as well as the state's extensive supply chain built around its hallmark automotive manufacturing and assembly subsector and its favorable offerings for industrial firms. The state's extensive portfolio in the automotive manufacturing and assembly subsector, and its large number of ethyl alcohol manufacturing and paper mills, offer some benefit to the state, when viewed against its peers: less carbon intensity per dollar of economic output (see Figure 5). Favorably, because Michigan's industrial sector is less coal-reliant than neighbors like Indiana and Ohio, the state will likely require less extensive interventions to achieve net-zero after full implementation of the reduction measures proposed in this roadmap.

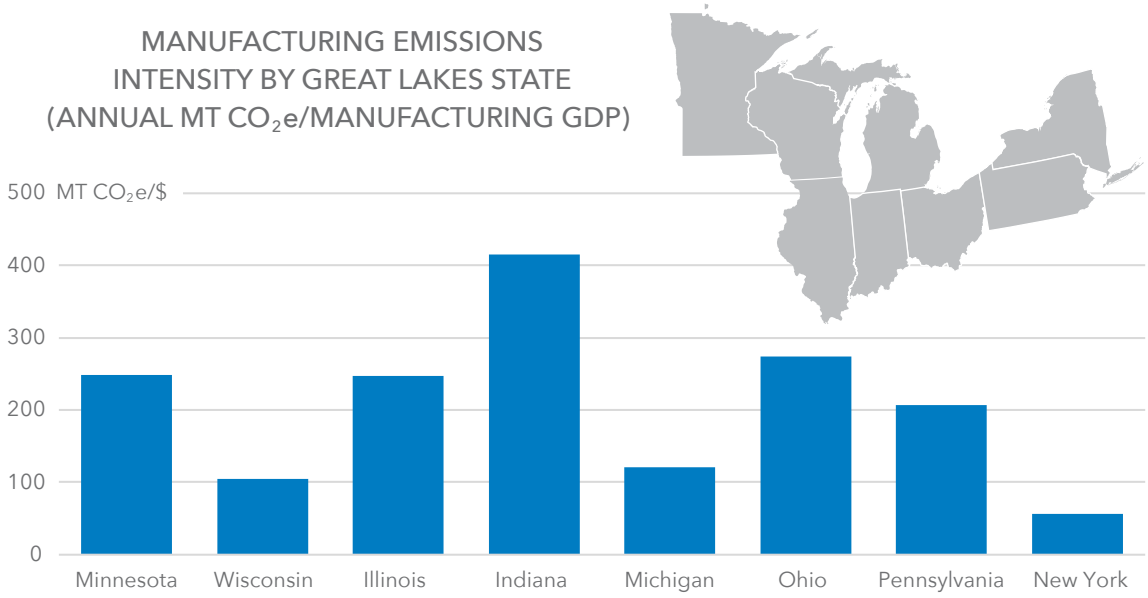


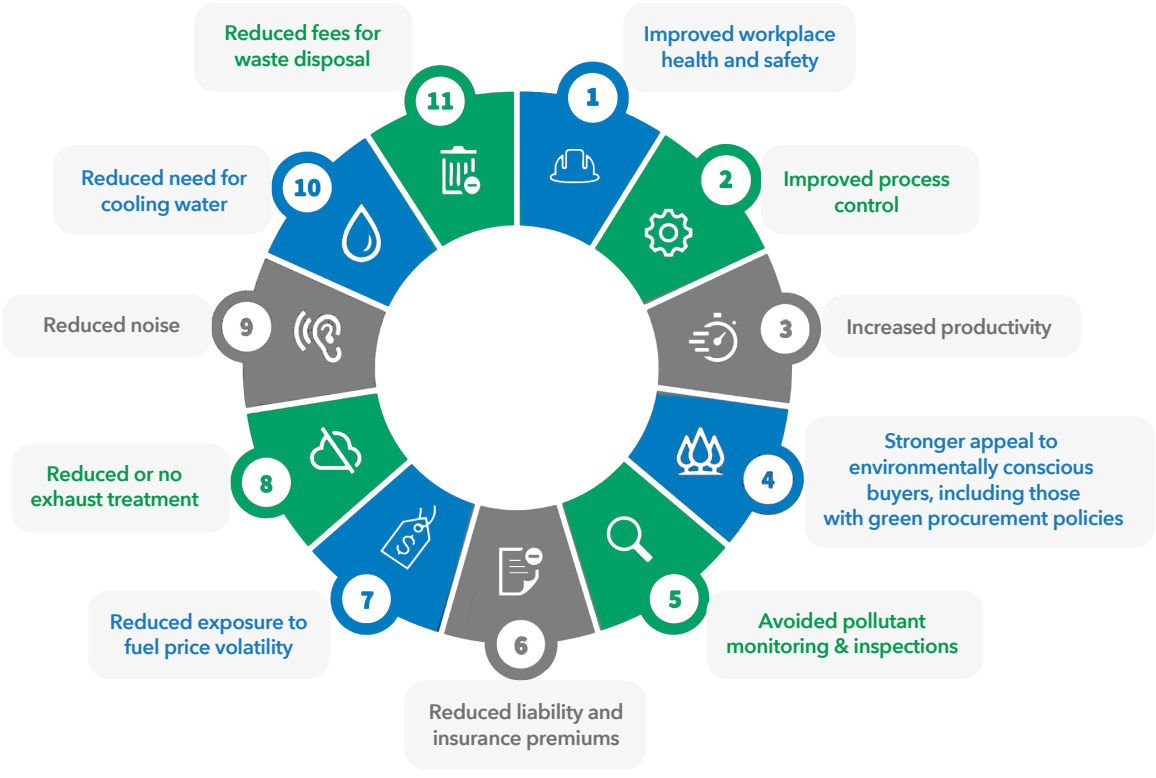
Figure 5 *Manufacturing emissions intensity by state in the Great Lakes region, represented in metric tons (MT) of CO_2e per U.S. dollar ($) of Gross Domestic Product (GDP) generated by the manufacturing sector. Michigan has the third least-carbon-intensive manufacturing sector in the region, at 104.7 MT CO_2e/$. Data adapted from U.S. Bureau of Economic Analysis.*

Benefits of Industrial Decarbonization

CLIMATE AND HEALTH BENEFITS

Modeling indicates that implementing the policies recommended in this roadmap could reduce annual industrial GHG emissions by up to 31% by 2050 relative to Michigan's business-as-usual (BAU) trajectory (see *Industrial Decarbonization Scenario Analysis*). Reducing GHG emissions is critical for mitigating the worst effects of climate change – which Michigan and the Great Lakes region are already experiencing. For example, the state is already recording more frequent extreme storm events, increased rates of rainfall during those storm events, and increased lake-effect snowfall.[17] Higher water temperatures and increased nutrient loads from runoff and sewage discharge are increasing the occurrence of harmful algal blooms.[18] Heat waves have significantly increased in southeast Michigan, while the number of cool, dry days in the summer has declined.[19] Continued warming is expected to alter freeze-thaw cycles, contribute to more variable lake water levels, and potentially increase the prevalence of certain communicable diseases.[20]

BENEFITS OF ELECTRIFICATION FOR INDUSTRIAL FIRMS



Modified from "Overcoming All Barriers to Industrial Electrification," by Energy Innovation (June 2025).

[17] "Climate Impacts," GLISA, accessed September 2026.

[18] "Climate Impacts," GLISA, accessed September 2026.

[19] "Climate and Health Overview," Michigan Department of Health and Human Services, accessed September 2026.

[20] "Climate and Health Overview," Michigan Department of Health and Human Services, accessed September 2026.

These effects both directly and indirectly impact Michigan's industrial sector, commercial entities, and manufacturers. The damage caused by extreme weather events and shifts in weather patterns, both in Michigan and elsewhere, are increasing operational expenses and insurance premiums, disrupting operations, and damaging critical infrastructure that manufacturers rely on.[21] Deep-freeze events in the South in recent years have caused significant spikes in natural gas prices and transport pipeline capacity constraints — leading to natural gas curtailments events or restrictions to manufacturers across 47 pipelines in the winter of 2025 alone, some with just 1-2 business days' notice.[22] Michigan's manufacturers rely on the same infrastructure and market pricing for their fuel, which makes them increasingly susceptible to future restrictions on natural gas or fluctuations in gas pricing. By decreasing emissions from the state's industrial sector, especially through efficiency improvements and electrification, Michigan's manufacturers can not only improve their operational outlook but also help drive down climate-warming emissions.

Combustion of natural gas and other fuels by industrial sources also leads to the emission of nearly 200 different regulated 'air toxics' — substances that are known to cause birth defects, cancer, reproductive harm, and/or severe ecological damage. A subset of these, known as criteria air pollutants (CAPs), are regulated by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act using health-based standards.[23] Michigan's industrial sector is a major contributor to statewide CAPs emissions, with emission sources of the different CAPs, like nitrogen oxides (NO_x) and fine particulate matter ($PM_{2.5}$), concentrated in different regions of the state, due to clustering of industrial point sources. The state-wide distribution of industrial point source emissions of carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic compounds (VOCs), fine particulate matter ($PM_{2.5}$), and ammonia are shown in Figure 6, with each aggregated at the county level.

Full implementation of the policies recommended in this roadmap could reduce the annual release of these harmful criteria air pollutants, including volatile organic compounds (VOCs), fine particulate matter ($PM_{2.5}$), and nitrogen oxides (NO_x), from industry by 7%, 22%, and 41% compared to BAU in 2050, respectively (see Figure 13 in *Industrial Decarbonization Scenario Analysis*). Air pollution is a critical public health concern. Poor air quality is associated with severe health problems including a variety of respiratory illnesses and allergic diseases, lung cancer, stroke, and premature death.[24,25] The World Health Organization estimates that in the United States the disability adjusted life-years (DALYs), meaning years of life affected by disability or lost to early death, attributable to ambient air pollution is 372 per 100,000 people — which is much higher than in neighboring Canada (183) and in other developed regions like Australia (126) or Western Europe (162 to 297).[26] Pollution from Michigan's cement and nonmetallic minerals, chemicals, and iron and steel manufacturers has been shown to contribute to a variety of negative health outcomes, such as asthma symptoms, emergency department visits, and premature death.[27] Health impacts from poor air quality are also exacerbated by extreme heat events, which are increasing in frequency due to climate change.[28]

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[21] D. McCauley, "Addressing climate change impacts," MIT Technology Review insights, in partnership with the Michigan Economic Development Corporation, 2024.

[22] "U.S. Manufacturers Need Permitting Reform," Wall Street Journal, October 13, 2026.

[23] "Overview of the Clean Air Act and Air Pollution," U.S. Environmental Protection Agency, accessed October 2026.

[24] "Environment, Climate Change, One Health and Migration," World Health Organization, accessed September 2026.

[25] "Climate change, air pollution, pollen and health: Technical brief," World Health Organization, accessed September 2026.

[26] "Air pollution attributable DALYs," The Global Health Observatory, World Health Organization, accessed September 2026.

[27] K. Rubin, A. Jobe, and H. Thonet, "Modernizing Industry in Michigan," RMI, November 2025.

[28] C. Brown and C. Kelso, "Extreme Heat is Exacerbating Air Pollution, a 'Double Whammy' for Health," The New York Times, June 24, 2025.

2022 HEALTH-HARMING INDUSTRIAL EMISSIONS (TONS), BY COUNTY

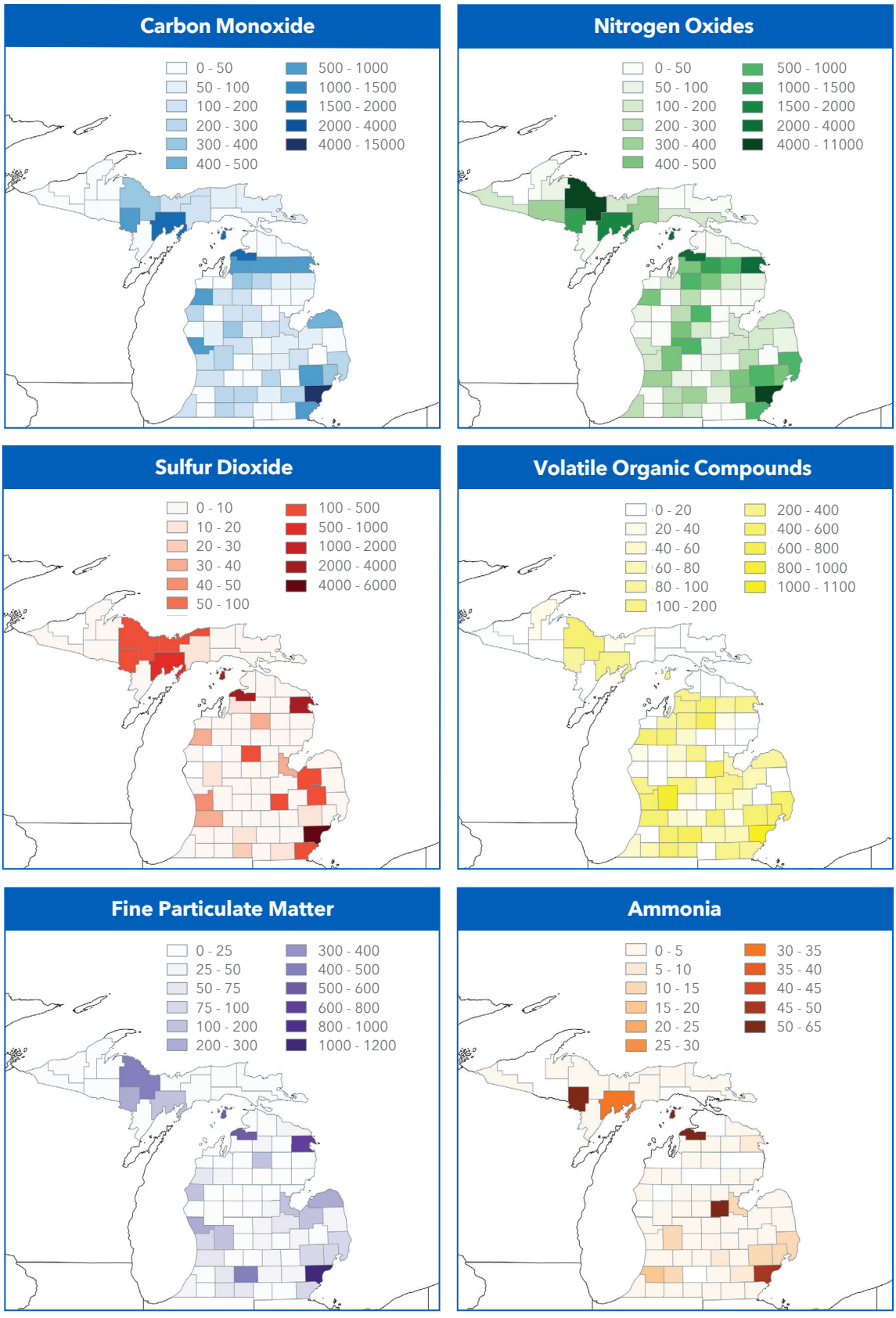


Figure 6 Health-harming air pollutants emitted by industrial sources in Michigan in 2022, totaled by county. Data provided by the Lake Michigan Air Directors Consortium (LADCO)

Improved air quality can support a wide range of benefits. Michigan's Comprehensive Climate Action Plan (CCAP) reports anticipated benefits in the form of fewer lost work days and school days, as well as fewer asthma incidents and emergency department visits for respiratory symptoms and reduced mortality events.[29] Studies in New York and London have shown reduced air pollution has resulted in improved cognitive and lung function development in children.[30,31] Improved air quality is also associated with reduced rates of school absenteeism, lost workdays, hospitalizations, and all-cause mortality.[32] Decreased industrial pollution can be particularly helpful for those living near industrial facilities, reducing disproportionate health impacts imposed on these often low-income and marginalized communities, often labeled as 'environmental justice' or EJ communities.[33,34] Industrial electrification can also improve health and safety for workers within facilities through reduced pollution and other risks related to on-site combustion.[35]

To learn more about industrial emissions and implications for air quality regulations in Michigan, see *GET THE FACTS: Decarbonizing industry can reduce air pollution*.

COMPETITIVENESS BENEFITS

Investments in industrial decarbonization can provide a range of benefits that increase business competitiveness. Facility retrofit projects that focus on energy efficiency, electrification, and other broad decarbonization approaches can support facility modernization by replacing aging equipment and improving controls and process integration. Beyond reducing emissions, these investments can also improve productivity, reliability, and product quality – all of which further support the state's interests in a more competitive manufacturing sector.

Electrification and decarbonization efforts can also protect Michigan's industrial sector against rising energy costs and price volatility, by reducing reliance on fossil fuels including natural gas, coal, propane, fuel oil, and more. Energy efficiency measures help reduce overall energy use, lowering costs and vulnerability to fuel price volatility. For example, because industrial heat pumps move heat instead of producing it, unlike fuel-fired boilers, heat pumps can operate at efficiencies greater than 100% – allowing for deep reductions in energy demand to drive the same key processes.[36] Additionally, flexible electrified technologies such as thermal energy storage can also allow facilities to shift energy consumption time windows if price structures allow, providing opportunities for further savings by aligning demand with low-price signals when excess clean electricity is available on the grid.

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[29] "Michigan's Comprehensive Climate Action Plan," Michigan Department of Environment, Great Lakes, and Energy (EGLE), December 2025.

[30] F. Perera, Y. Miao, et al., "Less air pollution previously related to clean air and climate policies is linked to improved cognitive scores over time in NYC children," Environmental Health, Vol. 25, 72, August 15, 2026.

[31] H. W. Wood, D. Phil, et al., "Impact of the Ultra Low Emission Zone on lung function growth in children in London, UK: a prospective parallel cohort study," The Lancet Public Health, Vol. 11, Iss. 10, October 2026.

[32] D. E. Schraufnagel, J. R. Balmes, et al., "Health Benefits of Air Pollution Reduction," Annals of the American Thoracic Society, 16(12), p. 1478-1487, December 2019.

[33] A. Hoffmeister, H. Chen, and J. Eisen, "The Industrial Heat Pump Opportunity Goes Beyond Energy Savings," ACEEE, June 2024.

[34] Michigan's Department of Environment, Great Lakes, and Energy hosts an environmental justice screening tool, MiEJScreen, that identifies stressors and demographics within Michigan communities that can impact local environmental conditions or public health considerations.

[35] A. Hoffmeister, H. Chen, and J. Eisen, "The Industrial Heat Pump Opportunity Goes Beyond Energy Savings," ACEEE, June 2024.

[36] E. Rightor, P. Scheihing, A. Hoffmeister, and R. Papar, "Industrial Heat Pumps: Electrifying Industry's Process Heat Supply," ACEEE, March 2022.

By investing in decarbonization measures, Michigan manufacturers can take advantage of customer demand for reduced-carbon products. Documenting reductions can help manufacturers meet new procurement requirements and help position them to participate in new markets for cleaner products. Michigan manufacturers can also capitalize on gaps in green markets. For example, the current disparity between the stated demand and supply of low-embodied-carbon steel is 31%, a figure expected to grow to 35% by 2030.[37]

This is particularly relevant to the positioning of Michigan manufacturers in the global market. In 2025, Michigan exported $60.3 billion of goods globally,[38] supporting hundreds of thousands of quality jobs across the state. Taking steps to reduce the carbon intensity of manufactured goods destined for export could provide competitiveness advantages as jurisdictions adopt stricter climate policies. The Council of the European Union,[39] a market into which Michigan sells nearly $7 billion in goods annually,[40] has announced its intention to expand its carbon border adjustment mechanism starting in 2028 to apply to raw materials, such as cement, iron, and steel, as well as to manufactured goods containing these material inputs. Other jurisdictions are considering similar policies, potentially expanding the markets in which manufacturers face carbon related trade requirements. Some jurisdictions are also developing domestic emissions trading systems and other carbon pricing mechanisms to reduce their exposure to these trade measures and strengthen the competitiveness of their industries.

Additionally, early deployment of emerging technologies will help manufacturers, technology providers, engineering companies, and workers build operating and maintenance experience and confidence in use cases, creating a future-ready state workforce and economy.

SYSTEM BENEFITS

Industrial electrification can improve manufacturers' operational flexibility — benefiting from the load-shifting capability of technologies like thermal battery systems and electric-powered heat pumps installed in parallel with fuel-fired boilers, enabling facility-side and system-wide benefits without affecting production. Flexible loads are key to supporting system benefits because they can respond to market-based electricity prices and system conditions and provide savings for the industrial customer while reducing grid strain. Additionally, load-shifting can be used to improve environmental performance by aligning high-energy-use periods with times when renewable resources are available in abundance on the power grid.

Thermal energy storage offers the opportunity to separate the timing of electricity consumption from the need for industrial heat. Facilities can produce and store heat during lower-demand periods for later use, reducing the magnitude of their peak electricity demand and supporting demand response.

Industrial clusters can create opportunities for proximal facilities to share waste heat, steam, thermal storage, and other energy infrastructure, further reducing strain on the energy system. Industrial decarbonization can also create other non-energy benefits including reduced

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[37] M. Bohmert and T. Vroman, "The sustainability reset: Decarbonization as a competitive advantage," McKinsey Sustainability, September 2026.

[38] "Michigan," Office of the United States Trade Representative, Executive Office of the President, accessed October 2026.

[39] "Council moves to strengthen the EU's carbon border adjustment mechanism," Council of the European Union, June 12, 2026.

[40] "The European Union's Trade and Investment Footprint in the United States," European Commission, accessed October 2026.

maintenance, improved process control and productivity, reduced waste and water consumption, improved working conditions, and reduced health impacts. These benefits often increase cost savings substantially even though they are typically not captured in initial scoping.[41]

WORKFORCE AND ECONOMY CONSIDERATIONS

Industrial electrification and decarbonization will have complex impacts on Michigan's state economy. Michigan has a robust manufacturing sector that is home to 20% of the state's workforce.[42] Concerns exist that decarbonization initiatives could result in lost jobs and could impart harm to this critical part of the state's economy, especially for workers and communities that depend on existing industrial facilities and supply chains.[43] Previous analyses suggest that net impacts of industrial decarbonization on total jobs will be positive, with modeled impacts of low-temperature industrial heat electrification indicating that 7.7 job-years are created on average for each 1 job-year that may be lost.[44] Other estimates suggest that scaling industrial electrification in Michigan could drive over $10 billion in economic activity and more than 40,000 new jobs over the next decade.[45]



Apprenticeships are key to building the workforce pipeline.

However, ensuring that newly created jobs are of high quality and can be accessed by impacted communities will be key. As the types of positions available change, Michigan will need to support workers with reskilling and upskilling opportunities, as described in our priority policy recommendation on industrial workforce training (see *Expanded/ targeted workforce training*). The impacts of decarbonization will not be uniformly distributed across the state, because industry in Michigan is deeply place-based and locally linked. Beyond broad sector concentrations, individual anchor employers and legacy facilities often form the bedrock of a community's local economy, tax base, and cultural identity. For example, of the more than 30,000 workers in primary metals manufacturing in the state of Michigan, over one-third are located in a single county, Oakland. Additionally, over 10% of all employment in Calhoun County is in the automotive

[41] A. Hoffmeister, H. Chen, and J. Eisen, "The Industrial Heat Pump Opportunity Goes Beyond Energy Savings," ACEEE, June 2024.

[42] "Michigan Labor Market Information," Michigan Department of Technology, Management, and Budget, accessed September 2026.

[43] "Michigan's Climate Goals at a Crossroads," Progressive Policy Institute, July 2026.

[44] J. Rissman, "Decarbonizing Low-Temperature Industrial Heat in the U.S.," Energy Innovation, October 2022.

[45] "Michigan: Economic Impacts of Scaling Industrial Electrification," excerpted from "Powering American Industry: The Economic Opportunity of Industrial Electrification," Renewable Thermal Collaborative, IHP Alliance, and Greenline Insights, June 2026.

manufacturing sector.[46] Michigan will need to take intentional steps, through initiatives organized by state entities such as the MI Community and Worker Economic Transition Office,[47] to ensure that industrial decarbonization does not severely disrupt these local communities and economies.

Some sub-policies recommended within this roadmap have demonstrated positive economic impacts on their own. In a decade, U.S. EPA's P2 grant program generated $2.3 billion in savings for businesses nationwide.[48] The Economy, Energy, and Environment (E3) framework, which is affiliated with the P2 grant program, has helped manufacturing communities retain and create thousands of jobs since its inception.[49] Additionally, Michigan's Commercial Property Assessed Clean Energy (C-PACE) coordinator reports over $300 million in total cost savings and nearly 4,000 jobs created through manufacturers' access to its lending resources.[50]

Improving local air quality represents one of the most immediate co-benefits of industrial decarbonization: it protects vulnerable communities while strengthening Michigan's broader economy. Research has demonstrated that poor air quality, beyond contributing to adverse health outcomes, can also constrain economic growth by reducing worker productivity and increasing lost work days.[51] Annual health costs due to emissions from industrial facilities, which could be avoided through electrification and decarbonization measures, are estimated at over $2 billion.[52] Lost economic activity, due to missed school and work days and restricted activity, may amount to over $60 million annually.[53] Success in decarbonization initiatives will support progress towards Michigan's climate targets, improved environmental and public health indicators, and economic growth goals. See *GET THE FACTS: Decarbonizing industry can reduce air pollution*.

[46] "The net-zero transition: What it would cost, what it could bring," McKinsey Global Institute, January 2022.

[47] "Michigan's Economic Transition Strategy," Michigan Community & Worker Economic Transition Office, accessed September 2026.

[48] "P2: Pollution Prevention," U.S. Environmental Protection Agency, January 2025.

[49] "About E3: Economy - Energy - Environment," U.S. Environmental Protection Agency, accessed September 2026.

[50] "Market Data," Lean & Green Michigan, accessed September 2026.

[51] "Economy and Air Pollution," Clean Air Fund, accessed September 2026.

[52] K. Rubin, A. Jobe, and H. Thonet, "Modernizing Industry in Michigan," RMI, November 2025.

[53] K. Rubin, A. Jobe, and H. Thonet, "Modernizing Industry in Michigan," RMI, November 2025.

Industrial Decarbonization Technical Pathways

Broadly, the technical pathways that can be accessed for decarbonizing Michigan's industrial sector are centered around four approaches: energy efficiency improvements, electrification of process heat and certain industrial processes, fuel-switching by adopting low-embodied-carbon (alternative) fuels, and carbon capture with utilization or storage. Many of the technologies needed to support the adoption of these pathways are market ready today even if not widely deployed, while others require further development before scaling.

TECHNICAL APPROACHES TO DECARBONIZING INDUSTRY

Energy efficiency improvements

Measures intended to increase facility or process efficiency and reduce waste are usually the most cost-effective for facilities interested in lowering their carbon intensity – they are also considered 'no regrets' strategies for states to invest in.[54] The most impactful opportunities for efficiency improvements in energy-intensive industries include the adoption of energy-efficient technologies, systems optimization, and waste heat recovery. While the specific solutions vary by subsector, facility, and process, in general steam systems and mechanical systems are good targets for efficiency improvements. Of the various heat recovery systems available, industrial heat pumps (IHPs) offer a unique opportunity to either supply core heat or support waste heat recovery with efficiencies exceeding 100%, because they transfer heat between locations instead of creating it. In contrast, the best fuel-powered boilers can only achieve efficiencies of 98%, with older models rated much lower. Related efficiency measures include waste heat-to-power systems, which use waste heat to generate electricity that can be consumed on site or sold back into the market.

Key barriers to increased adoption of energy efficiency measures in Michigan's industrial sector include internal competition for up-front capital (CAPEX), requirements for short-term return on investment, insufficient incentives for early retirement of existing fuel-powered systems, and a lack of familiarity and technical expertise in the available technologies at many manufacturing plants.

Electrification

In 2023, combustion-based process heating across all temperature ranges accounted for about 10.5 MMT CO_2e[55] in Michigan's industrial sector.[56] When paired, process heat electrification and grid decarbonization offer the state a powerful tool for reducing the carbon footprint of its manufacturers and the products they make (see *GET THE FACTS: Decarbonizing Michigan's power grid*). Process heat electrification offers more than air quality benefits – it can also offer dramatic energy efficiency improvements, reducing energy waste and heat waste.

Manufacturers today have a variety of electrified technologies to choose from to drive their heat-intensive processes (Figure 7). Some offer drop-in solutions, while others require custom configuration. Some replace the heat source directly, while others deliver the same product

[54] "Michigan's Comprehensive Climate Action Plan," Michigan Department of Environment, Great Lakes, and Energy, December 2025.

[55] In addition to CO_2, other GHGs include methane, nitrous oxide, hydrofluorocarbon, perfluorocarbon, and sulfur hexafluoride. Each gas has a known different global warming potential value, which is used to convert absolute emissions to a CO_2-equivalent (CO_2e) value for easier tracking and data comparisons.

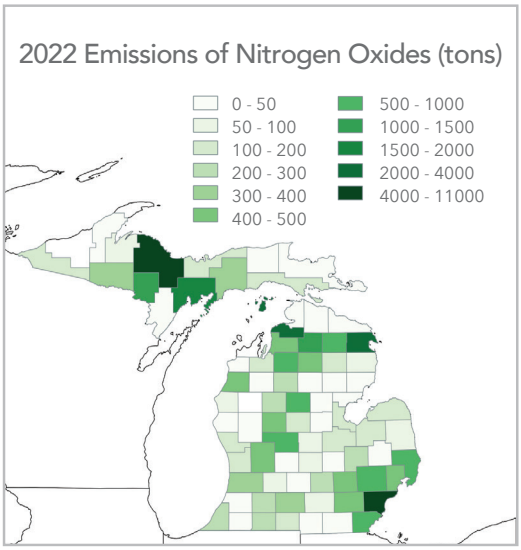
[56] 5LE analysis based on U.S. EPA GHGRP data reported in the Facility Level Information on GreenHouse gases Tool (FLIGHT) and U.S. EIA data. Included in 5LE analysis are all subsectors under NAICS codes 31-33, as well as iron ore mining.

GET THE FACTS

Decarbonizing industry can reduce air pollution

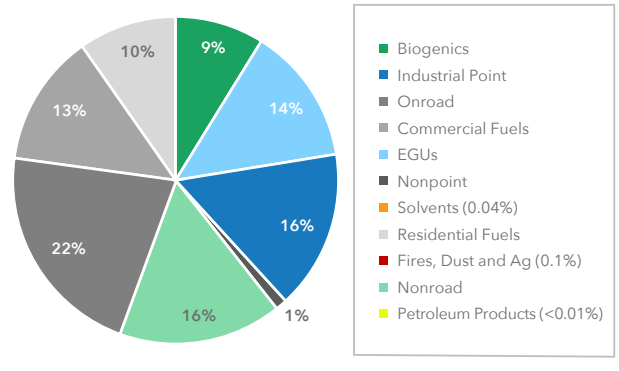
In addition to GHGs, many industrial stationary combustion sources emit significant amounts of criteria and hazardous air pollutants. Criteria air pollutants (CAPs) are six commonly emitted substances regulated by the U.S. EPA under the Clean Air Act using health-based standards. Hazardous air pollutants (HAPs) are a defined list of 188 airborne substances that are known to cause birth defects, cancer, reproductive harm, or severe ecological damage.[a] Many of the same processes at industrial facilities that emit GHGs also produce HAPs and CAPs, largely due to fuel combustion.

Industrial decarbonization strategies that improve energy efficiency, electrify high-emitting processes, switch to low-carbon fuels, or optimize energy usage can offer the "co-benefit" of reducing CAP and HAP emissions along with GHG reductions. Because different HAPs and CAPs can impact air quality both near and far from the source, the air pollution co-benefits of industrial decarbonization may have immediate and direct positive impacts on the health and welfare of the communities near the industrial facilities, on the workforce at those facilities, and statewide in Michigan.



Heat map of county total industrial point emissions of nitrogen oxides (NO_x) in 2022.

The 2023 National Emissions Inventory (NEI) reports over 1,400 industrial facilities across the state of Michigan that collectively emit over 48,000 tons of nitrogen oxides (NO_x) annually. The NEI records also indicate that 240 industrial facilities across Michigan emit over 20,000 tons of volatile organic compounds (VOCs) annually. Measures to reduce NO_x and VOC emissions are important for air quality management because both classes of pollutants have direct health impacts and transform in the atmosphere to form other types of pollution, including smog and fine particulate matter. Fine particulate matter ($PM_{2.5}$), in particular, can embed deep in lung tissues and contribute to a range of health harms. Industrial decarbonization strategies that use combustion-free technology will reduce both NO_x and VOC emissions.



Statewide 2022 emissions of nitrogen oxides (NO_x) in Michigan by sector. Industrial point sources contributed 16% of the statewide NO_x.

Because several areas in Michigan are above or near the National Ambient Air Quality Standards (NAAQS) for some CAPs, including ozone and fine particulate matter, CAP emissions reductions resulting from industrial decarbonization strategies may support compliance efforts to meet and maintain the NAAQS in the state. NAAQS compliance benefits communities by supporting better air quality and the economy by lowering barriers to stationary source permitting at industrial and other sites.

[a] "Summary of the Clean Air Act," U.S. Environmental Protection Agency, accessed October 2026.

ELECTRIFIED TECHNOLOGIES AND TEMPERATURE RANGES

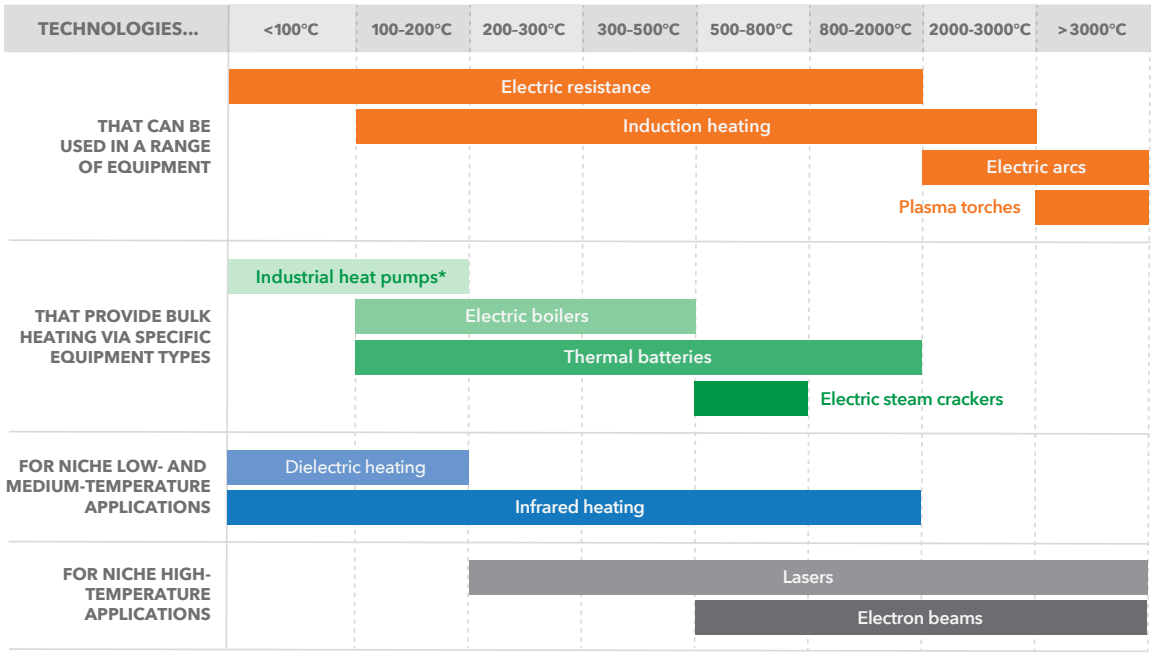


Figure 7 *Industrial electrified heating technologies and their temperature ranges. Image reprinted from S. Baldwin, S. Deshpande, et al., "Overcoming All Barriers to Industrial Electrification," Energy Innovation, June 2025.*

outcomes but through fundamentally different mechanisms. Some are market-ready and widely adopted in Europe and other regions, while others are in earlier stages of development and may require full-scale testbeds before widespread adoption. In general, electrified alternatives for delivering process heat are more advanced for lower-temperature applications. Examples include IHPs and electric boilers, which have existing commercial applications up to 400°F (200°C) and 660°F (350°C), respectively, as well as electrified drying technologies — all of which are relevant across a number of industrial subsectors in Michigan.

Thermal batteries are well-positioned to help utilities and their industrial customers unlock combustion-free process heat while reducing operating costs. Today's thermal batteries can provide heat up to 3,370°F (1,800°C), although such systems face additional engineering challenges before they can be scaled outside of the low- and medium-temperature industries. Despite this, the core features of thermal battery technology — an ability to convert electricity to heat and then store that heat for long periods with minimal losses — give them tremendous potential to boost competitiveness in the manufacturing sector, especially if industrial firms can access electricity rates that reflect variations in wholesale market prices. As an energy storage technology, similar to electrochemical batteries (e.g., lithium ion), thermal batteries offer Michigan an alternative means of managing load variability in its power grid.

The biggest barrier to industrial electrification in Michigan, regardless of industrial subsector, is the higher cost of electricity compared to fossil fuels — especially natural gas. Demand charges, which are based on a facility's peak electricity demand, not its total energy consumption, can be a significant contributor to this cost barrier, especially for electrification projects that increase peak demand. For more information on industrial electricity charges and rate structures, see *GET THE FACTS: Electric rate structures are key to unlocking industrial electrification potential*. Efforts to modernize electric utility rate structures in Michigan have

tremendous potential to reform demand charge structures, in a common-sense approach that could ultimately bring Michigan's manufacturers – and other ratepayers – cheaper cost of service and lower utility bills in the long term.

Fuel-switching

The barriers to widespread industrial electrification make fuel-switching to low-embodied-carbon fuels an attractive alternative for firms wishing to cut their GHG footprint. In some cases, alternative fuels can serve as a drop-in replacement with limited process-level retooling. The primary options are: solid biomass, biomass-derived liquids or gases (e.g., renewable natural gas or RNG), scrap tires, and hydrogen. The major constraints on the overall potential of these alternative fuel types to support widespread industrial decarbonization center around availability and cost.



Small-scale RNG production on a family-owned farm.

Solid biomass – including bark, sawdust, dried pulp, fruit pits, construction debris, agricultural residues – is combustible and can often deliver the heat temperatures needed across industry, while offering a reduced carbon footprint over fossil fuels. Biomass-derived liquid or gaseous fuels typically center around byproduct and waste processing strategies, such as biofuel production from black liquor at a paper mill or RNG production from landfill gas at an industrial landfill site. Practical considerations for adopting these alternative fuels include handling requirements, compatibility with existing equipment and processes, composition and pollution profile upon combustion, supply consistency, and transport logistics. Life cycle-based analyses routinely indicate that biomass-based alternative fuels offer the most advantage to industrial decarbonization efforts when combustion replaces landfilling.

In particular, RNG is a pipeline-grade methane gas that can be used interchangeably with conventional natural gas. Michigan's RNG potential was previously analyzed,[57] with that study finding technology readiness (i.e., thermal gasification) to be the key barrier to expanded RNG production from alternative feedstocks. While the state's technical RNG potential is sizable – estimated as on the order of 8.5% to 22% of existing natural gas demand – strategies that seek to develop RNG should again focus on life cycle-based analyses and targeted use cases, like on-site production and consumption. It should be noted that to realize the state's full RNG potential would be a significant undertaking, with project cost-effectiveness ranging greatly. In general, RNG blending in the existing natural gas distribution system is not an effective approach for supporting widespread industrial decarbonization because most of Michigan's

[57] "Michigan Renewable Natural Gas Study," ICF Resources, LLC, prepared for the Michigan Public Service Commission, September 2022.

GET THE FACTS

Electric rate structures are key to unlocking industrial electrification potential

Electric rate structures are a major factor in the economics of industrial electrification. For manufacturers considering industrial heat pumps, electric boilers, thermal energy storage, or other technologies to replace fossil-fuel-powered incumbents, electricity costs can determine whether that switch is economically sound. While electric technologies can offer efficiency improvements, the ratio of electricity to natural gas prices – and the structure of rates themselves – can create significant barriers to adoption.[a] Effective and appropriate utility rate design can help address barriers while maintaining reliability, recovering utility costs, and protecting other ratepayers, like residential customers.

Rates should be designed to better recognize and compensate for the system-wide benefits that flexibly-operated industrial electrification technologies can provide, including reduced peak demand, improved grid asset utilization, and increased flexibility to integrate renewable generation.



Technologies like Antora's 5-GWh thermal energy storage project in Big Stone City, South Dakota, can take excess power from renewable sources during peak production times and store it as heat, injecting that heat into their thermal processes at times of greatest demand. This approach can not only reduce facility-side energy costs, but can also provide a demand response resource capable of reducing utility-side infrastructure costs by ensuring grid generating assets are used to their maximum potential. Credit: Antora

Typical industrial rates

Like residential and commercial customers, industrial electricity bills include charges for the amount of energy consumed. Unlike these other customer classes, large industrial customers in particular are also often billed for "demand charges," which reflect the peak amount of electricity used, and indirectly, the cost that a utility sustains in supplying that peak demand. Energy charges can be flat or vary by time of use (TOU), while demand charges are typically based on a customer's highest demand during the billing period or a specific set of peak hours.

[a] A. Johnson, A. Hoffmeister, et al., "Industrial Rate Impacts on Electrification Projects in Illinois and Michigan," ACEEE, February 5, 2026.

Demand charges commonly hold back industrial electrification projects. Electric boilers and other high-capacity technologies can increase a facility's noncoincident peak demand — when peak power supply is available versus when a facility needs the most power — raising electricity costs even when the equipment operates during times of low demand across the broader power system.[b]

Industrial technologies have unique operational parameters and are designed to meet a range of industrial requirements. Some processes need continuous, uninterrupted heat, whereas others can adjust consumption by leveraging storage, hybrid heating, or scheduling. Rate structures that account for these differences can improve project economics and encourage electricity use during periods when grid generation capacity is available.

Power supply cost recovery (PSCR) factors also create variability, because utilities adjust charges when supply expenses change, making it difficult for manufacturers to forecast their operating and electrification costs.

Rate design in Michigan

Several approaches could help better align industrial electrification with efficient grid operation. Because industrial processes are so diverse — as are the time-based profiles of their power needs — offering multiple rate options in one portfolio is important.

- **Time-of-use (TOU) rates.** TOU-based rates can encourage electricity consumption during lower-cost periods by creating predictable price signals to which industrial facilities can respond by shifting their flexible loads.
- **Demand charge structures** Changing how billing demand is measured can enable electrification to help utilities leverage their off-peak resource availability.
- **Flexible load or interruptible service** Offering lower rates or incentives can help reduce demand during specific grid conditions.
- **Technology-specific or electrifi tion-focused rates.** Exploring eligibility and rate structures for the use of technologies that increase industrial flexibility or create other grid benefits can offer the deepest benefits to both utilities and their industrial customers.[c]

The effectiveness of these approaches will depend on the industrial process, metering capabilities, utility system conditions, and regulatory considerations.

Implications for Michigan

Michigan utilities and the state's Public Service Commission (MPSC) have an opportunity to evaluate how existing industrial rates affect the economics of electrification and whether additional rate options could better accommodate new loads. This process will likely require assessing the impacts of changing demand charges, determining the value of flexibility, and identifying the structures that best reflect the costs and benefits that industrial electrification can create for the grid.

Industrial electrification tariffs builds on these ideas by recommending the development and evaluation of rate options designed to support industrial electrification while maintaining utility cost recovery, grid reliability, and protections for nonparticipating customers, like residential ratepayers.[d]

[b] "Electric Rate Books," Michigan Public Service Commission, accessed October 2026.

[c] S. Deshpande and J. Rissman, "Electric Rate Design And Regulation To Promote Industrial Electrification," Energy Innovation, September 14, 2026.

[d] A forthcoming whitepaper authored by 5 Lakes Energy will focus on energy policy and rate design in Michigan, expounding on the considerations presented in this roadmap.

industrial natural gas consumption (by volume) occurs at upstream system nodes attached to interstate and large transport pipelines.

Presently, Michigan leans into the burning of scrap tires (i.e., tire-derived fuel or TDF) as a dual strategy for managing scrap tires and displacing coal from industrial processes. Industries like cement, paper, and others with large stoker boilers have adopted TDF.[58] Despite these potential benefits, in 2023,[59] changes to Michigan law explicitly excluded tires and TDF from classification as renewable energy resources, which now makes tire burning ineligible for renewable energy credits (RECs). While alternative, higher-value approaches to managing scrap tires[60] — like rubber-modified asphalt — now exist, it cannot be ignored that the state's largest cement producer only recently converted the majority of its production scheme to TDF, and thus may face long-term challenges decarbonizing its fuel source.

Hydrogen is a highly flammable gas that burns hotter than natural gas and is carbon-free at the point of combustion. However, depending on the production scheme, hydrogen's life cycle-based carbon footprint can be quite high. Similarly, despite the U.S. Department of Energy's prior interest in developing hydrogen at an effective cost point to enable combustion strategies,[61] recent shifts to federal tax credits[62] have reduced the short-term viability of hydrogen as an alternative fuel in the industrial sector, outside of niche applications. Even if an effective cost point can be achieved, the adoption of hydrogen to displace fossil fuels within the state's industrial sector will face several uphill challenges associated with storage, transport, and combustion. In the near term, the clean electricity needed to produce green hydrogen (i.e., carbon-free electrolytic hydrogen) will better serve Michigan's industrial decarbonization interests through industrial electrification efforts.

Carbon capture, utilization, and storage

Because industrial electrification and fuel-switching strategies are constrained by the various factors described above, CO_2 capture at the point of origin is increasingly viewed as an alternative intervention for reducing industrial GHG emissions. Many of Michigan's manufacturers also identify carbon capture, utilization, and storage (CCUS) strategies as core to their long-term planning. The MIHCP identifies CCUS as an option to explore in industrial applications where eliminating fossil fuel use is infeasible or cost prohibitive.[63] At the same time, CCUS remains controversial due to questions around scalability, economic viability, and the moral and safety hazard of continuing to rely on fossil fuels, which CCUS effectively enables.[64]

CCUS involves three main steps: 1) CO_2 capture at the point of generation, 2) compression and transport to a utilization or storage site, and 3) sequestration in a long-lived product or suitable geologic feature. While Michigan has relatively favorable geology for long-term CO_2

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[58] "2023 End-of-Life Tire Management Report," U.S. Tire Manufacturers Association, 2024.

[59] Legislative Analysis, Clean and Renewable Energy Standards, Senate Bill 271 (S-3) as passed by the Senate.

[60] E. Seltzer, B. Hall, and C. Theriot, "Scrap Tire Market Development Study," RRS recycle.com, prepared for Michigan Department of Environment, Great Lakes, and Energy, January 2020.

[61] "Pathways to Commercial Liftoff: Clean Hydrogen," U.S. DOE's Update 2024, December 2024.

[62] 45V is a clean hydrogen production tax credit up to $3.00/kg H2 available for 10 years after the production facility is placed in service. The federal budget passed in summer 2025 severely constrained the potential impact of the tax credit by shifting the deadline to initiate construction of production facilities from December 31, 2032, to December 31, 2027, for eligibility.

[63] "MI Healthy Climate Plan," Michigan Department of Environment, Great Lakes, and Energy (EGLE), April 2022.

[64] K. Lebling, A. Gangotra, K. Hausker, and Z. Byrum, "7 Things to Know About Carbon Capture Utilization and Sequestration," World Resources Institute, accessed February 2026.

sequestration, there are also prominent examples of effective utilization strategies in similar industrial facilities in other locations.[65] Regardless of sequestration approach, CO_2 capture, compression, and transport can be a highly energy-intensive process.

The energy needed to power CCUS activities makes up the largest fractional cost of any such project. Baseline costs can range from $20 to $70 per ton of CO_2, depending on the industrial subsector,[66] with transport and storage costs adding another $12 to $22 per ton. For these reasons, the 45Q federal carbon capture tax credit, which provides up to $85 per ton of CO_2 captured for 12 years of operation, is considered an essential incentive for enabling industrial CCUS projects, even though most Michigan industrial stakeholders indicate that 45Q is insufficient to truly offset the costs of many CCUS projects.

The major barriers to CCUS adoption include cost and scalability, limited existing infrastructure, and low technology readiness for certain CCUS strategies. Additionally, it should be noted that while CCU strategies do promote sequestration by using captured CO_2 as a feedstock, for net-zero targets to be achieved, strategies that Michigan pursues should promote long-term sequestration in durable goods[67] rather than short-term sequestration approaches like e-fuels production.

An alternative class of carbon capture technologies and approaches is known as atmospheric carbon dioxide removal (CDR). Many of the approaches under this umbrella require limited infrastructure investments, instead relying on changes to land use practices or environmental engineering. CDR approaches are commonly included in comprehensive industrial decarbonization strategies as an indirect approach to mitigating emissions that cannot be realistically eliminated from manufacturing. In this context, CDR includes both established, relatively inexpensive approaches, such as improved forest management, afforestation, and reforestation, and novel approaches under active development and facing many of the same barriers as the decarbonization approaches described above. Industry can support CDR efforts via financing of projects, knowledge and infrastructure sharing, project development, and integration of CDR into existing operations.

BARRIERS TO TECHNOLOGY DEPLOYMENT AND ADOPTION

The availability of potential emissions-reducing technologies does not necessarily mean they can be deployed immediately or at scale across Michigan's industrial sector. Industrial facilities are extremely heterogeneous, complex operating environments in which decision making is shaped by capital planning, infrastructure, production, risk, and workforce capacity. The impact of industrial decarbonization will depend on both technology readiness and whether technologies can be integrated into facilities at acceptable cost and risk levels at key points in investment cycles.

Manufacturers often operate major equipment for three or more decades, schedule upgrades and process changes around planned shutdowns, and commonly must face multiple rounds of engineering and corporate approval before finalizing plans and committing capital. However,

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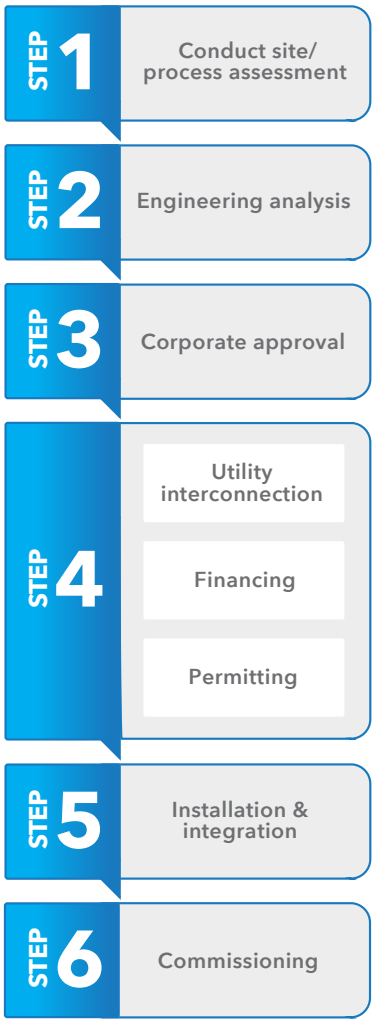
[65] Two direct-reduced ironmaking plants in Mexico, owned by steelmaking Ternium, have CO_2 capture systems installed on their exhaust gas lines. A third-party entity then cleans the captured CO_2, processing it for sale into the food and beverage industry, where it is used in carbonated beverage production.

[66] E. Middleton, M. Ford, M. Miranda, et al., "National Industrial Sector Decarbonization: Extent of Carbon Capture Opportunities and Network Optimization Across the United States," Carbon Solutions, May 2024.

[67] Examples of potential durable materials that could utilize captured CO_2 include concrete and other construction materials, carbon fiber, and plastics. For a detailed discussion, see: J. Bobeck, J. Peace, F. M. Ahmad, and R. Monson, "Carbon Utilization – a Vital and Effective Pathway for Decarbonization," Center for Climate and Energy Solutions, August 2019.

if manufacturers and the state delay investment until incumbent technologies reach the end of their useful lives, the associated emissions will remain locked into those long timelines — Michigan's GHG reduction goals will remain out of reach. Industrial decarbonization will need to create new opportunities for early investment, as well as support manufacturers in preparing to adopt new technologies when replacement and modernization cycles line up. Several interrelated economic, operational, organizational, and infrastructure barriers determine whether and how quickly this can occur.

THE INDUSTRIAL FACILITY PROJECT CYCLE



Economic and operational barriers

- **Capital requirements and competing priorities.** Some decarbonization technologies need significant upfront investment, especially where projects involve replacing process equipment, electrical upgrades, or installing other infrastructure. These investments compete internally with other projects that are often revenue-generating.
- **Production downtime.** Industrial facilities are vulnerable to prolonged or unpredictable interruptions to production. Installing new equipment may need planned shutdowns, modifications to existing processes, commissioning, or changes to production schedules. The economic consequences of lost production can sometimes be as important to the investment decision as the equipment costs. There are also many industrial processes that are not interruptible.
- **Long equipment lifetimes.** Boilers, furnaces, and other process equipment can remain in use for decades. Facilities are reluctant to retire functioning equipment before the end of useful life. Additionally, replacing equipment today with another long-lived fossil-fueled asset can create carbon lock-in. This means that decisions made in the 2020s and 2030s are consequential for the state's long-term emissions trajectory.
- **Energy costs and rate structures.** The economics of electrification depend on the cost of electricity and fossil fuels (the spark gap), as well as demand charges and other elements of electric rate structures. Uncertainty about energy prices can complicate investment decisions for equipment expected to operate for decades.
- **Facility infrastructure.** Electrification may necessitate upgrades to transformers, switchgear, substations, internal distribution systems, or other behind-the-meter infrastructure, adding significant costs.
- **Integration complexity.** Industrial processes are highly interconnected. New technologies must meet requirements for temperature, pressure, product quality, reliability, controls, space, and production and need to integrate with existing steam, electrical, and process systems.

Organizational barriers

- **Corporate decision making.** Major projects often require facility, business unit, and corporate approval and must compete for limited capital across facilities.
- **Limited staff.** Especially at small and mid-sized manufacturers, personnel have limited time to evaluate technologies and incentives, coordinate vendors, navigate utility requirements, and/or manage implementation.
- **Information gaps**. Manufacturers often lack data on internal process-level energy use, equipment performance, load profiles, or technology alternatives to evaluate projects. Net metering, studies, and/or feasibility analysis are often needed before investment.
- **Technology and performance risk.** Reliability is essential in industrial facilities. Manufacturers sometimes defer the early adoption of technologies without an operating history in associated commercial applications, even when the underlying technology is well proven. Demonstrations, performance guarantees, peer experience, and vendor support are great mitigators of this barrier.
- **Equipment lead times.** Engineering, workforce needs, air permitting, construction, and commissioning can add significant time between investment and implementation. Equipment itself sometimes has long lead times – especially when custom designs are required.
- **Utility interconnection.** Large electrification projects typically require utility studies, new service equipment, distribution or transmission upgrades, and coordination with utility planning processes.

It will not be necessary to address every barrier above for industrial electrification to gain momentum in Michigan. Instead, these barriers justify why Michigan must carefully design its support offerings and any associated sequencing. Near-term actions can focus on efficiency, waste heat recovery, commercially available electrification, and projects that can line up with planned equipment replacements, while preparing facilities and infrastructure for deeper decarbonization. Assessments, engineering, utility planning, workforce development, and financing today can position manufacturers to act when equipment reaches replacement windows.

Policy can also address barriers and help manufacturers prepare. Technical assistance and demonstrations can reduce information and performance risk; grants and other financing can reduce upfront costs and support early retirement; utility rates designed for electrification can improve operating costs; coordinated permitting and project navigation can reduce development complexity; and utility planning can help ensure infrastructure is available when projects are ready to advance. The policy challenge is both to ensure that technologies are available and to create the conditions that allow projects to advance on practical timelines.

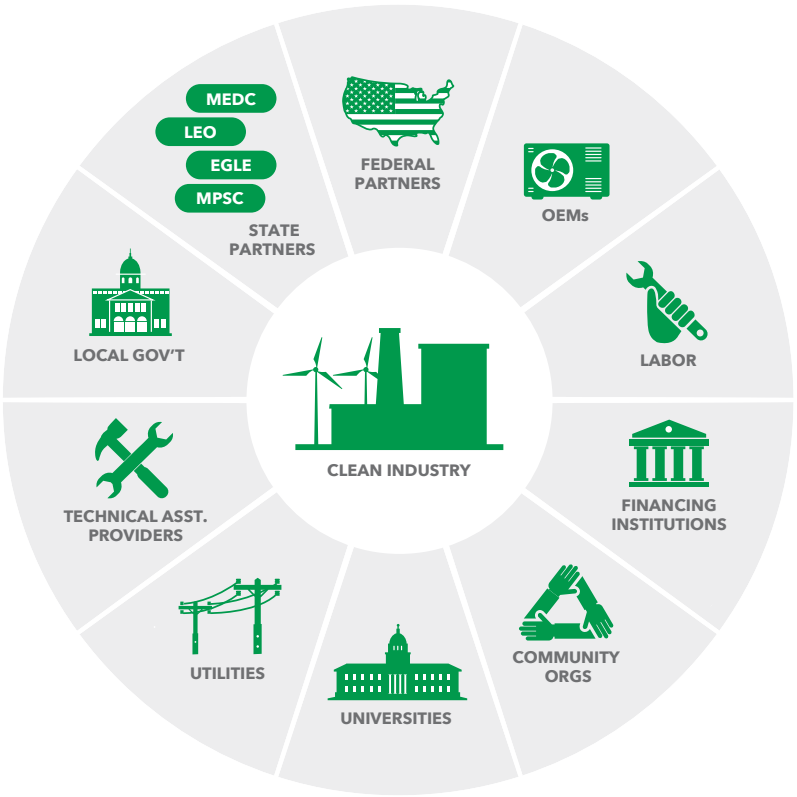
Michigan's Industrial Decarbonization Landscape

EXISTING PROGRAMS AND RESOURCES

Michigan's industrial firms and manufacturers can leverage a range of existing state, federal, utility, and private sector resources for energy assessments, technical assistance, efficiency improvements, financing, workforce development, and project implementation, including several programs specifically focused on industrial decarbonization. These resources may also offer opportunities for stacking funding and assistance across programs and jurisdictions. However, the available resources vary significantly in their purpose, scale, eligibility, and ability to support large projects. Understanding the current landscape helps identify where the state can build on existing programs and where major gaps still exist.

For additional perspectives on the key elements that Michigan needs to offer its industrial sector to ensure decarbonization efforts are financially tractable, see *GET THE FACTS: Manufacturers need effective, custom financing structures*.

THE INDUSTRIAL DECARBONIZATION LANDSCAPE IN MICHIGAN



State programs related to industrial decarbonization and energy use

- **MI Healthy Climate Challenge #4: Go Big, Go Clean.**[68] EGLE's over $1.8 million program, supports facility-level industrial decarbonization feasibility studies, which are an important building block for developing a project implementation pipeline in Michigan. Recipients include Bell's Brewery, the Detroit Zoological Society, Ford Motor Company, Michigan Green Building Collaborative on behalf of several manufacturing cohorts, and Michigan Technological University.
- **Small Manufacturers Retooling Program.**[69] Implementation funding for smaller manufacturers, focused on energy efficiency, energy waste reduction, and reducing energy use. Awards up to $50,000 with cost match, funded through September, 2027.
- **Retired Engineers Technical Assistance Program (RETAP).**[70] Provides free technical assistance and assessments for small and mid-sized manufacturers. Currently paused.
- **Michigan Climate Investment Hub** [71] Capital mobilization and financing infrastructure to accelerate climate and clean energy projects. Partners with local governments and Tribal nations, community based organizations, project developers, and financial institutions to deliver projects supporting state climate goals.
- **Michigan Industrial Clean Innovation Partnership** Newly launched collaboration between state agencies, nonprofits, technical experts, and industrial facilities to identify and overcome barriers and share solutions for industrial decarbonization.The partnership will also provide technical assistance and peer learning opportunities to help manufacturers advance projects.

State programs that support manufacturers and economic development

The Michigan Economic Development Corporation (MEDC) provides resources under the umbrella of Business Development Services:

- **Michigan Small Business Development Center (SBDC).**[72] Offers a range of free support to small businesses through consulting, tools, and resources, including market research, strategic planning, financing options, and more.
- **Michigan Manufacturing Technology Center (MMTC).**[73] Offers personalized consulting services and performance benchmarking to small and mid-sized manufacturers.
- **Strategic Site Readiness Program (SSRP).**[74] Financial incentives to support activities such as land acquisition, site preparation, infrastructure improvements, environmental remediation, or other site development at strategic or mega-strategic sites, i.e., sites used for either manufacturing/commercial activities or a large industrial project.
- **Second-Stage Growth Solutions (SSGS) program.**[75] Provides second-stage companies with technical assistance and business expertise to help them continue to grow profitably. For growing companies with 10-99 full-time employees, generating between $1 million and $50 million in annual revenue.

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[68] "Challenge #4: Go Big, Go Clean," Department of Environment, Great Lakes, and Energy, accessed October 2026.

[69] "Small Manufacturers Retooling," Department of Environment, Great Lakes, and Energy, accessed October 2026.

[70] "Retired Engineers Technical Assistance Program (RETAP)," Department of Environment, Great Lakes, and Energy, accessed October 2026.

[71] "Investment for Michigan's Future," Michigan Climate Investment Hub, accessed October 2026.

[72] "Owning a small business isn't a job. It's a calling," Michigan Small Business Development Center, accessed October 2026.

[73] "Michigan Manufacturing Technology Center," Michigan Economic Development Corporation, n.d.

[74] "Strategic Site Readiness Program," Michigan Economic Development Corporation, accessed October 2026.

[75] "Second-Stage Growth Solutions," Michigan Economic Development Corporation, n.d.

GET THE FACTS

Manufacturers need effective, custom financing structures

Financing is a key barrier for many businesses seeking to undertake electrification and decarbonization projects, as well as for public entities seeking to design effective industrial decarbonization policies. Electrification and decarbonization efforts involve both substantial upfront costs, related to the purchase and installation of new technology, facility retrofitting, and the production downtime required for that work to take place, and long-term increased costs due to the spark gap (i.e., the cost gap between electricity and natural gas per unit of heat) that exists in most markets. Even when favorable policy design mitigates some or all of the increased operational expenses associated with electrification, payback periods on the initial investment can range up to a decade, which can introduce risk. Policymakers must consider how to reduce the risk associated with these investments to make their decarbonization policies bankable.

Public actors, including governments and financial institutions, can utilize a variety of policy levers to de-risk investments in decarbonization projects and attract private investment partners. A report from the OECD summarizes the instruments that have been employed to facilitate institutional investment in green projects in G20 countries, including co-investments, co-financing, loans, and loan and revenue guarantees.[a]



[a] "De-risking Institutional Investment in Green Infrastructure: 2021 Progress Update," OECD, June 2021.

The stability of financing options is of particular concern to Michigan's manufacturers, given the uncertainty associated with federal grants and incentives at present. Ensuring that state programs are funded and supported for multiple cycles rather than just one-time grants or short-term projects allows for businesses to build more ambitious decarbonization plans. Longer-term programs send a clear market indicator for investors. Additionally, decision makers need to be certain that projects will survive the instability that can arise from frequency changes in political agenda. Unless funding mechanisms are properly designed upfront, firms run the risk of administration changes resulting in funding cuts – which can completely derail otherwise well-conceived projects. Michigan could consider grandfathering clauses or other guarantees to ensure recipients of funding or incentives are not left stranded in the event of new political leadership with differing interests.

Michigan must ensure that industrial decarbonization policy is designed to support a variety of business sizes and subsectors. Industrial facilities vary in their number of employees, amount of emissions, technological needs, tax liability, available capital, and annual revenue and expenditures. Other industrial decarbonization schemes have faced critiques that can serve as a guide for Michigan in designing its own state policies. For example, Germany's CCfD program, while still primarily focused on the country's largest emitters, has amended eligibility thresholds to encourage participation from interested small and medium enterprises in the next auction round.[b] Michigan policymakers will need to consider and account for the diversity of business needs by setting inclusive eligibility criteria, by diversifying how interested parties may access support, through both direct financing like grants and loans and other incentives such as tax credits, and by allowing for stacking of incentives.

Finally, to maintain prolonged financial support, whether through private or public sources, the results of electrification and decarbonization projects should be verifiable and easily accessible. Especially given the persistent constraints on public budgets, projects receiving support from the state through various loan, grant, and tax incentive programs will need to be accountable to constituents and policymakers to ensure the efficient usage of public funds. Transparency surrounding project outcomes will also be critical for assuaging concerns about industry greenwashing. The prioritization of financing for proven technologies, particularly in initial program phases, and timely publishing of outcomes can build the public's confidence in the efficacy of these policies and the willingness to continue financing them.

[b] "Carbon Contracts for Difference (CCfDs) as an instrument of choice: Bridging the funding gap for EU Energy Intensive Industries (EIIs)," Deloitte, November 2024.

- **BBC Entrepreneurial Training and Consulting (BBCetc).**[76] Assists technology-based entrepreneurs and early-stage companies in writing competitive proposals for R&D funding through the federal SBIR/STTR program.

Additional resources available through other state agencies include:

- **MI Supplier Conversion Grant Program.**[77] Provides support for small and mid-sized manufacturers to transition from producing parts and equipment for traditional internal combustion engine vehicles to battery electric vehicles. Funds may be used to offset costs associated with fixed assets, machinery and equipment, and workforce training. Priority is given to applicants demonstrating the strategic value of the proposed project and to the creation or retention of high-quality jobs.
- **SmartZones.**[78] Launched in 2000 to accelerate economic activity and increase the number of jobs and businesses in the high-technology sector. Houses technology business accelerators, tech transfer offices, and incubation facilities with offices and wet lab space. Promotes collaborations between universities, industry, research groups, state and local government, and other community institutions. Reported over $92 million in tax increment revenue from 2009 to 2023.[79]
- **Brownfield redevelopment.** Brownfield redevelopment puts contaminated properties back into productive use while protecting human health and the environment. Michigan's Transformational Brownfield Program:[80] Allows developers to capture a portion of specific incremental taxes generated from certain large-scale projects. Defined as transformational based on their expected impact on local economic development and community revitalization through metrics like population growth or employment rate. Michigan's Brownfield Renewable Energy Pilot:[81] Offers $10 million in grants to establish renewable energy and energy storage infrastructure on contaminated properties. No-cost environmental assessments are offered to facilitate brownfield redevelopment.

State programs specific to workforce development

The content below catalogues key resources that Michigan currently offers for workforce development. To explore the core strategies that stakeholders suggested Michigan should adopt to support its industrial decarbonization goals, see *GET THE FACTS: Meeting workforce needs will be key for Michigan's long-term goals*.

- **Registered apprenticeships and union training programs.** More than 23,000 active apprentices in the state, with the vast majority in construction (>15,000) and manufacturing (>3,000).[82] Nearly 750 active programs with apprentices currently enrolled. Over 350 of these programs are within manufacturing sectors, with a greater average wage ($25.66) than that of apprentices statewide ($21.58).[83] Apprenticeship Readiness programs are available to prepare individuals for U.S. Department of Labor Registered Apprenticeship Programs.
- **Michigan Works!** A statewide, unified workforce development system and advocacy organization. Legislative priorities in 2026 are reforming the implementation of SNAP/

[76] "Michigan Assistance Program," BBC Entrepreneurial Training & Consulting, Michigan Economic Development Center, accessed October 2026.

[77] "Michigan Supplier Conversion Grant Program," Michigan Department of Labor and Economic Opportunity, accessed October 2026.

[78] "Michigan SmartZones," Michigan Economic Development Corporation, accessed October 2026.

[79] Public Sector Consultants, "SmartZone Funding Analysis," November 2024.

[80] "Brownfield Redevelopment," Michigan Department of Environment, Great Lakes, and Energy, accessed October 2026.

[81] "Brownfield Renewable Energy Pilot," Michigan Department of Environment, Great Lakes, and Energy, September 2026.

[82] "Michigan Center for Data and Analytics," Michigan Center for Data and Analytics, accessed October 2026.

[83] "National Apprenticeship Active Programs," U.S. Department of Labor Apprenticeship, accessed October 2026.

Medicaid work requirements, scaling up apprenticeship programs, and expanding the Going PRO Talent Fund.[84] Offers a variety of services to jobseekers including resume assistance, interview practice, job search guidance, skills assessments, career advising, and workshops. Provides support through access to computers, printers, high-speed internet, funding opportunities for training, as well as childcare and transportation.[85]

- **Going PRO.**[86] Talent Fund that makes awards to employers to assist in training, developing, and retaining employees. Primarily supports small businesses, 59% of all awards have been to those with fewer than 100 employees. Focused on short-term training that fills a demonstrated talent need and leads to a credential.
- **Community colleges.** Michigan Community College Association offers the Strengthening MiWorkforce Pathways project to strengthen equitable access to workforce programs. Michigan New Jobs Training Program:[87] Allows community colleges to temporarily capture state income tax withholding associated with newly hired workers to pay for training.[88] MiTransfer and MiWorkforce: Allows community college students in certain in-demand fields to transfer specific courses or entire associates degrees to colleges and universities in Michigan.[89] A variety of short-term credentials and training programs are offered at community colleges across the state. Michigan Technical Education Centers (M-TECs): A community college network, provides a statewide educational, training, and workforce development infrastructure for Michigan's businesses.[90]
- **MEDC Workforce Support Programs.**[91] Michigan Achievement Scholarship: A scholarship of up to $5,500 per year for recent Michigan high school graduates to pursue higher education. Michigan Reconnect: Last-dollar scholarship program that helps Michiganders enter high-tech industries, particularly for individuals over 25 without tertiary education. Michigan EV Jobs Academy: Postsecondary credentialing programs targeting electrified vehicle and mobility-related occupational skills needs. Brings together over 100 partners, including employers, labor, industry stakeholders, and education institutions.
- **EGLE Workforce Support Programs.** Clean Energy Workforce Development Program: Grant funding for nonprofits and small businesses to strengthen and develop training and career pathways in clean energy through partnership with state agencies. Aims to address gaps in databases of training opportunities.[92] Sponsorship Program: Funding opportunities for public entities, nonprofits, and small businesses to run events and trainings related to clean energy and energy efficiency. Materials must be shared with EGLE to be published publicly.[93] Building Operator Training: Funding opportunity to train building operators in process efficiency and energy use reduction.[94]

Federal programs that provide technical assistance

- **U.S. DOE Industrial Training and Assessment Centers (ITACs).**[95] ITACs offer manufacturers free in-depth energy assessment by engineering faculty and advanced

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[84] "Michigan Works!," Michigan Works! Association, accessed October 2026.

[85] "Michigan Works!," Michigan Department of Labor and Economic Opportunity, accessed October 2026.

[86] "Going PRO Talent Fund," Michigan Department of Labor and Economic Opportunity, accessed October 2026.

[87] "Strengthening MiWorkforce Pathways Program," Michigan Community College Association, accessed October 2026.

[88] "Michigan New Jobs Training Program," Michigan Community College Association, accessed October 2026.

[89] "Transfer Your Associates Degree," Michigan Transfer Network, accessed October 2026.

[90] "Michigan Technical Education Centers Training and Workforce Development Solutions," Michigan Economic Development Corporation, March 2016.

[91] "Michigan Attracts the Talent it Takes to Lead," Michigan Economic Development Corporation, accessed October 2026.

[92] "Clean Energy Workforce Development Program," Michigan Department of Environment, Great Lakes, and Energy, accessed October 2026.

[93] "Sponsorship Program," Michigan Department of Environment, Great Lakes, and Energy, accessed October 2026.

[94] "Building Operator Training," Michigan Department of Environment, Great Lakes, and Energy, accessed October 2026.

[95] "Industrial Training and Assessment Centers," U.S. Department of Energy, accessed October 2026.

GET THE FACTS

Meeting workforce needs will be key for Michigan's long-term goals

For Michigan to succeed in decarbonizing its industrial sector while ensuring economic competitiveness, careful attention must be paid to the strategies put in place to support and develop the state's future workforce. Based on stakeholder conversations, two core strategies – focused on supporting current workers and building a pipeline of future talent – will be critical.

Rapid upskilling and reskilling of today's workers

Decarbonizing Michigan's industrial sector will require more than the adoption of new technologies – it will also require a workforce prepared to install, service, maintain, and operate that equipment. Fortunately, Michigan's workforce system won't need to start from scratch to build a workforce skilled in these newer, cleaner industrial systems. In some instances, occupations within the industrial sector that would be integral to any decarbonization strategy already possess most of the needed skills. For example, because electricians already possess the skills to replace and install a range of electric technologies, the leap to supporting the wide-scale installation of electric boilers will require minimal supplemental training. Even massive modernization projects – like converting blast-furnace-based steel mills to direct reduction and electric arc furnace technology[a] – are well positioned to succeed: Michigan's existing iron and steel workforce has the core skills and experience necessary to operate modern furnace technologies.



To rapidly scale industrywide upskilling and reskilling of incumbent workers, Michigan's employers will need to collaborate through industry-specific sectoral partnerships, instead of operating in isolation. These partnerships are formal structures that "bring together employers, training providers, workforce organizations, and worker representatives to build strong, industry-aligned talent pipelines."[b] To prepare their workforce, employers within a common sector will need to understand what new skills frontline workers need, to identify existing training curricula or programs available, or even to develop new curricula and programming altogether. Such partnerships should be supported through grants with specific outcome requirements, like worker reskilling attainment, and "high-road" requirements, such as family sustaining wages and benefits. Those partnerships should also be

[a] E. Boatman, "Dearborn Works: An Integrated Steel Mill Transition Study," 5 Lakes Energy, October 2024.

[b] "Strengthening Business and the Workforce Through Industry Sector Partnerships," National Skills Coalition, accessed October 2026.

directly linked to state-funded projects designed to reduce sectoral GHG emissions, such as the proposed *Industrial Modernization and Decarbonization Grant Program*.

A successful sectoral partnership will engage workers to play a key role in developing new training curricula and will support employers as they share resources such as equipment, training facilities, and funding. Michigan can supplement these partnerships with funding for the capacity building and administrative costs inherent in a collaborative model.

Registered apprenticeships: Creating a pipeline for the long term

To meet the long-term demands of industrial decarbonization, Michigan will need to make immediate and continued investments in evidence-based, high-road workforce strategies like registered apprenticeships. But registered apprenticeship programs require long-term planning and commitments: a new apprenticeship program can take a year just to register.[c] Moreover, high-quality apprenticeships can often take years to complete because of the complexity and quantity of skills that an apprentice must learn. For example, an industrial maintenance technician — an in-demand occupation needed at any large industrial site — takes 8,000 hours of on-the-job training, or roughly four years.[d] If new training programs are needed to meet industrial decarbonization needs, that timeline could be extended. New or updated registered apprenticeship programs would be able to leverage the intentional design efforts of sectoral partnerships that have developed new training curricula and programming.

The numbers indicate that it will take a substantial increase in Michigan's apprenticeship utilization to meet the demands of a decarbonized industrial sector. In FY 2025, Michigan was home to 2,638 active manufacturing apprentices[e] out of 587,700 total workers[f] in the state's manufacturing sector, and most of those apprentices belong to the automotive sector — not other high-emitting industries on the cusp of modernization, such as cement and steel. To increase the usage of registered apprenticeships, Michigan could tie the size of tax credits to apprenticeship utilization rates, such as through the proposed Clean Heat Production Tax Credit, modeled after apprenticeship requirements for construction under the federal Inflation Reduction Act.[g]

[c] Lengthy times to registration of apprenticeships were identified by certain stakeholders who participated in this process.

[d] "Industrial Maintenance Technician Apprenticeship," AJAC, accessed October 2026.

[e] "Apprentices by State," ApprenticeshipUSA, accessed October 2026.

[f] "2026 Michigan Manufacturing Industry Workforce Analysis: Employment and Wages," Michigan Center for Data and Analytics, accessed October 2026.

[g] "Frequently asked questions about the prevailing wage and apprenticeship under the Inflation Reduction Act," U.S. Internal Revenue Service, accessed October 2026.

students to provide recommendations for cost and energy savings. The ITAC at Michigan State University helps small and mid-sized manufacturers and commercial buildings save energy, improve productivity, and reduce waste.

- **DOE Onsite Energy Program.**[96] As a part of this program, regional Technical Assistance Partnerships (TAPs) offer technical assistance for industrial sites and other large energy users on a variety of on-site electricity generation and storage technologies, including geothermal energy, thermal and battery storage, solar, wind, heat pumps, and more. There is a network of 10 regional TAPs. The Midwest TAP is hosted at the University of Illinois Chicago.
- **DOE Better Plants.**[97] Helps manufacturers and wastewater treatment plants boost efficiency and cost savings while increasing reliability and competitiveness. Provides an online resource library. Partners can access free tools and software, on-site training, and technical assistance.



Workforce training starts with education. Students here perform energy assessments, walk through systems, ask questions, and come up with initial ideas for changes in this Michigan State University engineering class. Credit: MSU-ITAC

Energy waste reduction programs offered by utilities

- **Custom Incentives.** Michigan utilities such as DTE Energy[98] and Consumers Energy[99] offer both prescriptive and custom rebates for industrial and commercial customers through Energy Waste Reduction programs, with new incentives forthcoming under Efficient Electrification programs. In particular, EWR guidelines require all natural gas and electric utility providers to implement programs for customers to reduce overall energy usage in order to reduce future costs of service. Most utility providers have consistently exceeded statutory requirements for energy savings. In 2024, every $1.00 spent by utilities on EWR generated $2.40 in customer savings.[100] Rebates can be earned per kilowatt-hour (kWh) of electricity or million cubic feet (Mcf) of natural gas saved after boiler replacements, compressed air systems, lighting and HVAC upgrades, process improvements, or other custom energy-saving projects. The Energy Smart Commercial & Industrial Energy Efficiency Program helps businesses within the Michigan Public Power Association service area make energy-saving upgrades.[101] Utilities may also provide individualized energy management services and technical support to larger industrial customers to identify and implement energy saving projects.

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[96] "Onsite Energy Program," U.S. Department of Energy, accessed October 2026.

[97] "Better Plants," U.S. Department of Energy, accessed October 2026.

[98] "Rebates for Manufacturing Facilities," DTE, accessed October 2026.

[99] "Custom Business Incentives," Consumers Energy, accessed October 2026.

[100] D. Scripps, K. Peretick, and S. Myers, "2024 Utility Energy Waste Reduction Programs," Michigan Public Services Commission, October 6, 2025.

[101] "Energy Smart is Smart for Business," Energy Smart Program, accessed October 2026.

- **Strategic Energy Management (SEM) programs.**[102] Cohort-based program to help commercial and industrial customers reduce energy costs and GHG emissions by incorporating energy efficiency into everyday operations. Elevates low- and no-cost solutions.
- **Efficiency United Pilot Programs.**[103] A variety of pilot programs offered each year to give business the chance to test new innovative technologies for energy efficiency and cost savings.

Public financing options offered by Michigan

- **Michigan Saves.** Nonprofit green bank that provides affordable financing to make clean energy investments and building upgrades for homeowners, businesses, and public properties. Supported 58 projects at commercial buildings in 2025, saving over 100,000 MT CO_2e. Average annual utility bill savings at commercial properties has been $12,343.[104] While Michigan Saves has historically focused on residential and commercial projects, its infrastructure could potentially support industrial decarbonization investments.
- **On-Bill Financing.** On-bill financing programs enable customers to pay back the cost of energy efficiency or renewable energy upgrades via their monthly utility bill. Holland and Traverse City utilities have launched programs with Michigan Saves, which coordinates the loans.[105,106]
- **C-PACE.**[107] Financing for clean energy and energy efficiency projects repaid as assessment on property taxes. This structure spreads financing repayment over 25 years so that investments generate immediate cashflow. Industrial properties are eligible but utilize C-PACE programs at a lower rate due to barriers related to expertise, financing structure, and property ownership structure, which are discussed further in financing sub-polices, under *Industrial decarbonization and modernization grant program*.
- **State Grants and Loans.** The Energy Efficiency Revolving Loan Fund offers both grants and loans for energy efficiency audits, retrofits, and upgrades for commercial and residential buildings.[108] The Fuel Transformation Program is a first-come, first-served grant program to support the replacement or repowering of diesel equipment with zero emissions or alternative fuel options. Grants range from $50,000 to $5 million with some projects available for 100% funding coverage.[109] The Community Energy Management Program provides grants up to $50,000 for local and Tribal governments, and other public service entities to fund energy management, energy efficiency, renewable energy, fleet electrification, EV charging, sustainable financing, and clean energy workforce development projects.[110] The Agricultural Businesses Energy Incentive Program offers grants up to $50,000 (requiring a 100% match) that support the resilience and stability of agricultural entities and businesses through energy efficiency, renewable energy, and electrification projects.[111]
- **Tax Incentives. Plant Rehabilitation and Industrial Development Districts Act:** Provides a tax incentive to manufacturers for renovation and expansion of aging facilities, building new facilities, or the establishment of high-tech facilities. The term may vary in length based on the type of project. Final approval comes from the State Tax Commission. Has

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[102] "Strategic Energy Management (SEM) for Businesses," Efficiency United, accessed October 2026.

[103] "Commercial and Industrial Pilot Programs," Efficiency United, accessed October 2026.

[104] "Explore what we accomplished together in 2025," Michigan Saves, accessed October 2026.

[105] "Opt for On-bill Financing with Michigan Saves," Michigan Saves, accessed October 2026.

[106] D. Scripps, K. Peretick, and S. Myers, "2024 Utility Energy Waste Reduction Programs," Michigan Public Services Commission, October 6, 2025.

[107] "How PACE Works," Lean and Green Michigan, accessed October 2026.

[108] "Michigan Energy Efficiency Revolving Loan Fund," Michigan Department of Environment, Great Lakes, and Energy, accessed October 2026.

[109] "Energy Transformation Program," Clean Fuels Michigan, accessed October 2026.

[110] "Community Energy Management Program," Michigan Department of Environment, Great Lakes, and Energy, accessed October 2026.

[111] "Agricultural Businesses Energy Incentive Program," Michigan Department of Environment, Great Lakes, and Energy, accessed October 2026.

been expanded to include 'high-tech activity' such as advanced vehicle technology and other technology that assesses or prevents threats to human health or the environment.[112] **Tool and Die Recovery Zones:** Cover property owned or leased by a tool-and-die business that can be exempted from various taxes for up to 15 years to support economic revitalization.[113] **Renewable Energy Renaissance Zones:** Cover renewable energy facilities within designated zones that may be exempted from state education tax, personal and real property taxes, and/or local income tax for up to 15 years, with the incentive phasing out in 25% increments over the final three years of the program.[114] **Biomass Gasification and Methane Digester Property Tax Exemption:** Covers agricultural entities, which may claim a real and personal property tax exemption for biomass gasification and methane digesters provided that they allow for universities to collect data on the technology effectiveness.[115] **Nonrefundable Business Activity Tax Credit:** Businesses engaged in alternative energy research, development, and manufacturing, including solar, wind, biomass, fuel cells, energy storage systems and other related technology, can claim a nonrefundable credit from state business tax. This credit was repealed in 2019 and expires in 2031.[116,117] **Solar Energy Facility Exemption:** Entitles a qualified facility located in a solar energy district and generating at least 2 MW of capacity to an exemption from real property taxes for 20 years.[118] **Alternative Fuel Development Property Tax Exemption:** Offers an exemption for commercial alternative energy systems, personal property of alternative energy technology firms, or personal property used by a business for alternative energy research, development, or manufacturing.[119]

Public financing options supported by the federal government

- **Tax Incentives and Rebates** **Clean Fuels Production Tax Credit (45Z):** A credit that can be calculated on a per-gallon basis for the production and sale of low-emission transportation fuel. The value of the credit is adjusted for inflation and calculated based on federally established emissions factors.[120] **Credit for Carbon Oxide Sequestration (45Q):** Calculated on a per-ton basis for carbon oxide capture, storage, and utilization. The value of the credit is highest for direct air capture and the threshold for eligibility varies based on the type of facility. The credit is increased for facilities meeting prevailing wage and registered apprenticeship requirements.[121] **Clean Electricity Investment Credit (48E):** A tax credit of 6% of the investment (or up to 30%, if prevailing wage and apprenticeship requirements are met) for the installation of clean energy technology or storage on the site of a qualified facility. Cannot be claimed in combination with a production credit. Bonuses are available for facilities meeting domestic content requirements and those located within energy communities.[122] **Energy Improvement and Extension Act Federal Excise Tax Exemption:** Exempts some idling reduction devices from federal excise tax.[123] **Advanced Biofuel**

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[112] "Industrial Facilities Exemption," Michigan Department of Labor and Economic Opportunity, accessed October 2026.

[113] P. Affholter and D. Zin, "Tool & Die Recovery Zones S.B. 1483: Analysis As Enacted," January 2009.

[114] "Renewable Energy Renaissance Zones," Michigan Economic Development Corporation, August 2021.

[115] "MCL - Section 211.9 The General Property Tax Act (Excerpt)," Michigan Legislature, accessed October 2026.

[116] "Enrolled Senate Bill No. 583," State of Michigan Legislature, January 2007.

[117] N. Kelly, J. Stansell, and B. Gielczyk, "Legislative Analysis: Tax Credits For Merged And Acquired Entities," November 2019.

[118] "Solar Energy Facility Exemption," Michigan Department of Labor and Economic Opportunity, accessed October 2026.

[119] "Alternative Fuel Development Property Tax Exemption," U.S. Department of Energy, accessed October 2026.

[120] "Clean Fuel Production Credit," U.S. Department of Energy, accessed October 2026.

[121] "Credit for Carbon Oxide Sequestration,"U.S. Internal Revenue Service, accessed October 2026.

[122] "Clean Electricity Investment Credit," U.S. Internal Revenue Service, accessed October 2026.

[123] "Energy Improvement and Extension Act of 2008," U.S. Department of Energy, accessed October 2026.



Wind is a renewable energy resource.

- **Federal Loan Programs** **Energy Dominance Financing Program:** Offers loans to projects that add energy to the grid or enhance grid reliability, such as repurposing or replacing inactive energy infrastructures, increasing capacity, or enabling electric supply to meet specific time-based needs.[128] **American Nuclear Supply Chain Loans:** Offer conditional loans to support orders of long-lead-time components and prevent bottlenecks in nuclear plant construction.[129]
- **Federal Grant Programs** **Industrial Training and Assessment Center Implementation Grant:** Provides up to $300,000 per manufacturer to implement recommendations made during ITAC or functionally equivalent energy assessments, including projects such as machinery upgrades, process optimization, and power installation.[130] **Battery Manufacturing and Recycling Grants:** Grants for demonstration projects, construction, or retrofitting of battery component manufacturing, advanced battery manufacturing, and battery recycling facilities.[131] **Battery Materials Processing Grants:** Grants for demonstrations, construction, or retrofitting of battery material processing facilities.[132] **Domestic Automotive Manufacturing Conversion Grants:** Offers grants to support the conversion of closed or at-risk automotive manufacturing facilities to support the domestic electric vehicle supply chain. **Defense Production Act:** Expanded funding

[124] "Advanced Biofuel Feedstock Incentives," U.S. Department of Energy, accessed October 2026.

[125] "Biden-Harris Administration Launches Rebate Programs for Transformers and Critical Industrial Equipment," U.S. Department of Energy, August 2023.

[126] "Clean Electricity Production Credit," Internal Revenue Service, accessed October 2026.

[127] "Advanced Manufacturing Production Credit," Internal Revenue Service, accessed October 2026.

[128] "Introducing the Energy Dominance Financing Program (EDFP)," U.S. Department of Energy, accessed October 2026.

[129] "Department of Energy Announces American Nuclear Supply Chain Loans," U.S. Department of Energy, accessed October 2026.

[130] "Industrial Training and Assessment Center Implementation Grant Awards," U.S. Department of Energy, accessed October 2026.

[131] "Battery Manufacturing and Recycling Grants," U.S. Department of Energy, accessed October 2026.

[132] "Battery Materials Processing Grants," U.S. Department of Energy, accessed October 2026.

opportunities to include new technologies, including solar energy, transformers and electric grid components, heat pumps, insulation and electrolyzers, fuel cells, and platinum group metals, to accelerate domestic production and support a clean energy economy.[133] **Seeding Critical Advances for Leading Energy technologies with Untapped Potential (SCALEUP):** Supports early-stage transformative energy technologies to reach commercialization. It also has a pre-application support program for applicants to strengthen their submissions.[134]

Private financing options available to manufacturers

- **Michigan Launchpad for Industrial Innovation & Transformation (LIFT).**[135] A public-private platform that brings together industrial demand, private capital, and state resources to address manufacturing and supply chain challenges and support industrial innovation and production. Supported by Ford and JPMorganChase.
- **Energy-as-a-Service Model**.[136] A business model that allows customers to purchase energy services based on a subscription model rather than managing their own energy infrastructure and that requires no up-front capital investment, expanding access to expensive equipment upgrades.
- **Energy Services Company (ESCO)/Energy Savings Performance Contracting.** Energy upgrades are paid for using the generated savings, allowing for minimal up-front capital investment and positive cash flow. ESCOs make a profit from the energy efficiency measures through a performance-based contract. The customer and ESCO share the project risk.
- **Private Debt and Equity Financing.** Commercial banks, investors, and private equity firms can provide debt or equity financing for industrial decarbonization projects.
- **Specialized Industrial Decarbonization Investment Firms.** Some investment firms focus on financing industrial decarbonization projects specifically through structures that help address risks and mobilize private capital.

[133] "President Biden Invokes Defense Production Act to Accelerate Domestic Manufacturing of Clean Energy," U.S. Department of Energy, June 6, 2022.

[134] "SCALEUP Program," U.S. Department of Energy Advanced Research Projects Agency, accessed October 2026.

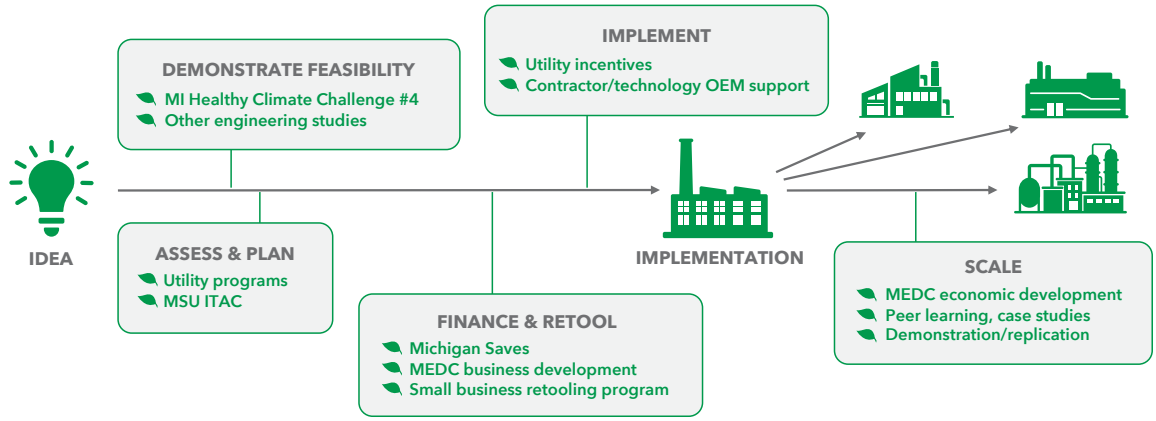
[135] "Michigan LIFT," Michigan Launchpad for Industrial Innovation & Transformation, accessed October 2026.

[136] K. Cleary and K. Palmer, "Energy-as-a-Service: A Business Model for Expanding Deployment of Low-Carbon Technologies," Resources for the Future, December 2019.

CLOSING GAPS BY PURSUING OPPORTUNITIES

Michigan has a significant foundation of programs, institutions, and financing mechanisms that can support the state's industrial decarbonization interests. These resources span energy efficiency, technical assistance, economic development, and workforce training. However, most programs were created to serve broader economic or energy objectives, not industrial decarbonization specifically. The *Policy Recommendations* that follow build on the resources enumerated above, look to leverage the opportunities below, and are intended to bring complementary programs together into an actionable framework to support industrial decarbonization and help Michigan close these programmatic gaps to provide the state with the tools needed to accelerate its industrial sector along the path towards net-zero.

- **Coordination** Michigan's industrial support landscape consists of multiple implementing and organizing bodies. However, the lack of connective tissue between implementers sometimes means that manufacturers have challenges in identifying which programs are relevant to their potential projects, understanding their eligibility, and accessing complementary assistance. Enhanced, focused coordination across disparate programs and offices can simplify manufacturer participation and help them navigate available resources.
- **From assessments to implementation** Michigan has an established technical assistance framework and demonstrated support for feasibility studies and assessments. However, a gap remains between assessing the opportunity and implementing corresponding projects due to capital and technical constraints and policy design, because programs that offer assessments often explicitly state that there is no obligation for implementation. While this reduces the burden to participation, it also contributes to the gap between assessment and implementation. Strengthening the established pipeline between the stages of deployment is a critical opportunity that the state should pursue.
- **Support for emerging technologies.** The existing utility EWR programs are largely focused on traditional energy efficiency, with limited incentives and technical assistance for industrial electrification and other emerging technologies, despite recent statutory changes that enabled incentives for so-called 'efficient electrification.' Moreover, existing program designs and implementation practices have not adapted to support industrial fuel-switching more broadly. Better aligning utility programs, economic development, and technical assistance with new technologies and strategies can ensure that industrial decarbonization activities address the diversity of Michigan's industrial sector, as well as explore all the necessary pathways to deeper decarbonization.



- **Financing and accessibility.** Although Michigan has historically offered a variety of grants, loans, tax incentives, and financing mechanisms to support energy-oriented projects, the existing and historical resources provided do not fully address the needs of manufacturers pursuing capital-intensive decarbonization projects. Project costs can range from hundreds of thousands of dollars for smaller equipment upgrades to tens of millions of dollars for major retrofits and facility-level decarbonization projects. Smaller manufacturers especially have faced challenges in matching requirements and access to affordable financing.
- **Connecting decarbonization with economic and workforce development.** Michigan's workforce infrastructure, research institutions, and economic development programs have created a strong foundation for industrial modernization and highlight the connection between decarbonization and economic competitiveness. But there are more opportunities to explicitly align resources with industrial decarbonization investments and emerging technology needs. Industrial decarbonization should also be a central focus of Michigan's future economic development strategy, with a keen eye on supporting long-term manufacturing investment and job creation.

STAKEHOLDER AND RIGHTSHOLDER PERSPECTIVES

The importance of engaging diverse perspectives in industrial decarbonization strategy

Michigan's implementation of a coordinated industrial decarbonization strategy will affect, and rely on, the actions of a range of groups, including manufacturers, workers, utilities, communities, environmental advocates, environmental justice organizations, technology providers, materials management organizations, and state, local, and Tribal governments.



Decarbonizing Michigan's industrial sector will take a lot of different forms. Incorporating the perspectives of diverse communities will ensure that the voices of those who are impacted the most – like the thousands of families living in the Dearborn industrial corridor – will be heard. Credit: Clear the Air

For the purposes of this roadmap, stakeholders are groups with interests in, or affected by, industrial decarbonization, while rightsholders are those with legally recognized rights that may be impacted by state actions.

Because stakeholders and rightsholders will experience different benefits, costs, risks, and constraints from and around the state's industrial transition, their perspectives are essential in both identifying policy priorities and determining whether policies can work effectively and equitably.

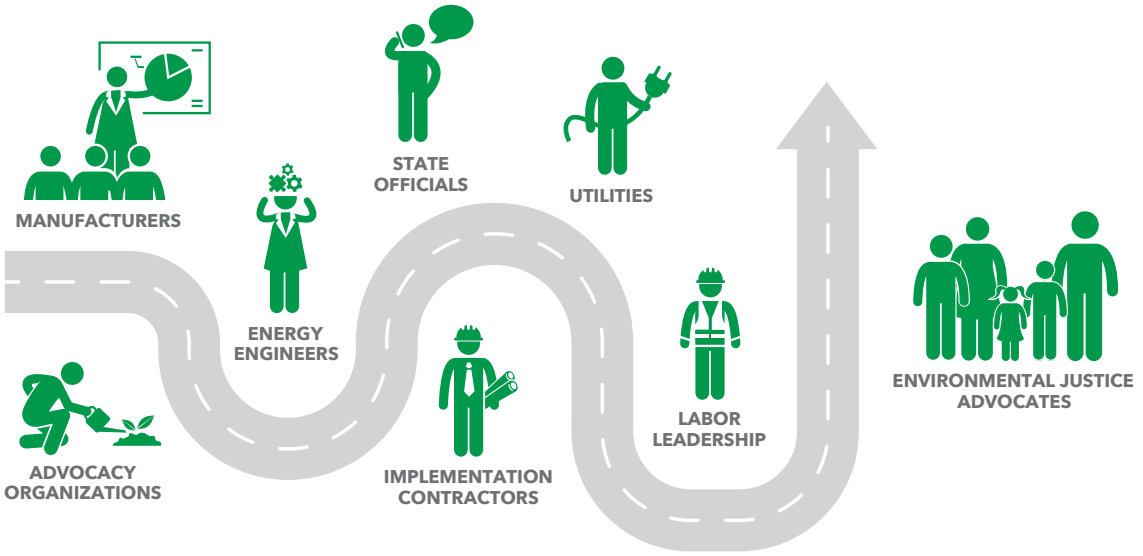
Additionally, many of the policy approaches considered in this roadmap cannot be fully determined on paper and thus will require robust additional stakeholder engagement, rightsholder consultation, and research to advance towards real implementation. Details can significantly change industrial participation and benefits, including:

- Eligibility requirements
- Incentive levels
- Rate structures
- Project selection criteria
- Community benefits
- Labor standards
- Permitting
- Environmental safeguards

This roadmap identifies policy directions and key design elements. However, continued engagement with affected rightsholders and stakeholders will be essential during further policy development and implementation. In many cases, implementation should include structured opportunities for groups to help shape program design before major decisions are made.

Engagement informing this roadmap

Development of this roadmap incorporated perspectives from across Michigan's industrial decarbonization ecosystem. The authors and research team designed engagement to capture the experiences of organizations that are directly responsible for implementing industrial



projects and the perspectives of workers, communities, advocates, public agencies, and other groups impacted by industry. Engagement occurred iteratively throughout roadmap development. The project team connected with:

- Manufacturers through virtual and in-person roundtables
- Environmental and community perspectives via environmental advocates and environmental justice roundtables
- Workers and unions through a skilled labor roundtable and individual discussions
- Materials and circularity via two focused meetings
- Manufacturers, engineers, technology providers, the Michigan Public Service Commission (MPSC) and utilities through a Michigan Industrial Electrification Utility Working Group
- State government through two presentations to a range of Michigan agencies
- Council on Climate Solutions via three presentations and feedback gathering sessions to the council's newly formed Industrial Decarbonization Working Group

Cross-cutting themes from engagement

- **Economics are critical to decision making.** Manufacturers consistently emphasized that decarbonization investments compete with other capital priorities and must meet internal requirements.
- **Implementation matters as much as identifying opportunities.** Stakeholders emphasized that the gap between identifying project opportunities and actually implementing projects can be sizable.
- **Predictability and simplicity are valuable.** Stakeholders repeatedly underscored that long-lasting industrial investments rely on their ability to have confidence in estimates of future costs and program conditions.
- **Different manufacturers need different kinds of support.** Large manufacturers often have internal teams and dedicated utility energy managers capable of identifying and managing complex decarbonization projects. Small and mid-sized manufacturers often face more barriers in staff capacity, technical expertise, and financing.
- **Public investment in industry should result in widespread benefits** State support provides an opportunity to consider who receives economic, workforce, health, and environmental benefits and whether investments reinforce or reduce disparities.Labor, environmental, and community stakeholders and rightsholders highlighted that industrial modernization needs to support high-quality job creation, air quality improvements, community benefits, and reduced environmental impacts.
- **Michigan should build on the existing landscape** Across groups, participants indicated value in leveraging existing skilled trades and training, utilities, technical assistance pathways, and other infrastructure.
- **Workers should share in the benefits o industrial decarb.** Labor stakeholders emphasized maintaining high-quality jobs, supporting union labor and apprenticeship pathways, and providing existing workers opportunities to develop new skills.
- **Workforce policy should build on existing skills and institutions.** Skilled trades stakeholders indicated that Michigan has substantial workforce and training capacity, and stated a clear interest that predictable project pathways, recruitment, and targeted upskilling should be considered critical features of policy design.

- **Industrial decarbonization should deliver local environmental and health benefits** Environmental justice rightsholders emphasized reducing criteria pollutants and cumulative burdens in addition to GHG emissions.
- **Tribes should be engaged as governments and partners** Because industrial and infrastructure development may create implications for Tribal lands, treaty rights, natural and cultural resources, workforce opportunities, and economic development, Michigan's Tribes should be engaged partners in policy development and implementation.
- **Communities should have a clear role in shaping projects** Rightsholders emphasized that community engagement should happen early enough to influence project design, especially where they affect air quality, infrastructure, or land use.
- **Community benefits should incorpo ate identified priorities** The benefits most valued by affected community rightsholders vary across the state, meaning community-specific engagement is essential.

Policy Recommendations

In-depth recommendations for a robust policy framework to support broad industrial decarbonization and competitiveness in Michigan are included herein. The recommendations are organized around three layers of action with the ability to work together to support Michigan's efforts towards a net-zero industrial sector: cross-cutting implementation infrastructure, the core policies that directly drive emissions reductions, and a series of supporting sub-policies that can strengthen or enable those core policies.

This section is designed to help readers understand how these three pieces fit together. It begins with overarching program structures – coordination frameworks, permitting and navigation support, shared carbon accounting schemes, and integrated utility planning – that create the institutional capacity Michigan will need to deliver industrial decarbonization at scale. Notably, these recommendations are not standalone programs; they are the connective tissue that Michigan will need to ensure consistency, predictability, and alignment across agencies, utilities, manufacturers, and communities.

Building on that foundation, the policy roadmap below presents a set of priority policies – grant programs, tax credits, procurement standards, electrification tariffs, and more – with the ability to directly accelerate the deployment of low-carbon industrial technologies and practices. Each policy is accompanied by design guidance, implementation considerations, and examples from other states or countries. Finally, this section outlines supporting sub-policies that could enhance the effectiveness of the core policies, such as financing tools, regulatory clarifications, and targeted expansions of existing programs. These recommendations should be designed and implemented to preserve the cost competitiveness of Michigan's manufacturing sector.

The emissions, economics, and other results of implementing these policies can be found in *Scenario results and findings*. Each policy recommendation is also summarized by a business card that includes implementation details, including potential lead and supporting agencies, authority and funding recommendations, implementation timing, policy pillars and guiding principles, where we identified stakeholder support, and complementary policies from elsewhere in the roadmap. The cards also identify how each recommendation aligns with the modeled Energy Policy Simulator (EPS) scenarios and associated policy levers. These cards are located in *Appendix A: Core Policy and Sub-Policy Business Cards*.

CROSS-CUTTING IMPLEMENTATION INFRASTRUCTURE

Industrial decarbonization in Michigan will depend on individual policies and practices, as much as on the institutional, analytical, and project delivery infrastructure needed to implement them effectively. This roadmap identifies three cross-cutting recommendations that establish the coordination, decision-making frameworks, and manufacturer-facing efforts needed to support the broader policy portfolio. These recommendations are intended to strengthen and connect existing state capabilities. They can be developed in phases and alongside priority policy implementation, allowing for near-term action and progress while longer-term capacity and coordination strategies are established.



Cross-cutting implementation infrastructure will be key for decarbonizing Michigan's industrial sector.

Michigan industrial modernization and decarbonization strategy and implementation structure

RECOMMENDATION:

Establish a statewide framework for coordinating industrial modernization and decarbonization across climate, manufacturing, economic development, energy, infrastructure, workforce, and community priorities. The strategy should build from existing Michigan initiatives and establish clear responsibilities for implementation.

CORE FUNCTIONS:

Interagency Industrial Decarbonization Implementation Team

- Establish responsibility and accountability across state entities.
- Coordinate the implementation of roadmap recommendations and related programs.
- Develop an implementation plan assigning responsibilities and timelines.
- Maintain ongoing manufacturer, utility, labor, community, and other stakeholder engagement.
- Track progress and identify emerging implementation barriers.

Coordinated State Permitting and Navigation Assistance

- Designate a state point of contact or create a new office for industrial decarbonization projects that require coordination across multiple agencies.
- Develop a project checklist or air permitting roadmap with requirements, dependencies, and sequencing.
- Help projects identify requirements early and navigate processes.
- Communicate recurring barriers back to agencies and policymakers.

Integrated Gas and Electric System Transition Planning

For greater understanding of the key interplay between grid decarbonization and industrial decarbonization – and the potential for industrial electrification to support an integrated system transition with careful attention given to affordability – see *GET THE FACTS: Decarbonizing Michigan's power grid*.

- Develop coordinated planning assumptions, led by the MPSC and supported by Michigan's Department of Environment, Great Lakes, and Energy (EGLE), utilities, and relevant state agencies, around industrial electrification, load growth, flexibility, and changing gas demand. This effort should complement existing utility planning processes.
- Create a mechanism for sharing industrial development information among the MPSC, utilities, and state planners, with voluntary participation by manufacturers and appropriate protections for confidential customer-specific information.
- Incorporate industrial flexibility resources, including demand response, energy storage, and others into planning.
- Use findings to inform utility planning, tariff development, and infrastructure investment.
- Address how fixed gas system costs will be allocated as industrial customers electrify.

IMPLEMENTATION CONSIDERATIONS:

- EGLE's Office of Climate and Energy (EGLE-OCE) could provide overall coordination, with roles for the Michigan Economic Development Corporation (MEDC), MPSC, Michigan Department of Labor and Economic Opportunity (LEO), Michigan Department of Transportation (MDOT), Michigan Department of Technology, Management and Budget (DTMB), Michigan Infrastructure Office (MIO), and other agencies, as well as Michigan utilities.
- The structure should use existing authorities and processes where possible and be durable enough to maintain coordination as technologies, markets, and administrations change.
- Durability could be strengthened through designated agency responsibilities, interagency agreements, or legislative authority.

ESPECIALLY ENABLES:

- Industrial modernization and decarbonization grants
- Industrial electrification tariffs
- Expanded/targeted workforce support
- Expedited air permitting for emissions-reducing projects

Common carbon accounting and project evaluation metrics

RECOMMENDATION:

- Establish a consistent framework for evaluating the emissions, environmental, community, and other relevant impacts of industrial decarbonization projects receiving state financial support. Common metrics would improve consistency across programs, provide clearer expectations for manufacturers, and help Michigan compare outcomes and prioritize investments that deliver the most emissions reductions and other co-benefits. For a more in-depth discussion of the importance of establishing a common carbon accounting framework, and the role that life cycle-based assessments should play in framework design, see *GET THE FACTS: Building a robust approach to carbon accounting in Michigan*.

CORE FUNCTIONS:

Common Carbon Accounting and Project Evaluation

- Establish consistent GHG and life cycle emissions methodologies to be used for evaluating applicants to state funding and programs, both during selection and in assessing program outcomes. Methodologies should be aligned with existing federal and other states' reporting methodologies (especially other states in the Great Lakes region), and with

protection for confidential business information. Where possible, the framework should coordinate with existing utility EWR evaluation frameworks.
- Calibrate evaluation requirements based on project size, technology, support, and potential impacts. These should be co-created by industrial partners and community advocates.
- Evaluate GHG reductions along with economic outcomes (such as cost effectiveness), workforce, air quality, and community considerations.

Coordinated Approach to Industrial Carbon Management
- Establish consistent criteria for evaluating CCS and other carbon management pathways, including appropriate applications, environmental impact, life cycle emissions, infrastructure needs, and alternatives.

Community Benefits Guidance for State-Supported Industrial Projects
- Develop guidance and model community benefits agreement (CBA) frameworks for state-supported industrial decarbonization projects scaled to the size of the project and the level of state support.
- The framework should include guidance on: (1) early, continuous, structured engagement of the community in both the project design and implementation phases; (2) benefits that are tailored to the local community; (3) specific, trackable commitments; and (4) opportunities to coordinate community engagement and commitments with air permitting and permit renewal processes.

Integrated Air Quality Framework
- Incorporate changes in criteria pollutants and other local air quality impacts relative to existing facility conditions into the carbon emissions reduction evaluation metrics of major projects seeking state funding or incentives.

IMPLEMENTATION CONSIDERATIONS:

- EGLE-OCE should lead development of the framework in coordination with MEDC, MPSC, and other relevant state agencies so that manufacturers are not subject to different methodologies, application requirements, and success measurements depending on the program.

ESPECIALLY ENABLES:

- Industrial modernization and decarbonization grants
- Clean heat production tax credit (PTC)
- 'Buy Clean, Buy Michigan'
- Expedited air permitting for emissions-reducing projects
- 'Cap and Invest' and other programs requiring carbon management/accounting frameworks

Integrated industrial modernization resource and project delivery system

RECOMMENDATION:

- Create a pathway that helps Michigan manufacturers move from interest through assessment, project development, financing, permitting, and implementation. As opposed to establishing additional standalone technical assistance programs, Michigan should better connect and expand existing resources around manufacturer needs.

CORE FUNCTIONS:

Resource Hub

- Centralize and maintain information on technologies, incentives, financing, utility programs, qualified providers, case studies, and implementation resources. Where possible, include a publicly accessible inventory of state-supported industrial decarbonization projects.

Assessment-to-Implementation Support

- Help facilities translate assessments to suggested next steps on project development, financing, incentives, and implementation.
- Recognize and connect to existing assessments.

Project Navigation Point of Contact

- Help manufacturers navigate financing, utilities/interconnection, permitting, contractors, approvals, and implementation requirements.

Clean Industrial Innovation, Demonstration, and Shared Infrastructure Hubs

- Support technology validation, demonstrations, hands-on learning, and shared infrastructure where individual manufacturers may be unable to justify investment independently.

IMPLEMENTATION CONSIDERATIONS:

- Build around existing resources (including ITACs, RETAP, utility programs, MEDC offerings, MMTC offerings, the Michigan ICIP, and private assessment/audit providers).
- Provide funding and staff capacity to coordinate resources and support manufacturers through project development and implementation, including through appropriations where needed.

ESPECIALLY ENABLES:

- Industrial modernization and decarbonization grants
- Expanded/targeted workforce support
- Expedited air permitting for emissions-reducing projects
- Industrial electrification demonstrations and full-scale projects
- Financing mechanisms needed to support industrial decarbonization projects

GET THE FACTS

Decarbonizing Michigan's power grid

Decarbonizing Michigan's electricity grid is an essential piece of decarbonizing the state's industrial sector. The benefits of industrial electrification, which is a key strategy for achieving the GHG and pollutant reductions modeled in *Industrial Decarbonization Scenario Analysis*, depend on the emissions associated with electricity generation. As the supply of electricity becomes cleaner, achievable reductions will increase. As of 2026, just 34% of Michigan's grid mix is classified as low carbon.

In 2025, Michigan emitted approximately 959 lbs of CO_2 per MWh of electricity generated – the 17th-highest carbon intensity of a state power grid in the country.[a]

Michigan's clean energy transition

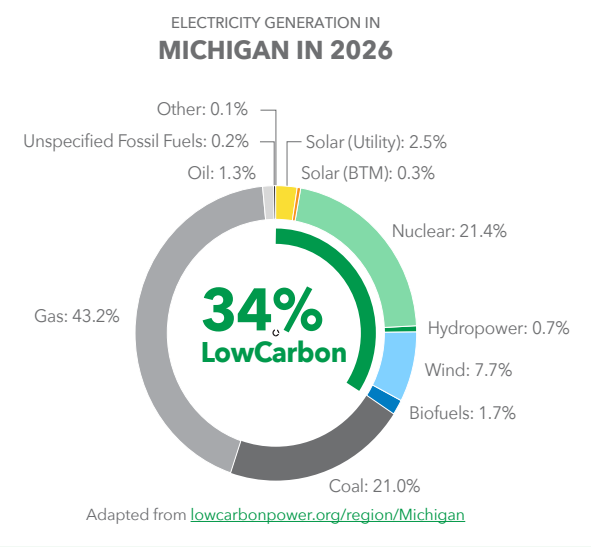
Despite the Michigan grid's current heavy reliance on fossil fuels, 2023 clean energy legislation[b] established a pathway towards a significantly cleaner electricity supply, including goals of:

- 50% renewable electricity by 2030 and 60% by 2035
- 80% clean electricity by 2035 and 100% by 2040
- A statewide energy storage target of 2,500 MW

These targets create an important foundation for reducing the emissions associated with industrial electricity use. Meeting them will rely on continued investment in generation, storage, transmission, and distribution infrastructure, along with efforts to maintain reliability and affordability, and will significantly increase the emissions reduction potential of electrification.

Building the grid to support decarbonization

Reaching Michigan's clean energy targets will require replacing retiring fossil fuel generation with cleaner resources, expanding storage, upgrading infrastructure, and improving grid flexibility. The scale of this transition is reflected in the current planning records of Michigan's utilities. DTE Energy anticipates allocating $30 billion to capital investments from 2026 to 2030, including $15 billion for cleaner generation and $11 billion for distribution.[c] Consumers Energy is planning for $24 billion in investments across electric and gas operations, including $8.8 billion for generation and $8.6 billion for distribution.[d] Industrial electrification will introduce new large loads expected to influence the scale, location, and timing of investments.



[a] "Electricity generation and resources," U.S. Energy Data, accessed October 2026.

[b] "2023 Energy Legislation," Michigan Public Service Commission, accessed October 2026.

[c] DTE's 2025 Form 10-K, U.S. Securities and Exchange Commission, accessed October 2026.

[d] Consumers Energy Company's Q2 2026 Form 10-Q, U.S. Securities and Exchange Commission, accessed October 2026.

Coordinating Michigan's power grid and industrial decarbonization initiatives

Because of these investments, coordination between utilities and industrials will be important for managing costs and supporting electrification, which will create both opportunities and challenges for the power grid. Large electric boilers, industrial heat pumps, and other electrification equipment will create new loads, potentially requiring infrastructure upgrades or additional capacity. The U.S. DOE's 2026 National Transmission Needs Study identifies growing industrial electricity demand and electrification as drivers of transmission infrastructure needs.[e]

However, some electrification technologies can support more efficient grid operation. Storage, hybrid heating, and well-designed industrial processes – supported by appropriate electric rates – can allow manufacturers to shift electricity consumption from times of peak demand on the grid towards periods of higher renewable generation. Research on electrified technologies shows that these coordinated approaches can shift electricity demand away from current peak demand times, reduce costs, and improve grid flexibility.[f] Peak-shifting can also reduce infrastructure needs, improve utilization of grid assets, help integrate renewables, and support residential customer affordability.

Implications for Michigan

Michigan's utility integrated resource planning (IRP) process can coordinate electricity system investments with anticipated industrial electrification needs. The state's updated IRP requirements and distribution planning efforts can address future load growth, system flexibility, and infrastructure needs.[g]

Several policies in this roadmap could help align Michigan's industrial and grid decarbonization efforts:

- **Industrial electrific tion tariffs.** Appropriate tariffs can encourage flexible electricity consumption and improve the economics of switching from fossil fuels.
- **Industrial decarbonization grants and a clean heat production tax credit.** Grants and tax credits can accelerate the deployment of efficient electrified technologies as Michigan's electricity supply becomes cleaner.
- **Integrate gas and electric system transition planning.** System-wide integrated planning can support the coordination of industrial load forecasts, utility infrastructure investments, and changes in natural gas demand.
- **Industrial energy sharing and co-location.** This policy can help Michigan's utilities identify opportunities for shared infrastructure, coordinated loads, and thermal storage within industrial clusters.

Michigan's grid and industrial decarbonization strategies must advance together. A cleaner electricity supply will increase the climate benefits of industrial electrification, while proactive planning and flexible industrial loads can help manage transition costs and infrastructure needs, helping to ensure affordability across all customer classes.

[e] "DOE's Office of Electricity Publishes 2026 Draft National Transmission Needs Study to Strengthen America's Grid," U.S. Department of Energy, July 9, 2026.

[f] A. Buonomano, C. Forzano, et al., "The flexibility-efficiency nexus in industrial heat electrification: Optimal operation of heat pump-storage systems under variable electricity pricing," Energy Conversion and Management, March 15, 2026.

[g] "Distribution System Planning," Michigan Public Service Commission, accessed October 2026.

GET THE FACTS

Building a robust approach to carbon accounting in Michigan

As Michigan pursues strategies to decarbonize the state's industrial sector, decisions and approaches must be grounded in quantitative and scientific analyses. The data resources required to track emissions over time, assess policy options, and disclose environmental information will vary by economic and industry subsector. To meet these needs, principles and frameworks will be required to enhance existing datasets, identify and fill data gaps, broaden monitoring and reporting to create new types of data, and incentivize or require data development by industry. Standardizing how Michigan chooses to address these needs will be key for establishing critical cross-cutting implementation infrastructure, especially *Common carbon accounting and project evaluation metrics*.

The development of — and ready access to — high-quality, publicly available environmental data will help Michigan's industrial decarbonization policies and programs be more effective while establishing credible methods for tracing reductions in emissions statewide. Achieving this will require the state to consider where supplemental data are needed, plans for using those data to support or drive policy, and benefits from investing in their collection or creation. This section discusses how life cycle assessment (LCA)-based approaches can support Michigan's strategies for industrial decarbonization through:

- Developing emissions data to support policies and programs
- Implementing and assessing policy
- Mitigating risks to Michigan's manufacturers to support their competitiveness

Developing complementary emissions data

In 2025, EGLE published updated statewide GHG inventory results which estimated emissions occurring within Michigan's borders, from all sources including industrial activities.[a] These findings offer an important perspective because they focus on emissions within the jurisdiction of Michigan policy intervention. However, several decarbonization strategies prescribed in the MI Healthy Climate Plan[b] (e.g., a clean fuel standard, 'Buy Clean, Buy Michigan,' clean energy resources) expand beyond this scope to address supply-chain-based emissions which commonly occur out-of-state. Moreover, standard emissions inventories are often limited in their ability to support analysis and decision making around specific interventions at the sector, community, or activity level.

It is therefore important to enhance the resolution of information in the statewide inventory by pursuing data development opportunities that can empower decision makers, industry actors, and program developers in Michigan. Techniques like LCA offer an interdisciplinary scientific method to evaluate environmental impacts associated with specific activities or interventions within sectors. LCA methods can be used to evaluate the full upstream (i.e., supply chain), direct, and downstream (e.g., end-of-life) impacts of defined processes, technologies, services, or products at varying scales of geographic and temporal resolution. EGLE's Office of Climate and Energy already uses an LCA approach to assess emissions across renewable

[a] "Michigan's Comprehensive Climate Action Plan," Michigan Department of Environment, Great Lakes, and Energy, December 2025.

[b] "MI Healthy Climate Plan," Michigan Department of Environment, Great Lakes, and Energy, April 2022.

energy planning, methane mitigation, and CCUS applications. LCA modeling activities can support other state agency programs, such as those that manage the potential and actual impacts from surface water body eutrophication,[c] particulate matter exposure, and water consumption. Additionally, several of the datasets and resources commonly used to inform industrial analyses, (e.g., EIA activity data, transportation life cycle inventory models) can also be deployed for LCAs in the electricity, residential, transportation, and commercial sectors.

Implementing and assessing policy using an LCA-based framework

Life cycle assessment-based tools and data can serve several roles in a state's policy agenda for pursuing environmental goals by supporting near-term decision making (e.g., by yielding product- or project-specific information), long-term benchmarking (e.g., by developing state- or industry-wide estimates), and program-specific regulatory uses. For example, product-specific LCAs underpin their environmental product declarations (EPDs) by allowing manufacturers to quantify resources consumed and impacts to humans and/or the environment, whereas an economy-wide approach can provide state decision makers insights into the relative carbon intensity of different industrial sectors, helping to focus initiatives and resources where they are most needed.

Near-term information and guidance. Consumers, businesses, and government operations all regularly partake in decisions around which commodities and services to buy or what investments to make. For example, around 10 states (e.g., California, Colorado, Minnesota) have advanced 'Buy Clean' policies that leverage pre-packaged LCA results to preferentially procure products based on cost and impact. Five state departments of transportation have each received approximately $30 million from the Federal Highway Administration's Low Carbon Transportation Materials (LCTM) grant program to develop LCA-based embodied carbon reduction programs.[d]

Life cycle assessment-based approaches can also inform the decision making of planners before a project starts, through approaches like Whole Building Life Cycle Assessment (WBLCA), which allowed architects to leverage LCA data during the design phase and served as an optional credit as of LEED v4.[e] LEED v5 then shifted to setting hard requirements around quantifying embodied carbon and rewarding reductions.[f] At the state level, California's Buy Clean California Act (BCCA) program[g] and CalGreen building code[h] operate to address embodied carbon in both public and private sector construction.

Stakeholders involved in the implementation of Materials Management Plans across Michigan could use LCA-based tools to evaluate and optimize the environmental performance of programs or capital asset designs. Other programs or green lending initiatives could use LCA to quantify site-specific impacts resulting from cleaner manufacturing processes, technology upgrades, and renewable energy projects to identify qualifying applicants.

[c] Eutrophication is a nutrient-driven process in which a fresh water body develops excessive plant matter or algae contents. It typically occurs due to runoff of excess nutrients like phosphorus and nitrogen from agricultural activities. In the worst cases, eutrophication can cause extensive 'dead zones' within the water body, as excess plant or algae growth blocks sunlight from reaching lower levels.

[d] "INVESTING IN AMERICA: USDOT Awards $1.2 Billion in Grants to Help State Departments of Transportation Utilize Cleaner Construction Materials," Federal Highway Administration, November 14, 2024.

[e] "Building Life-Cycle Impact Reduction," LEED v4.1, U.S. Green Building Council, accessed October 2026.

[f] "Reduced Embodied Carbon," LEED v5, U.S. Green Building Council, accessed October 2026.

[g] "Buy Clean California Act," California Department of General Services, Procurement Division, accessed October 2026.

[h] "CALGreen," California Department of General Services, Building Standards Commission, accessed October 2026.

Long-term benchmarking. Even though state environmental goals such as renewable energy production or waste diversion targets are specific and actionable,[i] the use of long-term LCA-based benchmarking is important to inform these targets and highlight hotspots of environmental impacts. Such methods can quantify the benefits of proposed programs and highlight where additional improvements are needed. In the context of Michigan, benchmarking efforts may be required to track progress for sectors not explicitly identified in the EPA State Inventory Tool (SIT)[j] that underpins Michigan's GHG inventory. Resources like state-specific Consumption-Based Emissions Inventories (CBEI)[k] can provide economy-wide hotspot analyses for the state in terms of direct and supply chain impacts, which in turn may indicate additional policy intervention priorities and opportunities.

Program-specific egulatory opportunities. Governments at all levels can use LCA data in regulatory and policy programs. The most prolific examples are for fuel, power, and construction materials, while emerging cases include regulations for packaging and other types of manufactured products (e.g., fertilizers, aluminum). The federal Renewable Fuel Standard, federal tax credits (e.g., 45Z), and state-level, low-carbon fuel programs all use LCA to quantify the cumulative, whole-supply-chain GHG benefits of using renewable or lower-carbon transportation fuels. Each program requires completing an LCA to quantify life cycle carbon emissions.[l,m]

In another example, Oregon, as part of its Extended Producer Responsibility (EPR) program, requires large packaging producers to complete LCAs of their leading products, with financial incentives for volunteering impact data and demonstrating environmental benefits from design choices over time. This incentivizes producers to use recycled materials and to invest in recyclable or reusable designs.[n]

The advantages of developing and using state-specific data

LCA datasets and tools are developed using a combination of average and source-specific data inputs. Agencies and industries across the nation are increasingly recognizing the value of developing regional- or state-specific data to support effective policy implementation. Under industrial decarbonization strategies like 'Buy Clean, Buy Michigan,' state-specific data would allow high-performing industrial actors to more accurately characterize their impacts, differentiate themselves from their competitors, and be rewarded for it – in other words, state-specific data can support the competitiveness of Michigan's manufacturers. Similarly, many states now evaluate the climate impacts of their materials management programs, particularly those focused on organic materials, which are sensitive to factors like collection logistics, processing techniques, and climatic conditions.

California, New Mexico, Oregon, Vermont, and New York have all developed state-specific LCA data for categories that include energy supply chains, waste management, water treatment, manufacturing, and raw material extraction. For a list of example policies, programs, or projects developed around state-specific LCA data, see Table A: Examples of state-specific LCA initiatives, below.

[i] For example, 33 states have long-term renewable or clean energy goals focused on reducing carbon emissions, according to "State Renewable Portfolio Standards and Goals," National Conference of State Legislatures, last updated August 13, 2021.

[j] "State Inventory and Projection Tool," U.S. Environmental Protection Agency, accessed October 2026.

[k] "Consumption-Based Emissions Inventory Summaries for Selected U.S. States: 2012-2019," U.S. Environmental Protection Agency, Office of Research and Development, last updated January 8, 2025.

[l] "Guidelines To Determine Life Cycle Greenhouse Gas Emissions of Clean Transportation Fuel Production Pathways Using 45ZCF-GREET," U.S. Department of Energy, Office of Critical Minerals and Energy Innovation, September 2026.

[m] "Clean Transportation Fuel Program," New Mexico Environment Department, updated September 8, 2026.

[n] "Life Cycle Evaluation," Oregon Department of Environmental Quality, accessed October 2026.

Using LCA to mitigate risk and support competitiveness for Michigan's manufacturers

Beyond in-state decarbonization priorities, policies enacted in jurisdictions outside Michigan indicate an increasing trend towards LCA-driven environmental disclosure programs that can affect the competitiveness of Michigan's manufacturers. Domestic examples include 'Buy Clean' policies or low-carbon fuel standards, while the current dominating international pressure on U.S. manufacturers is the European Union's Carbon Border Adjustment Mechanism (CBAM).[o]

Ensuring the availability of data resources to support disclosure under these programs is essential for mitigating risk and protecting Michigan's industrial competitiveness into the future. These data should be publicly available and auditable, centrally maintained, regularly updated, and conformant with international standards. By normalizing the reporting of LCA data across the state, Michigan industry will become more resilient to emerging policy landscape changes.

Next steps for adopting LCA frameworks in Michigan

Establishing baselines, directing funding, setting incentives, comparing technologies, and informing decisions will require an assortment of data resources. There are various ways that state and industry leaders can get started. For example, the state of Michigan could perform data needs and gap assessments for major LCA data required across the policy measures described in this roadmap and the greater MI Healthy Climate Plan.

Using this information, policymakers and agencies planning and implementing these decarbonization strategies can focus on developing and curating quality life cycle data.
This could include:

- Identifying overlaps in data needs across emissions reduction programs
- Engaging with the parties responsible for developing or reporting data to ensure quality data submissions
- Developing robust plans for data reproduction, access, and management
- Utilizing data quality frameworks to ensure high data quality and accuracy to support decision making

Quality data will better inform policymakers on how the policies and strategies are reducing emissions in Michigan.

Eastern Research Group, Inc. (ERG) is an environmental consulting firm that supports a variety of public work including air, water, climate, clean transportation and materials management. ERG's life cycle services division pioneered the application of LCA in American contexts 40 years ago and has since used this expertise to lead data and tool development, program development, and strategic planning.

[o] "Carbon Border Adjustment Mechanism (CBAM)," European Commission, Taxation and Customs Union, accessed October 2026.

Table A *Examples of state-specific LCA initiatives.*

POLICY TYPE	STATE / AGENCY	PROGRAM	GOALS OF LCA APPLICATION
Building Code	**California**	CALGreen	Establishes a first-in-the-nation green building code, for public and private construction projects.
'Buy Clean'	**California**	Buy Clean California Act	Enable informed public procurement of low-carbon materials and goods.
CBEI	**Oregon**	Oregon Consumption Based Emissions Inventory (CBEI)	Develop a state-specific consumption based emissions inventory to evaluate impacts associated with goods and services consumed within the state's borders.
CBEI	**USEPA**	Consumption-Based Emissions Inventory Summaries for Selected U.S. States, 2012-2019	Develop methods and results for consumption-based emissions inventories of all U.S. states (including Michigan), providing state-specific goods and services emission factors.
Energy	**New York**	NYSERDA Energy Sector Greenhouse Gas Emissions under the New York State Climate Act: 1990-2022	Develop high-resolution life cycle greenhouse gas emissions data for the New York state energy system. Analysis was limited to fossil and bio-based fuels.
Energy	**Vermont**	Vermont Energy Sector LCA	Develop a set of state-specific upstream emission factors to complement direct combustion factors offered by the EPA State Inventory Tool (SIT) for energy pathways consumed in the state of Vermont. This spans fossil, renewable, and nuclear sources of energy.
EPR	**Oregon**	Extended Producer Responsibility (EPR) Program	Require "life cycle evaluation" of applicable products to demonstrate environmental benefit and issue ecomodulated fee discounts.
Fuel (CFS)	**California**	Low Carbon Fuel Standard	Develop a version of Argonne National Laboratory's GREET specific to the state of California (CA-GREET). This tool is used by the state to estimate carbon intensities of fuels sold across the state and set annual reduction schedules.
Fuel (CFS)	**New Mexico**	Clean Transportation Fuel Program	Develop a version of ANL's GREET specific to the state of New Mexico (NM-GREET). This tool will be used by the state to estimate carbon intensities of fuels sold across the state and set annual reduction schedules.
Fuel (CFS)	**Oregon**	Clean Fuels Program (CFS)	Develop a version of ANL's GREET specific to the state of Oregon (OR-GREET). This tool will be used by the state to estimate carbon intensities of fuels sold across the state and set annual reduction schedules.
Fuel (CFS)	**Washington**	Clean Fuel Standard CFS	Develop a version of ANL's GREET specific to the state of Washington (WA-GREET). This tool will be used by the state to estimate carbon intensities of fuels sold across the state and set annual reduction schedules.
Corporate	**California**	Climate Corporate Data Accountability Act (SB 253)	Requires companies generating over $1B in revenue to disclose Scope 1, 2 and 3 emissions. Scope 3 will require use of relevant LCA data to calculate emissions associated with the company's value chain such as those embodied in purchased goods and services.

CORE POLICIES AND SUB-POLICIES

Building on cross-cutting infrastructure, the remainder of this policy roadmap identifies a core set of policies with the greatest potential to address key barriers to industrial decarbonization in Michigan. Additional policies considered through roadmap development are considered complementary and identified below as sub-policies under the relevant core policies.

Industrial modernization and decarbonization grant program

RECOMMENDATION:

Michigan should establish a recurring grant program to support industrial modernization and decarbonization activities to help manufacturers implement projects that reduce GHG emissions while supporting the long-term competitiveness of Michigan's industrial sector. The program should build on MI Healthy Climate Challenge #4 by clarifying a standardized pathway from project identification and assessment to implementation.

The program should focus public funding on projects where support can materially accelerate investment in emissions-reducing technologies, including projects that face high upfront costs, aim to replace emissions-intensive equipment before end of life, and build towards involving emerging technologies and applications.

PROGRAM DESIGN:

- **Eligible projects** Funding should support implementation of industrial energy and emissions-reducing projects including industrial heat electrification, energy and material efficiency, process optimization, waste heat recovery, thermal energy storage, other replacement or early retirement of emissions-intensive equipment or infrastructure, and other commercially available technologies that achieve reductions in GHG emissions. Emerging technologies, low-carbon fuels, and carbon capture should be eligible in later or separate funding rounds where such projects could provide a pathway for reducing remaining hard-to-abate emissions. The state could encourage implementing facilities to participate in the Michigan ICIP to strengthen the assessment-to-implementation project pipeline.
- **Deployment and demonstration.** The program should include both an initial commercial deployment track for proven technologies facing capital or implementation barriers and a demonstration pathway for early commercial technologies. Demonstration projects should be required to share performance/savings data.
- **Small and mid-size manufacturers.** Michigan should establish a pathway for small and mid-size manufacturers to participate, including reduced cost share, simplified application assistance, and/or further development assistance. Smaller facilities typically lack the engineering, application expertise, and capital available to larger manufacturers.
- **Project prioritization.** Awards should evaluate GHG reductions and cost effectiveness as priorities, in addition to possible private investment to be leveraged, competitiveness, project scalability, technology advancement, local air quality and community benefits, and workforce benefits. Project selection should consider the potential to demonstrate technologies that can deliver greater emissions reductions over time.
- **Provide recurring support** The program should be designed as a recurring, multi-year source of funding instead of a standalone grant. Industrial projects and corporate decisions

typically need long planning, budgeting, permitting support, and equipment replacement cycles – meaning that predictable funding is essential. Michigan should provide recurring appropriations or establish a dedicated funding mechanism so that manufacturers can incorporate state support into long-term capital planning and the state can build on learnings for future funding rounds.

FUNDING AND ADMINISTRATION:

Michigan should aim to initially fund the program at no less than $25 million and should then evaluate demand, project performance, and additional needs following the first rounds. Funding should be designed to leverage private capital and allow recipients to combine grants, where possible, with utility incentives, federal incentives, C-PACE, and other financing mechanisms. Larger commercial projects should typically include significant recipient cost share.

The Legislature should establish the program and a dedicated funding mechanism while providing the administering agency flexibility to update eligible technologies and selection criteria as industrial technologies evolve. EGLE-OCE should serve as the lead administrator, in coordination with MEDC, utilities, MPSC, and workforce agencies.

COMPARABLE PROGRAMS IN OTHER STATES:

See Table 2.

SUPPORTIVE ACTIONS:

To maximize the effectiveness of the grant program, Michigan should:

- Create an assessment-to-implementation pathway, including GHG quantification and reduction screenings.
- Provide project and permitting navigation, and enable funding to be stacked.
- Coordinate major electrification projects with utilities.
- Use demonstrations to build a Michigan project pipeline.

FINANCING SUB-POLICIES:

An industrial grant program is not the only way that Michigan can financially support or incentivize industrial decarbonization investments. While recognizing that the list of financing options presented here is not comprehensive, this section describes several further opportunities to improve the economic feasibility of decarbonization projects for interested companies, that are based on financing structures that already exist either in Michigan, the United States, or abroad. They are organized roughly based on the amount of additional capacity, funding, and/or expertise that might be necessary to implement them. For example, while a revolving loan fund is quite similar to existing state programs and requires less up-front capitalization due to its regenerative nature, a carbon contract for differences would require substantial background research, dedicated personnel, and significant capital investment for effective implementation.

Revolving Loan Fund A revolving loan fund (RLF) to support industrial decarbonization project implementation provides a self-sustaining option for long-term project financing to follow on after first-movers are supported through the proposed industrial modernization and decarbonization grant program. An RLF is a source of capital that makes direct loans that are

generally, but not always, long term and low interest. Proceeds from loan repayments are then recycled and made available for lending again. RLFs are an attractive financing option for ***Table 2***smaller businesses seeking cheap credit for energy efficiency and clean energy projects. Michigan should establish clear criteria (the same as those established in *Common carbon accounting and project evaluation metrics*) by which proposals would be evaluated, which may include cost efficiency, the degree of emissions reductions or energy savings, or innovation, to ensure financed projects are consistent with state decarbonization goals.

Similar programs in several other states, such as the Illinois Finance Authority/Climate Bank Energy Efficiency Revolving Loan Fund, can serve as examples for implementation. This particular fund is specifically designed as bridge funding to support customers looking to move forward with projects without needing to wait for tax credits or other incentives to kick in. Loans are less than $1 million, and the loan term is typically 12 to 18 months.

Additionally, EGLE already operates the Clean Water State Revolving Fund (CWSRF) within Michigan. The CWSRF combines state and federal funds to fund a range of water infrastructure projects. The expertise from managing this program would be invaluable in guiding the design of proposal criteria, budgeting, and program administration for an industrial decarbonization RLF. One barrier may be identifying a source of initial fund investment, because grants from the U.S. DOE or EPA may not be forthcoming. While the Illinois fund was initially financed with a $14 million investment from a U.S. DOE grant, other strategies exist. For example, Montana funds their RLF through air quality violation penalties. A 'Cap and Invest' program is another alternative funding mechanism.

Expansion or Replication of Pollution Prevention (P2) Grants. The P2 program is a federal grant program that supports manufacturers in decreasing their material, water, or energy use, reducing their carbon footprint, and saving on operating expenses. P2 grants are traditionally smaller in value ($10,000-$100,000+) and require a cost match of up to 50%. EPA provides free online calculators for grantees to use for reporting project outcomes, reducing the administrative burden for grantees and program administrators.

The design of P2 supports other priority policies as well, through workforce development and information sharing. Case studies and fact sheets highlighting successful P2 interventions are available on EPA sites.[137] Facilities that are required to report to the Toxics Release Inventory can also report P2 activities in their annual forms, providing a source of guidance for other businesses seeking to reduce waste, energy use, and emissions. Additionally, P2 technical assistance centers often hire student interns to support program implementation, providing an avenue for training and upskilling.[138]

This program could be enhanced with additional funds from the state of Michigan, or given the uncertainty of federal grant dollars, fully replicated at the state level. EGLE has run a similar funding program with loans instead of grants through the Small Business P2 Loan Program, which provided loans of up to $400,000 at rates up to 5%.[139] This program expertise could be leveraged to guide design elements such as project and business eligibility criteria and to connect potentially interested parties with relevant program information.

Expansion of C-PACE. Commercial Property Assessed Clean Energy financing for commercial properties has already been enabled and implemented via Michigan legislation. PACE allows property owners to finance up to 100% of up-front clean energy or energy efficiency project costs and to repay through a special property tax assessment. The amount of PACE financing

[137] "P2 Resources Search," U.S. Environmental Protection Agency, accessed September 2026.

[138] "P2 Technical Assistance Providers," U.S. Environmental Protection Agency, accessed September 2026.

[139] "Small Business Assistance Program," Michigan Department of Environment, Great Lakes, and Energy, accessed September 2026.

that a property is eligible for is determined by the property's value after the project has been completed, with the assessment-to-value ratio limited to 25%. PACE financing can have lower interest rates due to the high rate of payment on property taxes — only one project default had been reported nationally as of 2020. Repayment takes place over a longer period than traditional loans — up to 25 years — and the assessment can be transferred during sale of the property, reducing the risk of clean energy investments and allowing for positive cash flow. Michigan statute has expanded PACE to include water contamination mitigation, lead paint abatement, and projects that increase property resilience, which could support complex climate mitigation and adaptation projects at industrial properties.

While industrial properties are eligible for C-PACE, there has been less uptake of this financing mechanism for such properties, with less than 20% of PACE financing typically going to industrial projects in Michigan. Some examples of projects on this type of property do exist. In 2016, Heller Machine Tools of Troy was the first manufacturing company in Michigan to utilize PACE, financing a deep energy retrofit to reduce energy expenses and waste.[140] Additionally, under Michigan statute, recently completed facility upgrades that would qualify for PACE can also be refinanced with PACE to establish long-term financing. Powers Distributing utilized PACE to refinance a 95-kW solar installation and lighting upgrades.[141]

Several barriers may prevent industrial properties in Michigan from securing PACE financing, such as challenges in acquiring mortgage holder consent, limitations related to lower property value, uncertainty surrounding manufacturing equipment being categorized as real or personal property, or a bias among lenders towards large-scale projects. Michigan EGLE should work with in-state PACE financiers and program administrators to address barriers to uptake within industrial properties. Michigan policymakers could also consider revising the assessment-to-value ratio for certain properties or separately exploring whether PACE financing could support the use of lower-carbon construction materials.

Carbon Contracts for Differences. Carbon Contracts for Differences (CCfD) are long-term agreements that provide financial support for industrial emissions reductions by covering the gap between the cost of low-carbon production and alternatives — usually through a contractually agreed carbon price. CCfDs are dynamic, adjusting based on changes in market or carbon prices so that governments and taxpayers are not overpaying for emissions reductions. The subsidy can be either one-sided or two-sided,[142] where one-sided systems only involve payments made in the direction of the participating companies, while two-sided systems require businesses to pay the government back when market conditions are more favorable than the contract terms. The subsidy can also have ceiling and floor prices, which limit the amount paid in either direction. These long-term contracts send a consistent market signal to encourage investors and industry to take serious steps supporting decarbonization. Several countries, including the United Kingdom, the Netherlands, and Germany, have implemented similar policies.

The design of the German two-sided CO_2-Differenzverträge system appears to be well aligned with Michigan's industrial decarbonization targets. The first round of the subsidy has enrolled 15 projects with total compensation upwards of 2.8 billion euros. Contracts are awarded via

[140] "Heller Machine Tools," Lean & Green Michigan, June 2016.

[141] "Powers Distributing: Beer distributor uses PACE financing," Lean & Green Michigan, January 2016.

[142] "Carbon Contracts for Difference (CCfDs) as an instrument of choice: Bridging the funding gap for EU Energy Intensive Industries (EIIs)," Deloitte, November 2024.

reverse auction, prioritizing projects that promise the greatest emissions reductions for the lowest cost to promote effective utilization of public funds. Penalties are incurred if contracted emissions reductions are not achieved or if the company leaves the country, dissuading dishonest bids and further ensuring effective decarbonization. Michigan policymakers would need to make decisions about which industry sectors would be eligible, what emissions reductions thresholds to require, and whether to employ a one- or two-sided system with or without ceiling and floor pricing.

One complaint about the German system is that it was specifically designed to target the largest emitters, with a minimum project spend of EUR 15 million and minimum emissions reduction potential of 5 kT CO_2 per year (revised down from 10 kT in the first auction). To support small and mid-size manufacturers with this type of subsidy, Michigan could design a tiered system with varying thresholds. One potential barrier to this policy would be that it has primarily been implemented in countries where it could be paired with a carbon tax or cap and trade system, slowly driving up the 'gray' energy price to eventually converge with the 'green' energy price, which Michigan does not have. Michigan should evaluate whether a CCfD program can be designed to operate on a stand-alone basis and funded through state appropriations, rather than as an add-on to a carbon pricing program.

Table 2

INDUSTRIAL MODERNIZATION AND DECARBONIZATION GRANT PROGRAM			
STATE	**PROGRAM**	**FUNDING AMOUNT**	**RELEVANT FEATURES**
Minnesota	• Climate Smart Food Systems (CSFS) Industrial Innovation Technical Assistance and Implementation Grants	• Included $7.2 million in grant funding for technical assistance and planning[a] and $40 million for implementation (allocated by project size)[b] • Funded through the U.S. EPA Climate Pollution Reduction Grant program (CPRG)	• Capital expenditure grant program to improve operational efficiency, reduce OPEX, and decrease environmental impacts by reducing GHG emissions, criteria and hazardous air pollutants, and waste • Eligible projects must reduce GHG emissions through reduction of either utility energy demands or waste • Eligible facilities include food and beverage manufacturers and food system organic waste processors • Grant recipients must match at least 40% of project costs, exclusive of other federal funding
Pennsylvania	• Reducing Industrial Sector Emissions in Pennsylvania (RISE PA)[c]	• $396 million program funded through U.S. EPA CPRG • Second round of small-scale awards provided $3.5 million to support 15 projects[d] • Medium- and large-scale grants gave over $258 million to 28 grantees[e]	• Offers grants for small-, medium-, and large-scale projects at industrial facilities to reduce GHG and co-pollutant emissions • Eligible projects include industrial electrification, energy efficiency and process emissions reductions, fuel-switching, renewable energy installation, and CCS • Supports fugitive emissions reduction projects at fossil fuel facilities • Renewable energy installations constitute the most common project type in the medium- and large-scale category
New York	• Buy Clean Concrete[d]	• N/A	• EPD requirement and GWP thresholds for concrete • Covers only concrete mixes, works alongside state Executive Order 22 (2023) • GWP limits reflect 150% of the Eastern Region average figures • 3-phase implementation, starting with voluntary limits and EPDs • GWP limits to be revised in 2027 with state-specific data
California	• Industrial Decarbonization and Improvement of Grid Operations (INDIGO)	• Total expenditure of $68 million with $6.8 million for administrative costs and $61.2 million for the incentives[f]	• Distributed through a statewide competitive application processg • Emphasis on projects located in and benefiting disadvantaged or low-income communities • Eligible projects include energy efficiency, grid reliability, electrification of fossil fuel processes, energy storage, renewable resources, or deployment of novel decarbonization technologies • Projects benefiting oil and gas production, processing, or refining are ineligible

[a] "CSFS: Industrial innovation in food systems - technical assistance and planning (TAP)," Minnesota Pollution Control Agency, accessed October 2026.

[b] "CSFS: Industrial innovation in food systems - implementation," Minnesota Pollution Control Agency, accessed October 2026.

[c] "Reducing Industrial Sector Emissions in Pennsylvania (RISE PA)," Commonwealth of Pennsylvania Energy Programs Office, accessed October 2026.

[d] "Shapiro Administration Invests Nearly $3.5 Million to Help Small Businesses Cut Energy Costs and Reduce Air Pollution Across Pennsylvania," Commonwealth of Pennsylvania Department of Environmental Protection Newsroom, August 2026.

[e] "RISE PA MAT/LAT Grant Awardees Dashboard," Commonwealth of Pennsylvania Department of Environmental Protection, accessed October 2026.

[f] "California Energy Commission Expenditure Record for Industrial Decarbonization and Improvement of Grid Operations Program," California Energy Commission, December 2025.

[g] "Industrial Decarbonization and Improvements to Grid Operations (INDIGO)," California Energy Commission, October 2025.

Clean heat production tax credit

RECOMMENDATION:

Michigan should establish a clean heat production tax credit to provide predictable, performance-based support for industrial facilities that produce or use qualifying low- or no-carbon thermal energy. The credit should reduce the operating cost gap between fossil fuel generated heat and lower-carbon alternatives, and should provide manufacturers with greater long-term certainty when evaluating investment opportunities.

The credit should complement Michigan's industrial modernization and decarbonization grant program and other financing mechanisms by addressing operating cost gaps, leaving grants to serve reductions in upfront capital costs. Together, they can improve both the upfront and long-term economics of industrial decarbonization projects. Michigan should consider establishing an overall program funding cap and phasing down credit values over time, with higher levels of support available to early projects. The state should also evaluate long-term funding mechanisms, including potential future 'Cap and Invest' revenues, to support the program as implementation progresses.

PROGRAM DESIGN:

- **Performance-based credit.** The credit should be tied to the amount of qualifying low-carbon thermal energy produced or used. A production-based structure rewards project performance and provides ongoing support for technologies that face operating cost disadvantages.
- **Eligible technologies** Eligibility should be technology neutral within the bounds of emissions performance requirements. Potential qualifying technologies could include industrial heat pumps, electric boilers, geothermal and solar thermal systems, recovered waste heat, high-efficiency combined heat and power, and low-carbon fuels. Criteria for eligibility should include life cycle emissions, technology readiness level, and pollutant mitigation, and should be evaluated by a robust stakeholder process.
- **Credit value and emissions performance.** The state should evaluate whether the credit should provide a uniform incentive or vary based on emissions performance. An emissions-based structure could provide greater support for technologies that produce larger GHG reductions.
- **Long-term certainty.** The credit should be available for a multi-year period so that manufacturers can incorporate expected support into investment decisions and because of the long timelines of many decarbonization projects. Program rules should aim to provide certainty for capital planning while ensuring that eligibility standards for new projects strengthen as technologies and markets develop. Projects that qualify for the credit should retain eligibility at the qualifying credit value for the full credit period.
- **Interaction with other incentives.** The credit should be designed to complement grants, utility incentives, financing, and available federal support. Other financing should be used for upfront costs while the PTC can address operating cost barriers.
- **Small and mid-size manufacturers.** Program design should make sure that smaller manufacturers can access the credit, including consideration of refundability, or transferability if companies lack the tax liability to access the full value of the credit.

FUNDING AND ADMINISTRATION:

The Legislature should establish the tax credit, eligibility, duration, and fiscal controls. Michigan should conduct additional analysis to establish the initial credit value, estimate potential uptake and economic impacts.

EGLE-OCE should establish technical and emissions performance criteria in coordination with the Michigan Department of Treasury, while Treasury would administer the tax credit. MPSC, utilities, MEDC, and other relevant agencies should coordinate where projects also receive utility or state support.

The program should include scheduled reviews of technology costs, electricity and fuel prices, emissions performance, and market factors to determine whether credit levels or eligibility criteria should be adjusted.

COMPARABLE PROGRAMS IN OTHER STATES:

See Table 3.

SUPPORTIVE ACTIONS:

To maximize the effectiveness of the clean heat PTC, Michigan should:

- Establish common life cycle GHG accounting and eligibility criteria.
- Coordinate the credit with industrial electrification tariffs and utility programs.
- Allow stacking with grants and financing.
- Support technical assistance to identify suitable clean heat applications.
- Coordinate deployment with electric and gas system planning.

Table 3

CLEAN HEAT PRODUCTION TAX CREDIT			
STATE	**PROGRAM**	**FUNDING AMOUNT**	**RELEVANT FEATURES**
Federal	• A variety of Production Tax Credits were implemented under the Inflation Reduction Act (IRA) (but are now inactive)	• §45U - Estimated reduction in revenue of $2.6 billion per year from FY 2024 – 2028[a] • §45V - Estimated reduction in revenue of $400 million from FY 2025 to FY 2029[b] • §45Z - Estimated cost of $2.8 billion per year for the three years it is in effect[c] • §45X - Estimated reduction in revenue of $20.1 billion from FY 2025 to FY 2029[d]	• Applied to a variety of clean technologies, including legacy renewables (§45), nuclear energy (§45U), clean hydrogen (§45V), and clean transportation fuels (§45Z), as well as advanced manufacturing components (§45X) • All except §45X required Prevailing Wage and Apprenticeship compliance to capture maximum credit value • Credit earned per kWh of electricity sold or per component manufactured and sold • Included bonuses for projects in Energy Communities or meeting Domestic Content requirements
Minnesota	• Sustainable Aviation Fuel (SAF) Tax Credit[e]	• Allocate up to $11.6 million in credits	• $1.50 for each gallon of SAF that is both produced and sold in the state to be used in an aircraft departing from an airport within the state • Must produce SAF, or blend SAF with aviation, gasoline, or jet fuel • Available until 2030
Energy Innovation (Proposal)	• Clean Industrial Heat Production Tax Credit Policy Design Brief[f]	• Modeled effective clean heat PTC rate for Michigan was $12.10/MMBtu[g]	• Refundable tax credit ("direct pay"), meaning a firm receives the credit regardless of whether it has enough net tax liability • Should exclusively apply to heat used for industrial processes at facilities falling under NAICS codes 31–33 • Should be based on delivered heat, not total input energy, to avoid penalizing efficient technology • Adjusts credit rate by temperature • Excludes waste heat, byproducts, and biomass

[a] N. Buffie, "Nuclear Power Tax Credits," U.S. Congress, June 4 2025.

[b] N. Buffie and M. Offutt, "The Section 45V Clean Hydrogen Production Credit," U.S. Congress, March 30, 2026.

[c] N. Buffie, "The Section 45Z Clean Fuel Production Credit," U.S. Congress, February 18, 2025.

[d] N. Buffie, "The Section 45X Advanced Manufacturing Production Credit," U.S. Congress, August 13, 2026.

[e] "41A.30 SUSTAINABLE AVIATION FUEL; TAX CREDITS," Minnesota Legislature, accessed October 2026.

[f] J. Rissman, "A Production Tax Credit for Clean Industrial Heat," Energy Innovation, July 2024.

[g] H. Thonet, A. Jobe, et al., "Accelerating Industrial Clean Heat with a Production Tax Credit," RMI, July 2026.

Industrial electrification tariffs

RECOMMENDATION:

Michigan should direct or encourage the MPSC to investigate and establish electric rate structures designed for new or converted industrial loads that offset fossil fuels. Effectively-designed tariffs have the potential to improve the economics of industrial electrification by ensuring that rates, including demand charge structures, accurately reflect the cost of serving these loads and by recognizing the load characteristics and grid benefits of industrial electrification technologies.

Tariffs should be based on the costs of serving participating loads and should not shift costs to nonparticipating customers, including other customers within the same rate class. Utilities should retain a reasonable opportunity to recover infrastructure and service costs associated with new loads from the participating customers whose loads cause those costs, with contract terms and credit support proportional to the size and risk of the load. Rate structures should also provide predictability for manufacturers to incorporate expected electricity costs into long-term investment decisions. Industrial electrification tariffs should be developed within existing cost-of-service and production cost allocation frameworks and should not be used to alter the cost allocation methodologies applied to other customers.

Also see: *GET THE FACTS: Electric rate structures are key to unlocking industrial electrification potential*.

PROGRAM DESIGN:

- **Eligible loads** New rate structures should focus on new or converted industrial electric loads that offset or replace fossil fuel use and provide energy or GHG reductions. Potential applications include industrial heat pumps, electric boilers, thermal energy storage, and other electrified loads.
- **Rate design based on costs** Rates should reflect the costs that participating loads create for the grid, including generation, transmission, distribution, and infrastructure investments.
- **Demand charges** The MPSC should investigate whether existing demand charges reflect the cost of serving electrified industrial thermal loads, especially where technology-enabled flexibility, storage, or other characteristics reduce system costs. Any modifications should reflect cost causation and avoid unjustified cost shifts to other customers, while allowing flexibility in rate design to recognize the system benefits of electrified industrial loads.
- **Time-of-use and fl xible rates.** Rates should encourage consumption during periods when electricity is less expensive or the grid has available capacity. Rate design should account for differences in industrial customers' operational flexibility.
- **Interruptible and demand response options** Utilities should expand opportunities for industrial customers to participate in interruptible rate and demand response programs that compensate them for providing grid flexibility and reducing system costs.
- **Clarific tion.** The MPSC should clarify how existing efficient electrification authority applies to industrial customers and should address regulatory barriers to industrial participation in utility electrification programs. This would complement the development of industrial electrification-specific tariffs.

IMPLEMENTATION AND ADMINISTRATION:

Initially, the MPSC should open a proceeding, with opportunities for participation by industrial customers and other interested parties, to investigate industrial electrification loads, existing rate barriers, cost of service implications, and potential tariff designs. The investigation should create load profiles to represent industrial heat pumps, electric boilers, thermal energy storage, and other industrial electrification applications and should evaluate their impacts under existing rates.

The investigation should also examine:

- Where industrial loads can provide system benefits through flexible operation.
- Where existing transmission and distribution capacity may allow new loads to interconnect at low incremental cost.
- How tariffs for new industrial loads can recover incremental service costs, contribute to fixed system cost recovery, and potentially reduce costs for other customers.

Utilities should be identify infrastructure needs, operational barriers, and industrial electrification opportunities, as surfaced through the cross-cutting integrated planning process. Utilities could then propose pilots or tariffs for MPSC consideration in proceedings that provide opportunities for affected customers to participate.

Michigan context: Michigan's 2023 clean energy legislation (including 2023 PA 229, amending 2008 PA 295) established a framework for utilities to offer efficient electrification measures, but statutory requirements and differing interpretations of how the law may apply in practice may constrain explicit utility support for industrial electrification.

COMPARABLE PROGRAMS IN OTHER STATES:

See Table 4.

SUPPORTIVE ACTIONS:

To maximize the effectiveness of industrial electrification tariffs, Michigan should:

- Include tariff recommendations in state-supported industrial assessments and project navigation.
- Coordinate major electrification projects with utility system planning.
- Enable grants and clean heat incentives to complement tariffs.
- Support thermal storage and other flexible load technologies.
- Evaluate opportunities for industrial energy sharing and co-location.

ELECTRIFICATION SUB-POLICIES:

Expand or clarify EWR treatment of fuel-switching and efficient electrifi tion. Michigan's Energy Optimization framework requires utility Energy Waste Reduction (EWR) plans and provides a foundation for efficient electrification measures. However, there is significant uncertainty around how provisions apply to industrial fuel-switching, including whether industrial projects are eligible for support. Additional clarity is needed around how qualifying

projects should be evaluated, including cases of increased electricity consumption, reductions in fossil fuel use and total energy consumption, life cycle GHG benefits, cost effectiveness, and impacts on other customer classes. Uncertainties can make it difficult for utilities and industrial customers to develop programs and plan projects.

Greater regulatory clarity around industrial fuel-switching and efficient electrification could complement industrial electrification rate reform. EWR or efficient electrification programs could help reduce upfront project and equipment costs, while electrification-focused industrial tariffs could address operating costs. The MPSC could work with utilities and other stakeholders to clarify how requirements apply to industrial projects and identify where statutory changes may be needed to enable industrial participation. The MPSC should clarify how industrial efficient electrification projects can participate in utility programs, including through existing large customer self-directed EWR provisions, while ensuring protections for nonparticipating customers.

Industrial energy sharing and co-location. Industrial clusters can create opportunities to share waste heat, steam, storage, electricity, and/or other infrastructure between facilities. Shared systems could support the recapture of otherwise wasted energy and reduce infrastructure costs that may be prohibitive for individual facilities. Potential technology deployment depends heavily on proximity, compatibility, infrastructure costs, permitting, and utility requirements. Michigan should evaluate regulatory barriers to energy sharing among co-located industrial facilities.



A utility-scale battery energy storage system (BESS) project.

Michigan could begin with a statewide industrial cluster mapping initiative to identify locations with high potential for shared infrastructure, including existing industrial concentrations and brownfield redevelopment sites. This could be followed by planning and early demonstration grants in the identified locations to evaluate technical feasibility and test approaches to governance, financing, utility coordination, and community engagement.

New industrial electrification tariffs could complement clusters by recognizing the potential system value of shared or coordinated loads, including opportunities to manage demand across multiple facilities or assets. Initial projects could prioritize opportunities that align with other state objectives, including 'Buy Clean, Buy Michigan,' circular materials, and brownfield redevelopment. State-supported projects could also incorporate community benefit agreements to ensure that communities participate in project planning and benefits.

Incentives for large C&I battery energy storage system use and recycling. Behind-the-meter battery energy storage systems (BESS) can help industrial facilities manage new or increasing electric loads by reducing peak demand, shifting electricity use to low-cost periods, and providing backup power. Batteries can also enable participation in demand response or other utility programs. When paired with on-site renewable generation, such as solar photovoltaics, BESS can also help facilities use more of their generated electricity and align generation times with demand.

Michigan could consider targeted incentives for large commercial and industrial BESS, with incentive levels tied to peak reduction, load shifting, or dispatchability. Programs could prioritize batteries paired with industrial electrification projects where storage helps address demand charges or infrastructure concerns. Industrial electrification tariffs should be designed with incentives in mind so that rate structures value load shifting and encourage investment in storage.

Massachusetts has a program that could be emulated in ConnectedSolutions, a demand response program that provides performance-based payments to customers with battery storage for reducing grid demand during peak periods.[143] Program design should also address battery safety and end of life, including support for reuse and recycling.

[143] "ConnectedSolutions," Mass Save, 2026.

Table 4

INDUSTRIAL ELECTRIFICATION TARIFFS			
STATE	**PROGRAM**	**FUNDING AMOUNT**	**RELEVANT FEATURES**
Oregon	• Flexible Load Multi-Year Plan[a]	• Energy Partner on Demand Schedule 26: around $6 million per year in 2025-26 • Energy Partner Commercial Thermostats Schedule 25: around $1.5 million annually in 2025-26	• Enables commercial, industrial, and SME customers to contribute to VPP goals • Provides incentives for thermal batteries and controllable industrial heat pumps • Schedule 26 incentivizes custom load curtailment strategies and event-based energy shifts at large commercial and industrial partners • Schedule 26 customers can participate in up to 20, 40, or 80 hours of events per season and select one or more event windows based on time of day and season • Schedule 25 is a direct load control program for small and medium-sized businesses
Washington	• Time-of-use Rates available through Washington utilities	• Exact rate structures and reductions for off-peak energy use vary by utility	• Snohomish county ran a Time-of-Day pilot program for commercial and industrial customers, with the highest rates during weekday peak hours, moderate rates during weekday off-peak, and the lowest rates during weekends and nights[b]
New York	• Special Case Resource (SCR) program (NYISO) • Emergency Demand Response Program (EDRP) (NYISO) • Day Ahead Demand Response Program (DADRP) (NYISO) • Demand-Side Ancillary Services Program (DSASP) (NYISO)[c] • Commercial System Relief Program (CSRP) (National Grid) • Distribution Load Relief Program (DLRP) (National Grid) • Term- and Auto-DLM programs (National Grid)[d]	• Variable, depending on frequency of demand response events • For example, in 2024, NYISOs SCR program paid over $7.5 million across four demand response events	• Programs exist for NYISO and National Grid customers. If eligible, customers may be enrolled in both, but during overlapping events benefits may be reduced • National Grid demand response events occur May 1-Sep 30 • Certain programs relevant only during the weekday, while others may occur seven days per week • National Grid has a specific direct application process for customers who can reduce load by >50 kW • SCR and EDRP are now mutually exclusive, which has severely reduced participation in the EDRP program • National Grid programs have both reservation and voluntary payment options, where reservation customers commit to providing a set amount of curtailment during events and incentives are higher for these customers, while voluntary programs provide more flexibility. Reservation payments are given regardless of whether demand response events occur

[a] "Flexible Load Multi-Year Plan 2025-2026," Portland General Electric, December 2024.

[b] "SUPPLEMENTAL "TIME OF DAY" SERVICE SCHEDULE," Snohomish County PUD No. 1, December 2024.

[c] "NYISO Demand Response Programs Frequently Asked Questions (FAQs) for Prospective Resources," New York Independent System Operator, Inc. (NYISO), December 2020.

[d] "Save energy and earn financial incentives with Electric Demand Response," National Grid, March 2025..

'Buy Clean, Buy Michigan'

RECOMMENDATION:

Michigan should establish a phased 'Buy Clean, Buy Michigan' program that uses public purchasing power to create demand for lower-carbon construction and manufactured materials. The state should evaluate existing statutory authority and, where necessary, pursue legislation to establish the program, designate implementation responsibilities, and provide funding for agency capacity and technical assistance.

The program should establish a consistent statewide framework while allowing implementing agencies flexibility to develop procurement approaches designed for their respective projects and purchasing processes. Initial implementation should prioritize high-volume, emissions-intensive materials, including steel, cement, concrete, asphalt, glass, and tires, with opportunities to expand to additional materials and sectors as data, standards, and supplier capacity develop.

Implementation should start with improved emissions transparency, development of Michigan supplier and product baselines, and supplier capacity building before introducing emissions performance requirements. The state should pair procurement requirements with technical assistance and incentives that help Michigan manufacturers measure embodied emissions, develop environmental product declarations (EPDs), and invest in lower-carbon production.

Michigan should also evaluate complementary 'Build Clean' approaches that address embodied carbon during the design and planning stages of construction projects, including whole-building and whole-project life cycle assessment. These approaches can help reduce emissions through material selection, structural design, and material efficiency, while complementing 'Buy Clean, Buy Michigan' procurement requirements.

Together, these efforts should achieve measurable reductions in embodied emissions while strengthening the ability of Michigan manufacturers to compete as demand for lower-carbon materials grows within Michigan and elsewhere.

PROGRAM DESIGN:

- **Phased implementation** Michigan should implement the program in stages, starting with emissions disclosure and supplier capacity building before establishing emissions performance requirements. Initial disclosure requirements should not disqualify suppliers. Later performance requirements should provide adequate lead time and appropriate exceptions where compliant materials are not reasonably available or would materially increase project costs.
- **Environmental Product Declarations** EPDs should serve as the primary source of product-level embodied carbon information, reported through global warming potential (GWP). Michigan should establish consistent requirements for EPD quality and comparability, including product category rules, life cycle boundaries, acceptable EPD types, third-party verification, and GWP accounting methodologies. Product- and facility-specific EPDs should be encouraged where feasible. Confidential business and process information should be protected. Nonconfidential EPD and emissions baseline information should be made accessible to procurement agencies and the public to support informed purchasing decisions and transparency.

- **Supplier capacity and technical assistance.** Michigan should provide technical and financial assistance to manufacturers developing EPDs, improving emissions measurement, and identifying decarbonization opportunities, particularly small and mid-sized manufacturers, while supporting both first-time EPD producers and manufacturers interested in updating existing declarations. The state should also facilitate peer learning and knowledge sharing.
- **Project eligibility.** Both public buildings and infrastructure projects should be eligible. Initial applicability thresholds based on project size, cost, or material quantities should reflect agency capacity and supplier readiness, with opportunities to lower thresholds over time.
- **Material-specific and p oject-level emissions standards.** Michigan should develop material-specific emissions baselines and should evaluate appropriate performance requirements that reflect differences in production pathways, available technologies, and data quality. Implementing agencies should also evaluate complementary approaches, including project-level embodied carbon budgets, performance-based procurement, and incentives for projects or products that exceed established emissions targets.
- **'Build Clean '** Michigan should evaluate the phased adoption of whole-building or whole-project life cycle assessment for applicable public construction projects. 'Build Clean' requirements should complement 'Buy Clean, Buy Michigan' standards.
- **Agency implementation fl xibility.** Procurement agencies should be empowered to develop implementation approaches built around their existing purchasing processes, as long as they follow common statewide accounting, reporting, and performance principles. Agencies should receive resources and technical support to implement requirements.
- **Michigan manufacturing and sourcing.** Where consistent with procurement requirements, the program should strengthen Michigan supply chains and increase the use of qualifying Michigan-produced materials.
- **Circularity.** Procurement criteria should incorporate material efficiency, reuse, and recycled content where possible, including opportunities such as increased recycled asphalt use and greater use of recycled or secondary materials.
- **Workforce and community benefits** Michigan should evaluate opportunities to incorporate local workforce, labor, supplier diversity, and community benefit considerations into standards.

IMPLEMENTATION AND ADMINISTRATION:

Michigan should first evaluate existing statutory and procurement authority and should identify where additional legislation or administrative direction may be needed. The state should establish a 'Buy Clean, Buy Michigan' working group or implementation process, coordinated by a designated lead agency, involving state procurement and infrastructure agencies like MDOT, EGLE, MEDC, manufacturers, labor, local governments, contractors, environmental and community organizations, and other stakeholders. The lead agency should coordinate statewide EPD and emissions accounting requirements, supplier technical assistance, and related workforce development efforts.

The initial phase should identify covered procurement, establish common EPD and emissions accounting requirements, characterize Michigan supplier capacity, and develop material-specific emissions baselines. The program should establish consistent statewide requirements while allowing individual procurement agencies the flexibility needed to develop implementation approaches suited to their existing purchasing processes, supported by adequate funding and technical assistance.

State procurement should provide the initial market. Michigan should also evaluate mechanisms capable of allowing cities, counties, universities, schools, and other public entities to use aligned procurement standards over time. Existing cooperative procurement mechanisms such as MiDEAL may provide infrastructure for expanding access to consistent purchasing approaches.

Longer-term implementation could expand to additional materials, smaller state procurement projects, other public purchasers, and potentially qualifying public-private projects. Michigan should also pursue regional coordination where common standards could increase market size and reduce compliance complexity for manufacturers selling across state lines. The state should track embodied emissions, supplier participation, procurement costs, and manufacturing investment to evaluate program effectiveness and ensure that procurement requirements contribute to meaningful emissions reductions.

Michigan context: Michigan policymakers have previously considered legislation focused on evaluating low-carbon construction materials, which can serve as a foundation for a more comprehensive state procurement strategy. That bill, HB 5567, proposed that EGLE should evaluate low-carbon construction materials.

COMPARABLE PROGRAMS IN OTHER STATES:[144]

See Table 5.

SUPPORTIVE ACTIONS:

To maximize the effectiveness of 'Buy Clean, Buy Michigan,' the state should:

- Provide EPD development and carbon accounting assistance.
- Include both building and MDOT projects.
- Assess cost differences between conventional and lower-carbon materials to inform standards.
- Pair procurement with grants and financing for manufacturer decarbonization.
- Develop material-specific emissions baselines and standards.
- Coordinate workforce development with the expansion of lower-carbon manufacturing.
- Incorporate recycled and circular materials.
- Pursue alignment with local and regional procurement programs.
- Track material quantities, emissions, economic, workforce, and supplier impacts.

[144] See Carbon Leadership Forum's Buy Clean Policies Overview for additional information on state and local Buy Clean programs.

Table 5

'BUY CLEAN, BUY MICHIGAN'			
STATE	**PROGRAM**	**FUNDING AMOUNT**	**RELEVANT FEATURES**
California[a]	• Buy Clean California Act	• N/A	• Requires EPDs and applies maximum GWP limits to covered materials • Expanded from initial list of products to include concrete and asphalt • Faced implementation challenges due to lack of facility-specific EPDs
Washington	• Buy Clean and Buy Fair (BCBF)[b]	• N/A	• Includes concrete, steel, and wood • Pairs embodied carbon disclosure with manufacturing labor transparency to support responsible public procurement • The State Department of Commerce develops standards and publishes the Washington BCBF Database for transparency and consistency[c]
New York	• Buy Clean Concrete[d]	• N/A	• EPD requirement and GWP thresholds for concrete • Covers only concrete mixes, works alongside state Executive Order 22 (2023) • GWP limits reflect 150% of the Eastern Region average figures • 3-phase implementation, starting with voluntary limits and EPDs • GWP limits to be revised in 2027 with state-specific data
U S Federal Government	• Federal Buy Clean Initiative (inactive)	• $100 million grant program to support businesses developing EPDs for low-carbon products[e] • $2 billion in IRA funding for federal building projects eligible for low-embodied-carbon (LEC) materials in support of the FBCI • The U.S. DOT awarded $1.2 billion to 39 state DOTs to purchase low-carbon materials[f]	• Buy Clean Task Force established by EO to develop recommendations to incorporate consideration of embodied emissions in federal procurement and federally funded projects • Major federal contractors and suppliers required to publicly disclose emissions[g] • Buy Clean Initiative promotes use of construction materials with lower embodied life cycle emissions[h]

[a] "Buy Clean California Act," California Department of General Services Procurement Division, accessed October 2026.

[b] "Buy Clean and Buy Fair (BCBF)," Washington State Department of Commerce, accessed October 2026.

[c] "Washington Buy Clean and Buy Fair Database," Washington Department of Commerce, accessed October 2026.

[d] "NYS Buy Clean Concrete Guidelines," New York State Office of General Services, accessed October 2026.

[e] "Biden-Harris Administration Announces $100 Million in Grants to Support Manufacturers of Cleaner Construction Materials as Part of Investing in America Agenda," U.S. EPA Press Office, September 2023.

[f] "Four Years of President Biden's Federal Buy Clean Initiative," Office of the Federal Chief Sustainability Officer, Council on Environmental Quality, accessed October 2026.

[g] "Federal Supplier Climate Risks and Resilience Proposed Rule," Office of the Federal Chief Sustainability Officer, Council on Environmental Quality, November 2022.

[h] "Net-Zero Emissions Procurement by 2050," Office of the Federal Chief Sustainability Officer, Council on Environmental Quality

Expanded/targeted workforce support

RECOMMENDATION:

Michigan should expand and better coordinate existing workforce development, such as Department of Labor (DOL) registered apprenticeship training programs, to support and prepare workers for industrial modernization and decarbonization. The goal should be to strengthen the current and future worker pipeline and improve awareness of emerging industrial opportunities.

Workforce planning should be tied directly to Michigan's expected industrial investment and project pipeline so that apprenticeship programs, training providers, employers and contractors, and workers have a structured pipeline to best prepare and meet future demand. There are two workforce pathways:

1. Support future workforce development through apprenticeship readiness and pre-apprenticeships programs, DOL registered apprenticeships, reinvesting in middle and high school Career and Technical Education (CTE), expanding Michigan College Credits for Apprenticeship Program (union apprenticeship and community college credit towards associate degrees), and other entry pathways.
2. Expand incumbent worker upskilling by investing in journeyman upgrade training and ongoing engagement with union skilled trades Joint Apprenticeship and Training Committees (JATC) to ensure signatory contractors have the workforce needed for the installation, operation, and maintenance of changing industrial systems.

Both are needed for industrial decarbonization to occur.

PROGRAM DESIGN:

- **Build on existing infrastructure.** Leverage Michigan's existing pre-apprenticeship and apprenticeship training programs, community college pathways, union training centers, employer-led programs, and workforce initiatives. Examples include: DOL-registered apprenticeship programs and union training centers, community colleges and regional training providers, Michigan Works! and Going PRO Talent Fund, CTE, the Workforce Development Institute, MMTC, and other manufacturer-facing organizations.
- **Target emerging skill gaps with on-the-job training.** Focus new training resources towards existing DOL-registered apprenticeship programs that result in state licensure. As the needs of the state evolve, union skilled trades, in partnership with the Joint Apprenticeships Training Committees (JATCs), can connect registered apprentices and journeymen with the needed specific training. Prioritize equipment labs, demonstrations, site visits, OEM-led instruction, and peer learning.
- **Connect training to projects** Use industrial grants, demonstration projects, assessments, and cluster planning to identify workforce needs.
- **Improve geographic access** Support regional partnerships, mobile training, and shared facilities where existing training infrastructure is less accessible.
- **Reduce participation barriers** Consider paid training time, signatory contractor and employer needs, flexible schedules, transportation, and other wrap-around services to reduce barriers that can limit incumbent worker participation.
- **Local hiring** Incorporate Michigan resident or local hiring targets for state-supported projects to ensure public investments create opportunities for Michigan workers.

- **Skilled union labor and job quality.** Support high-quality skilled union careers by requiring prevailing wages, DOL-registered apprenticeships, project labor agreements (PLAs), voluntary labor neutrality agreements, and other high-road labor standards.
- **Tribal workforce participation.** Work with Michigan Tribal Nations to expand Tribal member access to training, apprenticeships, employment, and contracting opportunities associated with industrial decarbonization projects.

FUNDING AND ADMINISTRATION:

Michigan should initially target and expand existing workforce funding mechanisms to support industrial modernization priorities. Programs that have quantifiable outcomes resulting in state licensure and good-paying careers with healthcare and retirement benefits should be the focus of these funds. Going PRO, State Apprenticeship Expansion, and other LEO workforce programs already fund incumbent worker training, new hires, pre-apprenticeship, apprenticeship readiness, and DOL-Registered Apprenticeships and could provide platforms for targeted expansion.

Dedicated funding could support:

- Training equipment and facilities
- Instructor capacity
- Employer and worker outreach
- The development of new or updated curricula
- Hands-on demonstrations and mobile training
- Signatory contractor and employer costs associated with incumbent-worker participation

LEO should lead implementation in close coordination with MEDC, EGLE-OCE, employers, organized labor and their signatory contractors, training providers, community colleges, OEMs, and regional workforce organizations.

COMPARABLE PROGRAMS IN OTHER STATES:

See Table 6.

SUPPORTIVE ACTIONS:

To maximize the effectiveness of expanding support for the industrial decarbonization workforce, Michigan should:

- Incorporate workforce needs and commitments into industrial grant and incentive applications, including engagement with unions and other partners.
- Require state-supported industrial projects to develop workforce plans and track outcomes after implementation.
- Coordinate economic development with regional workforce development and capacity.
- Use state-supported (or tracked) demonstrations to identify emerging needs.
- Periodically reevaluate needs as the landscape changes.

Table 6

EXPANDED/TARGETED WORKFORCE SUPPORT			
STATE	**PROGRAM**	**FUNDING AMOUNT**	**RELEVANT FEATURES**
Wisconsin	• Several programs under WI Fast Forward, Clean Energy Plan and Workforce Solutions Initiative[a]	• $128 million Workforce Innovation Grant (WIG) Program[b] • 2023-35 Budget recommended $10 million for clean energy and job training, $2 million under Wisconsin Fast Forward, and $2 million for the Southeast Wisconsin Green Jobs Corps[c]	• Green Jobs Corps focused on young people facing barriers to employment in energy efficiency, conservation, and environment jobs • Investing in both Registered Apprenticeship and Youth Apprenticeship programs to support upskilling in conservation, energy, agriculture, clean water, urban forestry, etc. • WIG provides grants across the state to design and implement plans to tackle long-term local workforce challenges/barriers to entry • Business development tax credit can be used to support workforce training and housing • CEP brings together a range of funding, incentives, and education and training programs for workforce development to support a just transition
Illinois	• Several workforce training programs under CEJA and Future Energy Jobs Act.	• Variable based on program type and size • $3 million each annually for Craft Apprenticeship and Solar Pipeline Training programs; $22.9 million annually for Clean Jobs Workforce Network Program[d]	• Programs intended to train Illinoisans for jobs in the clean energy industry and to help clean energy businesses grow • Emphasizes diversity and access for underserved communities. Workforce network hubs are distributed across the state. Support is specific to reducing energy transition barriers
Minnesota	• Several grant programs administered by MN Department of Employment and Economic Development (DEED) and others.	• Clean Economy Equitable Workforce Program - $2.7 million (>$600,000 in private funding)[e] • Workforce Development Scholarship program - $4.5 million annually in FY 2022 and 2023, allocation has varied in each budget, piloted with $1 million[f] • Total FY 2024 Workforce Development Grants, Aids and Subsidies expenditure in MN was $140 million[g]	• Philanthropic groups issued an RFP to DEED grantees to align private funding with the state's economic goals • Partnership and pathways programs support educational institutions partnering with businesses to provide job training[h] • Some specific incentives provided for assisting low-income individuals or providing training toward jobs exceeding certain incomes thresholds • Scholarships of up to $2,500 per academic year to support students in high-demand educational programs (including manufacturing, agriculture, and IT) at both state colleges and universities
Maryland	• Several new and established workforce development programs for employees and students.	• Partnership for Workforce Quality (PWQ) allocated $1 million per year in the state's operating budget[i] • Grants range from $5,000 to $200,000 • EARN Maryland allocated $5 million in FY 2026 operating budget • Higher Education Clean Energy Grant Program - $8 million[j] • Maximum award of $145,000 each for campus clean energy master planning and clean energy sector course development, and up to $25,000 for student internships • Rural Pathways to Prosperity Network - $2.38 million (received federal funding)[k]	• PWQ focuses on small and medium businesses, dedicating 60% of available funds to employers with <150 employees, and prioritizes manufacturing and technology companies. Provides matching training grants up to 50% of qualified direct costs for training on job-specific skills for incumbent workers, up-skilling for new technologies, and new hires[l] • Rural pathways program providing workforce credentials, paid internships, registered apprenticeships, and other work-based learning opportunities in high-demand fields for rural students

[a] "State of Wisconsin Clean Energy Plan Progress Report," Wisconsin Office of Sustainability and Clean Energy, August 2026.

[b] "Workforce Innovation Grant Program," Department of Workforce Development, accessed September 2026.

[c] "Moving Wisconsin's Workforce Forward, with Investments in Green Jobs and Sustainable Opportunities," Department of Workforce Development, April 2023.

[d] "CEJA Workforce Training Programs," Illinois Department of Commerce and Economic Opportunity, accessed October 2026.

[e] "Governor Walz Announces Funding to Train Underrepresented Workers for Clean Energy Careers," Office of Governor Tim Walz & Lt. Governor Peggy Flanagan, June 11, 2024.

[f] "Workforce Development Scholarship Program," Minnesota State, February 1, 2023.

[g] "2026-27 Biennial Budget Workforce Development Services Program Expenditure Overview," State of Minnesota, January 2025.

[h] "DEED Training Grant Programs," MN Department of Employment and Economic Development, accessed October 2026.

[i] "Operating Budget FY 2026 Volume 2," State of Maryland, accessed October 2026.

[j] "Higher Education Clean Energy Grant Program," Maryland Energy Administration, accessed October 2026.

[k] R. Mackesey, "Maryland rural colleges receive $2.38 million federal grant for career pathways," WBOC, October 5, 2026.

[l] "Partnership for Workforce Quality (PWQ)," Maryland Department of Commerce, accessed October 2026.

Expedited air permitting for emissions-reducing projects

RECOMMENDATION:

Michigan should establish a coordinated permitting pathway for qualifying industrial emissions-reducing projects, focused on the early identification of requirements, interagency coordination, concurrent review, and predictable timelines. The coordinated pathway should also address utility service extension and interconnection timelines for qualifying projects. Following experience with project navigation and an assessment of permitting barriers, Michigan could provide targeted expedited review for projects that create verifiable GHG and local air pollution reductions.

Expedited review should not weaken environmental standards, substantive review, or existing opportunities for public and community participation.

PROGRAM DESIGN:

- **Targeted eligibility.** Limit expediting to projects that demonstrate substantial, verifiable emissions reductions using transparent eligibility criteria. Eligibility criteria could include: quantifiable GHG emissions reductions, local environmental benefits and pollutant reductions, project readiness within a defined timeframe, strategic alignment with the state's industrial decarbonization priorities, and the ability to meet applicable environmental requirements.

- **Coordinated review.** Designate a project coordinator to identify relevant air, water, waste, electrical, utility, and other requirements and facilitate coordination across permitting authorities and agencies (should be lined up with *Michigan industrial modernization and decarbonization strategy and implementation structure*). Identify permitting barriers as early as possible in project development.
- **Community and EJ safeguards.** Engage EJ and affected communities in program design, and maintain existing public participation and environmental review requirements.

FUNDING AND ADMINISTRATION:

EGLE should initially assess where and why permitting delays occur for industrial emissions-reducing projects and use projects receiving state grants or technical assistance as an initial source for identifying barriers.

Implementation should build from the coordinated industrial project navigation function, with a designated coordinator helping projects navigate offices and other state, local, and utility requirements.

COMPARABLE PROGRAMS IN OTHER STATES:

See Table 7.

SUPPORTIVE ACTIONS:

To maximize the effectiveness of expedited permitting:

- Establish coordinated industrial project navigation.
- Incorporate permitting reviews into industrial assessments and project development.

- Coordinate permitting with utility interconnection and infrastructure planning.
- Use state-supported projects to track permitting timelines and identify barriers.
- Engage EJ and affected communities before establishing eligibility criteria or expedited methodology.

PERMITTING SUB-POLICIES:

Incentives and permitting ease for brownfields Brownfield sites can provide opportunities for industrial development while reusing already developed land and infrastructure. Michigan should provide incentives and coordinated permitting assistance for industrial decarbonization and shared infrastructure projects at brownfield sites, building on existing brownfield redevelopment programs. This could include early coordination between agencies, clearer permitting pathways, and targeted financial support for site preparation or remediation. This approach could complement expedited permitting by prioritizing redevelopment without weakening environmental review or cleanup requirements, while also supporting industrial co-location and shared infrastructure opportunities.

Phased industrial emissions performance and/or clean heat standards. An industrial emissions performance standard would create requirements for facilities or industrial processes to reduce GHG emissions or emissions intensity over time, while a clean heat standard would require an increasing proportion of thermal energy to be generated by qualifying low- or zero-emission sources.

Either could be phased in gradually, starting with common measurement and reporting requirements and sector-specific analysis before establishing standards tailored by sector, process, facility size, and/or temperature requirements. Assessments could help facilities identify compliance pathways and align changes with equipment replacement windows.

Standards would need to be coordinated with policies that make compliance technically and economically feasible. Grants and other financing could reduce upfront costs, while a clean heat PTC, EWR changes, and/or industrial rate reform could improve operating costs. Project navigation and permitting assistance could support implementation, while 'Buy Clean, Buy Michigan' could create demand for lower-carbon products.

Table 7

EXPEDITED PERMITTING FOR EMISSION-REDUCING PROJECTS			
STATE	**PROGRAM**	**FUNDING AMOUNT**	**RELEVANT FEATURES**
Massachusetts[a]	• MassDEP Fast Track Permitting	• Applicants may negotiate reduced or delayed fee schedules	• Projects must be of "significant environmental interest," be in line with sustainable development principles, promote smart growth, and have permitting complexity • Qualifying project types may include biotech, energy, transit-oriented development, brownfield redevelopment, or recycling • One project manager as single point of contact
New York[b]	• RAPID Act	• No requirement for additional funding appropriations	• Consolidated state review of projects with uniform standards and timelines • Specifically for large renewable energy generation development and electric transmission Reduces time to issue a permit by up to 50%
Illinois[c]	• Clean and Reliable Grid Act (CRGA)	• No requirement for additional funding appropriations	• Creates state-level back stop so that local permitting procedures cannot be more restrictive of clean energy development • Gives the Illinois Commerce Commission (ICC) the authority to both address siting disputes through an expedited dispute resolution procedure and to issue siting certificates • Designed to reduce permitting uncertainty by preventing renewable energy and storage projects from facing inappropriate denials or delays
U S Federal Government	• Federal Buy Clean Initiative (inactive)	• No requirement for additional funding appropriations	• Buy Clean Task Force established by EO to develop recommendations to incorporate consideration of embodied emissions in federal procurement and federally funded projects • Major federal contractors and suppliers required to publicly disclose emissionsg • Buy Clean Initiative promotes use of construction materials with lower embodied life cycle emissionsh

[a] "MassDEP Fast Track Permitting - Fact Sheet, Contacts, Section 40 Overview & Project Requirements," Massachusetts Department of Environmental Protection, November 2017.

[b] "RAPID Act Regulations Set to Lower Costs and Accelerate Grid Modernization in New York," New York State Department of Public Service, February 2026.

[c] "Public Act 104-0458 Implementation," Illinois Power Agency, accessed September 2026.

Expand markets and infrastructure for recycled and circular materials

RECOMMENDATION:

Michigan should expand investment, market development, and coordination for recycled and circular materials, building on NextCycle Michigan and the state's Materials Management Planning framework. The goal should be to strengthen the supply of recovered materials and end markets that allow Michigan manufacturers to substitute recycled and secondary materials while supporting material efficiency, reuse, and strategies that reduce the demand for virgin materials.

Priority should be given to material streams with strong potential for emissions reductions, economic development, and market growth.

PROGRAM DESIGN:

- **End-market development.** Pair investments in collection and processing with support for manufacturers that can use recovered materials.
- **Priority material streams.** Target high-potential opportunities such as construction materials, metals, batteries (and other electronic waste containing recoverable critical minerals), wood, organics, industrial byproducts, plastics, and other manufacturing feedstocks.
- **Industrial byproduct exchange.** Support and expand participation in existing platforms, such as the EGLE-supported Michigan Materials Marketplace, and regional networks that connect one facility's residual materials or byproducts with manufacturers that can use them.
- **Manufacturer technical assistance.** Help manufacturers evaluate recycled feedstocks, product specifications, process modifications, quality control needs, and supply availability.
- **County plan implementation.** Expand existing state financing and technical support to implement county Materials Management Plans (MMP), especially projects that improve collection, processing, reuse, composting, or market access. Michigan's updated Part 115 framework shifts county planning towards recycling, composting, and broader sustainable materials management. Consider requiring implementation work plans and progress reporting with state funding tied to demonstrated progress towards MMP and statewide goals
- **EPR evaluation** Evaluate 'extended producer responsibility' as a potential long-term financing mechanism for collection, recovery infrastructure, and implementation of priority material management needs, with detailed sector-specific design before adoption.
- **Circular procurement** Coordinate with 'Buy Clean, Buy Michigan' and other procurement policies to create demand for recycled and lower-carbon materials.
- **Product reuse and waste prevention.** Evaluate opportunities to reduce the unnecessary disposal of usable manufactured products, including reviewing manufacturer and distributor destruction policies and identifying alternatives such as reuse, donation, and recycling.
- **Circular design** When developing new products, consider materials and specifications that prioritize reuse, repairability, and recycling as end-of-life management options.
- **Food and organics** Expand food waste prevention, organics recovery, composting, and anaerobic digestion (with beneficial use of biosolids, e.g., composting) where life cycle and local environmental benefits are demonstrated.
- **Permitting and project development** Improve navigation and technical assistance so that permitting and grant timelines do not unnecessarily delay recycling and circular economy infrastructure.

FUNDING AND ADMINISTRATION:

EGLE's Materials Management Division should serve as the primary lead, building on NextCycle, Circular Economy Grants, recycling programs, and county Materials Management Planning. NextCycle has already supported more than 170 teams, and Michigan has provided substantial grant funding for circular supply chains and recycling infrastructure.

Funding should support:

- Collection, sorting, processing, and reuse infrastructure
- End-market and manufacturing investments
- Technical assistance and project development
- County MMP implementation
- Demonstration and commercialization of new recovery technologies

Michigan should evaluate EPR, recycled material incentives, tipping-fee or disposal-fee mechanisms, and other dedicated revenue sources as potential pathways to provide more durable funding.

COMPARABLE PROGRAMS IN OTHER STATES:

See Table 8.

SUPPORTIVE ACTIONS:

- Expand NextCycle and other circular-economy grants.
- Provide technical assistance for manufacturers using recycled feedstocks.
- Support implementation of county Materials Management Plans.
- Develop industrial byproduct exchange networks.
- Coordinate with 'Buy Clean, Buy Michigan' and public procurement.
- Develop sector-specific strategies for batteries, construction materials, organics, wood, and other priority streams; additionally, evaluate codes (transportation and buildings) for limiting reuse of recycled materials.
- Evaluate EPR and other long-term financing mechanisms.

Table 8

EXPAND MARKETS AND INFRASTRUCTURE FOR RECYCLED OR CIRCULAR MATERIALS			
STATE	**PROGRAM**	**FUNDING AMOUNT**	**RELEVANT FEATURES**
Minnesota[a,b]	• Packaging Waste and Cost Reduction Act (Minn. Stat. § 115A.144-115A.1463)	• N/A	• Requires producers to join a producer responsibility organization (PRO), to coordinate and fund statewide program • By the end of the first term, covered materials production should be reduced by 15%, 10% of materials must be marked for reuse, and 60% must be marked for recycling or composting[c] • Requires all packaging to either be refillable, reusable, recyclable, or compostable by 2032 • By 2032, MPCA will contract a study to identify the contribution of covered products to litter and water pollution using funds from the PRO[d] • Producers reimburse at least 90% of costs related to refill, reuse, recycling, and composting • Will conduct a needs assessment every 5 years • Fee calculated based on the total amount of covered materials each producer introduces in the prior year on a per-unit basis
Oregon[e]	• Recycling Modernization Act	• FY 2025 participant producer fee revenue totaled $167.9 million	• First-of-a-kind policy • Packaging producers join and pay a fee to a PRO that finances improvements to the recycling system[f] • Producers and processors must ensure that recycled materials reach responsible end markets • Establishes a uniform statewide list of what can be recycled, regardless of collection point • Penalties for non-compliance up to a maximum of $25,000 per day • In 2025, ~96% of materials delivered to self-attested end markets[g] • Covers nearly 3,000 producers and over 400,000 tons of products sold into Oregon • Fee structure determined based on actual system costs related to specific materials and producer supply; designed to motivate producers choosing more recyclable packaging
California	• Recycling Market Development Zone (RMDZ) Revolving Loan Program	• Amount varies annually based on applications, peaked in FY 2022-23 at over $28 million[h]	• Provides permitting and technical assistance, loans and product marketing to California businesses using recycled materials from California's waste stream • RMDZ loans can be used for machinery and equipment purchasing, working capital, real estate purchase or improvement, and refinancing[i] • Private business, nonprofit organizations and local government bodies are eligible

[a] "Extended producer responsibility for packaging," Minnesota Pollution Control Agency, September 2024.

[b] "Packaging waste and cost reduction act," Minnesota Pollution Control Agency, September 2024.

[c] "MN Extended Producer Responsibility for Packaging and Paper Products," Partnership on Waste and Energy, nd.

[d] "Minnesota House File 3911 (2024) - (Passed)," Sustainable Packaging Coalition, May 2024.

[e] "Plastic Pollution and Recycling Modernization Act," State of Oregon Department of Environmental Quality, September 2021.

[f] "Recycling Modernization Act Frequently Asked Questions," State of Oregon Department of Environmental Quality, December 2021.

[g] "Oregon Annual Report 2025," Circular Action Alliance, 2025.

[h] "Loan Count and Amounts by Fiscal Year Approved," CalRecycle, September 2026.

[i] "RMDZ Eligibility Criteria," CalRecycle, October 2023.

'Cap and Invest'

RECOMMENDATION:

Michigan should evaluate the development of, or participation in, a regional Midwest 'Cap and Invest' program covering major industrial GHG emitters. A regional approach could establish a declining emissions cap and market-based compliance framework while reducing competitiveness and emissions leakage risks associated with a Michigan-only industrial program.

Michigan should begin with economic, emissions, legal, and market analysis and regional coordination. Program development should include substantial engagement with industry, labor, environmental justice and community organizations, neighboring states, and other affected stakeholders.

PROGRAM DESIGN:

- **Regional market.** Prioritize coordination with neighboring Midwest states to create a larger, more consistent market.
- **Industrial coverage** Focus on large industrial sources, using clear emissions thresholds and consistent GHG reporting systems.
- **Competitiveness and leakage protections.** Develop protections for emissions-intensive, trade-exposed industries, such as output-based or no-cost allowance allocations while maintaining incentives to reduce emissions. Protections should consider compliance costs, as well as indirect carbon costs.
- **Flexible compliance** Allow facilities to determine the most effective mix of efficiency, electrification, process changes, material efficiency, carbon management, and other qualifying emissions reductions.
- **Community and air quality safeguards.** Evaluate facility-level emissions and local co-pollutant impacts with statewide GHG outcomes. Include safeguards for community engagement to address concerns that allowance trading could allow pollution to persist in already overburdened communities.
- **Revenue reinvestment** Establish priorities for auction proceeds, including potential investment in industrial decarbonization, affected workers and communities, clean energy deployment, technical assistance, and other public benefits.

FUNDING AND ADMINISTRATION:

EGLE should lead the emissions, environmental, and program design analysis in coordination with MEDC, Treasury, and other state agencies. Because 'Cap and Invest' affects industrial competitiveness, commerce, economic development, and community outcomes, program development should be an interagency initiative.

Initial state funding would be needed for feasibility analysis, stakeholder engagement, emissions and economic modeling, and regional coordination. If implemented, allowance auctions could generate a recurring revenue stream, the uses of which should be established in legislation.

Before program adoption, Michigan should conduct a comprehensive feasibility assessment addressing:

- Industrial emissions and potential covered facilities
- Expected allowance prices and compliance costs
- Impacts on electricity and natural gas rates paid by industrial customers
- Impacts on production, investment, employment, product prices, and competitiveness
- Leakage risks by industrial sector
- Potential emissions and air-quality outcomes, including health and community benefits
- Expected revenue and potential uses
- Administrative and legal requirements
- Opportunities and interest among neighboring Midwest states

COMPARABLE PROGRAMS IN OTHER STATES:

See Table 9.

SUPPORTIVE ACTIONS:

- Conduct sector-specific competitiveness and leakage analysis.
- Develop common industrial GHG accounting and reporting approaches.
- Engage neighboring Midwest states on potential regional coordination.
- Establish community and air quality safeguards.
- Define principles for revenue reinvestment.

'CAP AND INVEST' SUB-POLICIES:

Other trading mechanisms Michigan should evaluate other mechanisms that create an economic or regulatory incentive to reduce industrial emissions, including emissions trading, carbon or fuel-based pricing, and/or performance-based approaches. These mechanisms differ in whether they establish an emissions limit, attach a price to emissions or fuels, or would require facilities to meet a performance benchmark.

Any of these approaches would rely on a robust analysis of covered facilities and emissions, compliance costs, competitiveness and emissions leakage risks, administrative requirements, and impacts on communities near industrial facilities. Performance or trading-based approaches could also be paired with incentives and technical assistance to provide manufacturers with multiple pathways to reduce their emissions.

Table 9

'CAP AND INVEST'			
STATE	**PROGRAM**	**FUNDING AMOUNT**	**RELEVANT FEATURES**
Northeastern U S States (CT, DE, ME, MD, MA, NH, NJ, NY, RI, VT)	• RGGI[a]	• Since 2005, the RGGI states have raised over $10 billion to invest into local communities[b]	• Fossil fuel power plants generating >25 MW must acquire allowances to cover their emissions (one allowance = 1 U.S. ton of CO_2) • Allowances distributed via auction • Each state has full discretion over how to invest RGGI proceeds • Funds from RGGI have been invested in a variety of programs including energy efficiency, direct bill assistance, renewable energy, climate adaptation, and beneficial electrification • Starting in 2027, RGGI states will no longer award carbon offset allowances
California	• Cap-and-Invest Program	• As of 2025, the program had generated around $35 billion for the state's Greenhouse Gas Reduction Fund (GGRF)[c]	• Free allowances allocated to trade-exposed industries • As of 2026, companies in the Cap-and-Trade Program can invest in offsets to cover up to 6% of their annual compliance obligations[d] • Covers ~80% of the state emissions • Achieved its 2020 GHG reduction target four years early • Establishes an annually-increasing floor price for auction of allowances • Uses reserves to limit price increases
Québec, CAN	• Québec Cap-and-Trade System	• Auction in 2025 generated US$800 million in revenues, bringing total revenue from the beginning of the program to US$7.85 billion	• Formally connected with CA's market • Covers CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, NF_3 • 99.3% compliance rate in 2013-2023 • Targets 37.5% reduction from 1990 GHG levels by 2035 • As of 2023, covers 79% of total emissions
Washington	• Cap-and-Invest Program	• $4.3 billion into state revenue since inception[e]	• Protects trade-exposed manufacturers and utilities through the allocation of no-cost allowances • Production/carbon intensity baselines help stop carbon leakage and support competitiveness • At least 35% of investment must benefit communities overburdened by pollution and 10% must go to projects with Tribal support[f] • Cap-and-Invest participants can cover up to 8% of their emissions via offsets

[a] "The Investment of RGGI Proceeds in 2024," The Regional Greenhouse Gas Initiative, June 2026.

[b] "About the Regional Greenhouse Gas Initiative," The Regional Greenhouse Gas Initiative, July 2026.

[c] "USA - California Cap-and-Invest Program," International Carbon Action Partnership, accessed October 2026.

[d] "Canada - Québec Cap-and-Trade System," International Carbon Action Partnership (ICAP), nd.

[e] "USA - Washington Cap-and-Invest Program," International Carbon Action Partnership, accessed October 2026.

[f] "Climate Commitment Act 101," State of Washington Department of Ecology, July 2024.

Industrial Decarbonization Scenario Analysis

OVERVIEW OF THE ENERGY POLICY SIMULATOR

The Energy Policy Simulator (EPS) is a system dynamics model developed and maintained by the think tank Energy Innovation. It is used to assess how a wide range of energy and climate policies influence key economic, environmental, and societal outcomes. The model simulates interactions across sectors of the economy to calculate how specific policy actions affect GHG emissions, energy use, industrial output, employment, GDP, public health, and other outcomes.

Scenario modeling within the simulator enables policymakers to assess the combined impacts of a suite of policy actions and technology deployment targets. For this roadmap, EPS modeling is used to illustrate how different levels of industrial decarbonization policy ambition and technology deployment could influence Michigan's industrial emissions, energy consumption, economic activity, and public health through 2050. These scenarios represent potential outcomes under different sets of assumptions, not predictions of the impacts of individual policies or forecasts of future conditions.

The EPS model architecture consists of three main layers:

1. **Input layer.** Defines the BAU conditions for a specific region. It contains detailed datasets on the region's energy system, economic structure, GHG inventory, demographic and industrial composition, fuel prices, and other characteristics. The model includes input layers for the United States as a whole, each of the 48 contiguous U.S. states individually, and several international regions. Modeling for this roadmap used the Michigan EPS, which employs Michigan-specific economic and energy data.
2. **Policy layer.** Provides a large menu of policy levers that users can adjust to explore the impacts of different policy scenarios. These levers represent policy actions that affect key components of the GHG inventory, including the buildings, electricity, transportation, and industrial sectors. Each lever typically takes the form of a numerical setting representing the ambition of a given policy. Each policy lever also has a customizable implementation schedule, allowing users to define both the magnitude and timing of policy interventions.
3. **Output layer.** Produces thousands of metrics reported annually through 2050. These include sectoral and economy-wide GHG emissions, cash flow and cost impacts, changes to employment and GDP, health impacts from changes in air pollution, electricity generation mix, and numerous other indicators. These outputs allow users to evaluate tradeoffs and co-benefits across multiple policy goals.

For this roadmap, the modeling focuses on industrial sector outcomes, while also considering broader economic, electricity system, and public health impacts. Key outputs examined include industrial GHG emissions, fuel and electricity consumption, industrial energy use by subsector, electricity capacity construction costs, changes in employment and compensation, air pollutant emissions, and avoided adverse health outcomes.

Modeling approach

To illustrate the potential impacts of industrial decarbonization policies and technology deployment in Michigan, four scenarios were developed:

- **Business-as-usual (BAU).** Represents projected conditions under existing policies and assumptions, providing a baseline for comparison.
- **Foundational** Represents an initial package of industrial decarbonization policies focused on establishing enabling conditions, expanding existing programs, and supporting early technology adoption.
- **Accelerated** Represents a more ambitious package of policies that expands financial and regulatory support, accelerates deployment of technologies, and addresses barriers.
- **Transformational.** Represents the highest technically plausible decarbonization pathway with wide deployment of industrial decarbonization technologies, stronger policy requirements, and sustained investment.

The scenarios are intended to evaluate the combined effects of different levels of policy ambition and technology deployment, rather than to attribute specific emissions reductions or economic benefits to individual roadmap recommendations. They also illustrate how the pace of implementation influences cumulative emissions reductions and other outcomes through 2050.

Translating roadmap policy recommendations into EPS policy levers

The policy recommendations in the roadmap were translated into EPS policy levers to evaluate their potential impacts. This involved identifying the EPS levers most closely associated with each recommendation and establishing deployment assumptions to match the goals of each scenario.

The most-relevant EPS levers reflect changes in industrial energy efficiency, electrification, industrial equipment retirement, process emissions, and deployment of technologies including CCUS and hydrogen. Other levers show changes in electricity generation and various energy conditions.

Not all roadmap recommendations can be modeled through EPS policy levers. For example, technical assistance, workforce development, permitting reforms, coordination between agencies, and other enablers that are critical to accelerating industrial decarbonization do not result in independent impacts within the model. However, those policies do support the conditions needed to reach the reductions represented in the scenarios.

Modeled outcomes illustrate the potential impacts of the broader policy packages, including both directly modeled measures and the enabling policies needed.

INPUT AND MODELING ASSUMPTIONS

BAU assumptions

For the industrial sector, certain EPS default inputs for BAU industrial fuel use and process emissions were replaced with our team's internally developed profile of Michigan's industrial sector,[145] where such inputs were available, to better reflect Michigan-specific conditions. The BAU assumptions otherwise account for the latest changes in federal and state policy, including the One Big Beautiful Bill Act (OBBBA) and Michigan's 2023 clean energy laws, particularly Public Acts 235 and 233.

[145] 5LE analysis based on U.S. EPA GHGRP data reported in the Facility Level Information on GreenHouse gases Tool (FLIGHT) and U.S. EIA data. Included in 5LE analysis are all subsectors under NAICS codes 31-33, as well as iron ore mining.

Technology deployment and policy assumptions

For each EPS lever, an upper bound was identified through literature review to represent the highest technically plausible level of impact. Implementation was then increased across scenarios and years towards that upper bound to represent a range of outcomes under increasingly strong policy packages and over time. These values are illustrative scenario assumptions.

Implementation of most industrial policy levers is assumed to begin in 2027, with effects ramping linearly from zero to modeled 2030 values. CCUS is first deployed in 2028, while hydrogen combustion and feedstock-shifting begin in 2029 to reflect longer project development, infrastructure, and technology deployment timelines. 'Buy Clean, Buy Michigan' implementation begins in 2030.

Deployment assumptions vary by technology and policy mechanism due to differences in EPS use recommendations, technical potential, commercialization, applicability, and the level of policy intervention needed to support adoption. For example, industrial energy efficiency improvements are modeled across manufacturing subsectors, while methane capture and destruction is limited to applicable industries.

The full set of EPS assumptions, implementation schedules, upper bounds, and sources can be found in *Appendix B: EPS Methodology Details and Assumptions.*

SCENARIO RESULTS AND FINDINGS

Industrial greenhouse gas emissions

Our EPS modeling results demonstrate the potential for significant reductions in Michigan's industrial GHG emissions. Under the business-as-usual (BAU) scenario, industrial emissions are relatively stable through 2050, increasing 1% from 2026 to 2050 (Figure 8). However, all three of our intervention scenarios result in sustained emissions reductions relative to BAU levels.

By 2050, industrial emissions fall to approximately 35 MMT CO_2e under the foundational scenario, 32 MMT CO_2e under the accelerated policy scenario, and 29 MMT CO_2e under the transformational policy scenario, compared to 42 MMT CO_2e under the BAU scenario, representing reductions of approximately 15%, 23%, and 31%, respectively. By 2035, Michigan's annual industrial GHG emissions are already approximately 8%, 14%, and 18%, respectively, below BAU under the foundational, accelerated, and transformational policy scenarios.

Across the modeled scenarios, the largest annual reductions occur during the initial decade of implementation, especially between years 2028 and 2035. After that, annual reductions are smaller, especially in our foundational and accelerated policy scenarios. These results reflect the modeled deployment trajectories of industrial decarbonization measures and highlight the importance of early implementation of long-term emissions-reducing strategies and technologies.

Despite the reductions observed, approximately 29 MMT CO_2e of industrial emissions remain in 2050 under the transformational policy scenario, which represents the deepest reductions secured by any modeled scenario. This result reflects both the limits of our assumptions and the challenges of decarbonizing certain industrial processes. Even in our transformational policy scenario, full deployment of all available technologies – including CCS, alternative fuels,

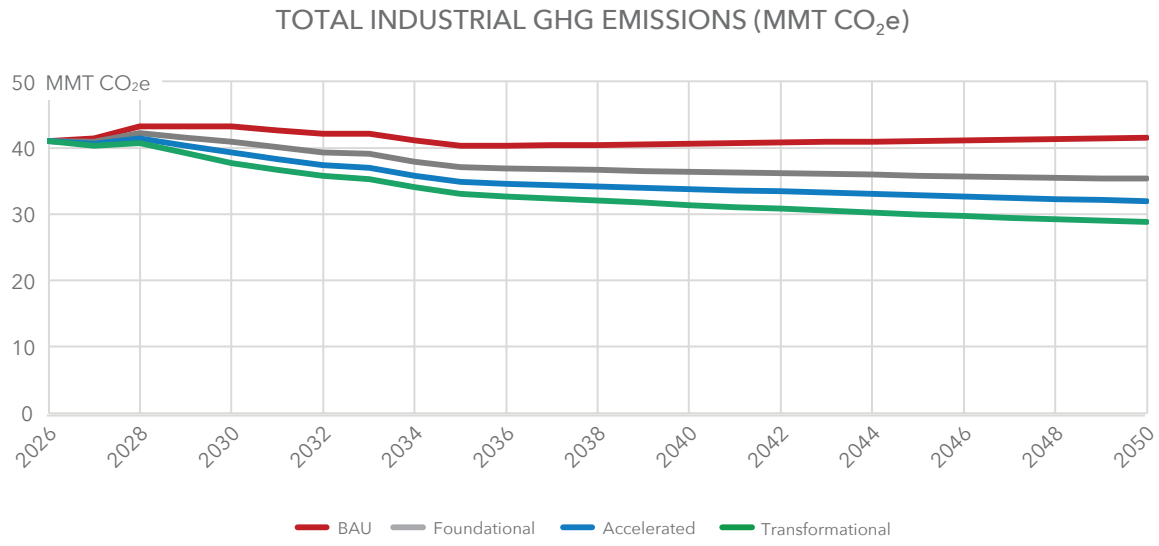


Figure 8 *Modeled annual industrial CO_2 emissions in million metric tons (MMT) in Michigan through 2050, under the four policy scenarios investigated in this study. Results derived from the Energy Policy Simulator, by Energy Innovation.*

and alternative feedstocks – cannot be assumed. Additionally, some emissions sources and mitigation strategies are not fully addressed by the interventions modeled here, such as certain industrial process emissions and activities that fall outside the manufacturing focus of the roadmap but are nonetheless modeled within "industry" as part of the EPS framework.

Michigan's ultimate potential to achieve net-zero industrial emissions will rely on more widespread deployment of existing solutions, continued development and commercialization of technologies, and the adoption of additional strategies to address remaining emissions sources.

Industrial fuel mix

EPS results indicate that industrial decarbonization efforts enacted over time could significantly change both the quantity and composition of the energy consumed by Michigan's industrial sector. Under BAU conditions, total industrial energy consumption increases by approximately 8% total between 2030 and 2050, with continued heavy reliance on fossil fuels – especially natural gas and petroleum. In our transformational policy scenario, total industrial energy consumption falls by about 11%, despite increased electricity use, mostly due to efficiency improvements. By 2050, total industrial energy consumption reaches approximately 860 trillion BTU under BAU, compared with just 682 trillion BTU under the transformational policy scenario (Figure 9).

The most significant change in the transformational policy scenario is a shift from natural gas towards electricity for core industrial energy needs. By 2050, natural gas consumption decreases from approximately 223 trillion BTU under BAU conditions to 61 trillion BTU in the transformational policy scenario, constituting a decrease of approximately 73%, while electricity consumption increases by about 20%. As a result, electricity's share of total industrial energy consumption increases from around 13% in the BAU scenario to 20% in the transformational policy scenario by 2050 (Figure 9). These changes reflect the effects of industrial electrification, energy efficiency improvements, waste heat recovery, and other levers that reduce fossil fuel and overall energy use. Assumptions for our calculations modeled using EPS are located in *Appendix B: EPS Methodology Details and Assumptions*.

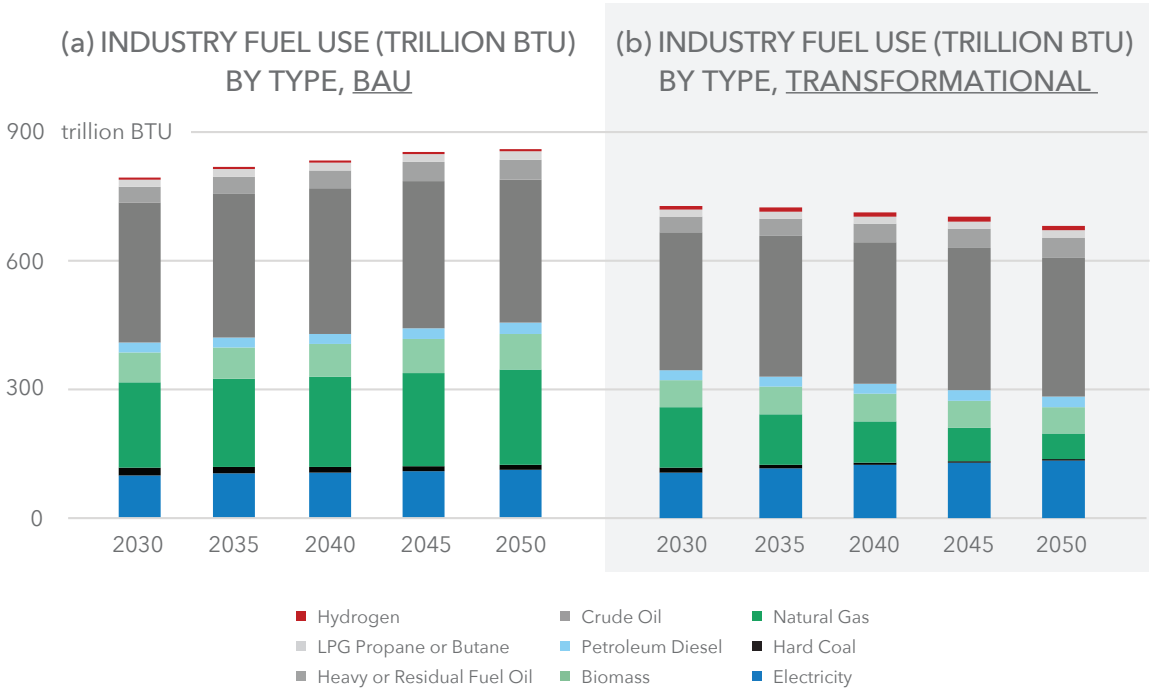


Figure 9 *Modeled shifts in annual industrial energy consumption by fuel type through 2050, under the (a) business-as-usual (BAU) and (b) transformational scenarios. Results derived from the Energy Policy Simulator, by Energy Innovation.*

Despite progress, fossil fuels – especially petroleum-related fuels – still account for a significant proportion of industrial energy consumption in Michigan in 2050 in all our modeled scenarios. This is likely responsive to the EPS treatment of petroleum refining and fuel exports, which limit the extent to which modeled industrial decarbonization measures can reduce petroleum consumption.

Electrification and grid impacts

Industrial electrification is a key decarbonizer in our modeled decarbonization scenarios, but decarbonizing through electrification also results in increased electricity demand. Electricity consumption grows under all four modeled scenarios through 2050, with greater growth observed under our more ambitious deployment assumptions. Specifically, by 2050, annual industrial electricity demand reaches approximately 33 TWh under BAU, compared with 36 TWh, 38 TWh, and 39 TWh under the foundational, accelerated, and transformational policy scenarios, respectively. In all cases, demand grows from the initial baseline of 28 TWh, representing growth of 18% in BAU, and from 29% to 40% in our modeled scenarios (Figure 10).

This increase in electricity demand has implications for Michigan's electricity generation capacity, transmission and distribution infrastructure, and utility planning efforts. At the same time, electrification can be part of the solution to energy affordability challenges by spreading fixed utility system costs across more consumption, especially when flexible loads can make use of existing capacity and reduce renewable curtailment. The state's ability to meet this additional load while continuing to reduce grid emissions will rely on coordinated investment in electricity supply and infrastructure, both in front of and behind the meter. The scale and timing of investments will depend on both total electricity consumption and the timing of electricity consumption at Michigan's industrial facilities, as well as their ability to adjust electricity demand timing. The significance of this interdependency will grow as electricity demand increases in parallel in Michigan's other economic sectors, which include transportation, commercial buildings and homes, and data centers.

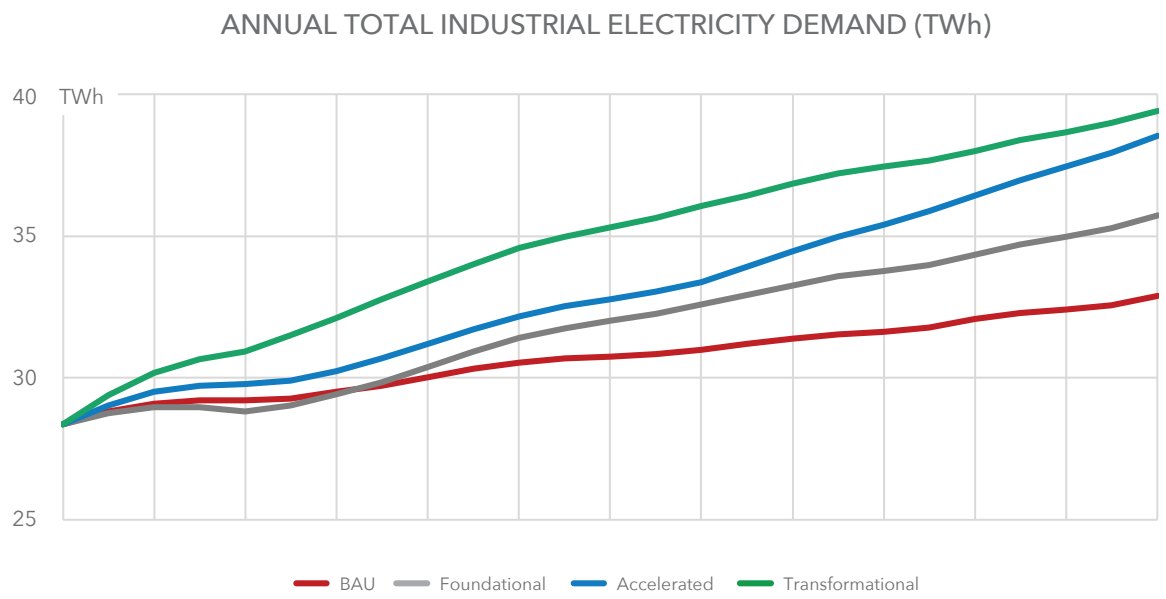


Figure 10 *Modeled annual industrial electricity demand in terrawatt hours (TWh) in Michigan through 2050, under the four policy scenarios investigated in this study. Results derived from the Energy Policy Simulator, by Energy Innovation.*

The modeling also estimates approximately $32.8 billion in cumulative electricity generation capacity construction spending under the transformational policy scenario between 2026 and 2050, compared to $31.1 billion under BAU – marking approximately $1.7 billion (5%) in additional generation investment.

Employment impacts

EPS results indicate that industrial decarbonization could generate employment benefits beyond manufacturing facilities and across Michigan's broader economy. These impacts include direct changes in jobs, indirect effects through supply chains, and induced effects from changes in household spending. These economic benefits could complement improvements in manufacturing competitiveness.

The results indicate that employment impacts vary across scenarios and time horizons, with significant gains across all scenarios in the mid 2030s and more sustained long-term employment growth under the transformational policy scenario. The foundational policy scenario produces the smallest employment gains, while the transformational policy scenario generates the largest long-term gains. By 2050, annual increases in direct, indirect, and induced jobs are 4.2x, 18.2x, and 2.4x higher under the transformational scenario than BAU, resulting in a cumulative 240,274 additional jobs relative to BAU between 2026-2050 (Figure 11). Notably, the foundational policy scenario has the weakest jobs outlook, with employment gains falling below BAU in some years and showing annual losses in manufacturing and construction jobs when all other scenarios demonstrate growth (Figure 12). These results suggest the importance of fully committing to decarbonization policy for the best outcomes – both environmentally and economically – for the state of Michigan.

Employment impacts also vary by sector.

Health and air quality benefits

In addition to reducing GHG emissions, industrial decarbonization can improve air quality and deliver public health benefits by reducing the release of harmful air pollutants. The EPS results estimate changes in pollutant emissions and associated health outcomes under each scenario, including avoided premature deaths, asthma attacks, and respiratory-related emergency department visits. These benefits accrue to both those working at industrial facilities and in surrounding communities, which often include environmental justice communities.

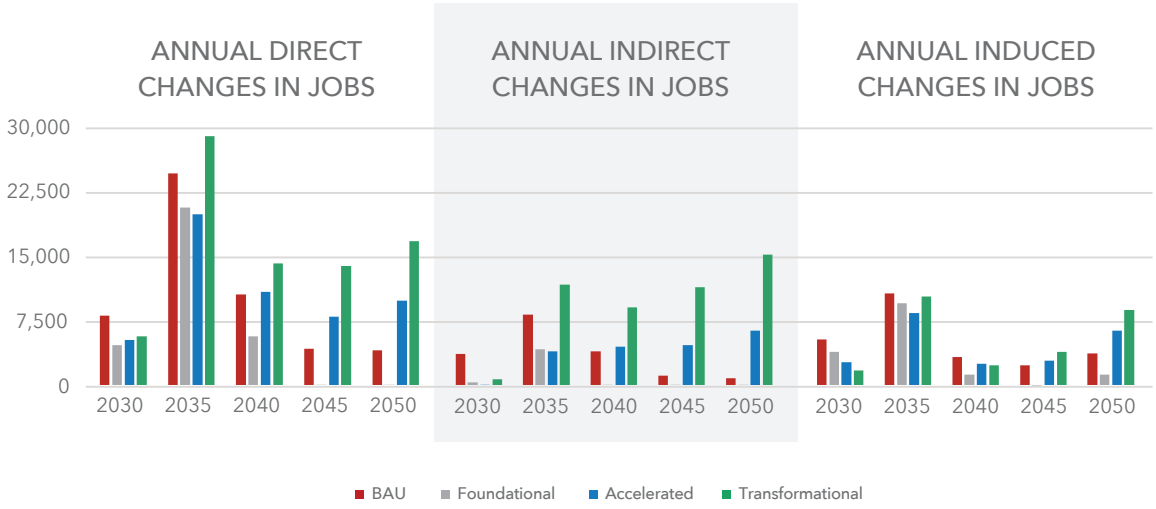


Figure 11 *Modeled shifts in annual industrial direct, indirect, and induced changes in employment in Michigan through 2050, under the four policy scenarios investigated in this study. Results derived from the Energy Policy Simulator, by Energy Innovation.*

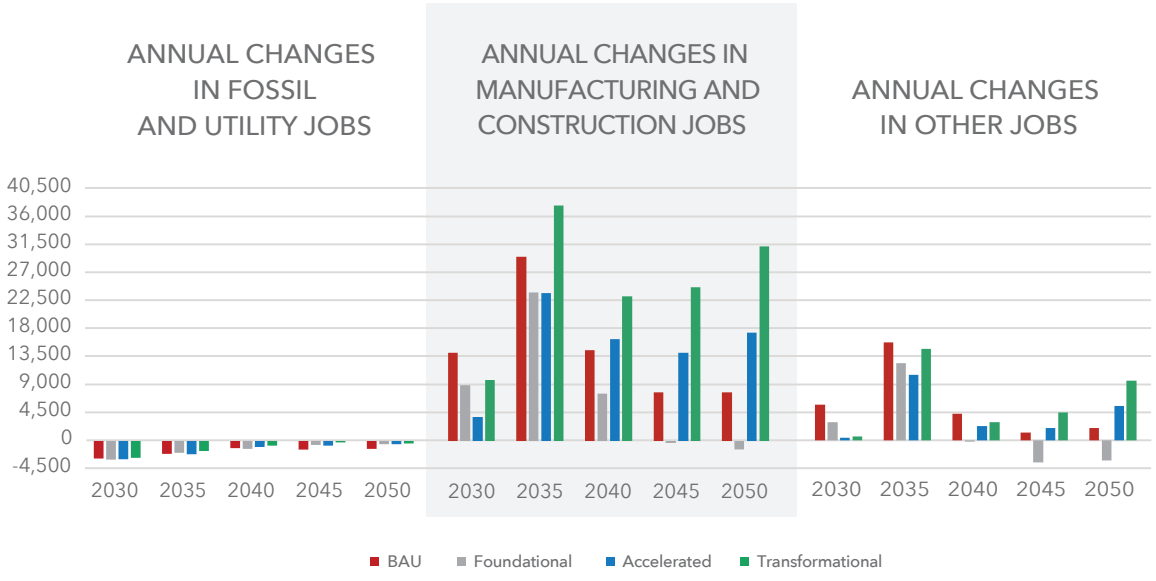


Figure 12 *Modeled shifts in annual changes in employment in select economic sectors in Michigan through 2050, under the four policy scenarios investigated in this study. Results derived from the Energy Policy Simulator, by Energy Innovation.*

The modeling shows that more ambitious industrial decarbonization efforts produce greater air quality improvements and thus greater associated health benefits. By 2050, annual emissions of several harmful air pollutants are reduced substantially by the transformational policy scenario. Specifically, nitrogen oxides (NO_x), carbon monoxide (CO), and sulfur oxides (SO_x) – three criteria air pollutants (CAPs) – are reduced by approximately 41%, 33%, and 33%, respectively, under the transformational policy scenario compared to BAU (Figure 13). Notably, under the transformational scenario, fluorinated gases (F gases) are slightly higher than BAU, driven by the chemicals subsector, which highlights the demand for targeted complementary mitigation in this area.

Figure 14 shows the annual NO_x emissions in a selection of industry subsectors in the BAU and transformational policy scenarios. Nitrogen dioxide (NO_2) is a CAP associated with a range of negative health outcomes including the aggravation of respiratory diseases, such as asthma, leading to coughing, wheezing, or difficulty breathing. This pollutant primarily enters the air through fuel combustion and forms by the oxidation of NO, hence the categorization of both pollutants as the more general 'NO_x'. By 2050, annual NO_x emissions from the highlighted industrial subsectors decrease by over 63% from the 2026 baseline, with especially strong reductions in road vehicles manufacturing (93%) and rubber and plastic products manufacturing (95%).

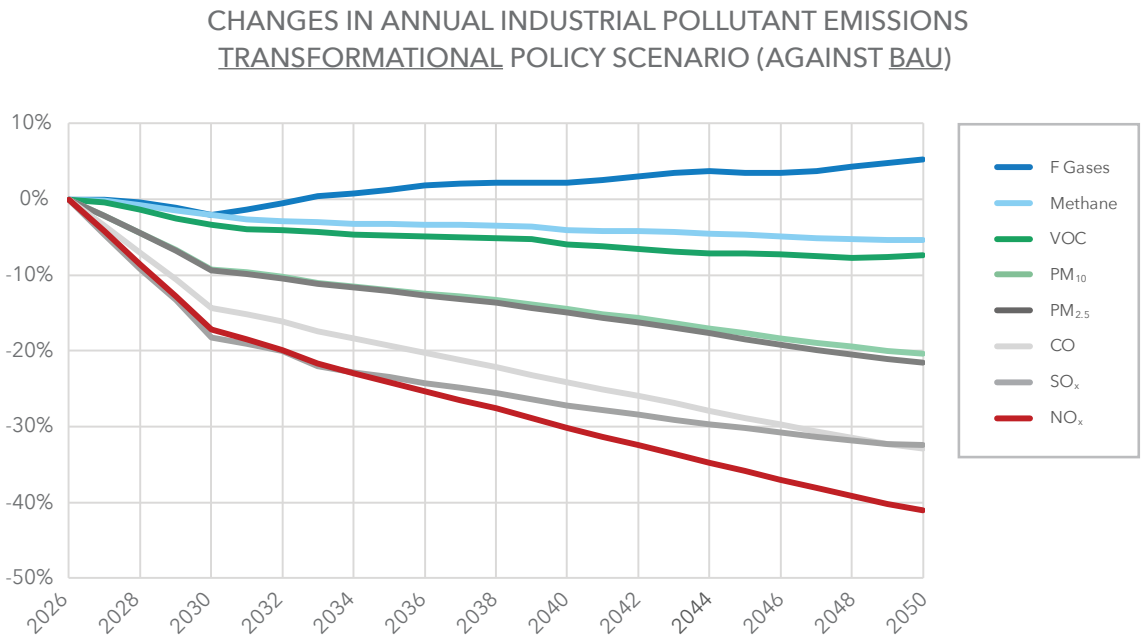


Figure 13 *Modeled annual reductions in industrial air pollutant emissions in Michigan through 2050, under the transformational policy scenario investigated in this study relative to BAU. A slight increase in fluorinated gases (F gases) under the transformational policy scenario indicates a need for complementary mitigation measures within the chemicals subsector. Results derived from the Energy Policy Simulator, by Energy Innovation.*

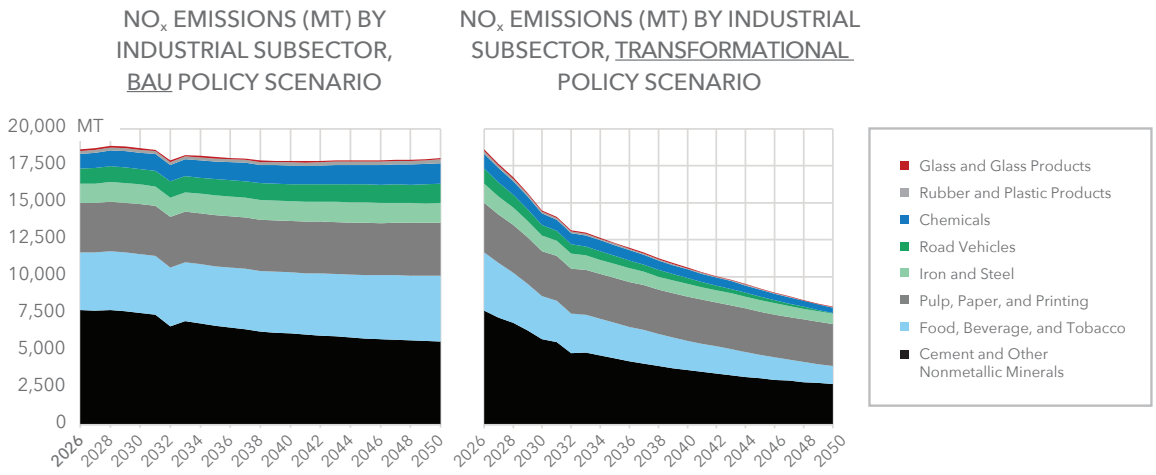


Figure 14 *Modeled annual NO_x emissions in metric tons (MT) from select industrial subsectors through 2050, under BAU and the transformational policy scenario investigated in this study. Total annual NO_x emissions from the selected subsectors decrease from 19,900 MT CO_2e in 2026 to 9,500 MT CO_2e in 2050. Results derived from the Energy Policy Simulator, by Energy Innovation.*

Coarse and fine particulate matter (PM10 and $PM_{2.5}$) are CAPs associated with severe health impacts such as aggravated asthma, arrhythmia, cardiac arrest, and premature mortality. According to the modeling results, communities will benefit from increasing avoided health impacts with deeper reductions in industrial air pollution over time – especially PM. As shown in Table 10, reductions in industrial emissions achieved through 2030 could prevent an additional 10 respiratory-related emergency room (ER) visits and more than 1,100 asthma attacks from 2027-2030, relative to the BAU policy scenario, with the further potential to prevent 83 premature deaths that could otherwise arise from industrial air pollution exposure. By 2050, the benefits of avoided industrial air pollution relative to the BAU policy scenario could accumulate to as many as 137 avoided respiratory-related ER visits and more than 15,100 avoided asthma attacks (over the 2027-2050 timeframe) – while preventing more than 1,130 additional premature deaths. These results highlight the potential for industrial decarbonization to create benefits beyond emissions mitigation by reducing, at least, the CAP exposure faced by members of the public, as described in *Benefits of Industrial Decarbonization*.

The economic value of the health benefits gained from industrial decarbonization also increases with greater levels of modeled deployment. By 2050, the annual monetized public health benefits associated with avoided premature mortality reach approximately $304 million greater than BAU under the foundational policy scenario, $448 million greater than BAU under the accelerated scenario, and $616 million greater than BAU under the transformational scenario (Figure 15). The estimates reflect the economic value of avoided adverse health outcomes, not direct financial savings.

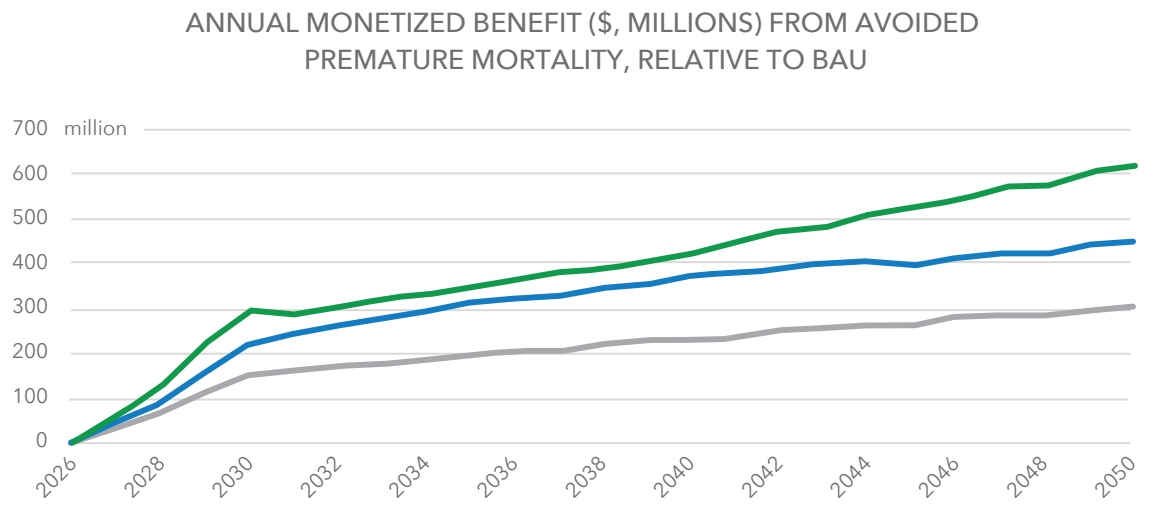


Figure 15 *Modeled annual monetized benefit in millions of U.S. dollars ($) associated with avoided premature mortality through 2050, due to reductions in air pollution across all three policy scenarios investigated in this study relative to BAU. Results derived from the Energy Policy Simulator, by Energy Innovation.*

Sector-specific GHGs

While the modeling results show the potential for deep reductions in statewide industrial GHG emissions, the extent of those reductions differs across industrial subsectors. Differences in manufacturing processes, energy use, and available technologies change the emissions trajectories of individual industries. Under the transformational policy scenario, some manufacturing subsectors reach near net-zero by 2050 while others still emit significant residual emissions.

Among the highlighted manufacturing subsectors, food and beverage, pulp and paper, and textiles undergo the greatest percentage reductions in GHG emissions relative to the 2026 baseline by 2050 – all declining by over 96% (Figure 16). Meanwhile, the glass, iron and steel, and chemicals sectors experience more limited reductions, with annual emissions remaining approximately 62%, 77%, and 59% below baseline, respectively. These differences illustrate the varying potential for emissions reductions across Michigan's industrial economy, even under more ambitious deployment assumptions.

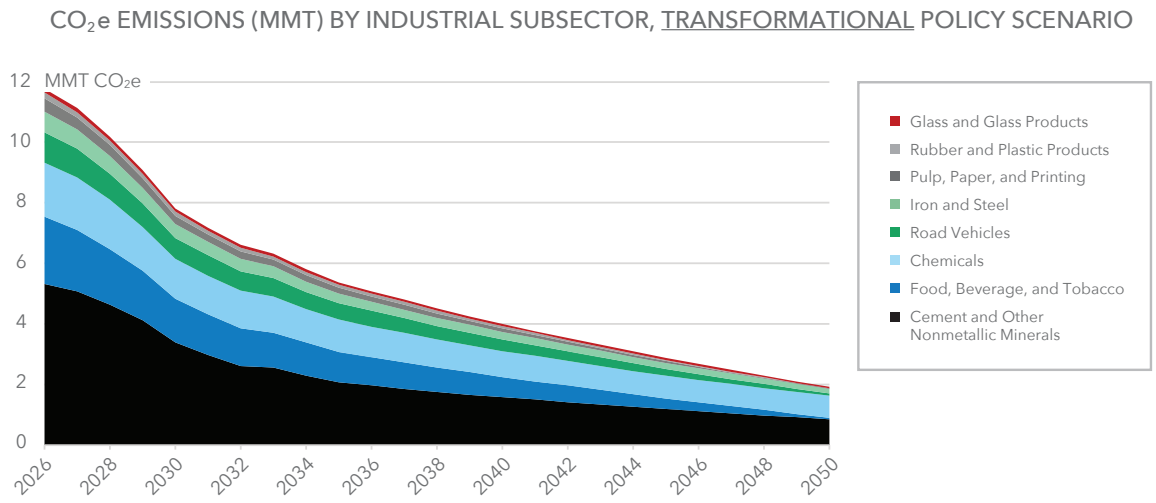


Figure 16 *Modeled annual greenhouse gas emissions in select industrial subsectors in Michigan through 2050, under the transformational policy scenario investigated in this study. Total annual GHG emissions from the selected subsectors decrease from 11.7 MMT CO_2e in 2026 to 1.9 MMT CO_2e in 2050. Results derived from the Energy Policy Simulator, by Energy Innovation.*

Sector-specific results highlight the interaction between GHG mitigation and air pollution reduction. Combined, the food, beverage, and tobacco manufacturing subsectors experience substantial reductions in air pollutant emissions relative to BAU alongside strong GHG emissions reductions. By 2050, annual emissions of methane – a potent greenhouse gas – and the criteria air pollutant SO_x are about 97% and 86% lower than BAU, respectively (Figure 17).

Persistent emissions in certain subsectors highlight the challenges associated with decarbonizing industrial processes that rely on high-temperature heat, carbon-intensive feedstocks, or chemical reactions that generate process emissions. Deeper reductions in these subsectors will necessarily rely on additional technology development and deployment, including alternative production processes, low-carbon feedstocks, carbon capture, and other solutions designed for specific industrial activities. Expanded widespread deployment of existing technologies could also reduce emissions beyond the levels reached in the transformational policy scenario.

These findings highlight the importance of an industrial decarbonization strategy that combines broadly applicable approaches, including energy efficiency and electrification, with targeted strategies for industries facing unique technical and economic barriers. They also underscore the need to support the continued innovation and commercialization of emerging technologies to address emissions that are beyond the reach of the scenarios modeled in this study.

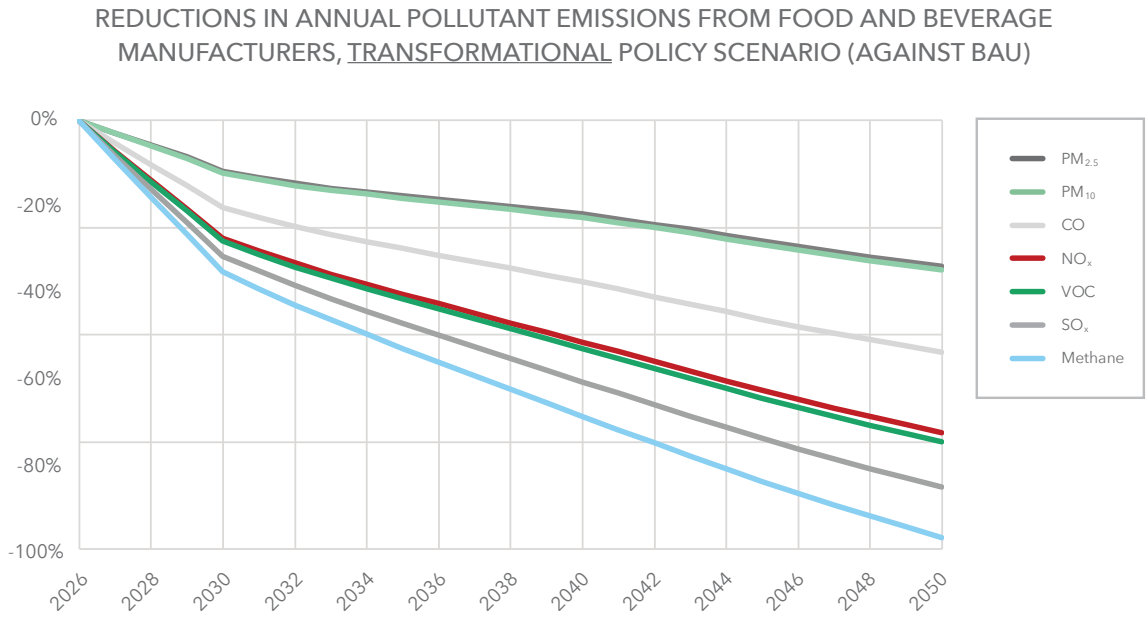


Figure 17 *Modeled annual air pollutant emissions from the food, beverage, and tobacco product manufacturing subsectors under the transformational policy scenario investigated in this study relative to BAU. Fluorinated gases (F gases) are not included, because no emissions of that type originate from this sector, when using the Energy Policy Simulator, by Energy Innovation.*

Policy Sequencing and Implementation

The EPS modeling results presented in *Scenario results and findings* show the potential for industrial decarbonization to reduce emissions and create economic and public health benefits. Reaching those outcomes, however, will require coordinated policy implementation and — especially — sequencing. Effective policy sequencing can also help increase Michigan's industrial competitiveness by reducing uncertainty and managing costs. The effectiveness of individual policies will depend on both their individual design and rollout, as well as their timing and interaction with other policy measures and state programs.

The sequencing framework presented below identifies recommended timing for scaling policies and pathways over time. It is informed by the modeling results, stakeholder engagement, and considerations related to technology readiness, implementation capacity, and the interrelationships among policy recommendations. The framework identifies opportunities to establish enabling conditions in the near term while preparing for increased deployment of technologies and strategies in the future. Figure 18 shows how selected policies should be sequenced over the near, medium, and longer term.

NEAR-TERM PRIORITIES: 2027-2030

Near-term efforts should prioritize policies that build supply chain capacity, address existing barriers to industrial decarbonization, and support the deployment of commercially available technologies. Many pathways can build on existing Michigan programs, allowing the state to scale implementation while engaging stakeholder groups to develop more comprehensive approaches.

Expanding and clarifying EWR programs and eligibility, strengthening industrial energy assessments and implementation assistance, and establishing centralized industrial decarbonization resources can help facilities identify and pursue cost-effective emissions reductions. These policies are especially important for small and mid-sized manufacturers, which often lack the same access to technical expertise or financing as larger facilities. Coordinating efforts with existing technical assistance providers can help avoid redundancy. Financial support should also be an early priority. Industrial decarbonization grants and targeted incentives can help reduce upfront capital costs, mitigate risk, and support the early deployment of technologies such as IHPs, electric boilers, thermal energy storage, and waste heat recovery. Demonstration projects and innovation partnerships can demonstrate feasibility and provide case studies for additional deployment.

In parallel, Michigan should start to address the regulatory and infrastructure barriers that are likely to limit the future deployment of electrified technologies. Developing new industrial electrification tariffs, improving permitting navigation, and coordinating industrial electricity demand with utility planning will help prepare the grid for additional industrial loads. Early gas system transition planning will also support coordination between electric and gas utilities and industrial customers. Workforce development initiatives should be launched to make sure that the skills and labor capacity needed are available as the transition continues.

Development of several policies with longer timelines should also begin before 2030 — including emissions reporting and performance baselines, developing 'Buy Clean, Buy Michigan' procurement frameworks, evaluating clean heat incentives and standards, and advancing the regulatory framework for CCUS. Early planning and stakeholder engagement will reduce implementation barriers and prepare policies for adoption or expansion.

MEDIUM-TERM PRIORITIES: 2030-2035

As near-term programs grow, Michigan should focus on scaling success and expanding the reach of industrial decarbonization policies. The medium term could involve increased deployment, deeper investment, the introduction of policies that depend on market development, and the commercialization of developing technologies. Industrial grants and technical assistance programs should be expanded to support new kinds of facilities and more capital-intensive projects. Experience from early demonstrations and assessments could help inform program design and reduce uncertainty for both end-users and financial institutions. Over time, financing mechanisms should largely transition from reliance on direct funding towards more self-sustaining models that leverage private capital, revolving funds, and other approaches that reinvest into future projects.

Market-facing policies will be critical in this stage. 'Buy Clean, Buy Michigan' requirements should progress from emissions reporting and EPDs towards procurement preferences or performance thresholds for selected materials. Clean heat or industrial emissions performance standards should be introduced or strengthened as technical assistance, financial incentives, and alternative technologies become more available. Pairing requirements with ongoing, long-term implementation support will be important for maintaining competitiveness.

Infrastructure development will be another essential factor. Industrial clusters and shared infrastructure projects could support the coordinated deployment of technologies and services that may be difficult or costly for individual facilities. Continued utility coordination, infrastructure planning, and rate design improvements will be important for growing industrial electricity demand while managing costs.

LONGER-TERM PRIORITIES: 2035-2050

Longer-term efforts should focus on sustaining deployment, creating deeper reductions, and addressing emissions sources that are hard to abate through established approaches. As technologies commercialize and markets develop, Michigan could strengthen existing performance requirements, expand incentives, and pursue more comprehensive emissions reduction strategies. Policies supporting alternative industrial processes, low-carbon feedstocks, shared infrastructure, and CCUS may be increasingly important for facilities that have limited opportunities for efficiency improvements or electrification.

The EPS modeling results presented in this report show that significant industrial emissions remain in 2050, even under the transformational policy scenario. Addressing those emissions will likely require additional policies or technologies beyond those modeled here. Continued innovation, technology commercialization, and reassessment of emissions-reducing opportunities will be important.

Longer-term implementation could also include broader market-based approaches, including a regional 'Cap and Invest' program.

BUILDING ON EARLIER POLICIES, COORDINATING IMPLEMENTATION

Although the framework identifies three implementation periods, many policy recommendations should be developed and implemented simultaneously and continuously. Several policies have the potential to enable or strengthen the effectiveness of others, making coordination of new policy rollout essential.

For example, industrial energy assessments and technical assistance can identify opportunities for efficiency improvements and electrification, but financial support and new utility rate structures may be necessary for facilities to implement recommendations. Additionally, industrial electrification tariffs and utility planning should advance before large-scale deployment creates significant new electricity demand. Workforce development and permitting improvements can further support broader efforts by reducing delays and implementation barriers. For additional insights, see *Appendix A: Core Policy and Sub-Policy Business Cards*.

Other policies will benefit from more deliberate progression. 'Buy Clean, Buy Michigan' procurement policies should begin with emissions reporting and data collection before creating procurement requirements. Clean heat and emissions performance standards could build on early investments in technical assistance, financial incentives, and technology demonstrations, to ensure that facilities have well-known compliance pathways. Industrial clusters and shared infrastructure projects will likely rely on feasibility studies, partnerships, and coordinated infrastructure planning.

These relationships and others reflect the importance of considering the roadmap's recommendations as a coordinated policy portfolio and not as isolated ideas. Policies that reduce barriers, build capacity, and support early deployment will establish the conditions for more significant reductions over time.

Policy sequencing should also be adaptive. Changes in costs, federal policy, grid conditions, industrial investment, and available resources will change the feasibility and/or urgency of individual recommendations. Michigan should reevaluate implementation progress and adjust priorities with stakeholder input. This will allow the state to aggressively pursue near-term emissions reductions while maintaining flexibility for emerging opportunities and challenges.

FROM ROADMAP TO IMPLEMENTATION

Michigan should take four immediate steps:

1. Identify lead agencies and implementation partners for priority recommendations, especially for policies that rely on cross-agency coordination.
2. Evaluate near-term implementation opportunities, including existing program authorities, available funding, and potential legislative or regulatory actions.
3. Maintain stakeholder engagement to refine policy design, identify demonstration opportunities, and address barriers.
4. Establish a process for tracking progress and revisiting priorities as technologies, markets, and other circumstances evolve.

Michigan has an opportunity to advance industrial decarbonization while strengthening its manufacturing economy, supporting workers, improving public health, and improving affordability. The analysis presented in this roadmap demonstrates that significant industrial emissions reductions are possible. However, the modeling also illustrates that deeper reductions will require progressively greater deployment, supporting infrastructure, and continued innovation.

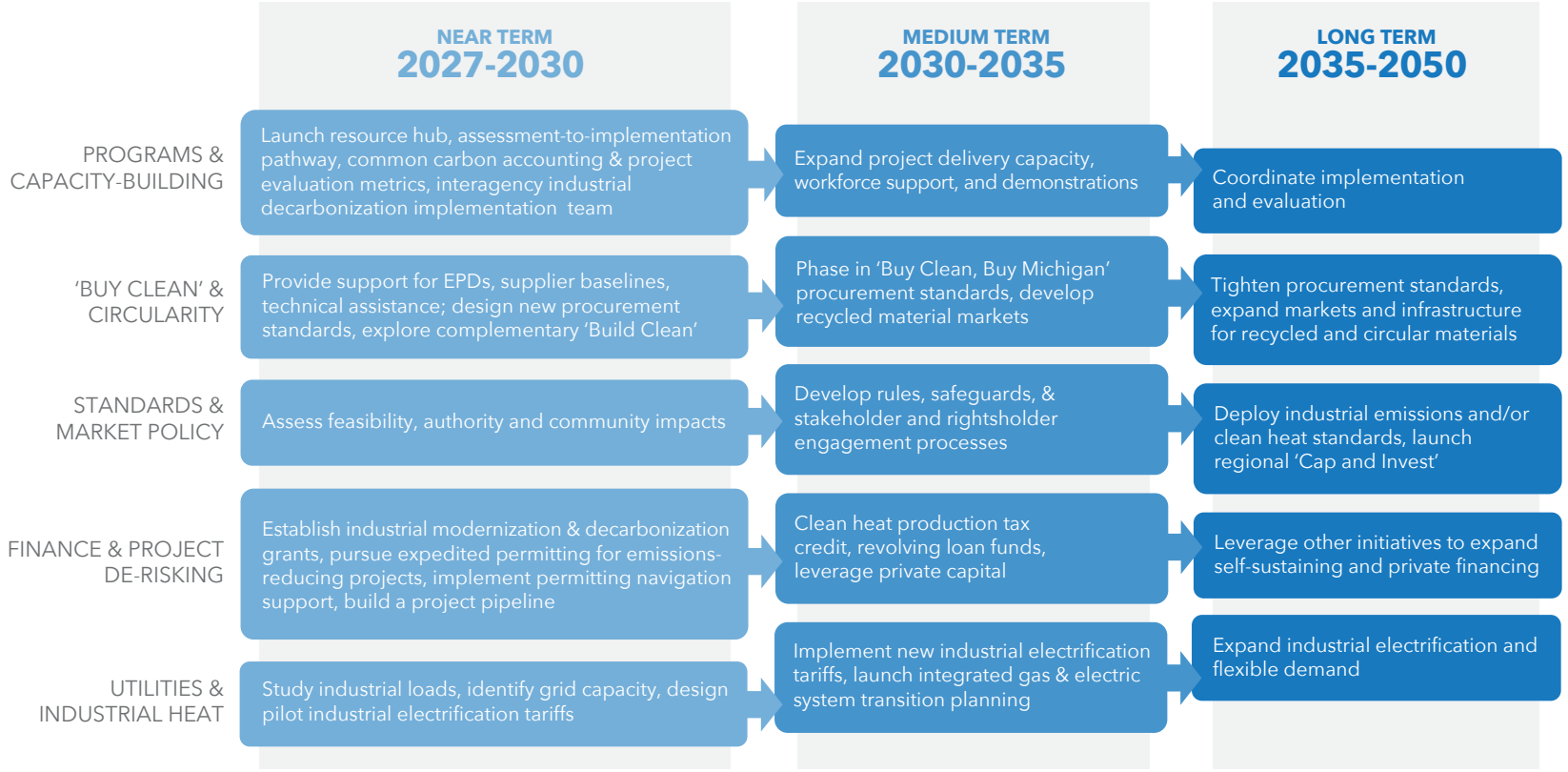
The policy recommendations in this roadmap provide a framework for addressing these challenges. No single policy or technology can stand on its own — and the effectiveness of interventions will depend on how each is implemented with complementary measures. Early investments in technical assistance, financing, workforce development, and infrastructure planning can help unlock near-term opportunities while establishing the conditions for more action. Michigan should also begin preparing for longer-term challenges, including hard-to-abate industrial processes and emissions sources.[146]

The transition will take sustained collaboration between state government, manufacturers, utilities, workers, communities, and others. By building on existing programs, coordinating policy implementation, and adapting approaches as technologies and markets evolve, Michigan can translate the recommendations of this roadmap into meaningful progress towards its climate goals while supporting a competitive and resilient industrial economy.

146 M. Kostylev, E. Boatman, and H. Ma, "Net-Zero Industry in Michigan: Groundwork for Mitigating Hard-to-Abate Emissions," 5 Lakes Energy, March 2026.

Figure 18

CRITICAL POLICY SEQUENCING FOR DECARBONIZING MICHIGAN'S INDUSTRIAL SECTOR



Note that this graphic is for illustrative purposes only, and does not include every policy identified in the roadmap text.

Appendix A: Core Policy and Sub-Policy Business Cards

INDUSTRIAL MODERNIZATION AND DECARBONIZATION GRANT PROGRAM

Lead	• EGLE OCE
Supporting offices/g oups	• MEDC, MPSC/utilities, workforce partners, implementers
Authority	• New legislation and appropriations
Initial funding	• $25+ million
Timing	• Near-term establishment, recurring funding based on demand and feedback
Policy pillars	• Funding and recognition, financing, technical assistance, economic development
Guiding principles	• Ground the work in the MI Healthy Climate Plan, focus on implementation-oriented recommendations, advance emissions reductions while supporting competitiveness, address barriers directly, recognize the diversity of Michigan's industrial sector
Stakeholder support	• Manufacturers, environmental advocates, implementers, national NGOs, technology OEMs, state agencies
EPS scenario pathway	• **Foundational**: Early deployment and demonstrations • **Accelerated**: Broader deployment, early retirements • **Transformational**: Grants complement standards and market signals, focus on hard-to-abate applications
Key EPS levers	• Early retirement, electrification, improved system design, energy efficiency, cogeneration, feedstock shifting, CCS
Complementary policies	• Assessments, integrated industrial modernization resource and project delivery system, EWR clarification, industrial electrification tariffs, 'Buy Clean, Buy Michigan,' phased emissions reduction standards

CLEAN HEAT PRODUCTION TAX CREDIT

Lead	• MI Department of Treasury, EGLE OCE
Supporting offices/g oups	• MEDC, MPSC/utilities, technical assistance providers, other state offices
Authority	• New legislation
Initial funding	• TBD
Timing	• Near-term establishment, multi-year availability
Policy pillars	• Funding and recognition, financing, economic development
Guiding principles	• Ground the work in the MI Healthy Climate Plan, advance emissions reductions while supporting competitiveness, address barriers directly, recognize the diversity of Michigan's industrial sector
Stakeholder support	• Manufacturers, environmental advocates, implementers, national NGOs, technology OEMs
EPS scenario pathway	• **Foundational**: Targeted support for commercially available technologies • **Accelerated**: Broader uptake across industrial applications • **Transformational**: Mature markets with PTC complementing stronger standards and market signals
Key EPS levers	• Electrification, hydrogen combustion, industry energy efficiency; potentially feedstock/fuel-related levers depending on final eligibility
Complementary policies	• Industrial modernization and decarbonization grant program, industrial electrification tariffs, EWR clarification, common carbon accounting and project evaluation metrics, assessments, integrated industrial modernization resource and project delivery system, phased emissions reduction and clean heat standards

INDUSTRIAL ELECTRIFICATION TARIFFS

Lead	• MPSC
Supporting offices/g oups	• Electric utilities, EGLE OCE, MEDC, industrial customers, technology providers
Authority	• MPSC investigation and utility rate proceedings- possible that additional statutory direction is needed
Initial funding	• Regulatory/utility administrative resources
Timing	• **Near-term**: Investigation and load profile development • **Near- to medium-term**: Pilots/tariff proposals
Policy pillars	• Financing, technical assistance, end-user energy intensity
Guiding principles	• Ground the work in the MI Healthy Climate Plan, address barriers directly, recognize the diversity of Michigan's industrial sector
Stakeholder support	• Manufacturers, technology OEMs/implementers, environmental advocates, national NGOs, Utility Working Group
EPS scenario pathway	• **Foundational**: Tariffs enable early electrification projects • **Accelerated**: Broader electrification supported by improved rate structures and flexible load deployment • **Transformational**: Tariffs support widespread industrial electrification with incentives, standards, and grid investment
Key EPS levers	• Electrification, efficiency
Complementary policies	• Industrial modernization and decarbonization grant program, clean heat production tax credit, EWR clarification, integrated gas and electric system transition planning, industrial energy sharing and co-location, BESS incentives, phased emissions reduction and clean heat standards

'BUY CLEAN, BUY MICHIGAN'

Lead	• State procurement agencies with EGLE OCE and MEDC
Supporting offices/g oups	• MDOT, DTMB, MEDC, local governments, contractors
Authority	• Combination of legislation, procurement policy/rules, and agency implementation
Initial funding	• Administrative resources and dedicated funding for EPD development, supplier technical assistance, and manufacturer capacity building
Timing	• **Near-term**: EPDs, supplier baseline, and program development • **Medium-term**: Emissions preferences/thresholds • **Long-term**: Tighter standards and expansion to additional materials and purchasers
Policy pillars	• Funding and recognition, technical assistance, economic development, end-user energy intensity
Guiding principles	• Ground the work in the MI Healthy Climate Plan, advance emissions reductions while supporting competitiveness, address barriers directly, recognize the diversity of Michigan's industrial sector, support workers and workforce development, support frontline, neighboring and Tribal communities, use transparent data and shared assumptions
Stakeholder support	• Manufacturers, EJ groups, labor, environmental organizations, and others
EPS scenario pathway	• **Foundational**: Disclosure/EPDs and procurement requirements for priority materials • **Accelerated**: Emissions thresholds/preferences and broader supplier participation • **Transformational**: Increasing standards, expanded procurement coverage, and demand for low-carbon materials
Key EPS levers	• Cement clinker substitution, material efficiency, longevity and re-use, buy in-region products
Complementary policies	• Industrial modernization and decarbonization grant program, common carbon accounting and project evaluation metrics, expand markets and infrastructure for recycled and circular materials, expanded/targeted workforce support, apprenticeships and upskilling, integrated industrial modernization resource and project delivery system

EXPANDED/TARGETED WORKFORCE SUPPORT

Lead	• LEO
Supporting offices/g oups	• MEDC, EGLE OCE, community colleges, organized labor, technology OEMs, and regional workforce organizations
Authority	• Existing workforce program authority, potentially additional appropriations for future program direction
Initial funding	• Expand existing workforce and apprenticeship funds, potential dedicated funding for training capacity, equipment, and outreach
Timing	• **Near-term**: Assess and coordinate existing programs • **Medium-term**: Expand recruitment, apprenticeship, and upskilling as deployment increases • **Long-term**: Continue updating curricula with new technology development
Policy pillars	• Funding and recognition, technical assistance, economic development
Guiding principles	• Ground the work in the MI Healthy Climate Plan, address barriers directly, recognize the diversity of Michigan's industrial sector, support workers and workforce development
Stakeholder support	• Labor, EJ, environmental advocates, state agencies, and manufacturers
EPS scenario pathway	• Workforce is an enabler across all three scenarios. The scale needed increases directly with deployment.
Key EPS levers	• Enabling policy
Complementary policies	• Industrial modernization and decarbonization grant program; clean heat PTC; industrial electrification tariffs; 'Buy Clean, Buy Michigan;' clean industrial innovation, demonstration, and shared infrastructure hubs

EXPEDITED PERMITTING FOR EMISSIONS-REDUCING PROJECTS

Lead	• EGLE
Supporting offices/g oups	• EGLE AQD
Authority	• Primarily administrative coordination
Initial funding	• Staff capacity for navigation, technical assistance, and coordinated review
Timing	• **Near-term:** Navigation and barrier assessment • **Medium-term:** Targeted expedited pathway
Policy pillars	• Technical assistance, economic development
Guiding principles	• Ground the work in the MI Healthy Climate Plan, advance emissions reductions while supporting competitiveness, address barriers directly, use transparent data and shared assumptions
Stakeholder support	• Manufacturers, OEMs, and others
EPS scenario pathway	• Enabling policy, supports tech deployment in all scenarios
Key EPS levers	• Supports deployment of all scenarios
Complementary policies	• Michigan industrial modernization and decarbonization strategy and implementation structure, industrial modernization and decarbonization grant program

EXPAND MARKETS AND INFRASTRUCTURE FOR RECYCLED AND CIRCULAR MATERIALS

Lead	• EGLE Materials Management Division
Supporting offices/g oups	• MEDC, counties/local governments, DTMB/MDOT, manufacturers, recyclers/processors, NextCycle partners
Authority	• Build on existing materials management and grant authorities • Legislation needed for EPR or other new revenue mechanisms
Initial funding	• Expand existing circular economy/recycling grants, and evaluate EPR and other funding mechanisms
Timing	• **Near-term**: Prioritize material streams, fund infrastructure/end markets, support MMP implementation • **Medium-term**: Scale markets and evaluate new financing mechanisms
Policy pillars	• Financing, technical assistance, economic development, end-user energy intensity
Guiding principles	• Ground the work in the MI Healthy Climate Plan, advance emissions reductions while supporting competitiveness, address barriers directly, use transparent data and shared assumptions
Stakeholder support	• Manufacturers, technology OEMs, EJ groups, circularity groups
EPS scenario pathway	• **Foundational**: Efficiency, material efficiency, buy in-region products • **Accelerated**: Methane capture, destruction • **Transformational**: Greater uptake/impact
Key EPS levers	• Material efficiency, longevity and re-use, buy in-region products
Complementary policies	• 'Buy Clean, Buy Michigan,' industrial modernization and decarbonization grant program, integrated industrial modernization resource and project delivery system, expedited permitting for emissions-reducing projects, expanded/targeted workforce development

'CAP AND INVEST'

Lead	• EGLE
Supporting offices/g oups	• MEDC, MI Department of Treasury, other agencies, neighboring states, industry, labor, EJ/community organizations
Authority	• New legislative authority required
Initial funding	• Near-term state funding for analysis and program development, potential future auction proceeds
Timing	• **Near-term**: Feasibility, engagement, regional coordination • **Medium- and long-term**: Program design and potential regional implementation
Policy pillars	• Funding and recognition, financing, economic development, end-user energy intensity
Guiding principles	• Ground the work in the MI Healthy Climate Plan, advance emissions reductions while supporting competitiveness, address barriers directly, use transparent data and shared assumptions
Stakeholder support	• EJ groups, circularity groups
EPS scenario pathway	• **Foundational**: Analysis and regional coordination • **Accelerated**: Development of regional support and complementary investments • **Transformational**: Declining regional cap creates economy wide industrial decarbonization signal
Key EPS levers	• Electrification, efficiency, material efficiency, system design, feedstock shifting, CCS, clinker substitution, and other emissions reducing pathways
Complementary policies	• Industrial modernization and decarbonization grant program, 'Buy Clean, Buy Michigan,' common carbon accounting and project evaluation metrics, expanded/targeted workforce support, community benefits/air-quality framework

Appendix B: EPS Methodology Details and Assumptions

The Energy Policy Simulator (EPS) has levers that model the impacts of industrial decarbonization in emissions, economics, public health, and more. To use EPS to effectively model the policies included in the roadmap, we cross-walked those policies to the available levers in EPS, and adjusted lever settings across four policy scenarios: BAU, foundational, accelerated, and transformational. To identify plausible levels of deployment, we used a combination of EPS default assumptions and literature review to establish upper-bound assumptions for the transformational scenario. We then scaled down the lever settings by scenario at select intervals (2030, 2040, and 2050) to illustrate ranges of potential deployment and impacts.

We identified industrial fuel consumption inputs using sector-specific estimates for 11 ISIC categories (07-08, 10-12, 19, 20, 231, 239, 241, 242, 25, 28, and 30). These estimates replaced the corresponding EPS default inputs, while fuel consumption for other industrial categories continued to use existing EPS assumptions. As a result, aggregate industrial fuel consumption outputs reflect a broader set of subsectors than those for which inputs were updated.

It is important to note that the BAU scenario developed for this analysis is not equivalent to the default baseline in EPS. Our BAU scenario incorporates existing policies and anticipated changes across multiple sectors of the economy, including decarbonization of Michigan's electricity generation and other sectors. The differences between the BAU scenario and the foundational, accelerated, and transformational scenarios represent the modeled impacts of additional industrial decarbonization measures. This is important when interpreting our results, especially emissions reductions, energy consumption changes, economic impacts, and health outcomes. For example, the BAU scenario may show improvements in health outcomes even as industrial air pollutant emissions remain constant or increase, due to reductions occurring in other sectors.

We chose not to include several available EPS levers because they were beyond the scope of our policy inputs. There were also many subsectors and processes that various levers should not impact based on standard decarbonization principles. For example, we did not attempt to use the electrification lever to decarbonize processes such as cooling, machine drive, or electrochemical processes, which are generally already electrified.

Although these excluded levers, subsectors, and processes may be indirectly affected by roadmap policies, we did not explicitly model those impacts. These exclusions, along with the limits of our modeled policy and technology deployment assumptions, help explain why the scenarios do not achieve net-zero industrial emissions by 2050.

The EPS levers that were not adjusted from BAU settings included:

- F-gas substitution
- F-gas destruction
- F-gas recovery
- F-gas maintenance retrofit
- Industrial livestock measures

- Industrial tillage
- Non-BAU industrial process emissions
- Industrial shift to non-animal products
- Non-BAU industry CCS subsidy
- Industrial N_2O abatement

For each lever, we detail below the meaning of a 'full' in the context of EPS; which subsectors were impacted by the lever pull; the lever settings modelled for each scenario in 2030, 2040, and 2050; the roadmap policies driving and/or supporting each lever; and the source of the upper bound value. For some levers, we detail additional refinements that we made to account for differences in applicability across subsectors and processes.

METHANE CAPTURE

A 100% lever setting represents capture of all methane emissions eligible for capture under the model's assumptions. We applied methane capture to food beverage and tobacco, pulp, paper, and printing, and water and waste. The foundational scenario reflects implementation of the policy recommendation that Michigan should expand markets and infrastructure for recycled and circular materials. The accelerated scenario assumes stronger implementation of circular material policies and extended producer responsibility (EPR). The transformational scenario assumes more extensive implementation of these policies. The transformational scenario assumes an upper bound of 75% methane capture by 2050, using U.S. EPA's recommended default landfill gas collection efficiency as a proxy benchmark. EPA reports collection efficiencies ranging from 50% to 95%, depending on landfill design and operating conditions.[147]

SCENARIO	2030	2040	2050
Foundational	10%	20%	30%
Accelerated	15%	35%	50%
Transformational	25%	55%	75%

METHANE DESTRUCTION

A 100% lever setting represents destruction of all methane emissions eligible under the assumptions in EPS. We applied methane destruction to food, beverage, and tobacco, and pulp, paper, and printing. The scenarios reflect increasing implementation of the policy recommendation that Michigan should expand markets and infrastructure for recycled and circular materials, especially measures supporting landfill methane beneficial use or destruction. The transformational scenario assumes an upper bound of 100% methane destruction by 2050 – the maximum modeled potential. EPA guidance indicates that methane destruction efficiencies in landfill gas flares typically exceed 99%.[148]

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[147] "Background Information Document for Updating AP42 Section 2.4 for Estimating Emissions from Municipal Solid Waste Landfills," U.S. Environmental Protection Agency, 2008.

[148] "Continue to Operate Gas Collection System and Flare," U.S. Environmental Protection Agency, accessed September 2026.

SCENARIO	2030	2040	2050
Foundational	10%	25%	40%
Accelerated	20%	65%	78%
Transformational	30%	70%	100%

CEMENT CLINKER SUBSTITUTION

A 100% lever setting represents reducing the clinker-to-cement ratio to 60%, meaning clinker accounts for 60% of cement composition, while 40% is made up of alternative materials. The scenarios reflect increasing implementation of 'Buy Clean, Buy Michigan,' industrial decarbonization and modernization grants and other financing mechanisms, and emissions performance requirements. The transformational scenario assumes full deployment of the cement clinker substitution lever by 2050, reducing the cement-to-clinker ratio to 60%. This is consistent with U.S. DOE modeling of clinker factors of approximately 65%-66% and the IEA's Net Zero Emissions by 2050 Scenario, which projects a ratio of 57% clinker substitution by 2050.[149,150]

SCENARIO	2030	2040	2050
Foundational	10%	20%	30%
Accelerated	20%	40%	60%
Transformational	30%	65%	100%

INDUSTRIAL EARLY RETIREMENT

A 100% lever setting represents full implementation of accelerated retirement and the replacement of existing industrial equipment before the end of its anticipated useful life. The transformational scenario assumes an upper bound of 50% implementation by 2050, reflecting the roadmap's emphasis on accelerating equipment turnover through incentives and performance requirements. EPS estimates that full implementation of the lever reduces industrial fuel consumption by approximately 2%-9% by 2050 for most industries.

[149] "Pathways to Commercial Liftoff: Low-Carbon Cement," U.S. Department of Energy, July 2025.

[150] "Cement," International Energy Agency, September 2023.

SCENARIO	2030	2040	2050
Foundational	5%	10%	15%
Accelerated	10%	20%	30%
Transformational	15%	30%	45%

INDUSTRIAL SYSTEM INTEGRATION

A 100% lever setting represents full deployment of industrial system integration measures, resulting in an estimated 3.6% reduction in industrial fuel consumption under EPS assumptions. The transformational scenario assumes full implementation by 2050 because system integration improvements are broadly applicable, relatively mature, and directly supported by roadmap policies related to assessments, technical assistance, EWR, financing, and performance requirements.

SCENARIO	2030	2040	2050
Foundational	10%	20%	30%
Accelerated	20%	40%	60%
Transformational	30%	60%	100%

INDUSTRIAL CHP

A 100% lever setting represents full deployment of combined heat and power (CHP) measures under EPS assumptions, resulting in an estimated 7.9% reduction in industrial fuel consumption. The transformational scenario assumes full implementation by 2050, using the maximum EPS lever setting as the technical upper bound.

SCENARIO	2030	2040	2050
Foundational	10%	20%	30%
Accelerated	20%	40%	60%
Transformational	30%	60%	100%

INDUSTRIAL EFFICIENCY STANDARDS

Unlike most other EPS levers, the setting itself corresponds directly to the percentage reduction in industrial energy use relative to BAU. The scenarios reflect increasing implementation of energy waste reduction (EWR), industrial energy assessments, the Technical Resource Hub, industrial decarbonization and modernization grants and financing, and an industrial emissions performance standard. We excluded agriculture and forestry, extractive industries, pipelines and gas processing, water and waste, and construction. The transformational scenario assumes an upper bound of 17% energy savings by 2050, based on the maximum industrial energy efficiency improvement estimated by EPS. This assumption is supported by a U.S. DOE industrial efficiency potential analysis finding that manufacturers in the United States could double their annual rate of industrial energy-efficiency improvement relative to BAU.[151]

SCENARIO	2030	2040	2050
Foundational	0%	5%	5%
Accelerated	5%	10%	10%
Transformational	5%	10%	17%

INDUSTRIAL SHIFT TO ELECTRICITY

A 100% lever setting represents full electrification of eligible industrial energy uses relative to BAU under EPS assumptions. We excluded non-manufacturing sectors, including agriculture and forestry, coal mining, oil and gas extraction, other mining and quarrying, energy pipelines and gas processing, water and waste, and construction. We also excluded cooling, machine drive, and electrochemical processes across all manufacturing sectors because those processes are generally already electrified.

Unlike other levers, we applied different levels of electrification across manufacturing subsectors and end uses to account for differences in technical feasibility and deployment potential. We developed four electrification tiers (low, medium, high, and very high) to show greater levels of electrification relative to BAU. Each tier was assigned a set of lever settings for the scenarios in 2030, 2040, and 2050. Manufacturing subsectors were then assigned electrification tiers for boilers and non-boiler low-temperature, non-boiler medium-temperature, and non-boiler high-temperature processes based on our assumptions of electrification potential. Electrification tiers for boilers and non-boiler medium and high-temperature processes varied by subsector. 'Other processes' were assigned the same settings as non-boiler medium-temperature processes.

The scenarios reflect increasing implementation of roadmap policies supporting industrial electrification, including grants, EWR, financing, clean heat emissions standards, and a PTC.

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[151] "Better Plants Frequently Asked Questions," U.S. Department of Energy, March 2016.

Electrification tier by subsector:

SCENARIO	BOILERS	NON-BOILER MED TEMP	NON-BOILER HIGH TEMP
Food & Textiles	Very High	Very High	High
Pulp, Paper, & Wood	Very High	High	Medium
Chemicals	High	Medium	Low
Refinin	High	Medium	Low
Glass	High	High	Medium
Cement & Nonmetallic Minerals	High	Medium	Low
Iron & Steel	High	High	Medium
Other Metals	High	High	Medium
Fabrication, Assembly, & Rubber	Very High	High	High
Other Manufacturing	High	High	High

Electrification tier by EPS lever impact:

ELECTRIFICATION TIER	SCENARIO	2030	2040	2050
Very High	Foundational	10%	25%	35%
	Accelerated	10%	45%	65%
	Transformational	30%	65%	100%
High	Foundational	10%	20%	30%
	Accelerated	15%	35%	55%
	Transformational	25%	55%	85%
Medium	Foundational	5%	15%	20%
	Accelerated	10%	25%	40%
	Transformational	15%	40%	60%
Low	Foundational	0%	5%	10%
	Accelerated	5%	10%	20%
	Transformational	10%	20%	30%

INDUSTRIAL SHIFT TO HYDROGEN

A 100% lever setting represents full substitution of eligible industrial fuel use with hydrogen under EPS assumptions. We applied the hydrogen lever to specific energy-intensive manufacturing subsectors, including refined petroleum and coke, chemicals, glass, cement

and other nonmetallic minerals, iron and steel, and other metals. We differentiated hydrogen deployment across industrial end uses, modelling only boilers and non-boiler medium- and non-boiler high-temperature applications, where electrification will be more difficult. We prioritized the high-temperature processes.

The scenarios reflect increasing implementation of our policies, including industrial decarbonization and modernization grants, innovation hubs, shared infrastructure, and industrial emissions performance requirements. The transformational scenario assumes an upper bound of 15% hydrogen substitution for non-boiler high-temperature processes by 2050. This was informed by estimates that hydrogen could supply approximately 12%-13% of overall industrial process heat by 2050, with higher potential in higher-temperature applications.[152]

END USE	SCENARIO	2030	2040	2050
Boilers	Foundational	0%	0%	0%
	Accelerated	0%	0%	5%
	Transformational	0%	5%	5%
Non-Boiler Medium Temp	Foundational	0%	0%	5%
	Accelerated	0%	0%	5%
	Transformational	0%	5%	10%
Non-Boiler High Temp	Foundational	0%	5%	10%
	Accelerated	0%	5%	10%
	Transformational	0%	10%	15%

INDUSTRIAL FEEDSTOCK SHIFTING

A 100% lever setting represents full substitution of eligible fossil-based industrial feedstocks with lower emissions alternatives under EPS assumptions. We applied the lever to natural gas feedstocks in chemicals and iron and steel, and coal feedstocks in iron and steel. We did not apply additional feedstock shifting to refined petroleum and coke. The scenarios reflect the increasing implementation of roadmap policies supporting alternative feedstocks, including industrial decarbonization and modernization grants, innovation hubs, shared infrastructure, and emissions performance requirements. The transformational scenario assumes upper bounds of 45% natural gas feedstock substitution in chemicals, 30% natural gas substitution in iron and steel, and 15% coal substitution in iron and steel by 2050.[153,154]

[152] "Decarbonized Hydrogen in the US Power and Industrial Sectors: Identifying and Incentivizing Opportunities to Lower Emissions," Resources for the Future, December 2020.

[153] "Primary Chemicals," International Energy Agency (IEA), September 2023.

[154] "Iron and Steel Technology Roadmap: Towards More Sustainable Steelmaking," International Energy Agency (IEA), October 2020.

SECTOR AND FUEL	SCENARIO	2030	2040	2050
Chemicals – Natural Gas	Foundational	0%	5%	10%
	Accelerated	5%	15%	25%
	Transformational	10%	30%	45%
Iron and Steel – Coal	Foundational	0%	0%	5%
	Accelerated	0%	5%	10%
	Transformational	5%	10%	15%
Iron and Steel – Natural Gas	Foundational	5%	10%	15%
	Accelerated	10%	15%	20%
	Transformational	15%	25%	30%

REDUCE FOSSIL FUEL EXPORTS

A 100% lever setting represents the elimination of modeled fossil fuel exports relative to BAU. We applied the lever to petroleum gasoline, petroleum diesel, and jet fuel and kerosene to account for reductions in refinery production associated with decreasing fossil fuel demand. The transformational scenario assumes an 80% reduction in gasoline and diesel exports and a 50% reduction in jet fuel and kerosene exports by 2050. These values are illustrative assumptions meant to prevent declining domestic petroleum demand from being offset by production for export.

FUEL	SCENARIO	2030	2040	2050
Petroleum Gasoline & Diesel	Foundational	0%	10%	25%
	Accelerated	5%	30%	55%
	Transformational	10%	50%	60%
Jet Fuel or Kerosene	Foundational	0%	5%	10%
	Accelerated	5%	15%	30%
	Transformational	5%	30%	50%

INDUSTRIAL CARBON CAPTURE AND SEQUESTRATION

A 100% lever setting represents capture of all eligible industrial CO_2 emissions under EPS assumptions. We applied the CCS lever to specific emissions-intensive manufacturing subsectors, including cement and other nonmetallic minerals, chemicals, iron and steel and other metals, and refined petroleum and coke. We differentiated in deployment between industrial process emissions and energy-related emissions, prioritizing process emissions where other mitigation strategies and technologies may be difficult. We assigned energy-related emissions lower capture levels to prioritize electrification, energy efficiency, and fuel switching.

The scenarios reflect increasing implementation of policies supporting CCS, including a CCUS regulatory framework, industrial decarbonization and modernization grants and other financing mechanisms, shared infrastructure, and emissions performance requirements. The

transformational scenario assumes the highest deployment for process emissions in cement and other nonmetallic minerals, reaching 90% by 2050, followed by chemicals at 50%, refined petroleum and coke at 45%, and iron and steel and other metals at 30%. Energy-related CCS deployment reaches 20% across the same subsectors in the transformational scenario by 2050.

Other industrial subsectors were not assigned additional CCS deployment, with their emissions addressed through other decarbonization levers.[155,156]

SUBSECTOR	EMISSIONS TYPE	SCENARIO	2030	2040	2050
Cement & Other Nonmetallic Minerals	Process	Foundational	5%	15%	30%
		Accelerated	10%	30%	60%
		Transformational	15%	50%	90%
	Energy	Foundational	0%	5%	5%
		Accelerated	5%	10%	15%
		Transformational	5%	15%	20%
Chemicals	Process	Foundational	5%	10%	20%
		Accelerated	10%	20%	40%
		Transformational	15%	35%	50%
	Energy	Foundational	0%	5%	5%
		Accelerated	5%	10%	15%
		Transformational	5%	15%	20%
Iron & Steel (Plus Other Metals)	Process	Foundational	0%	10%	15%
		Accelerated	5%	20%	30%
		Transformational	10%	20%	30%
	Energy	Foundational	0%	5%	5%
		Accelerated	5%	10%	15%
		Transformational	5%	15%	20%
Refine Petroleum & Coke	Process	Foundational	5%	10%	15%
		Accelerated	10%	20%	30%
		Transformational	15%	30%	45%

BUY IN-REGION OUTPUTS

A 100% lever setting represents the elimination of modeled fossil fuel exports relative to BAU. We applied the lever to petroleum gasoline, petroleum diesel, and jet fuel and kerosene to account for reductions in refinery production associated with decreasing fossil fuel demand. The transformational scenario assumes an 80% reduction in gasoline and diesel exports and a 50% reduction in jet fuel and kerosene exports by 2050. These values are illustrative assumptions meant to prevent declining domestic petroleum demand from being offset by production for export.

[155] "CCUS in Clean Energy Transitions," International Energy Agency, September 2020.

[156] "Innovation Gaps: Industry," International Energy Agency, 2019.

SECTOR	SCENARIO	2030	2040	2050
Core materials	Foundational	5%	5%	10%
	Accelerated	5%	10%	20%
	Transformational	10%	20%	30%
Secondary materials	Foundational	0%	0%	0%
	Accelerated	0%	5%	10%
	Transformational	5%	10%	20%

REDUCTIONS OF NON-ENERGY PRODUCT DEMAND

A 100% lever setting represents the maximum reduction in demand for newly-produced industrial materials under EPS assumptions, through measures such as material efficiency, reuse, recycling, and circularity. We applied the lever to concrete, iron and steel, other metals, and metal products. The scenarios reflect increasing implementation of policies supporting material efficiency, including expand markets and infrastructure for recycled and circular materials and 'Buy Clean, Buy Michigan.' The transformational scenario assumes upper bounds of 30% reduced concrete demand and 40% reduced demand for iron, steel, and other metals by 2050.[157,158]

SECTOR	SCENARIO	2030	2040	2050
Concrete	Foundational	5%	10%	10%
	Accelerated	10%	15%	20%
	Transformational	15%	25%	30%
Iron, steel, & Other metals	Foundational	5%	10%	15%
	Accelerated	10%	20%	25%
	Transformational	15%	30%	40%

[157] "Mission Possible: Reaching Net-Zero Carbon Emissions from Harder-to-Abate Sectors by Mid-Century," Energy Transitions Commission, November 2018.

[158] "Iron and Steel Technology Roadmap: Towards More Sustainable Steelmaking," International Energy Agency, October 2020.