# Clean Energy Technology Adoption Roadmap

An overview of the adoption of clean energy technologies within Michigan manufacturing

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The Economic Growth Institute leverages the University of Michigan and other public/private resources, research, technologies, and expertise to foster innovation and equitable economic growth. EGI has provided innovative economic development programming and applied research for almost 40 years.

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# Executive Summary

Accelerating the adoption of technologies that decrease energy use during production is a critical avenue to achieving decarbonization goals. These "clean energy technologies" are defined as the installation of any hardware, software, or product that reduces energy consumption and/or increases energy efficiency in the manufacturing process compared to previous iterations. The research team evaluated CETA behind the meter in two areas: process efficiencies and fuel switching for energy intensive processes. Process efficiencies encompass energy efficiencies in the process of manufacturing a product. Fuel switching references the changing of the energy source for a company's on-site energy generation for high-energy processes. The findings outlined in this report are a synthesis of 40 interviews with companies and industry stakeholders and desktop review of more than 56 resources. Based on the research, our team identified the following:

- A CETA framework with three components supporting a company in the process. The environmental component identifies how factors external to the company influenced their CETA and/or sustainability plans more broadly. This includes customer requirements, government regulations, supporting organizations, and incentives. The organizational component highlights the internal structures within the company that influence the implementation of CETA including the motivation of adoption, the required business case, the chain of command, and the capacity for adoption. Finally, the technological component outlines what technologies are readily available to the firms (as evidenced through implementation) related specifically to process efficiencies and fuel switching.
- An overview of a company's process of adoption, which includes two general stages - initiation and implementation. During the initiation stage a company tackles agenda setting and matching for the adoption of an innovation. Next, in implementation a company goes through redefining/restructuring, clarifying, and routinizing for the adoption of technologies.
- The current gaps in the value chain include the lack of requirements for decarbonization activities, knowledge and skills to match technologies, funding to support implementation, workforce capacity and capabilities, objective advice and insights for implementation.
- The categories of CETA adopters, to provide an overview of the current state of adoption.

To accelerate CETA within Michigan, the research team identified two recommendations to accelerate adoption. First, launching an industry-led collaborative will provide impactful peer-to-peer learning as industry wrestles with how to implement technologies to support decarbonization goals. A key objective for this collaborative is identifying how to implement requirements for their suppliers to address Scope 3 emissions. Second, companies need technical assistance programs to address the broad range of projects needed and navigate the resources available to them.

Accelerating the adoption of clean energy technologies is a complex process through which targeted investments can move the needle as Michigan seeks to reduce its carbon footprint. The state of Michigan is uniquely positioned through its current policy and funding priorities to support companies as they seek to adopt clean energy technologies. This report provides insight into critical mechanisms that can support the acceleration, thus increasing the environmental sustainability of these businesses and their surrounding communities. The resulting programs and investments from these findings will benefit companies, residents, and our future generations in Michigan.

# Introduction

Addressing carbon emissions is a critical emphasis for both the United States and Michigan. The Department of Energy released its *Industrial Decarbonization Roadmap*[1] in September 2022 which identified pathways within industries nationwide to achieve President Joseph Biden's goal of net-zero greenhouse gas (GHG) emissions by 2050.[2] Within Michigan, the state's commitment and plan for state-wide decarbonization are documented in the *MI Healthy Climate Plan*,[3] which was commissioned by Governor Gretchen Whitmer[4] and released by Michigan Department of Environment, Great Lakes, and Energy (EGLE) in April 2022. One of the key recommendations of the plan is to "drive clean innovation in industry." The GHG emissions from Michigan's industries account for 15% of the state's total, thus, identifying strategies for adopting clean energy technologies is critical to achieve the state's decarbonization goals. Alongside this, the Michigan Council on Climate Solutions: Energy Intensive Industries Workgroup[5] identified energy efficiency and process improvements as key levers to assisting companies in decarbonization. Specifically, the workgroup identified that industrial companies need process changes and technological upgrades to achieve carbon neutrality by 2050.

This report identifies the clean energy technology adoption (CETA) roadmap and value chain related to energy and process efficiencies. From this basis, recommendations are provided to set priorities, allocate resources, and focus future efforts. It is critical to achieving decarbonization goals that the state leverage the strengths of current efforts as well as take action on identified opportunities.

Accelerating the adoption of technologies that decrease energy use during production is a critical avenue to achieving decarbonization goals.[6] These "clean energy technologies" are defined as the installation of any hardware, software, or product that reduces energy consumption and/or increases energy efficiency in the manufacturing process compared to previous iterations.[7] The research team evaluated CETA behind the meter in two areas: process efficiencies and fuel switching for energy intensive processes. Process efficiencies encompass energy efficiencies in the process of manufacturing a product. Fuel switching references the changing of the energy source for a company's on-site energy generation for high-energy processes. Additionally, the team identified key challenges and opportunities to accelerate adoption.[8] The findings outlined in this report are a synthesis of 40 interviews and desktop review of more than 56 resources.

## Terminology

**Decarbonization** references goals that organizations and companies set to reach net-zero carbon emissions or reduce carbon emissions from Scope 1, Scope 2, and/or Scope 3 sources. These "scope" levels reference where the carbon emissions originate. Scope 1 are the emissions directly created by the company. Scope 2 are indirect emissions associated with the company's purchase of electricity, steam, and heating & cooling. Scope 3 are indirect emissions from purchases and activities that the company does not directly control, such as suppliers.

**Clean Energy Technology Adoption (CETA)**: The installation of any hardware, software, or product that reduces energy consumption and/or increases energy efficiency in the manufacturing process compared to previous iterations.

**Sustainability**: This is a broad term that has no universally-agreed upon definition. Within this report, sustainability refers broadly to energy-saving activities, goal-setting, and environmental considerations within industry.

1 United States Department of Energy. 2022. Industrial Decarbonization Roadmap. Washington, DC: n.p. https://www.energy.gov/sites/default/files/2022-09/Industrial%20Decarbonization%20Roadmap.pdf.
2 "Executive Order 14008 of January 27, 2021, Tackling the Climate Crisis at Home and Abroad," Code of Federal Regulations, Title 86 (2021): 7619–7633, https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisisat-home-and-abroad.
3 See more about the MI Healthy Climate plan here: https://www.michigan.gov/egle/about/organization/climate-and-energy/mi-healthy-climate-plan
4 In September 2020, Governor Whitmer signed Executive Directive 2020-10, identified the goal of economy-wide carbon neutrality in Michigan by 2050 and tasked EGLE with developing the state action plan, MI Healthy Climate Plan
5 See more on the workgroup recommendations here: https://www.michigan.gov/egle/about/groups/council-on-climate-solutions/workgroup-recommendations
6 This assumes there is parallel work occurring in the decarbonization of the grid, which is another pillar of the MI Healthy Climate Plan. This report focuses only on the actions that can be taken by industry, assuming decarbonization of the grid advances in parallel. Additionally, this report is specifically focused on energy-related technology adoption, but adoption related to the circular economy, such as waste reuse are critical questions participants are also grappling with.
7 For this report, the team identified any adoption that decreased energy use as "clean energy technology adoption." This is a broad definition and the writers acknowledge that the technology implemented may not have been the "cleanest" (i.e. lowest carbon emitting) process, but instead "cleaner" than the previous process.
8 Additional critical questions outside of the scope of this project include: the implementation of renewable energy generation sources by companies, purchase power agreements, how recycling and the circular economy could be incorporated into decarbonization goals, and power generation in front of the meter. These all represent components necessary to achieving the State's decarbonization goals.

# Methodology

Through this qualitative study, the team completed 40 interviews with industry representatives and stakeholders from 33 different organizations. The organizations represented include large original equipment manufacturers (OEMs), tier 1 and tier 2 suppliers, small and medium-sized manufacturers (SMMs), ecosystem stakeholders (such as nonprofits, non-governmental organizations, and consultants), and utility companies. See Chart 1 for a participant breakdown.[9]

The companies ranged from those with detailed public commitments to those just beginning to implement energy-saving projects or identify energy-related goals. To participate in the study, each participant had either an energy-reduction goal or had completed at least one project that reduced energy consumption. Data was collected through semi-structured interviews during which the research team asked questions about the implementation of energy efficiency projects. If the participant mentioned "sustainability" or "decarbonization" these terms were utilized as well. Neutral language, such as energy efficiency, was utilized in recruitment and interviewing.

*Comparison to MSU's Industrial Assessment Center data*

Throughout the report findings are compared to data provided by the Michigan State University Industrial Assessment Center (MSU IAC), which is funded by the Department of Energy.[10] The data comes from companies engaging with the IAC, which helps small and medium-sized US manufacturers and commercial buildings save energy, improve productivity, and reduce waste by providing no-cost technical assessments conducted by a team of students and faculty. Companies are eligible if they are located within Michigan or surrounding areas, have annual energy bills between $100K and $3.5M, annual sales under $100M, fewer than 500 employees per site, and no in-house energy professional on staff. The cross reference to the MSU IAC data from their clients provides validation for this qualitative study as well as additional insights into CETA within Michigan.

9 Industries represented include: automotive manufacturing, chip manufacturing, cement production, furniture manufacturing , chemical production, food processing, plastic manufacturing, and more.
10 More information on the MSU IAC is available at https://iac.msu.edu/

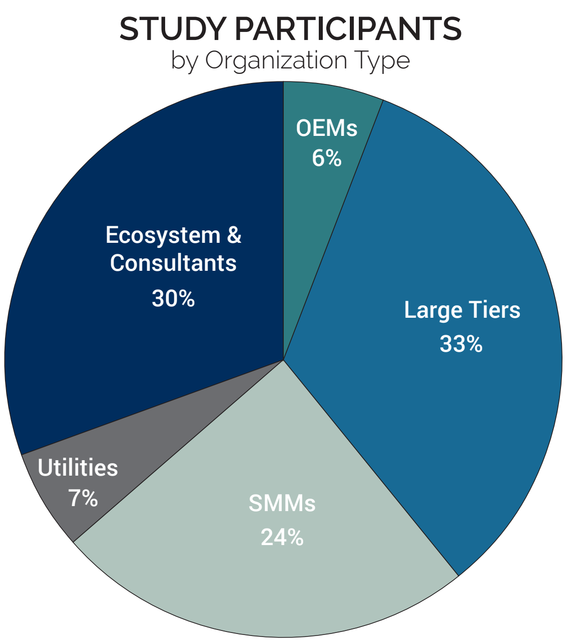



**Chart 1**. Participant Breakdown by Organization Type, n=33

# Clean Energy Technology Adoption: Roadmap and Value Chain

- Framework of Adoption: Environmental, Organizational, and Technological Components
- Company Process of Adoption
- Gaps in Adoption
- Categories of Company Adopters

# CETA Framework of Adoption

The mechanisms influencing CETA by Michigan manufacturers are critical to identify so that we can understand and map the current state of adoption. Using technology, organization, and environment model[11] of technology adoption, three contextual factors emerged from the data: the technological component (specifics of the technology availability and characteristics), the organizational component (leadership, capacity, etc.), and the environmental component (industry requirements, government regulations, and support mechanisms).

Infusing this model to represent the roadmap and value chain for CETA within Michigan manufacturers (Figure 1), the emerging themes within each component are as follows:

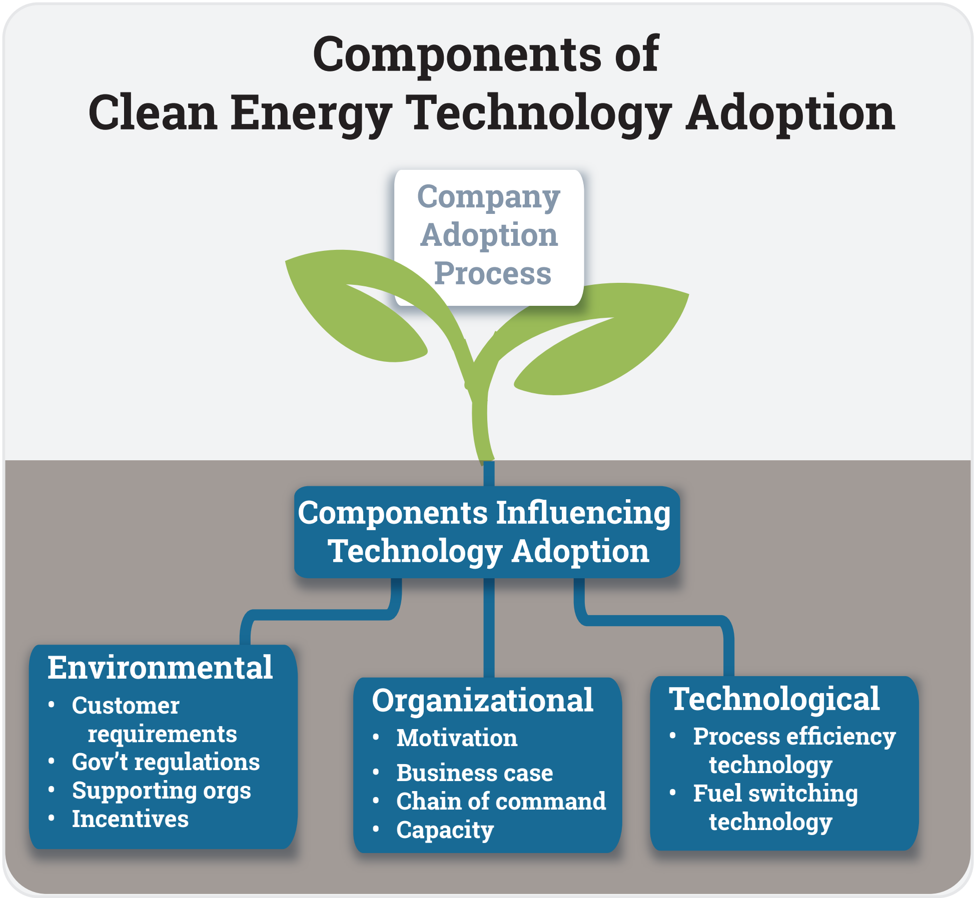



***Figure 1.*** Components of Clean Energy Technology Adoption. Model adopted from the Technology, Organization and Environment model from Tornatzky and Fleischer (1990) and integrated with participant interview data.

**Environmental**: Participants discussed how factors external to the company influenced their CETA and/or sustainability plans more broadly. This included customer requirements, government regulations, supporting organizations, and incentives.

**Organizational**: The internal structures within the company influenced the implementation of CETA and thematic commonalities between the participants included motivation of adoption, required business case, the chain of command and capacity for adoption.

**Technological**: This highlights what technologies are readily available to the firms (as evidenced through implementation) related specifically to process efficiencies and fuel switching.

These three components provide the foundational framework that feed into a company's decision to adopt new clean energy technologies. Additionally, these categories influence each other. For example, incentives can be available for technology development. And the requirements of a company's customers, such as an OEM, also influence the business case. Below are the details for each component and how these are influencing CETA for process efficiencies and fuel switching within industry.

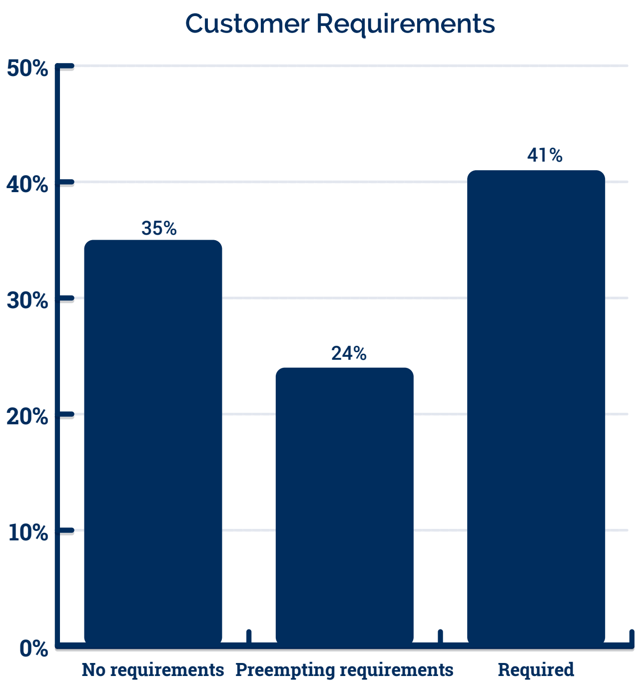
11 The rate of firm-level adoption of new technologies is most commonly analyzed through two models: the diffusion of innovation (Rogers 2003) and the technology, organization, and environment (TOE) models (Tornatzky and Fleischer 1990, Oliveria and Martins 2011). Rogers highlights the three main factors impacting innovation adoption by organizations: 1) a leadership champion, 2) the organizational structure (such as size, capacity and technical capacity to implement innovations, linkages between departments and chain of command), and 3) connections to others in the system. The TOE model utilizes similar categories and builds by adding more systemic context. The TOE model has been utilized to explain the adoption of websites, e-commerce, ERP systems, knowledge management systems, and more (Oliveria and Martins 2011)

## Environmental Components

The environmental component influencing CETA within industry includes four areas: customer requirements, government regulations, supporting organizations, and incentives.

### *Customer requirements*

The requirements of a company's customers can be a critical factor influencing a company's adoption of clean energy technologies. Many large manufacturers are beginning to require some level of commitment to sustainability for their suppliers. The specifics of this request are still evolving, and participants were split on their experiences. Of the companies discussing customer requirements, there is still a clear division between no requirements (35%) and requirements from customers (41%), with the remaining (24%) seeing the "writing on the wall" and trying to preempt requirements by implementing sustainability strategies now. However, the specifics of customer requirements are still developing,




**Graph 1.** Customer requirements for decarbonization.

as reported by participants, with the large companies still developing requirements and support structures. Current requirements varied greatly and included: setting science-based targets initiatives (SBTi), completing customer-specific spreadsheets, and/or reporting to the Carbon Disclosure Project (CDP). The variability in requirements points to the uncertainty of how to track actual progress within the supply chain and the gap that still exists between the public commitments to sustainability and implementation.

In interviews with ecosystem participants (utility companies, consultants, and nonprofits), 66% reported their clients/members directly referencing customer requirements for evidence of sustainability efforts. The other 33% discussed knowledge of the public commitments by customers and/or investor pressures to address their carbon footprint.

There are multiple steps between a commitment to decarbonization or net-zero carbon footprint and the implementation of these goals. As one ecosystem participant shared, "*I'm just seeing so many companies making these commitments, when they really don't even know what they're committing to. Do they know what it's going to take to get to net-zero energy for their portfolio? They are going to make that commitment, but they have no idea what that's going to take. They are just doing and saying what they think the popular thing is or what's going to get them business, but do they have a strategy? Do they have any idea what it's going to cost?*" This sentiment was expressed both by those assisting industry adopt clean energy technologies as well as staff trying to implement strategies.

### *Government regulations*

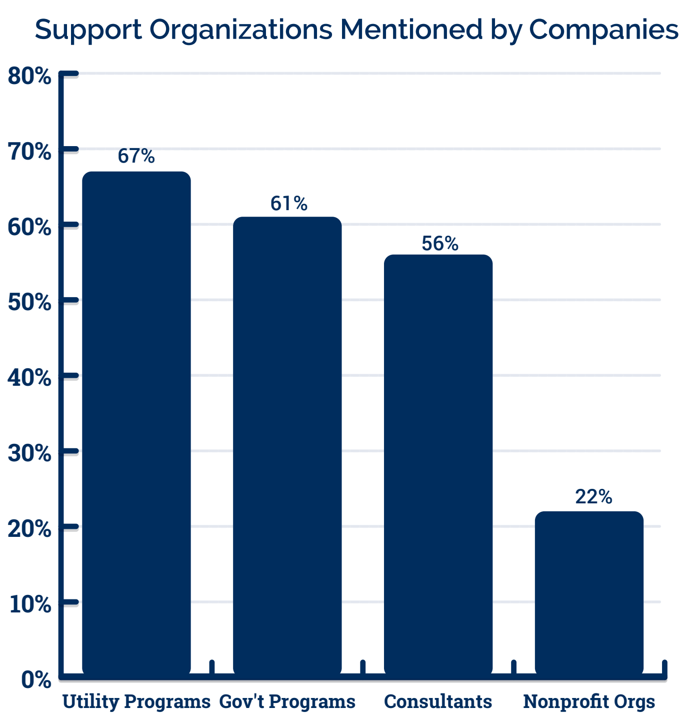
Government regulations were also mentioned by participants as a motivator in adopting clean energy technologies. However, these were from participants that were part of multinational corporations and the regulations were from other countries and/or regions (such as Europe). The regulatory requirements from other countries trickled down to companies within Michigan as the decarbonization goals required involvement from all locations of the corporation, even if local requirements were less stringent. Fourteen percent of the company participants mentioned this as a motivating factor. However, another 14% expressed a desire for greater government regulation within the United States to help level the playing field and increase the value of their efforts.

## Environmental Components (con't)

*Support organizations*

Support organizations is a broad category encompassing the programs and organizations within the ecosystem aiding companies in CETA. These include: programs within utility companies, federal and state governments, nonprofits, nongovernmental organizations, and consultants. Participants either mentioned ways in which support organizations were helping them to assess and reduce their energy usage, and/or programs that provided incentives that helped them implement projects such as compressed air leak studies and LED lighting.[12]

While over 86% of company respondents directly mentioned a support organization, these resources were still seen by many as insufficient to address the needs within their company. Manufacturers expressed needs for (1) more technical assistance to evaluate both their energy strategy and specific projects feasible for their company given their unique processes and constraints and (2) assistance in identifying consultants who can implement these projects or consultants to manage the implementation. Manufacturers of all sizes are operating on very limited staff capacity, especially post-Covid, and thus dedicating (and finding) the personnel resources is a very real challenge.




**Graph 2.** Support organizations mentioned by companies

Another key component of support organizations is the growing body of resources, such as webinars, conferences, and newsletters, about CETA in fuel switching and process efficiencies for manufacturing. The research team identified 56 relevant resources from federal, state, and nonprofit organizations to support companies in CETA. These resources help to educate the multiple stakeholders on the value of these projects and give generalized insights on adopting clean energy technologies. However, usually these resources are not detailed enough for immediate implementation by companies.[13] Consultants and nonprofits are helping to bridge the knowledge gap between what companies want to do and their current state.

*Incentives*

Incentives programs, such as grants, tax credits and rebates, are a significant factor boosting the business case of CETA. With company participants, 43% directly mentioned utilizing incentives for sustainability-related projects. These programs help to decrease costs and payback periods, thus making energy-use changes more feasible for companies. Additionally, a preference was expressed for grants and tax credits over loan programs; loan programs were not even considered an incentive by some participants. For participants who did not mention a specific project with an incentive, they instead discussed evaluating options or expressed a lack of knowledge about available options. Additionally, some companies highlighted that an incentive program was a prerequisite for even considering a project. Thus if an incentive program was not available, then an energy efficiency project was often tabled or devalued compared to other projects vying for capital. As a participant at a large supplier shared, *"When I say I need this capital expense for this project, [management's] first question is, 'what is your rebate? What can the energy companies do for you? What are the incentives?'"*

Incentives are part of the overall puzzle that companies evaluate from the environmental component. One participant from a large company shared that his company evaluates the following questions as considering CETA: *"What's going on in the country? What are their policies and procedures? What kind of incentives do they have? Where do we see their regulations evolving?"* These types of questions help to capture the many facets of the environmental components as companies consider CETA.

12 LED lighting is included in this count because participants consistently saw this as part of their own energy reduction. While technically this falls into a category of "building energy usage" manufacturers categorized this as part of their process efficiencies and it was a key first step for many of them.
13 EGI conducted a desktop review of more than 56 federal, state, and nonprofit/NGO resources in early 2022.

## Organizational Components

Organizational components highlight how the internal company environment can influence CETA. This includes motivation, the business case, chain of command, and capacity.

### *Motivation*

Industry participants discussed their motivation in several ways. Some identified corporate decarbonization goals which included targeted dates for net-zero emissions. This was especially true for large, multinational companies. Of the companies interviewed, 48% had public commitments on their website to sustainability or decarbonization goals, while 52% did not list any public commitments. For the OEMs, 100% of these participants had public commitments. For large suppliers, 63% noted specific commitments. For small and medium-sized manufacturers (SMMs) the goals identified their role as a responsible corporation. Only 12% publicly listed commitments on their website, but many discussed their desire for a positive impact on the local community within the interviews. Motivation for all companies was also linked to the need to decrease costs related to energy.

### *Business case*

The business case for any project or sustainability effort was at the forefront of discussions with participants and included mentions of payback periods, return on investments (ROI), capital constraints, and cash flow. Companies of all sizes had requirements around the business case, though the timeline of payback periods ranged widely. Some reported shorter payback periods of 12-18 months, while others listed 2-4 years. The longest payback periods reported were 6-7 years. Chart 2 represents the distribution payback periods as reported by the companies disclosing this information with most companies falling between 2-3 years.[14] Additionally, at the 2022 Michigan Sustainability Conference (MISCON),[15] participants reported similar short payback periods for projects related to sustainability: 21% reported less than 18 months and 32% reported 2 years, thus more than 50% had very short payback periods. Companies that engaged with MSU's IAC reported longer payback periods with the average between 4-5 years. It is probable that this study's participants and those attending MISCON had shorter payback period requirements because some were not actively seeking the energy-reduction services of the IAC.

Interviewees also highlighted many challenges with the business case of CETA. There was often a discussion about the misalignment between the public rhetoric (for larger companies) and the actual money dedicated to decarbonization strategies. While there is a social cost to carbon emissions, the relative financial cost of emitting GHGs is still intangible and thus low. Two companies mentioned looking at quantifying the cost of offsetting carbon emissions within their financial calculators and/or in their evaluation of projects to help achieve internal payback period requirements. However, this practice is still developing because there is no standardized carbon price.

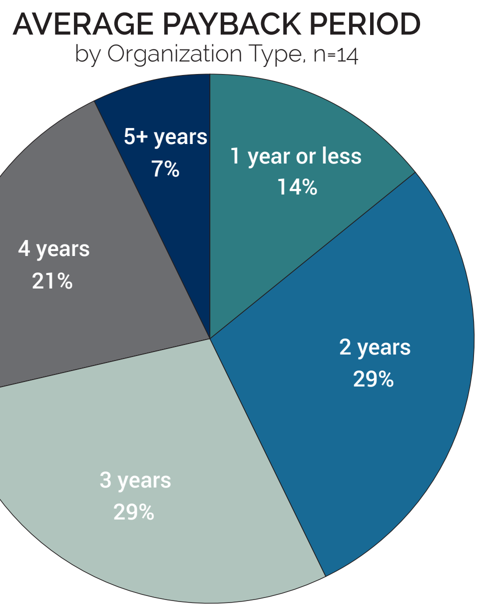



**Chart 2.** Average payback periods

### *Chain of Command & Capacity*

CETA is largely dependent on who assumes (or is assigned) the task and the level of their authority. As one stakeholder described *"I can quickly tell you how serious an organization takes sustainability, if you talk to the sustainability person and understand who they report to…the ones that report to the C-suite or directly to the CEO, those are the organization where (sustainability personnel) have a lot more teeth."* Even for those at the leadership level, if they were only advising plant managers or engineers, implementation was convoluted because there is an intersection of both sustainability knowledge and passion,

14 When companies provided a range for pay-back-periods within the interviews, this was converted to the lowest year mentioned to allow for comparability.
15 Twenty participants who attended the Industrial Assessment Center session submitted responses to the in-session poll on 10/25/22.

## Organizational Components (con't)

and the technical knowledge to implement changes. One participant summed up the challenge stating, "*Many companies commit [to decarbonization] but the 'devil is in the details'...Once you start talking about specifics of what the company needs to do...to hit those particular goals or contribute to those goals, it becomes contentious. Even within a larger company, you need to find a person with enough power in that organization that has a passion for wanting to do it because there's going to be a lot of constraints and if it's just another assignment that you have and it's not necessarily required to be delivered, it will fall off the table.*"

Thus, digging into the technical challenges and the ability to overcome these is a key aspect of CETA. Additionally, larger companies are wrestling with where to place the responsibility of CETA. For example, is it part of compliance? Or does it belong within engineering departments? Or is there another way to distribute the responsibility? These are all questions that companies are currently wrestling with as they implement plans to decrease their carbon footprint.

Alongside the chain of command theme, the capacity of those charged with the task was also a critical concern. Most companies did not have the expertise internally to identify and execute projects, thus were relying on consultants if they had the funding available. Additionally, the staff capacity to oversee initiatives related to sustainability was limited, especially post-Covid. Often even large companies only had 1-2 individuals dedicated to sustainability efforts, and some also had other responsibilities in compliance and safety. As one participant at a large supplier shared, *"I have negative 15% of my time to devote to this*," he said while discussing the lack of capacity for sustainability efforts. "*I really need another employee in my department because it is just me and one other person right now, and we already had full-time jobs before this was added."*

## Technological Components

The technological component addresses both what technologies are available to a company and how these fit within their current technologies. For this project, the research team discussed what type of process efficiency technologies or fuel switching technologies the company had adopted. This is compared with Michigan State University's Industrial Assessment Center (MSU IAC) energy audit findings.

*Process Efficiency technologies*

Companies have actively adopted accessible technologies related to process efficiencies, with 71% mentioning some type of implementation. The most common technologies included companies implementing projects related to compressed air, such as leak studies and installing variable frequency drivers (38%). Data from MSU IAC mirrors this finding with about 30% of their client base already implementing compressed air projects before engaging with their program. Other projects mentioned by company participants included monitoring and occupancy-based load controls to better measure and manage their energy use within the manufacturing line, conducting "treasure hunts" to identify opportunities to decrease energy usage, and installing new equipment.

However, these projects were usually in the early stages or only one of many options that had been implemented. Companies still discussed the need for more advanced analyses of internal processes, or implementation of a broad energy strategy related to process efficiencies.

When MSU IAC engages with small and medium-sized companies, they provide energy reduction recommendations for processes as well as the production facility itself. Chart 3 outlines the top 20 recommendations given to companies for energy efficiency projects in Michigan since 2010. The top recommendations are split with about 65% addressing process efficiencies and 35% referencing improvements to the building improvements. When looking at the most commonly implemented projects by companies (Chart 4), MSU IAC reported 73% were in process improvements and 37% were in building improvements. Thus, many companies are making progress in addressing process efficiencies, however, only an average of 48% of all top process efficiency recommendations are implemented. There is still significant room for further adoption.

| Manufacturing Process Efficiency | Assessment Recommendation Description | # of Times Recommended since 2010 | Average Savings | Average Cost | Average Payback in Years | Implementation Rate |
|---|---|---|---|---|---|---|
| | Utilize higher efficiency lamps and/or ballasts | 89 | $14,773 | $31,507 | 2.3 | 57% |
| Y | Install compressor air intakes in coolest locations | 88 | $3,303 | $2,810 | 1.4 | 53% |
| Y | Reduce the pressure of compressed air to the minimum required | 66 | $4,678 | $1,176 | 0.3 | 43% |
| Y | Recover waste heat from equipment | 58 | $31,038 | $39,671 | 1 | 47% |
| | Install occupancy sensors | 57 | $3,109 | $3,126 | 1.4 | 52% |
| Y | Use waste heat from hot flue gases to preheat | 44 | $69,714 | $92,284 | 2 | 32% |
| Y | Use adjustable frequency drive or multiple speed motors on existing system | 28 | $11,060 | $9,783 | 1.6 | 38% |
| | Conserve energy by efficient use of vending machines | 27 | $990 | $182 | 0.2 | 41% |
| Y | Insulate bare equipment | 23 | $5,927 | $3,754 | 1.1 | 50% |
| Y | Eliminate leaks in inert gas and compressed air lines/ valves | 21 | $7,878 | $1,914 | 0.3 | 91% |
| Y | Turn off equipment when not in use | 20 | $1,718 | $133 | 0.4 | 67% |
| Y | Optimize plant power factor | 18 | $11,345 | $13,701 | 1.4 | 36% |
| | Install vinyl strip / high speed / air curtain doors | 18 | $4,642 | $4,804 | 1.2 | 50% |
| Y | Upgrade controls on compressors | 17 | $4,277 | $4,934 | 1.4 | 43% |
| Y | Analyze flue gas for proper air/fuel ratio | 15 | $95,132 | $71,627 | 0.4 | 46% |
| Y | Use or replace with energy efficient substitutes (motors) | 15 | $10,897 | $112,174 | 3.9 | 33% |
| | Improve air circulation with destratification fans / other methods | 15 | $19,574 | $33,667 | 2.2 | 25% |
| | Close holes and openings in building such as broken windows | 13 | $2,996 | $4,272 | 1.3 | 100% |
| Y | Eliminate or reduce compressed air usage | 12 | $7,709 | $5,917 | 0.9 | 46% |

**Chart 3.** Most commonly identified assessment recommendations in Michigan from 2010 to present by IAC assessments with an implementation rate > 0%, data provided by MSU IAC with EGI's research team determining which were related specifically to manufacturing process efficiencies as denoted by "Y".

## Technological Components (con't)

| Assessment Recommendation Code (ARC) | Manufacturing Process Efficiency | Assessment Recommendation Description | # Times Recommended since 2010 | Average Savings | Average Cost | Average Payback | Implementation Rate |
|---|---|---|---|---|---|---|---|
| 2.4236 | Y | Eliminate leaks in inert gas and compressed air lines/ valves | 21 | $7,878 | $1,914 | 0.3 | 91% |
| 2.6218 | Y | Turn off equipment when not in use | 20 | $1,718 | $133 | 0.4 | 67% |
| 2.7142 | | Utilize higher efficiency lamps and/or ballasts | 89 | $14,773 | $31,507 | 2.3 | 57% |
| 2.4221 | Y | Install compressor air intakes in coolest locations | 88 | $3,303 | $2,810 | 1.4 | 53% |
| 2.7135 | | Install occupancy sensors | 57 | $3,109 | $3,126 | 1.4 | 52% |
| 2.2511 | Y | Insulate bare equipment | 23 | $5,927 | $3,754 | 1.1 | 50% |
| 2.2437 | Y | Recover waste heat from equipment | 58 | $31,038 | $39,671 | 1 | 47% |
| 2.4231 | Y | Reduce the pressure of compressed air to the minimum required | 66 | $4,678 | $1,176 | 0.3 | 43% |
| 2.6211 | | Conserve energy by efficient use of vending machines | 27 | $990 | $182 | 0.2 | 41% |
| 2.4146 | Y | Use adjustable frequency drive or multiple speed motors on existing system | 28 | $11,060 | $9,783 | 1.6 | 38% |
| 2.2414 | Y | Use waste heat from hot flue gases to preheat | 44 | $69,714 | $92,284 | 2 | 32% |

**Chart 4.** Most commonly implemented assessment recommendations in Michigan from 2010 to present by IAC assessments, data provided by MSU IAC, with EGI's research team determining which were related specifically to manufacturing process efficiencies as denoted by "Y".

*Fuel switching technologies*

Fuel switching of high energy processes to electrification or other sources (such as hydrogen or geothermal energy), is still in a very early stage and only considered by companies tangentially.

Contrary to carbon reduction goals some companies are actually switching from electricity to natural gas[16] due to cost. While hydrogen and geothermal energy were ideas that a few had briefly considered, the costs of adoption were far beyond what they would consider. For high-heat processes, natural gas is still the most effective from both a process and business perspective.

The technologies needed for fuel switching to green energy such as green hydrogen or geothermal energy are still in their infancy and not cost effective. Hydrogen technology is technically available for high-heat (energy intensive) processes replacing natural gas. However, the Manufacturing Readiness Level (MRL) is not high enough for cost-effective adoption, especially by small and medium-sized manufacturers. High upfront costs for geothermal energy make the economics too challenging for most. Building owners must adopt a long-term return strategy and have the cash flow and balance sheet position to allow it. Most financing models are not attractive for geothermal (especially for existing buildings or areas of limited land or water resources). Technically geothermal has a high MRL and offers efficiencies and carbon reduction through natural gas reductions. However, low-temperature geothermal energy (available in Michigan) can only meet low energy applications and is not feasible for energy intensive (specifically high heat) manufacturing processes.

16 Assumes the grid is "clean energy," i.e. not supplied by a coal powered facility or power generated by a feedstock with a higher carbon footprint than natural gas.

## Process of Adoption

The process of adoption moves through two general stages - initiation and implementation[17], within which are five specific phases. **Agenda setting** and **matching** are part of the initiation of the adoption of an innovation, while **redefining/restructuring, clarifying**, and **routinizing** are part of implementation. CETA can both be looked at as the adoption of individual technologies as well as the adoption of a more broad sustainability plan that then leads to specific technology adoptions.

The components of the technology, organization, and environment influence how the company is approaching CETA (either as individual technologies, as part of a large system-wide effort, or somewhere in between these two). The initiation stages of **agenda setting** and **matching** are when the company decides to prioritize a problem or need (**agenda setting**) and seeks the appropriate solutions (**matching**). Within CETA, the identification of decarbonization goals is driven often by environmental components, such as customer requirements and government regulations. Rising energy costs can also increase the need for more energy efficient processes thus creating a need for more cost-effective solutions. The **matching** of solutions is the stage where companies are assessing readily-available technologies for how to meet the goals.

The implementation phase includes **redefining/restructuring, clarifying**, and **routinizing**. During **redefining/restructuring**, companies are determining how clean energy technologies can fit within their company, how processes and procedures might need to change for adoption to occur, and if more customization is necessary for the technology to address their needs. The unique processes of each company in addition to their specific local utility incentives and support networks, require some level of customization of CETA for all companies. Through the

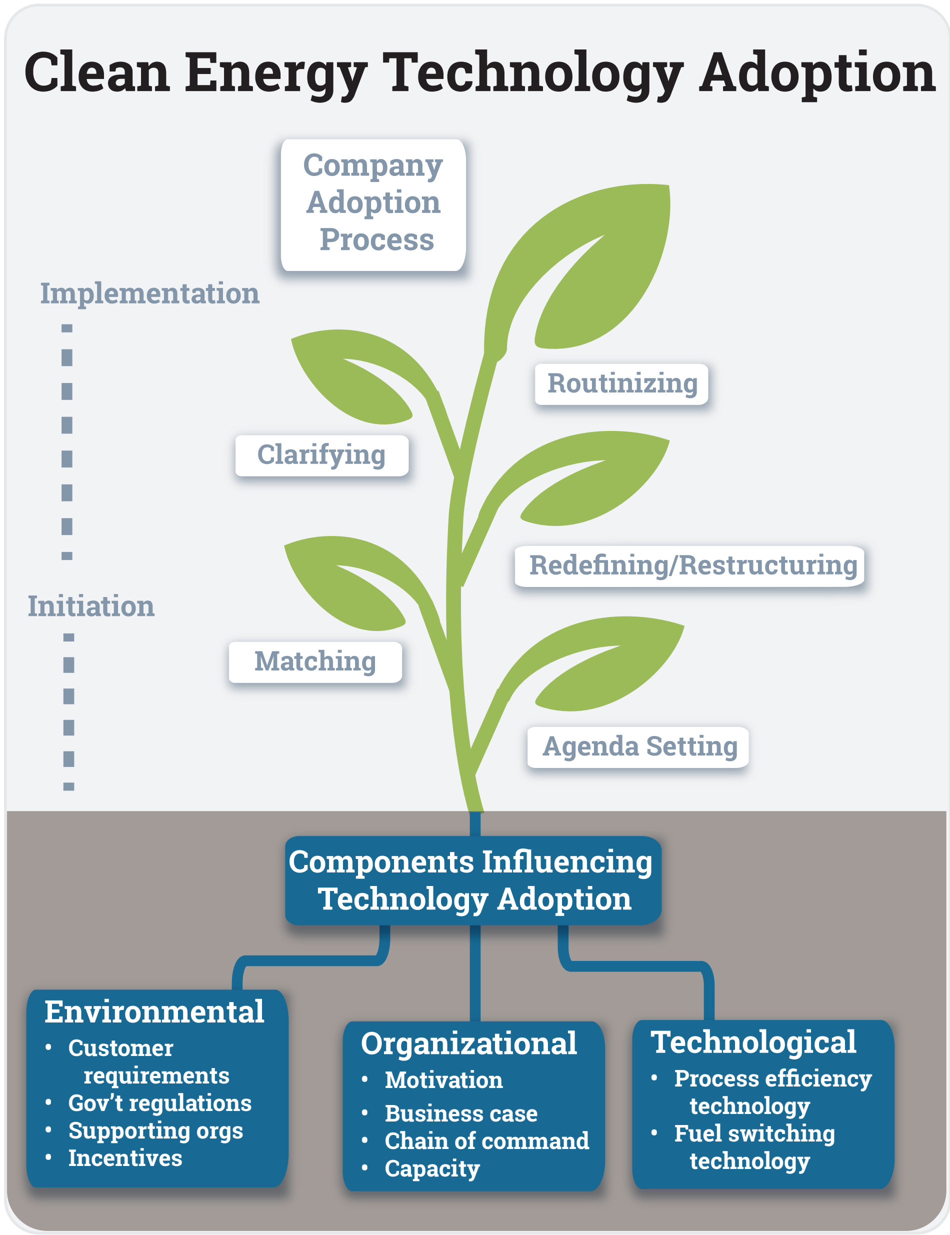



**Figure 2.** Clean Energy Technology Adoption Components and Process

17 Rogers, Everett M. 2003. Diffusion of innovations. Vol. 5th. New York: New York Free Press.

## Process of Adoption (con't)

clarifying stage, the adoption of clean energy technologies is discussed broadly throughout the organization and many questions arise about who is leading the process and where responsibility lies. This stage pulls from the organizational component, especially with the themes emerging from "chain of command" where participants discuss the challenges of determining responsibility and alignment with current job responsibilities. During this phase, sustainability managers at larger companies are often trying to work with plant managers or engineers to find ways to collaborate and meet collective goals. For example, a participant from a large company shared "*Even when we have leadership on board, we still find that the individuals that are actually implementing these projects in certain locations are still very hesitant to pursue them and will strongly oppose them.*" These are critical issues that companies are navigating as they are adopting clean energy technologies.

Finally, in routinizing, clean energy technology is fully embedded within the organization and broadly accepted by all departments. Instead of these technologies being part of an isolated incentive, they are integrated within the company culture and no longer identified as "new."

## Gaps in Technology Adoption

Synthesizing the framework and data, several gaps within the process of CETA are identified. Within Figure 3, these are highlighted within the company's process (illustrated through the sprout); however, as with a plant, the roots (or components) influence the strength or weakness of the plant and its stem and leaves.

sustainability efforts and the engineers who had the technical expertise of the processes. External, neutral advisors who can inform companies about technologies and solutions for implementation are needed to advance CETA. Additionally, for fuel switching for high energy processes, the technologies were still too nascent for companies to consider adoption (see page 14).

### *Gap 1 - Lack of requirements and/or penalties*

A critical gap is the lack of requirements from customers and/or the government, which influences initiation phases of CETA. While pressure on the industrial sector to decrease emissions exists, the specific requirements are still emerging. Participants discussed their commitments and motivations, however, there were few (to no) actual penalties to not decreasing emissions. While some mentioned how their efforts could increase their competitiveness, even these cases were the exception instead of the norm. Thus, the environmental components of requirements are still weak and create a gap for companies even considering CETA (agenda setting).

### *Gap 2 - Knowledge and skills to match technologies*

The knowledge-base and skill-set necessary to identify the CETA opportunities to increase energy efficiency is a critical gap in the ecosystem. Participants had limited knowledge of energy or carbon reduction technologies beyond those that have been extensively promoted or incentivized (such as LED lighting). Additionally, in larger companies there were often silos between those working on

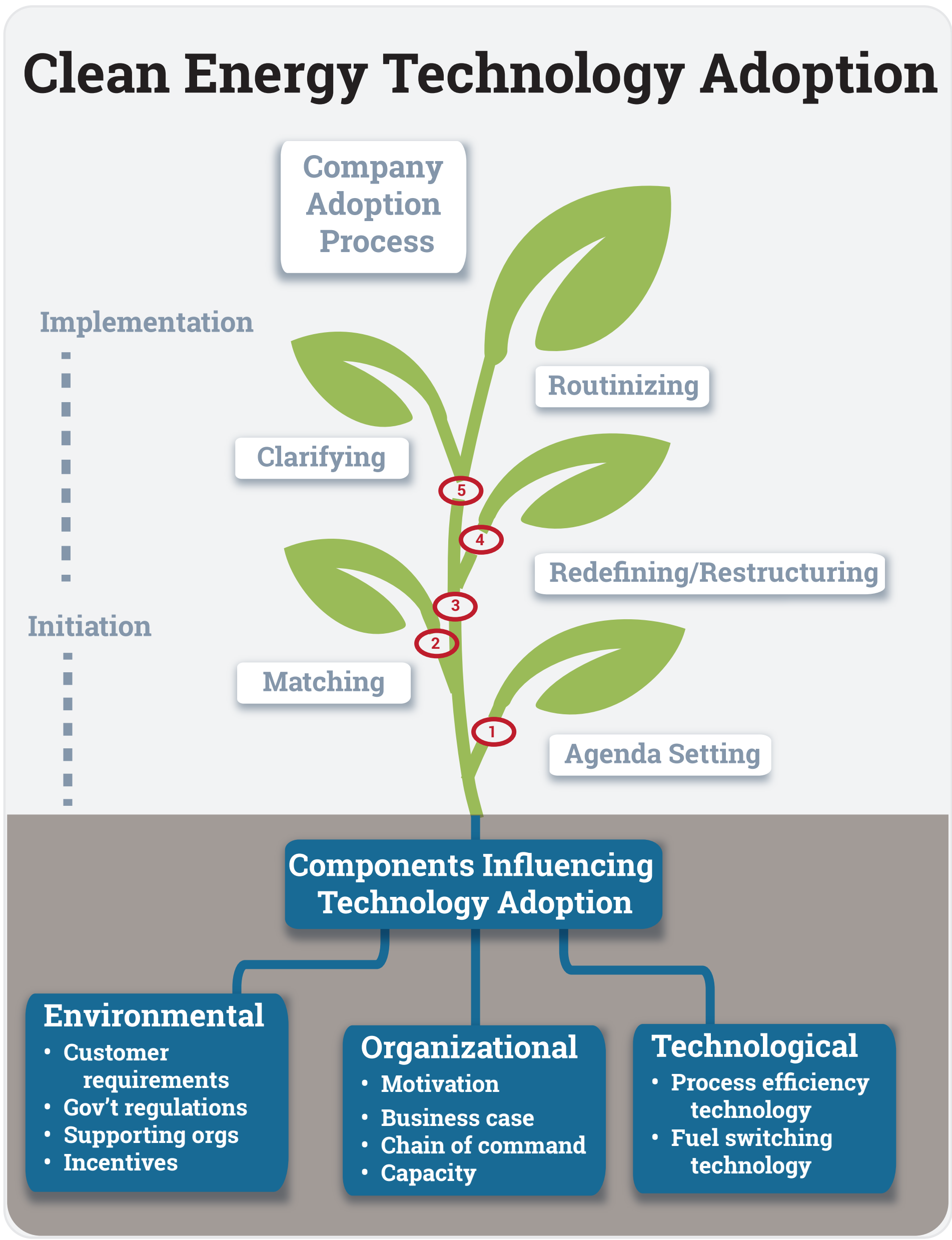



**Figure 3.** Gaps in Clean Energy Technology Adoption

## Gap in Adoption (con't)

*Gap 3: Funding to support implementation*

As participants emphasized repeatedly, the return on investment (ROI)/payback period/business case of any new CETA was a critical component of the discussion. The payback periods for many capital projects are still out of reach for many companies. While the increased efficiencies are enticing, companies are unable to sustain the cash flow hit (as discussed more below). This gap is felt for companies as they move from the initiation stage into the implementation stage and the business case becomes a critical component of figuring out if they can adopt a clean energy technology. This gap is also particularly salient for less resourced companies in underserved and underrepresented communities that already struggle for access to capital.[18]

Additionally, designing incentive programs to address process energy efficiencies is challenging. Programs for LED lighting and compressed air leak studies are very successful, in part because they are easy to understand and implement. These incentive programs fit nearly all businesses and require very little customization. However, for increased efficiencies and company-specific evaluations, incentive programs need to be developed that allow for the customization for different types of manufacturing.

*Gap 4: Workforce capacity and capabilities*

Many companies lack the capacity currently to take on decarbonization and related CETA efforts. Energy efficiency and sustainability initiatives are often still "extra" jobs duties or siloed into a specific committee or department. However, the solutions are cross-cutting within companies and thus cross-cutting vertical and horizontal support is needed. Yet, critical changes to the environmental and organizational components (such as requirements, business case, etc.) must change for these efforts to be further integrated into companies.

*Gap 5: Objective advice and insights*

Companies expressed the strong need for objective guidance as they were implementing new technologies. Throughout the process of CETA, broader questions emerged about their overall strategy related to energy efficiency and decarbonization. While many recommended and trusted their consultants, they also wanted to have more information from a neutral party who didn't have a product to sell them. There is a desire for customized business intelligence from an external and objective source that strengthens their company, from which they can decide which projects to implement and with whom.

18 Farrell, Diana, Christopher Wheat, and Carlos Grandet. 2019. "Place Matters: Small Business Financial Health in Urban Communities" JPMorgan Chase Institute. https://www.jpmorganchase.com/content/dam/jpmc/jpmorgan-chase-and-co/institute/pdf/institute-place-matters.pdf

## Categories of Adopters

In addition to mapping the CETA process, it is also critical to understand the stages of CETA adoption. Innovations diffuse into society through five categories of adopters.[19] New technologies are initially adopted by innovators, then move through to early adopters, early majority, late majority and then finally to laggards; the size of each category corresponds to a normalized distribution of curve (See Figure 4). The categories of adopters are:

- **Innovator companies** are typically large companies with significant financial resources to buffer a loss, accept the uncertainty of their investment, and have the ability to navigate complex technical challenges
- **Early adopter companies** are role models and leaders within the ecosystem, and early adoption is part of what makes them leaders. They play a critical role in demonstrating the value of new technologies.
- **Early majority companies** will spend significant time evaluating technology opportunities and costs before deciding what to implement. While they are eager to adopt new technologies, they want to see a higher level of proof of concept and business case.
- **Late majority companies** adopt technologies because it is an economic requirement and/or there is peer pressure to do so.
- **Laggard companies** usually have very limited resources and wait as long as possible to ensure risk is minimal or completely mitigated.

The implementation of new clean energy technologies was evaluated in this research through two different energy efficiency measures: process efficiencies and on-site fuel switching technologies. In evaluating implementation by the category of adopters, the research team overlaid the three foundational components from CETA framework in Figure 5:

- Technology Complexity is the number of barriers to adoption and implementation, including the level

19 Rogers, Everett M. 2003. Diffusion of innovations. Vol. 5th. New York: New York Free Press.

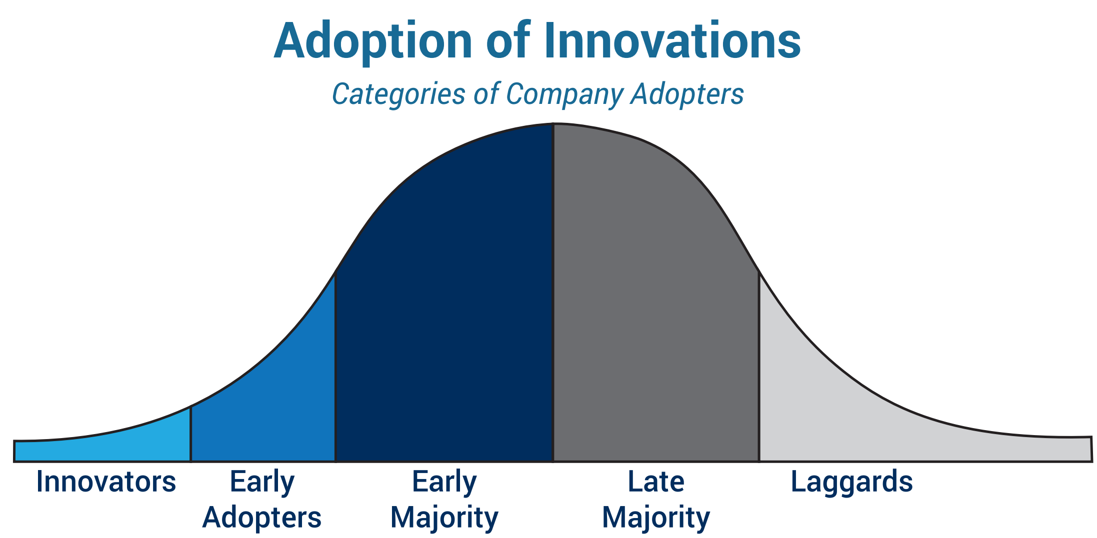



**Figure 4.** CETA innovations diffuse into industry through five categories of company adopters; based on Rogers (2003).

## Categories of Adopters (con't)

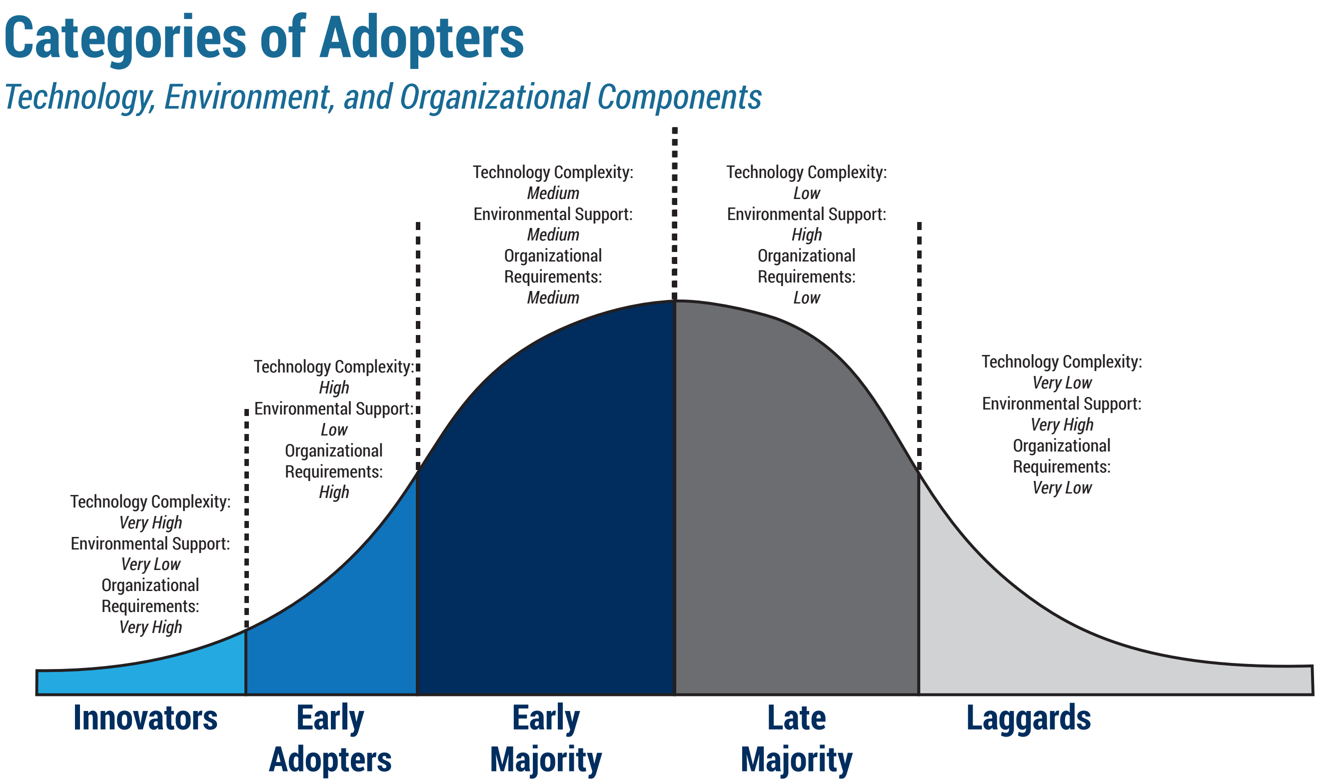



**Figure 5.** Categories of companies by adoption of innovations with detail on the technology, environment, and organizational components based on participant data.

of skills and knowledge required (aligns with the Technological Component).

- Environmental Support refers to customer requests and/or regulatory requirements to implement new clean energy technologies as well as the ecosystem supports for these activities, including state and federal programming, utility companies, nonprofits, incentives, etc. (aligns with the Environmental Component).
- Organizational Requirement captures the internal support necessary (such as leadership, capacity of staff, and required business case) to adopt a new technology (aligns with the Organizational Component).

Process efficiency technology adoptions are still within the Early Majority category because multifaceted, broad adoption is still developing. While energy audits and consultants can readily identify solutions for process efficiencies, the implementation rates are still below 50% as evidenced in the MSU IAC data. For fuel switching, only Innovators are embracing fuel switching at this point in time because the technologies are still developing. Both are conceptually placed on the Figure 6.

Process efficiency technology could be approaching expansion to a majority of organizations as technology complexity declines and environmental support accelerates. Technologies are improving and environmental support for energy efficiency is growing. Organizational requirements should start to adjust to meet these trends.

Fuel switching must still overcome technical shortcomings before it can overcome organizational hurdles. Even moderate levels of new environmental support will not overcome the current technical limitations of fuel switching.

## Categories of Adopters (con't)

Additionally, it must be noted that those adopting CETA early must have significant access to human and financial capital. Companies in underrepresented and underserved communities often face significant hurdles in securing both of these, and thus CETA is out of reach for them. These companies do not have the capacity to assume any levels of additional risk or debt. State-sponsored initiatives and programming must include equity levers for owners and businesses within these communities.

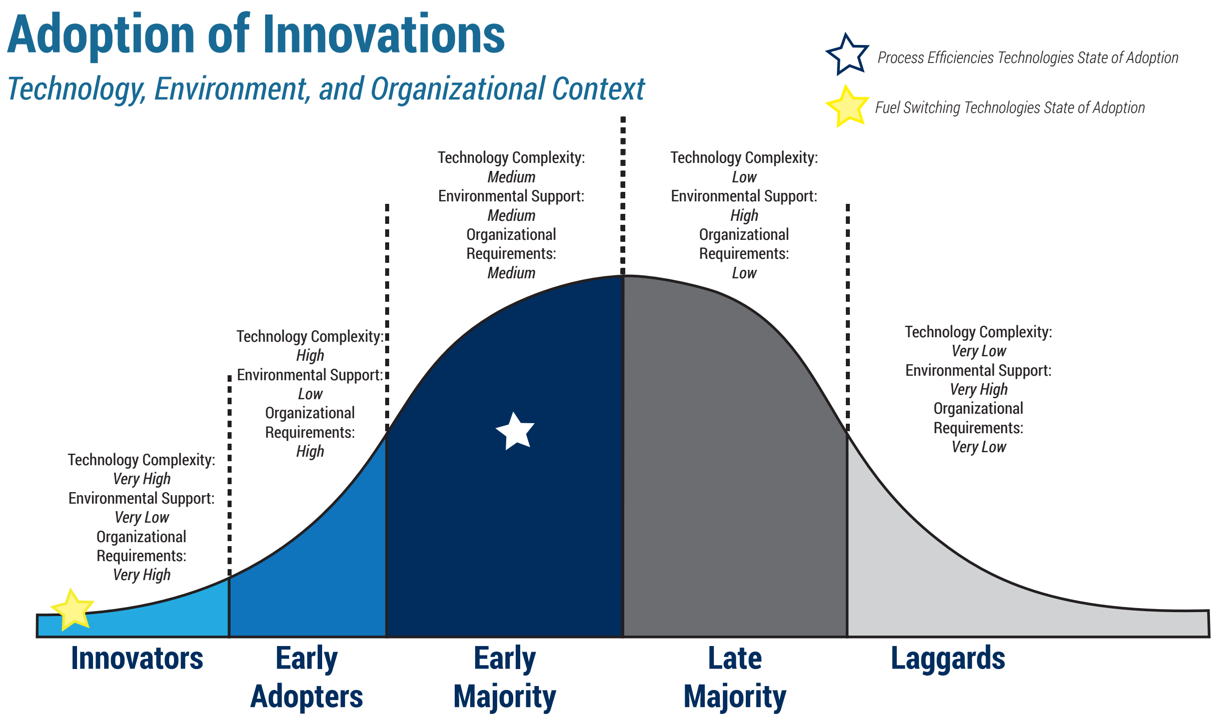



**Figure 6.** Process efficiency and fuel switching state of adoption conceptually represented within categories of companies.

### Social Intrapreneurs

Those leading CETA within companies from a sustainability perspective are social intrapreneurs - internal entrepreneurs who are developing and adopting innovations rooted in social change, such as addressing climate change. These social intrapreneurs (who rarely use that label to describe themselves) are able to do the following:[20]

1. Navigate the context and timing of CETA to fit within the organizational goals, even if those goals are primarily cost-based
2. Frame the CETA in a manner through which peers and leadership understand and develop partners in the work
3. Utilize internal tools to implement clean energy technology adoptions.

However, these social intrapreneurs are only within the organizational component, and the environmental and technological components influence how quickly (or slowly) the clean energy ideas and technology can be adopted and make sense to others within the company. Social intrapreneurs are critical in accelerating CETA within the company, and also for industry as a whole. When these individuals are able to connect with their counterparts at other companies and learn from each other, they together help advance clean energy technologies from just innovations to broadly accepted practices within industry, as outlined in the categories of adopters.

20 White, Christopher J., and Gerald F. Davis. 2015. "The New Face of Corporate Activism." Stanford Social Innovation Review 13, no. 4: 40–45. https://doi.org/10.48558/84WQ-5N33.


# Implications

- Recommendations
- Conclusion

# Recommendations

Leveraging the themes within the combined frameworks of Figure 2, the research team has identified critical recommendations to accelerate CETA within industry. The goal is to move the technologies through the categories of adopters faster, which would be represented by the yellow and white stars moving to the right. This accelerated momentum will require policy, programming, incentives and education to change the state of the environmental, technological, and organizational context. It is the intention of the research team to recommend programs that minimize the negative externalities while providing the most prudent approaches to reduction of energy use and decarbonize the supply chains. The recommendations fall into two categories: launching an industry-led collaborative and developing technical assistance programs (Figure 7).

## Recommendation 1: Launch an industry-led collaborative

A critical component of supporting CETA in industry is the environmental context set by industry itself through customer requirements. As industry wrestles with how to implement technologies to support decarbonization goals, a huge part of the puzzle is requirements for their suppliers, which is part of addressing Scope 3 emissions. Absent any financial incentives, customer requirements of OEMs and large suppliers are a main decision driver for those within the supply chain to adopt new technologies. Incentivizing OEMs and upper tier suppliers to drive clean technology goals through their supply chains would increase the adoption of existing clean technologies and drive innovation. The most direct method to accomplish this would be to deploy and enforce government regulations that accelerate the timeline for net-zero GHG emissions for the OEMs,[21] thus changing the environmental demands for CETA. However, given the financial burden (discussed later) it would place on the supply chain with the relative immaturity of the decarbonization ecosystem and associated lack of measurements and controls, this approach could also be the most disruptive to an already fragile supply chain. A more desirable approach than customers driving down requirements due to governmental regulations is an industry-wide initiative to collaborate, share best practices and develop similar mechanisms to collect emission data from suppliers. These objectives can be accomplished through an industry-led collaborative, where leaders collectively identify pain points and create solutions together. This group can be convened and facilitated by an external third party (such as a nonprofit organization) as a neutral platform, which can then allow industry to identify issues around scope three emissions, share ideas and resources to support suppliers, and identify shared solutions to decarbonization challenges. This approach has successfully been modeled by the Michigan Alliance for Greater Mobility Advancement

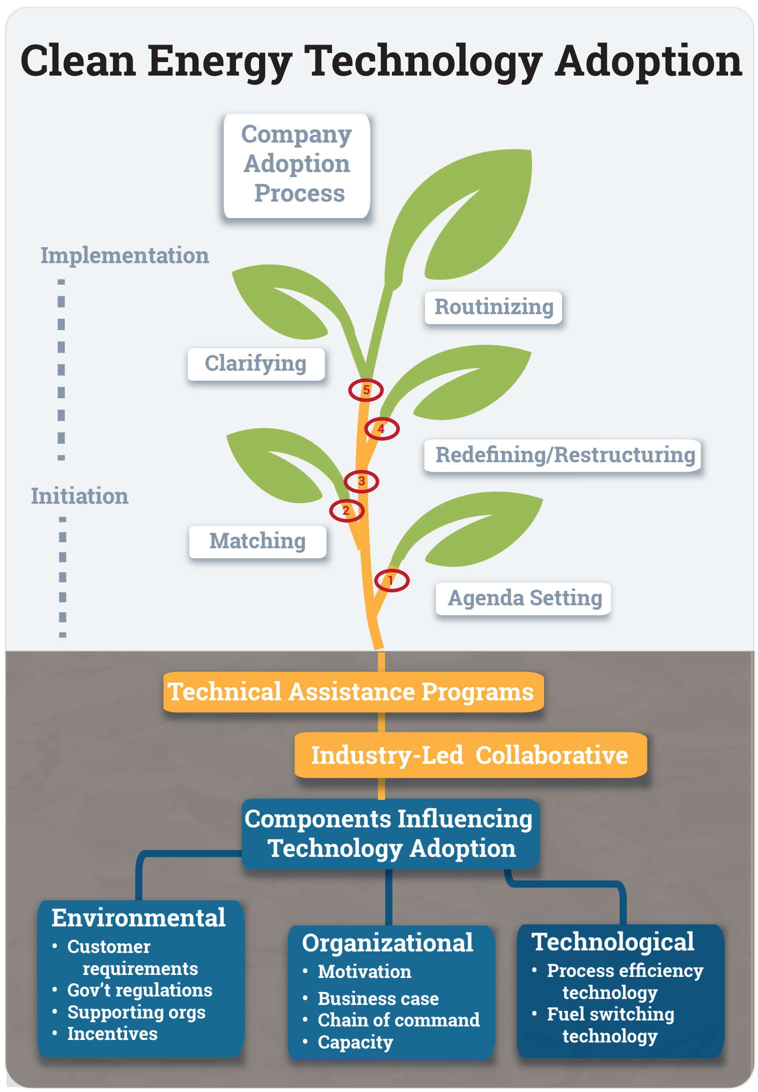



**Figure 7.** Recommendations to accelerate clean energy technology adoption.

21 Through required decarbonization targets for OEMs, the requirements would quickly trickle throughout the supply chain.

# Recommendations (con't)

(MAGMA)[22] to address workforce development. MAGMA is a consortium that includes OEMs, tier suppliers, educational institutions, workforce organizations, and state government, whose goal is to address the automotive industry's skills and training needs, particularly around mobility solutions, connected, and automated vehicles (CAV). MAGMA has been successful in supporting numerous programs focused on addressing the workforce gaps identified by industry. They do this through an active governing board and also through advisory council meetings (which are open to any industry participant).

A decarbonization-focused industry collaborative should similarly serve two purposes: 1) develop a strong governing board to begin to collectively address and develop industry-driven standards for their suppliers as well as discuss decarbonization issues, and 2) provide educational and networking opportunities for all companies around decarbonization. It is critical for standards and measurements to be developed that lay out a common landscape and tools provided to level the playing field for all suppliers. OEMs are ideal for driving this kind of activity as they typically are well resourced and ahead of their suppliers in adoption. The educational opportunities can inform top management and help them understand the business case, related cost drivers and relief (such as new incentives and programs) related to energy efficiency and decarbonization strategies. Within the governing board, company representatives can share among themselves their experiences and real costs, benefits and best practices. As outlined in the social intrapreneur model, the collective sharing between organizations can accelerate CETA.

## Recommendation 2: Develop technical assistance programs

Both industry representatives and ecosystem stakeholders referenced the growing gap for detailed clean energy implementation plans specific to a company's unique processes and constraints. Government-sponsored programming that coaches companies through the entire process (agenda setting through routinizing as outlined in Figure 2) will help to close the gaps in the current CETA process. These types of programs are historically highly effective and have outstanding award winning returns on investment for state and federal governments.[23] The program must be designed to maximize throughput of companies while giving them the detailed analysis, planning and implementation assistance to maximize results. Programs must address the contextual environmental factors, organizational factors, and technological components while also walking alongside companies as they navigate setting the agenda, matching, redefining/restructuring, clarifying, and routinizing. A program/programs should include the following to accelerate CETA:

*Industry-savvy Energy Coaches*

Crucial to the success of these programs are experienced professionals with solid industrial and manufacturing knowledge, market and product lifecycle intelligence as well as deep financial skills that coach companies through each step of the CETA process. These "energy coaches," supported through governmental programmatic funding, can help companies set agendas, identify solutions, and then guide them through the implementation process. Companies have made it clear that they do not have the expertise or capacity to identify all the energy efficient projects needed and/or do not have the knowledge and expertise to identify the resources/consultants/service providers to perform the projects. Energy coaches[24] that are objective and paid from an external source can come alongside the companies from the initiation stages through implementation stages by providing assistance in identifying and vetting the consultants who can implement these projects. The coaches must act as trusted advisors who can provide unbiased expert advice and guidance (i.e. they are not selling their own services, but instead identifying projects and assisting the company in identifying potential consultants and resources).

This external infusion of human capital must be met with internal company engagement as well. The efficacy of CETA is largely dependent on who assumes (or is assigned) the task and the level of their authority within an organization. Technical assistance programming

22 More information on MAGMA is available at https://miautomobility.org/
23 For example, see EDPNC's Existing Industry Expansions Team at the Economic Development Partnership of North Carolina as outlined in the 2022 IEDC Excellence in Economic Development Awards: https://www.iedconline.org/clientuploads/Awards/2022/Awards_Binder_Final_web_v2.pdf
24 A popular programming technique that can enhance or supplement the ecosystem is also programming utilizing retirees from the ecosystem or with the expertise needed to help the companies as consultants, trusted advisors or providers to bridge the capacity and knowledge gap between what companies' appetites are motivated to and the current capacity of the ecosystem.

# Recommendations (con't)

should be delivered to incentivize upper management participation as well as integration across company departments. CEO-driven efforts are more effective than initiatives being led from down the chain of command.

For energy coaches to be successful, governments and agency entities must be prepared to invest in program dollars supporting their work, fully understanding that these coaches are a key lever for maximum returns. Additionally, this type of program often has financial offsets to project cost available to incentivize implementation and accelerate execution, as discussed next. If companies do not implement projects identified by the energy coaches, there is a risk of wasting the funds spent identifying projects and planning just mentioned.

*Resources for implementation*

Incentive programs, such as grants, tax credits and rebates, have been a significant factor boosting the business case of CETA. Incentives (within the environmental component) spill over heavily into the organizational components, directly affecting the business case which is the largest influencer on the leadership decisions (motivation). Incentive programs help to decrease costs and payback periods, thus making CETA business cases more feasible for companies. Loan programs can be offered as an incentive, however most companies do not consider a loan program as an incentive, and SMMs (and some larger companies) typically do not have the balance sheet strength to take on more debt and maintain a desirable banking position nor do they have the room in their cash cycle to service more debt. Although details and subtleties of required ROI and payback periods were given a lot of focus, the underlying connection of those items is their effect on debt, cash flow and the need to improve working capital, net profit and earnings. The need to consider SMMs debt and cash position and relative capital constraints, consistently reinforced the need for technical assistance programs in the form of grants or other non-dilutive awards to motivate CETA. Studies for the central US (which includes Michigan) show the percentage of cash after servicing debt relative to sales is zero percent and negative for the median and lower quartile of companies respectively.

The data also shows that currently more than 50% of companies have zero cash for self-financed growth and 25% of firms have negative cash after servicing current debt. This is consistent with pre-pandemic levels despite overall improvement in financial statement.[25] These numbers get worse and when narrowing to Michigan's primary industry (3363 automotive manufacturing) where the most conservative measure of liquidity (the "acid test" in financial terms) shows a (ratio less than one) dependency on inventory and less current assets to satisfy short term debt for 50% of all manufactures in this category.[26] This is a reflection of negative cash resulting in no working capital for self-financed growth before even thinking about spending additional capital on clean technology implementation. Several interviewees emphasized they will not adopt clean technologies unless there is a significant business case or they have to due to customer requirements or regulations. Tax incentives are a common offering as incentives, but tax incentives still take upfront cash and require the company to take on debt for equipment.  Any cash flow or debt relief is delayed and is still difficult if the change ultimately increases the company's cost of goods sold (as the direct portion of factory overhead). Grants or technical assistance that immediately offset the cost of technology implementation are highly desirable and a positive motivator as they allow for immediate cash relief and are non-dilutive offering balance sheet relief as well. These types of programs are more costly to the state or federal funding agency in the beginning, but also provide a greater return on investment and positive economic impact.

*Inclusion and equity*

Businesses with limited human and financial capital (key organizational components) are very limited in their abilities to engage in CETA. Recent national data demonstrates the lack of financial capital of minority businesses - those with emergency case reserves (more than 14 days) totaled six percent of small businesses in majority-Black communities and only 11 percent of small businesses in majority-Latinx communities.[27] This is compared to 65 percent of businesses in majority-white communities. Rural small businesses struggle to access financing, retain a talented workforce, and identify

25 Risk Management Association, 31Y Manufacturing (cost of sales), 2022 – 23 Annual Statement Studies, Central, https://www.rmahq.org/statementstudies
26 Risk Management Association, 3363Y Automotive Manufacturing (cost of sales), 2022 – 23 Annual Statement Studies, Central
27 Farrell, Diana, Christopher Wheat, and Carlos Grandet. 2019. "Place Matters: Small Business Financial Health in Urban Communities" JPMorgan Chase Institute. https://www.jpmorganchase.com/content/dam/jpmc/jpmorgan-chase-and-co/institute/pdf/institute-place-matters.pdf

# Recommendations (con't)

opportunities available to them.[28] Within any developed program, the financial inclusion of underserved and historically marginalized communities is vital as well as systemized mechanisms to uplift these companies to comparative levels with their counterparts.

Access to workforce that can provide the necessary technical knowledge for implementation can also be a challenge for companies within underserved and underrepresented regions and populations. Energy coaches can provide this technical knowledge, however, the program must also include company assessments that provide recommendations that leverage the strengths and assets of the owners. Additionally, energy coaches should be trained in power dynamics and strengths-based coaching. This is to ensure the consulting-like relationships are built on "power with" not "power over" dynamics,[29] so that their technical knowledge is incorporated as a collaborative, empowered decision, not as an authoritative, one-side decision by an external partner.

Finally, the mechanism of engagement and standards for engagement should be co-created with businesses/representatives from historically disadvantaged and marginalized communities. Co-creation (not just consultation) is a foundational element for designing equitable and inclusive programming. Examples of this can include facilitated workshops, iterative designs, and more.

*Technology matching for energy efficiency projects*

Programming to address the integration of new technologies should start with education on the availability and pace at which these new technologies are coming and business case studies that calculate/demonstrate the benefits. Many companies do not have knowledge of energy or carbon reduction technologies beyond those that have been previously promoted or incentivized. These technologies, often known as the "low hanging fruit," due to their ready availability and documented cost effectiveness/ROI include items such as: lighting, electric motors, the currently trending compressed air system leak control, and systems motor upgrades. Although these systems are not considered energy intensive, the use of these systems is common to most manufacturing processes and culminates into significant energy use and waste (leaks or run at times when not needed). Typically, most lighting and motors are updated due to the existing equipment aging or a required update due to high maintenance or unrepairable equipment replacement. Newer equipment comes equipped with the latest energy efficient electric motors.

Education programs would still be effective in this area to help some of the often less-informed SMMs understand the business case benefits of these important changes they can make to their processes. However, technical assistance should be added to take SMMs to the next level. With a small incremental addition of business case incentives to adopt monitor and control process efficiency technologies (which overlap with Industry 4.0 technologies), an education and incentive model could be much more effective. Today's sensors, monitoring communications, and analytics technologies are often not adopted by SMMs because of the lack of knowledge and fear of the unknown. HVAC technology, compressed air, motors throughout the manufacturing system and other non-energy intensive heating and cooling processes can be monitored and controlled with great ROI for SMMs and service providers to support these systems are becoming more numerous and readily available.

*Innovation support for fuel switching*

CETA for energy intensive processes is a much more difficult situation because non-carbon alternatives are limited. High heat ovens, or metal melting processes that require natural gas, have no substitutes with a manufacturing readiness level near what many companies can absorb relative to cost or risk. As identified in Figure 6, the technology is still at the "innovator" stage where costs are very high and support is very low. Thus a few programs are recommended to accelerate CETA:

**Lab-to-market**: Often surprising solutions come from SMMs through partnership with a university. SMM can sometimes solve a problem that would otherwise

28 Small Business Majority. 2019. "Examining the Unique Opportunities and Challenges Facing Rural Small Businesses." https://smallbusinessmajority.org/our-research/entrepreneurship-freelance-economy/examining-unique-opportunities-and-challenges-facing-rural-small-businesses.
29 Pansardi, P. and Bindi, M. "The new concepts of power? Power-over, power-to and power-with." 2021. Journal of Political Power Vol 14, no. Issue 1 (March): 51-71. https://doi.org/10.1080/2158379X.2021.1877001

# Recommendations (con't)

have taken years to solve in the university or federal labs. Michigan has a translational research and commercialization program called MTRAC, and it currently supports companies in agriculture, computing, mobility, materials, and biotech but not energy. It is our recommendation that the MTRAC program be expanded with an energy component. It would likely be best run by a university with energy audit program personnel and the MTRAC model allows other universities to participate with project selection coming from a heavily weighted industry panel. The small company innovation program (SCIP) should also be revived. SCIP allows a small company to receive technical assistance and utilize university resources to help push their company's technology into the right place.  SCIP is also a model that several universities can participate in. Both SCIP and MTRAC are international award winning programs.

Materials engineering assessments and innovation: Energy intensive processes can be eliminated by substituting the materials processed or the part being manufactured itself. All components and processes can be pursued with an eye for substitution. Programming for SMMs in materials engineering assistance would be effective in this area. SMMs typically do not have the advanced engineering and research capabilities to tackle material substitution challenges of this caliber. Investment in specific research to overcome technology hurdles as a whole could be effective.

Hydrogen hubs & TA for companies: An outstanding need is the substitute for natural gas. The thought of natural gas substitution is typically not even on the radar of most companies, except the very large companies. However, if hydrogen hubs become a reality,[30] this alternative fuel source could solve the high heat process challenges manufacturers face (melting metals is not feasible through induction heat). Technical assistance programs that take an early look at current high heat energy intensive processes in a particular company through the hydrogen-substitute lens would be beneficial for the company's future adoption as well as give a set of problems that need to be solved for the manufacturer to de-risk the implementation of zero-emission (green) hydrogen. If green hydrogen becomes cost effective to produce, store and transport, there is still the embrittlement problem to solve. Hydrogen embrittlement affects everything hydrogen touches in the manufacturer's process equipment. Even when the processes are adjusted to use the gas in place of natural gas, components used in today's processes and made of materials available today would corrode and fail due to hydrogen embrittlement at an unaffordable rate when implemented in the factory. This is really a market failure technical problem that needs advanced laboratories and the best scientists to solve. As a state we should be challenging our universities as well as encouraging the federal government to make major investments to solve hydrogen embrittlement.

30 The Department of Energy launched the Regional Clean Hydrogen Hubs program (H2Hubs) in 2022 through the Bipartisan Infrastructure Law. Applications are due in April 2023 for up to $7 billion to establish six to 10 regional clean hydrogen hubs across America. More information on the DOE program is available here: https://www.energy.gov/oced/regional-clean-hydrogen-hubs

# Conclusion

Addressing carbon emissions within industrial sectors is a critical component of reaching Michigan's decarbonization goals. This report provides the roadmap of clean energy technology adoption including the value chain currently supporting CETA and recommendations to accelerate adoption related to energy and process efficiencies. Based on the research, our team identified the following:

- A CETA framework with three components supporting a company in the process. The environmental component identifies how factors external to the company influenced their CETA and/or sustainability plans more broadly. This includes customer requirements, government regulations, supporting organizations, and incentives. The organizational component highlights the internal structures within the company that influences the implementation of CETA including the motivation of adoption, the required business case, the chain of command, and the capacity for adoption. Finally, the technological component outlines what technologies are readily available to the firms (as evidenced through implementation) related specifically to process efficiencies and fuel switching.
- An overview of a company's process of adoption, which includes two general stages - initiation and implementation. During the initiation stage a company tackles agenda setting and matching for the adoption of an innovation. Next, in implementation a company goes through redefining/restructuring, clarifying, and routinizing for the adoption of technologies.
- The current gaps in the value chain include the lack of requirements for decarbonization activities, knowledge and skills to match technologies, funding to support implementation, workforce capacity and capabilities, objective advice and insights for implementation.
- The categories of CETA adopters, to provide an overview of the current state of adoption.

To accelerate CETA within Michigan, the research team identified two recommendations to accelerate adoption. First, launching an industry-led collaborative will provide impactful peer-to-peer learning as industry wrestles with how to implement technologies to support decarbonization goals. A key objective for this collaborative is identifying how to implement requirements for their suppliers to address Scope 3 emissions. Second, companies need technical assistance programs to address the broad range of projects needed and navigate the resources available to them.

Accelerating the adoption of clean energy technologies is a complex process through which targeted investments can move the needle as Michigan seeks to reduce its carbon footprint. The state of Michigan is uniquely positioned through its current policy and funding priorities to support companies as they seek to adopt clean energy technologies. This report provides insight into critical mechanisms that can support the acceleration, thus increasing the sustainability and resiliency of these businesses and their surrounding communities. The resulting programs and investments from these findings will benefit companies, residents, and our future generations in Michigan.

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