Clean Energy
ROADMAP

MICHIGAN AGENCY FOR ENERGY
NEXTENERGY
OHIO DEVELOPMENT SERVICES AGENCY
TEAM NEO
US DEPARTMENT OF ENERGY

PROJECT PARTNERS

Project Team

The **Michigan Agency for Energy (MAE)** is a government agency within the Michigan Department of Licensing and Regulatory Affairs. MAE coordinates, analyzes, advises on, and advocates for the state's policies, programs, and proposals related to energy.

MAE's purpose is to set Michigan on a path toward affordable, reliable energy. It serves as a single entity dedicated to provide all of state government the information and context they need to support Michigan's energy priorities.

MAE brings together the Air Policy Director and the Retired Engineers Technical Assistance Program from the Department of Environmental Quality; the Michigan Energy Office from the Michigan Economic Development Corporation; and the Michigan Public Service Commission.

The **Ohio Development Services Agency, Office of Energy and Redevelopment (OERD)** works to grow and strengthen Ohio's economy by building upon its strategic investments in the state's energy-based sector. As part of this effort, OERD utilizes U.S. State Energy Program (SEP) funds to connect companies and communities to financial and technical resources in order to deploy renewable energy and energy efficiency technologies throughout the state.

The Ohio Development Services Agency works to grow the economy of the state by connecting companies and communities to financial and technical resources to increase efficiency and reduce costs.

NextEnergy is a 501(c)(3) nonprofit organization established in 2002 to drive advanced energy investment and job creation in Michigan. Located in Midtown Detroit's innovation corridor, NextEnergy serves as a catalyst for advanced energy technology demonstration and commercialization in the state. Since its inception, NextEnergy has helped to attract more than $1.5 billion of new investment, including over $160 million generated by programs in which it has directly participated.

Team NEO is a regional, private-sector organization serving the 18 counties of Northeast Ohio. The organization collaborates with its partners and others to attract new businesses, help those in Ohio to grow, and accelerate the pace and impact of innovation in the region. As one of eleven SBA Regional Innovation Centers, Team NEO has experience in analyzing, roadmapping, developing and supporting the growth of innovation clusters, and has done so successfully with extensive Northeast Ohio roadmapping and cluster development initiatives completed for Flexible Electronics, Water Technologies, Waste and Biomass to Energy, Energy Efficiency, Energy Storage, and Fuel Cells.

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About the Report

The Clean Energy Roadmap is a collaborative effort between Michigan and Northeast Ohio to accelerate the region's clean energy sector. To identify and advance energy efficiency building technologies, products, services and clean energy manufacturing, the authors conducted the following tasks:

- Developed an inventory of regional energy efficient building technology assets
- Identified energy-intensive processes in clean energy manufacturing
- Developed supply and value chain analyses
- Produced technology roadmaps
- Hosted events with clean energy industry partners
- Recommended economic development strategies based on research results

This report shares results and recommendations that can be utilized to build the region's clean energy cluster and accelerate regional economic development.

Acknowledgments

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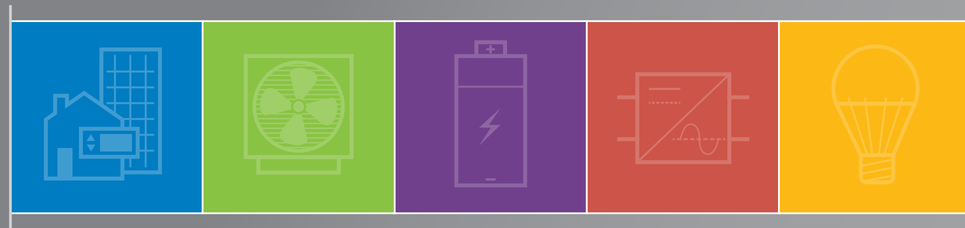
The full Clean Energy Roadmap Report can also be viewed at **michigan.gov/ereports**.



Executive Summary

The market for clean energy technology is growing rapidly and, according to numerous market research firms, that growth is anticipated to continue in the coming years. The combination of new technology, a growing United States economy, greater electricity demands and a need to reduce emissions has helped to push energy efficiency interest and incentive programs.[1] The Clean Energy Roadmap is a collaborative effort between Michigan and Northeast Ohio[2] to accelerate the region's clean energy cluster and capitalize on these trends. Funded by the U.S. Department of Energy (DOE), the Michigan Agency for Energy (MAE) led the project in partnership with the Ohio Development Services Agency, Office of Energy and Redevelopment (OERD) to provide project management and public sector involvement. NextEnergy and Team NEO (formerly NorTech) conducted the technical analysis and provided private sector involvement and perspective. The overarching vision of the project team is to create regional economic development strategies that foster more competitive private-sector clean energy manufacturing and energy efficiency clusters in each state.

To accomplish this vision, the partners focused on two main goals: 1) developing focused strategies for advancing the energy efficient building technology cluster, and 2) developing clear technology roadmaps for several energy-intensive, clean energy manufacturing processes to reduce the energy cost of these processes. The multi-year roadmapping process utilized multiple market research and analysis tools—asset mapping, value and supply chain analyses, and technology roadmapping—to understand and identify the strengths on which to build, the barriers impeding success, and create strategies that will move the region's cluster forward.

First, NextEnergy and Team NEO identified companies within the clean energy and energy efficiency value chain in Michigan and Northeast Ohio, respectively. The teams then conducted primary in-depth interviews, site visits, in-person interviews during events, and quantitative surveys to develop a robust understanding of the energy efficiency building technology (EEBT) value chain and supply chain for specific clusters, including light-emitting diode (LED) lighting in both states, and building automation and heating, ventilation, and air conditioning (HVAC) in Michigan only. At the same time, to examine the energy use in manufacturing for

1 Annual Energy Outlook 2015 – U.S. Energy Information Agency – Accessed Jan. 2016
2 A 21-county region focused on Greater Cleveland and Greater Akron metropolitan areas and including the following counties: Ashland, Ashtabula, Carroll, Columbiana, Crawford, Cuyahoga, Erie, Geauga, Holmes, Huron, Lake, Lorain, Mahoning, Medina, Portage, Richland, Stark, Summit, Trumbull, Tuscarawas, and Wayne.

clean energy and energy efficiency technologies, NextEnergy conducted an analysis of processes used in manufacturing LED lighting, power electronics, and energy storage (batteries) through a combination of interviews and manufacturing site visits. Secondary research on clean energy market drivers showcased the national and local factors that stimulate demand and create an attractive environment to foster clean energy products and services growth. Project findings laid the framework for developing individual state and regional implementation plans including vision, goals, and recommendations for developing the clean energy cluster.

Energy Efficiency Value Chain

It is important to understand the distinction between value chain and supply chain. The value chain refers to all industry stakeholders that are responsible for adding value to a product both pre-and post-sale, including engineering, financing, installation, and service. The supply chain refers specifically to companies that provide services, equipment, or materials that relate to delivery of a product to customers, including raw material suppliers, equipment manufacturers, subcomponent suppliers, and engineering firms.

Each region conducted an analysis on the energy efficiency value chain in varying scopes. In analyzing the overall energy efficiency value chain, NextEnergy identified a total of 2,802 companies and stakeholders that serve the energy efficiency (in residential, commercial or industrial markets), renewable energy, or energy-related software/sensors/controls markets in Michigan. Team NEO research had a narrower scope and focused on the LED lighting, non-fiberglass insulation, and building efficiency services markets, and identified 220 companies and stakeholders in the value chain within Northeast Ohio.

While each state and respective value chain had unique strengths and challenges, findings were also cross-cutting regionally, with strengths including significant robust research and development (R&D) activity, strong engineering and manufacturing talent, a strong network of entrepreneurs and innovation, as well as challenges such as untapped deployment potential. The tools recommended to bridge the deployment gap differed by state due to program preference and available opportunities. In Michigan, strategies may focus on increasing awareness of energy efficiency benefits, reducing barriers to engage in energy efficiency programs, and increasing training in connected systems or building automation. In Northeast Ohio, opportunities lie in helping companies focus on profitable retrofit markets and build consortiums for building envelope and service providers to foster more effective working relationships and a collective voice in the market.

Energy Efficient Building Technologies

As a result of the value chain analysis, more rigorous analysis was conducted for specific EEBT-related sectors that were prioritized on the basis of their potential impacts on the regional clean energy cluster. NextEnergy and Team NEO conducted statewide and regional analyses of the LED lighting sector, and NextEnergy also conducted analyses of the building automation and HVAC sectors.

In the LED lighting market, there are a handful of cross-cutting findings, including a robust and growing supply chain in fixtures and luminaires with limited ability to influence global chip or light engine technology, and robust R&D activities and talent in the LED lighting industry. However, the challenges facing Michigan and Northeast Ohio are also divergent. For example, much of Michigan's luminaire manufacturing process is still manual in nature. Therefore, Michigan's industry can improve manufacturing efficiency through automation. At the same time, Michigan's industry is diversifying with an increased focus on the controls systems in lighting. In Northeast Ohio, while process automation is a challenge for some, the more urgent challenges lie with organizing the cluster more effectively, which can be addressed by engaging the various levels of the supply chain through more effective collaboration within the cluster and fostering next-generation lighting products in large, global companies in the region. As a result, there are opportunities for the region to leverage the research and development (R&D) pipeline, foster cluster development, and capitalize on greater retrofit and deployment potential.

The building automation and HVAC clusters' analysis is limited to Michigan and finds growing sectors that are still relatively niche markets. There are some similarities between these clusters, but by definition, the building automation market is more heavily focused on software, sensors, and controls developers while the HVAC market includes more manufacturers and hardware developers. At the installation level, HVAC installers may install a portion of the building automation system; however, a comparatively small number of installers and integrators now specialize in incorporating different building systems into building automation systems specifically.

Within the building automation sector, Michigan is home to small, innovative companies with strong deployment potential that require resources and capacity to scale deployment. In addition, the state is strong in web services/data analytics and process automation, which can help advance this sector. To improve the prospects of the cluster, NextEnergy finds that developing a demonstration of the technology and providing regular support from the state or an industry consortium would help to foster growth. The cluster would also benefit from greater software development, as well as contractor training about the systems to help encourage adoption at the customer level.

In Michigan's HVAC cluster, the industry is not centered on the residential sector, instead focusing on commercial and industrial niche products. However, within those sectors, Michigan has a number of manufacturers offering products throughout the HVAC ecosystem. Challenges for the cluster include the unsettled nature of the regulatory environment and difficulty finding the right sales channel. Tools to combat these challenges and grow the cluster overall include developing a combined heat & power (CHP) cluster, fostering control system partnerships, cultivating buy-sell relationships and pushing existing "Buy Michigan" programs.

Clean Energy Manufacturing

By creating more efficient and cost-effective manufacturing processes, clean energy manufacturers will be more competitive globally, which may in turn positively impact growth in the clean energy products industry. To identify areas of manufacturing in clean energy industries that offer potential areas of significant energy use improvement, NextEnergy analyzed the following strong Michigan sectors: energy storage, LED lighting, and power electronics.

In examining the processes required for manufacturing batteries, the energy drivers vary by the type of batteries being manufactured. For example, much of Lithium Ion (Li-Ion) battery manufacturing requires production inside a temperature, humidity, and dust-controlled room that uses a lot of energy. In lead-acid (Pb-A) battery manufacturing, the melting, mixing, and drying of lead is energy intensive. Within LED lighting and power electronics manufacturing processes, the energy use patterns are similar: basic materials, assembly, and testing drive energy use for facilities, but are small on a per unit basis. Therefore, mitigating energy use in these three applications will take significant effort to improve raw material efficiency, improve yield from production, or in the case of Li-Ion, leapfrog the technology to reduce clean room necessity.

Implementation Plans

The focus of the Clean Energy Roadmap is to conduct a baseline assessment of the clean energy cluster ecosystem, as well as create tangible goals and recommendations that can be implemented to directly generate more economic activity within the cluster. The following implementation plans document each state's vision for moving forward, as well as a shared vision for regional cluster development.

Michigan Implementation Plans

After conducting the body of research presented in this report, project stakeholders including MAE, Michigan Economic Development Corporation (MEDC), and NextEnergy assembled to review key findings and outcomes from the EEBT and the clean energy manufacturing research.

Michigan EEBT Implementation Plan

Real opportunities exist to strengthen Michigan's existing energy efficiency ecosystem, specifically, in sectors such as LED lighting, HVAC, and building automation, which are either generating new innovations or manufacturing EEBT products. During the stakeholder meeting, participants crafted a broader vision and specific goals that leverage current strengths in the above areas and help grow each sector where opportunity has been identified. For example, there is an opportunity to strategically coordinate Michigan's broader energy efficiency value chain (service providers) and its specific ecosystems innovating and manufacturing products for LED lighting, HVAC, and building automation. There is great potential to generate a potent combination and advance Governor Snyder's plan to reduce energy waste by creating energy pillars of a strong energy future: affordability, reliability, and environmental protection. The following vision and goals could help realize this possibility.

VISION

Leverage the energy efficiency and EEBT sectors to strengthen and diversify Michigan's economy while eliminating energy waste

GOAL

Strengthen R&D where most intellectual property development and investment occurs

Recommendations

1. Encourage university researchers to pursue federal and non-federal funding opportunities by assisting with partnership collaboration, and matching funds by actively promoting funding opportunities to researchers and continuing the State's current match funding programs

   Next Step:

   - Develop strategy for reaching university researchers and actively promote matching fund opportunities

2. Stimulate venture development by regularly promoting relevant federal R&D funding, such as Advanced Research Projects Agency-Energy (ARPA-E) and Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) and by providing advisors to assist ventures and pull them into the application process

   Next Step:

   - Continue venture advisor support and hold regular webinar session on ARPA-E and SBIR/STTR opportunities

3. Stimulate technology innovation through the regular administration of technology challenges, both through program management support and monetary prizes

   Next Step:

   - Develop a strategy for technology challenge focus areas and secure funding to support program management and prize money

GOAL

Strengthen the energy efficiency value chain

Recommendations

1. Investigate leveraging the MEDC Pure Michigan Business Connect program or another relevant tool that encourages new matchmaking and partnerships within the energy efficiency value chain, both for technology developers and for service providers such as architects, specifiers, and contractors

   Next Step:

   - Schedule planning sessions with the MEDC Pure Michigan Business Connect program to discuss leveraging program

2. Encourage Michigan's current software/IT ecosystem to apply its talent throughout the energy efficiency value chain

   Next Step:

   - Conduct a matchmaking event through local technology accelerators

3. Develop forecasting and economic analysis models of Michigan's energy efficiency ecosystem

   Next Steps:

   - Secure funding and develop forecasting/economic impact data. Continue to track and survey EEBT assets in Michigan on an annual basis to support the energy efficiency value chain
   - Secure funding to continue annual survey of energy efficiency ecosystem.

4. Leverage the MEDC Pure Michigan Talent Connect program and job portal to attract, retain, and connect recent graduates from Michigan-based institutions with Michigan-based companies seeking a trained workforce

   Next Step:

   - Conduct planning session with the MEDC Pure Michigan Talent Connect program

GOAL

Increase deployment efforts

Recommendations

1. Perform an analysis on the opportunity of streamlining existing energy efficiency utility programs into a statewide program to create ease of use, consistent incentives, and eliminate confusion amongst programs – all focused on creating a stronger market

   Next Step:

   - Secure funding to perform analysis of other statewide energy efficiency programs

2. Develop stronger workforce development opportunities for contractors/installers focused both on "selling" energy efficiency technology and on educating contractors on emerging technologies by developing and deploying training sessions through existing utility contractor programs and trade associations

   Next Step:

   - Conduct strategy sessions with contractor and trade associations regarding the development of new training modules

3. Strengthen sales channels for smaller manufacturers and service providers that have niche products or early innovations and are competing against entrenched, out-of-state companies by leveraging the MEDC Pure Michigan Business Connect program, providing sales advisors, establishing a statewide energy efficiency product database, and creating a strong "Buy Michigan" program for State purchases

   Next step:

   - Conduct strategy sessions to develop broader sales channels implementation model that leverages the above recommendations

4. Identify and prioritize "low-hanging fruit" targets (i.e., sectors and building types) that are more easily achievable

   Next Step:

   - Utilize Clean Energy Roadmap research as a basis to conduct a building sector segmentation opportunity analysis

Michigan Clean Energy Manufacturing Implementation Plan

The focus of this work is two-fold: evaluate the manufacturing processes of key clean energy manufacturing sectors and generate tangible goals and recommendations that will lead to a more competitive manufacturing sector. For Michigan, real interest lies in strengthening clean energy manufacturing activity as a means to diversify and strengthen the economy. During the stakeholder meeting, participants crafted a broader vision and specific goals leveraging current strengths in the LED lighting, energy storage, and power electronics sectors with a focus on helping manufacturing activity grow. By implementing the following recommendations, clean energy manufacturing will continue to play a role in advancing Governor Snyder's pillars of a strong energy future: affordability, reliability, and environmental protection.

VISION

Foster clean energy manufacturing activity as a means to both diversify and grow Michigan's economic activity

GOAL

Generate more R&D in materials, components, subsystems, and production processes that will lead to increased clean energy manufacturing activity

Recommendations

1. Increase clean energy manufacturing activities through funding assistance

   Next Steps:

   - Communicate regional industry needs to appropriate DOE and Advanced Manufacturing Office leads in these areas
   - Increase awareness of programs such as the Small Business Voucher program with the National Labs
   - Capitalize on existing state funding programs such as the Michigan entrepreneurial support programs

GOAL

Foster the creation of more competitive clean energy manufacturing products by focusing improvements on design and yield, while still making gains in energy reduction costs

Recommendations

1. Capitalize on automation expertise and industry cross-pollination

   Next Steps:

   - Encourage improving industry cross-pollination during events and including production automation companies in cluster specific activities
   - Continue retooling grants and loans, technology challenges, or other funding opportunities focused in this area

2. Promote increase in yields, design, and integration

   Next Steps:

   - Specifically promote National Lab Small Business Voucher grants targeting yield, design, or integration improvements
   - Set up planning sessions for ways to involve Michigan organizations with experts in improving efficiency in industrial operations like the DOE Industrial Assessment Centers and Michigan Manufacturing Technology Center

GOAL

Strengthen Michigan's export activity

Recommendations

1. Utilize existing Michigan programs for established and mature firms

   Next Steps:

   - Increase awareness and opportunities through Michigan State Export Program
   - Continue and strengthen matchmaking activities through strategic service providers and Pure Michigan Business Connect

2. Assist small clean energy product manufacturers with commercializing their products and establishing sales channels

   Next Steps:

   - Continue and strengthen matchmaking activities through strategic service providers and the MEDC Pure Michigan Business Connect program
   - Launch an accelerator program dedicated to helping commercialize early stage clean energy manufacturing companies
   - Conduct an annual event that showcases clean energy manufacturers' products

Northeast Ohio Implementation Plan

Key stakeholders from the OERD, Team NEO, and NextEnergy discussed the key findings of the EEBT and clean energy manufacturing roadmapping work for Northeast Ohio. The group vetted recommendations based on these findings and determined that a real opportunity exists in the LED lighting sector of the solid state lighting industry. Stakeholders examined the strengths that exist in the region that lend to a burgeoning LED lighting industry, including core parts of the manufacturing supply chain.

Northeast Ohio EEBT and Clean Energy Manufacturing Implementation Plan

The following goals and implementation paths will help move the project beyond the roadmapping phase and further develop the LED lighting industry in Northeast Ohio.

VISION

Continue to establish Northeast Ohio as a co-leader in LED lighting. Strengthen the ability for Northeast Ohio LED lighting manufacturers to connect with the regional supply chain.

GOAL

Provide broad ecosystem support

Recommendations

1. Work with economic development, small business, and entrepreneurial assistance entities to convene events

2. Help develop and support initiatives to emphasize Northeast Ohio companies

   Next Steps:

   - Assist in knitting together a more coordinated cluster development activity to form the majority of a regionally integrated supply chain, a task that original roadmap participants, such as GE Lighting, already indicated would be of interest to regional original equipment manufacturers (OEMs)
   - Take advantage of momentum of Clean Energy Roadmap-related activities before the opportunity to solidify a distinct regional identity has passed

GOAL

Focus on upstream R&D opportunities

Recommendations

1. Capitalize on potential funding opportunities

   Next Steps:

   - Investigate potential channels for matching dollars to help secure awards
   - Focus on attraction, retention, and innovation, including what is necessary to grow companies located in the region and attract companies to the region

2. Assist Northeast Ohio-based companies with funding, collaborations, and establishing meaningful engagements with potential customers within Northeast Ohio, between Northeast Ohio and Michigan, nationally, and globally

   Next Step:

   - Engage in planning sessions with economic development partners and engaged LED companies to foster development and opportunities needed to attract international companies to Northeast Ohio

3. Increase deployment efforts
4. Streamline and improve effectiveness of rebate programs

   Next Step:

   - Work with utilities to analyze and streamline rebate programs

Collaborative Implementation Plan for Michigan and Northeast Ohio

A goal of the Clean Energy Roadmap is to develop the region's clean energy cluster and manufacturing activity. The scope of the regional implementation plan focuses on developing a vision specifically for the LED lighting sector since research findings revealed that both Michigan and Northeast Ohio are home to robust LED lighting sectors. This Plan can be used as a model for cluster growth and replicated in other clean energy-focused sectors. The LED lighting sector drives activity from an EEBT perspective and from a clean energy manufacturing perspective. When looking at the entire LED lighting value chain and supply chain, the activity spans from early innovation and R&D to manufacturing activity to significant implementation activity. Value is created by the development of new intellectual property, manufacturing activity, and ability for energy savings and the associated economic activity resulting from implementing projects.

If both states work together to grow the LED lighting sector and associated manufacturing activity, the region will be positioned as a national and global leader in advanced lighting.

VISION

Leverage the LED lighting sector in Michigan and Northeast Ohio to position the broader region as a leader in LED lighting

GOAL

Stimulate R&D activity

Recommendations:

1. Encourage both matchmaking between university researchers and private sector companies and the pursuit of federal and non-federal funding opportunities

   Next Step:

   - Conduct in-person sector meetings that promote federal funding opportunities and partnership collaboration

2. Building on the diverse LED lighting ecosystem that exists in both states, host technology challenges targeted at both new and existing market segments to strengthen innovation pipelines between entrepreneurs and established supply chain partners

   Next Step:

   - Secure funding to host technology challenges and promote to LED lighting ecosystems in both states

3. Facilitate relationships between larger lighting companies and smaller, entrepreneurial innovators across both regions

   Next Step:

   - Secure funding to host annual multi-state innovation summit

GOAL

Foster lighting cluster development and strengthen the supply chain

Recommendations:

1. Foster better interaction, identify opportunities for partnership, and grow a stronger, multi-state regional LED lighting cluster

   Next Step:

   - Host annual convening event

2. Communicate supply chain capabilities to help foster cross pollination and increased levels of activity throughout the ecosystem on a regional basis

   Next Step:

   - Develop a supply chain capabilities matrix and communicate it across the lighting ecosystems

GOAL

Increase deployment opportunities

Recommendations:

1. Host an annual multi-state advanced lighting conference that provides an excellent opportunity to connect supply chain partners with potential end users

   Next Step:

   - Secure funding and conduct planning for an annual advanced lighting event

2. Leveraging existing utility and trade programs, expand advanced lighting training with contractors in Michigan and Northeast Ohio

   Next Step:

   - Develop a plan and secure funding to expand contractor training

3. Develop Michigan and Northeast Ohio LED lighting product database for local and state governments and utility programs to strengthen purchasing programs of regional lighting products

   Next Step:

   - Conduct inventory of Michigan products and develop database

4. Create synergy and paths to market for Michigan-and Northeast Ohio-made products

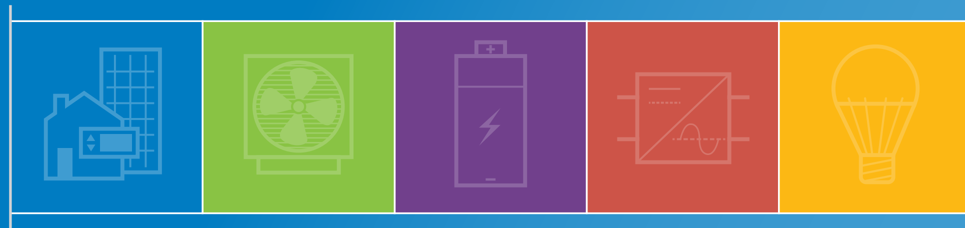
   Next Step:

   - Host combined events, training opportunities, and industry days

Conclusion

The Clean Energy Roadmap offers not only a detailed understanding of the current position of the clean energy ecosystem and its assets, but also discusses the current barriers, opportunities, and solutions that capitalize on opportunities moving forward in Michigan and Northeast Ohio. Ultimately, the prospect to grow the clean energy and energy efficiency sectors is strong. While both Michigan and Northeast Ohio face similar challenges across the value chain and within the specific supply chains examined, each have unique strengths, including Michigan's diversity in HVAC, and building automation clusters and Northeast Ohio's large lighting manufacturers shifting focus towards the next generation of solid state lighting. Yet both regions have common strengths that can be leveraged, setting the framework for success.

By capitalizing on each other's strengths and sharing this analysis with agencies that support regional innovation cluster development, including the DOE, the U.S. Department of Commerce Economic Development Agency, and the U.S. Small Business Administration, the region is poised for continued growth. The implementation plans outline a variety of critical steps for developing comprehensive action to advance the region's EEBT cluster and clean energy manufacturing process improvements that will contribute to regional economic growth.



Introduction

In 1990, economist Michael Porter introduced the concept of clusters within the framework of competitive advantage. A cluster is simply defined as "a geographic concentration of related companies, organizations, and institutions in a particular field that can be present in a region, state, or nation."[3] A strong cluster creates a competitive playing field for job creation and private investment, fostering an environment that increases productivity, accelerates growth, and stimulates new business development. The Clean Energy Roadmap is a collaborative effort between Michigan and Northeast Ohio to accelerate clean energy clusters within the region. The stakeholders manufacturing and providing services within the clean energy sector focus on developing solutions that reduce the use of natural resources and related emissions or waste.

MAE and OERD in partnership with the NextEnergy and Team NEO—advanced energy and economic development nonprofit organizations based out of Michigan and Northeast Ohio, respectively—were tasked with creating regional economic development strategies to foster more competitive private-sector clean energy manufacturing and energy efficiency clusters in each state. This research specifically examines activities taking place in the entire state of Michigan and is concentrated on Northeast Ohio, Team NEO's geographic focus. While each state will develop its own unique economic development strategies, the regional focus is important because industry clusters that are more effectively linked and operate with greater efficiency generate sustainable economic growth.

Specifically, the Clean Energy Roadmap has focused on establishing a baseline of the regional assets in energy efficient building technologies (EEBTs)—technologies used in a built environment that optimize energy use—and examining energy usage in clean energy manufacturing processes. This assessment is crucial as it is important to understand the current status and role of the clean energy sector to develop an impactful regional economic strategy that will build off of strengths, address the barriers impeding success, and identify the key goals, recommendations, and next steps necessary to achieve the regional vision.

Further, work has concentrated on examining existing regional manufacturing capabilities to assess alignment with clean energy market opportunities. Accounting for 30% of U.S. manufacturing in 2010, the Midwest serves as a hub for industry

3 "What are Clusters?" – Harvard Business School Institute for Strategy and Competitiveness – Accessed Oct. 2015

activities and boasts a long track record of success.[4] Opportunities exist to utilize the talents and resources that lie within the region, diversify from existing areas of expertise (e.g., automotive), and infuse the advanced manufacturing know-how into the clean energy sector.

This effort involved a variety of activities that engaged energy industry stakeholders, companies, and policy makers throughout the process, including:

- Development of an inventory of regional energy efficient building technology assets
- Identification of energy-intensive processes in clean energy manufacturing
- Analysis of the linkages between assets, supply chain, and value chain maps to identify high-value interventions to drive regional cluster growth
- Identification where white space exists and programs or policies are needed to grow targeted segments of the value chain
- Production of technology roadmaps
- Execution of convening events with a focus on clean energy
- Analysis of external factors and regional dynamics that impact the speed of technology commercialization

The analysis focused on identifying robust sectors, or those with strong potential, in each state through rigorous analysis of its respective EEBT clusters and companies with a strong clean energy manufacturing base. While sector importance differed by state, there was some overlap in sectors selected for analysis (see Table 1).

Table 1: Sector Analyses Summary by State

			MICHIGAN	NORTHEAST OHIO
Energy Efficiency Building Technologies	Value Chain Analysis	Energy Efficiency Building Technologies	X	X
	Supply Chain Analysis	LED Lighting	X	X
		HVAC	X	
		Building Automation	X	
Clean Energy Manufacturing	Manufacturing Process Analysis	LED Lighting	X	X
		Energy Storage	X	X
		Power Electronics	X	

Source: NextEnergy

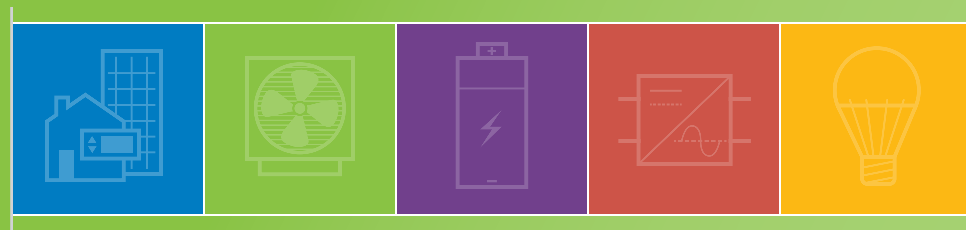
4 America's Smartland: Growing our Advanced Manufacturing – Midwestern Governors Association – Accessed Oct. 2015

There are many perceived outcomes anticipated in maturing the clean energy cluster, including:

- Job creation and retention
- Attraction of investment
- Reduced cost of manufacturing goods
- New value chain market entrants
- Supply chain partnerships
- Product development partnerships
- Joint development agreements (JDA)/Joint ventures (JV)
- Licensing
- Mergers and acquisitions
- Intellectual property (IP), patents

Results from the Clean Energy Roadmap will impact stakeholders from all facets of the clean energy value chain. Clean energy product manufacturers may identify more efficient manufacturing processes that lower manufacturing costs of clean energy products by reducing energy waste. Clean energy contractors and service providers will gain visibility throughout the clean energy value chain and identify more means for improved competitive market positioning and adoption of clean energy technologies. Building owners and managers will be provided with the resources to navigate new technologies and identify areas that will improve energy efficiency within their operations, reducing operating costs and ultimately, their bottom line. Thus, information resulting from the Clean Energy Roadmap project will help companies increase profitability, support job retention and creation, and increase overall global competitiveness.

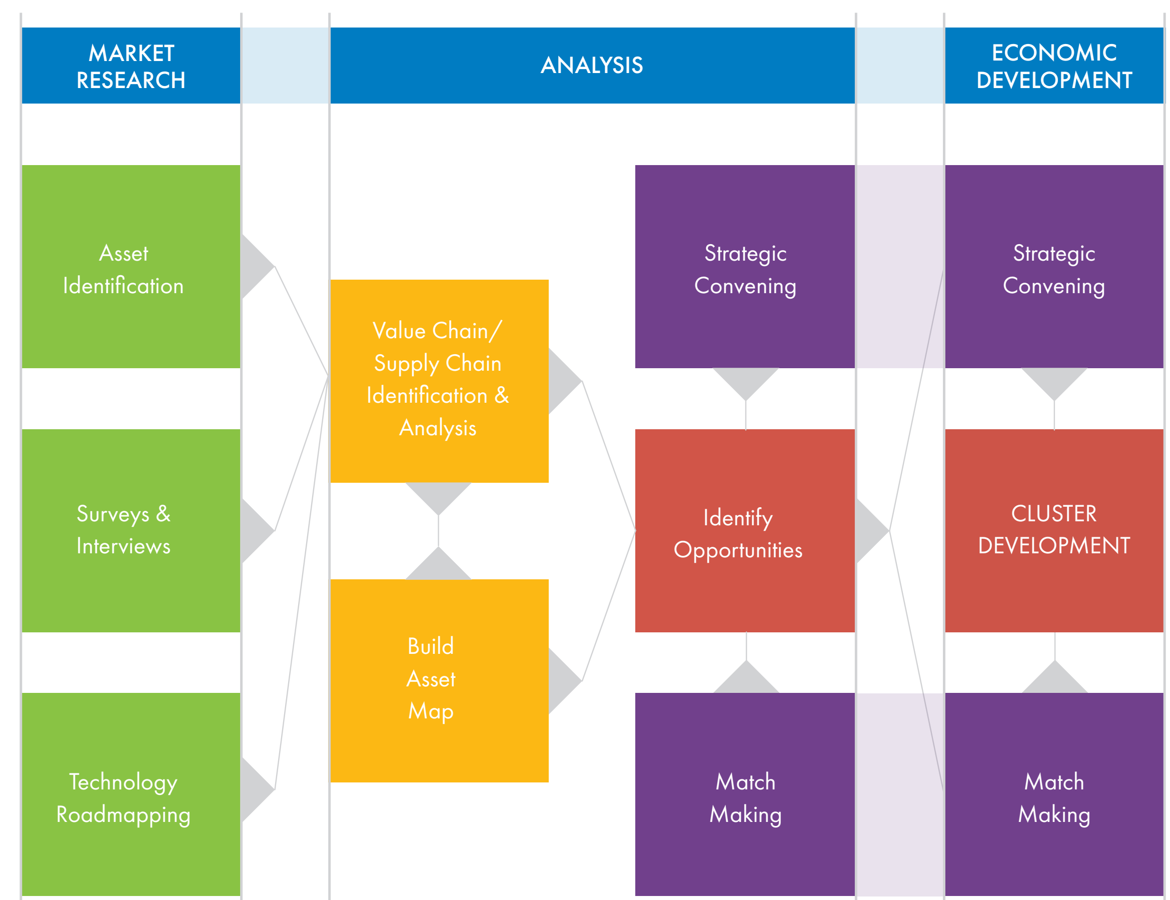
The Clean Energy Roadmap highlights each state's commitment to the clean energy sector and recognition of the cluster's potential impact for supporting a strong regional economy. Information generated from this project will be utilized by each state's energy office to advance energy efficient building technologies, products, services, and clean energy manufacturing processes that will aim to accelerate regional economic development.



Methodology

The project was broken down into multiple stages to help identify and strengthen clusters. These stages are identified broadly as "Market Research", "Analysis", and "Economic Development". While the Market Research stage by definition led to the Analysis stage, the Economic Development stage spanned the entire process. In the end, the process to develop strong clean energy clusters was an iterative, rather than a linear process.

Figure 1: Cluster Development Strategy



Source: NextEnergy

Within the Market Research stage of the project, NextEnergy and Team NEO first compiled a list of clean energy assets in each state. In the case of Northeast Ohio, much of this work had been started with the roadmapping efforts of previous years. NextEnergy methodically developed a list of assets within Michigan and then conducted additional research to further refine and identify participants in the clean energy economy.

1.1 Market Research Methodology

The market research conducted in Michigan and Northeast Ohio varied in methodology to take advantage of both NextEnergy and Team NEO's existing strengths.

Michigan Methodology

NextEnergy utilized a methodology of determining sector opportunities in Michigan that has been proven to be effective and rigorous. In essence, the process was one of conducting asset mapping analysis, including supply chain and value chain analyses, as well as technology roadmapping to identify potential high-value sectors and products.

Identifying Value Chain Assets in Michigan

The first step was to develop a preliminary value chain with contributions from NextEnergy, Team NEO, MEDC, and other consultants. The value chain was used as an initial guide to help NextEnergy identify what type of organizations should be included in the asset list, which includes a list of companies and organizations that have locations in Michigan. This robust list was further refined and narrowed as NextEnergy engaged in market research to understand what assets within the value chain and supply chain are active in Michigan.

In order to identify assets for the asset map, NextEnergy built a list of companies from multiple sources. NextEnergy's internal database consists of manufacturers, technology developers, research organizations, and financing organizations focused on clean energy sectors that have worked with NextEnergy in the past. Additional lists were acquired by NextEnergy from utilities, the MAE, trade associations, consultants, news sources, and attendees at state-focused energy related events.

The result was an extensive initial list that was reviewed against the preliminary value chain to get a better understanding of any gaps in the list, as well as assess the value chain for accuracy. After adding entities through list purchases and searching within specific clusters, the list was revised into a master list to be used in the asset mapping.

The database already existed to some degree as NextEnergy has been working with a number of its constituent companies for several years. This existing database consisted of technology developers, both large and small, in the energy efficiency and clean energy markets. NextEnergy also had established relationships with the utilities, universities, governments, and others that make up the organizations that contribute to the market, but are not necessarily commercial entities.

The database was supplemented by four data sources throughout the project:

Table 2: Data Source Description

DATA SOURCE	DESCRIPTION
Utilities' Trade Allies Lists	NextEnergy and Team NEO worked with utilities to include installers who self-identified to utilities as energy efficiency system or device installers, including HVAC, insulation, windows, and doors
Events and Trade Associations	The database was supplemented with lists from Michigan Solid State Lighting Association (MSSLA), Michigan Energy Efficiency Contractors Association (MEECA), and Michigan Energy Innovation Business Council (EIBC)
News and Referrals	The database was supplemented throughout the project by referrals and information collected from news reports and local business and energy news blogs
Purchased List	NextEnergy purchased a list with contact information from Hoovers of manufacturers that produce products or equipment used in manufacturing, weatherization, or energy related products; the purchase was based on Standard Industrial Classification (SIC) codes and although efforts were made to make this as efficient as possible, many companies were weeded out based on interviews or review of product offerings

Source: NextEnergy

Michigan Asset Mapping

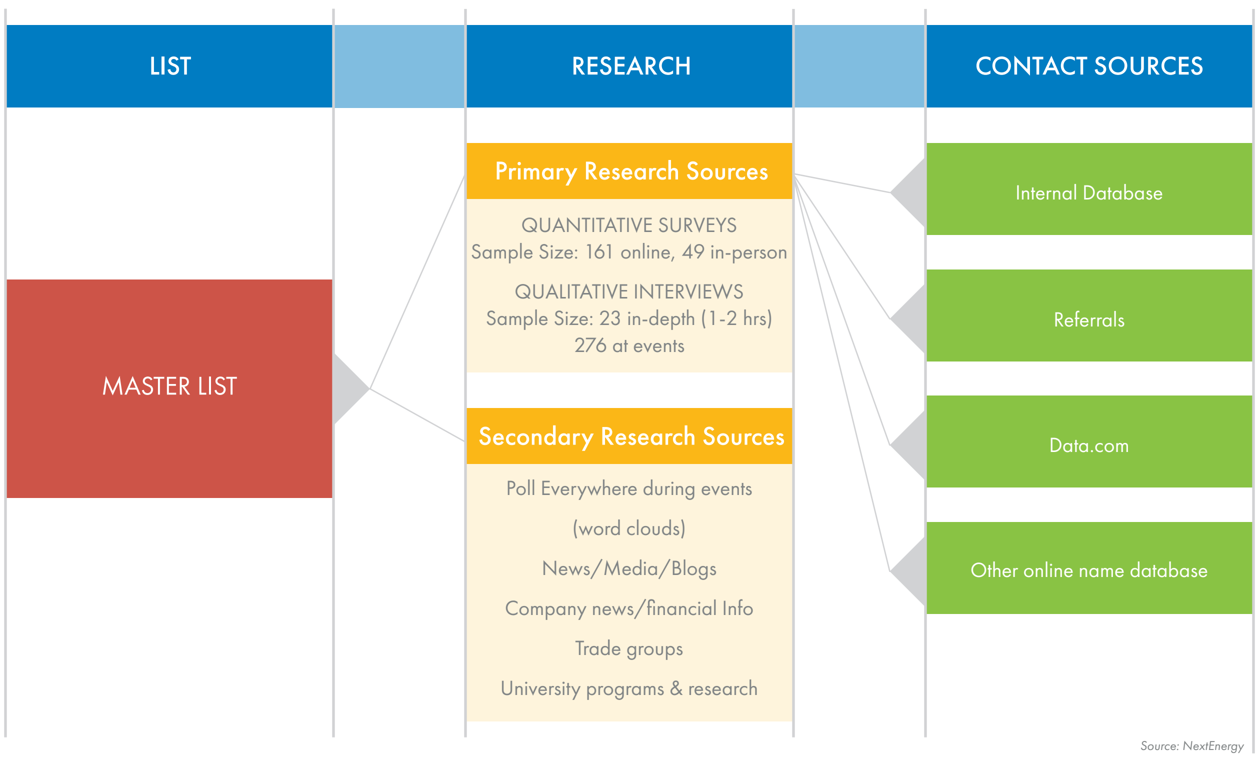
NextEnergy developed a robust research design for the Clean Energy Roadmap to ensure data was captured statewide across the broad value chain, as well as detailed information on specific supply chains and production processes. To achieve this challenging goal, multiple analysis methodologies were required. Specifically, NextEnergy began two separate market research efforts in order to build the asset map once the master list of statewide companies and stakeholders was developed.

An online quantitative survey was designed and implemented to provide information about the company size and markets served. NextEnergy fielded the quantitative survey among the population of identified organizations in the Clean Energy Roadmap database. The goal of the survey was to provide a set of data for the asset mapping project that provides a profile of the entities in the asset map. The data to be collected included the following:

- Company size
- Jobs in MI/Northeast OH/U.S./Globally
- Company annual revenue (Globally vs. U.S. vs. MI vs. Northeast OH)
- Product annual revenue (Globally vs. U.S. vs. MI vs. Northeast OH)
- Market applications served
- Value chain needs/challenges/gaps
- Operation type in MI/Northeast OH/U.S./Globally
- Investment in MI/Northeast OH operations
- Supply chain partners in MI/Northeast OH/U.S./Globally
- Supply chain needs/challenges/gaps
- Product development plan
- Current R&D and product development partners
- Product testing and validation in-house vs. outsourced
- R&D needs/challenges/gaps
- Talent or workforce development challenges
- Amount of IP or number of patents developed in Michigan

This survey was fielded between August 5, 2014 and September 10, 2014 utilizing SurveyMonkey as the online survey tool. We received 161 responses out of 3,274 invitations to participate, for a 4.9% response rate. The survey included an incentive of a $10 gift certificate to Amazon.com for those who participated and were willing to share contact information. Potential participants were notified up to four times via email using NextEnergy's email system and Constant Contact to track participation and responses. These survey data were combined with past work, stakeholder interviews, and additional secondary research on economic clusters within the database to identify several potential clusters as targets for detailed analysis.

Figure 2: Asset Map Research Methodology



In-depth qualitative interviews and site visits were scheduled with companies in key economic clusters, including LED lighting, batteries, power electronics, building automation, insulation, and contract electronics manufacturing that supports multiple clean energy markets. These data were analyzed to construct the asset map by building value chain and supply chain maps. As the project progressed, the field was further narrowed into the LED lighting, HVAC, and building automation clusters for energy efficient building technologies, and energy storage, power electronics, and LED lighting for the clean energy manufacturing analysis. The asset map was also further refined as the research continued, providing an iterative process for identifying, assessing, and assigning companies and stakeholders to value chain and supply chain positions.

Northeast Ohio Methodology

The purpose of the Team NEO roadmapping exercise was 1) to identify the sector's business, physical, intellectual, and human capital — the assets on which the sector can best focus its efforts to grow; and 2) to bring major stakeholders together to articulate the sector's seven-year goals and a plan for achieving them. The InSeven® process is a proprietary methodology (described below), which involves extensive research and analysis of the sector's assets and global opportunities, and an intensive visioning and planning effort by industry, government, and research community stakeholders. The resulting roadmap is fact-based and intellectually rigorous, and reflects a consensus of key sector participants and stakeholders.

The seven-step methodology includes:

Step 1: Plan for launch: define scope, convene working group participants, "kick off"

Step 2: Define subsectors, technologies, products; determine "core" vs. "supporting" value chain elements

Step 3: Catalog the region's "core" assets; map to subsectors; identify region's critical mass and determine focus subsectors

Step 4: Define market segments; quantify growth potential, drivers, and projections for the region's potential participation

Step 5: Identify top globally and nationally competitive regions; assess to determine share potential

Step 6: Based on insights, draft a seven-year plan to capitalize on strengths and opportunities

Step 7: Syndicate plan throughout the region and revise as appropriate; finalize roadmap

This original roadmapping process spanned eight months and fostered multiple collaborative relationships, rallying a range of sector participants to support and accelerate the growth of the energy efficiency sector in Northeast Ohio. As a result, roadmap contributors with interest in LED technologies may be valuable stakeholders for the cluster development activities resulting from this renewed effort.

Identifying Value Chain Assets in Northeast Ohio

Significant effort was devoted to clarifying the operational definition of energy efficiency to frame the roadmapping work. Four criteria were used to determine which energy efficient solutions would be included in the asset inventory:

1. Product-level efficiency should be a primary factor in the technology's purchase, as opposed to a side benefit of products that would be purchased by convention anyway.
2. If nationally recognized, third-party efficiency standards or certifications are available for a given technology system, the technology must achieve the appropriate rating.
3. If no appropriate third-party designation exists, the technology must include specific components or sub systems that contribute to system efficiency, as identified by subject matter experts.
4. Energy efficiency must be driven by advances in technology that are most likely to provide the greatest opportunities for economic impact and growth (rather than behavioral efficiency improvements). For this reason, the asset inventory includes a limited number of services.

Northeast Ohio Asset Mapping

The roadmapping team conducted a broad review of the energy efficiency sector and then carefully vetted the results with subject matter experts and working group members to identify the relevant technology systems and services, ultimately grouping them into 13 general categories:

1. Steam Generation comprises the boiler system and steam distribution system used in either an industrial process or building application.
2. Heat Recovery includes technologies that capture and re-purpose waste heat energy, again in an industrial process or building application, either for steam/power generation (e.g., packaged CHP systems) or for other process use (e.g., indirect fired absorption chillers, heat recovery desiccant dehumidifiers).
3. Process Heating is specific to industrial process applications and includes a range of fuel-based and electric-based process heating systems. Again, components such as controls, insulation, and certain elements of heat transfer sub systems or material handling were identified as markers of "efficient" process heating technology.
4. Compressed Air includes both air compressors and compressed air distribution systems for industrial use. "Efficient" systems are identified by the presence of advanced motor technology or certain controls, as well as certain components within the distribution system.
5. Advanced Motors, Pumps, and Fans includes National Electrical Manufacturers Association (NEMA) Premium motors, and pumps, and fans categorized as efficient by their motors and certain additional, often friction-reducing, components. Although motors are identified here in their own system, they are also a cross-cutting sub-system in several of the other categories in this hierarchy.
6. Industrial Cooling comprises a compressor system, the associated industrial chiller/heat pump system, and the cooling tower system involved in industrial cooling processes. Efficient systems are identified by the presence of sub-systems such as advanced motors, fans, pumps, and controls.
7. Data Center technologies were included based on the DOE's emphasis on their potential energy savings opportunities. Data center power systems and liquid cooling systems were identified as the currently available technologies with an efficiency play, based on a range of critical components.
8. Advanced HVAC is a building technology category including furnaces, central air conditioners, air- and water-source heat pumps (including geothermal systems) and the air handling and distribution system. For the air handling and distribution system, efficiency was assessed based on dampers, insulation, and other equipment.
9. Building Envelope includes cool and green roof systems, insulation (which was then expanded to include refractory for non-building use), building phase change materials, exterior window and door systems, smart glass, and daylight systems. Some of these, such as exterior windows, doors, and cool roof technologies, have long-standing ENERGY STAR® designations, but their efficiency thresholds were adjusted to reflect more stringent anticipated updates based on third party raters such as the National Fenestration Rating Council and the Cool Roof Rating Council. The others were identified as efficient based on certain components. All thermal insulation was considered an efficiency play.
10. Advanced Lighting includes solid state (LED and Organic LED [OLED]), linear fluorescent, compact fluorescent, metal halide, and low or high-pressure sodium lighting systems. They were then further categorized into solid state and non-solid state technologies, based on supply chain differences. Some of these lamps for particular applications have ENERGY STAR® and Federal Energy Management Program designations available, but most were identified as efficient based on the presence of certain components and ballast advances.
11. Water Heating Appliances include solar thermal, high-efficiency gas storage, electric, gas condensing, whole home tankless, and micro-CHP water heater systems. When applicable, ENERGY STAR® designations are used; otherwise, components are identified to designate a particular water heater as efficient.
12. Additional Major Appliances include refrigerators and freezers, dehumidifiers, and clothes dryers. These were selected on the basis of residential appliances' direct energy use (based on DOE data), and therefore, exclude dishwashers and clothes washers, whose primary energy efficiency play is in conservation of water that is heated outside the device. Commercial counterparts to these residential appliances are also included.
13. Advanced Controls comprise energy management systems for buildings, advanced process controls for industrial applications, and demand response systems that create efficiencies across multiple sites (and particularly among power generation assets). All of these systems are considered "efficient" as long as energy efficiency is part of their publicly communicated purpose.

Figure 3: The Energy Efficiency Technology Sector: Technology Categories and Segments

STEAM GENERATION	INDUSTRIAL COOLING	BUILDING ENVELOPE	WATER HEATING APPLIANCES
S01: Boiler System S02: Steam Distribution System	S14: Compressor System (Industrial Chiller/Heat Pump) S15: Chiller/Heat Pump System S16: Cooling Tower System	S24: Cool Roof System S25: Green Roof System S26: Insulation & Refractory System S27: Building Phase Change Material System S28: Exterior Window System S29: "Smart Glass" Window System S30: Exterior Door System S31: Daylight System	S37: Solar Thermal Water Heating System S38: High Efficiency Gas Storage Water Heating System S39: Electric Water Heating System S40: Gas Condensing Water Heating System S41: Whole-Home Tankless Water Heating System
HEAT RECOVERY	**DATA CENTER**	**ADVANCED LIGHTING**	**ADDITIONAL MAJOR APPLIANCES**
S03: Heat Recovery System S04: Indirect Fired Absorption Chiller System S05: Heat Recovery Desiccant Dehumidifier System S06: Combined Heat & Power System (Packaged)	S17: Data Center Power System S18: Data Center Liquid Cooling System	S32: LED Lighting Systems S33: Linear Fluorescent Lighting System S34: Compact Fluorescent Lighting System S35: Metal Halide Lighting System S36: Low/High Pressure Sodium Lighting System	S43: Refrigerator/Freezer System S44: Dehumidifier System S45: Clothes Dryer System
PROCESS HEATING	**ADVANCED HVAC**		**ADVANCED CONTROLS**
S07: Fuel-Based Processing Heating System S08: Electric-Based Process Heating System	S19: Furnace System S20: Central Air Conditioner System S21: Air-Source Heat Pump System S22: Water-Source Heat Pump System (Incl. Geothermal) S23: Air Handling & Distribution System		S46: Energy Management System S47: Advanced Process Controls Systems S48: Demand Response System
COMPRESSED AIR			
S09: Air Compressor System S10: Compressed Air Distribution			
ADVANCED MOTORS, PUMPS, FANS			
S11: Advanced Motor Systems S12: Advanced Pumping Systems S13: Advanced Fan Systems			

**Numbers were used in graphic to classify the technology segments in the asset mapping analysis and have no further significance.*

Source: Team NEO

Taken together, the 48 technology segments shown in Figure 3 define the energy efficiency technology sector. The sub systems, components, and raw materials that make up these segments are also characterized as core, enabling, and supporting, based on their importance or role in improving the energy efficiency of a system, the value they add to the segment, and their position in the value chain.

Core sub systems, components, or raw materials have the strongest potential to create economic value and generate jobs for the state, because their sales generate higher economic value and offer greater potential for suppliers to capture that value in the form of profits.

Enabling services provide important know-how and are essential to commercialization. These supporting elements, though they may be necessary to the operation of energy efficiency systems, are less important to sector growth; they are typically selected on the basis of cost or a supplier's proximity to its customer, and they tend to follow industry growth rather than lead it.

For the purposes of this effort, the following services were categorized as enabling and were therefore quantified and categorized as part of the asset inventory:

- Comprehensive energy service companies (ESCOs)
- Building optimization (Architecture & Engineering [A/E] services)
- Industrial process optimization (A/E services)
- Specialized financing services (excluding banks)
- Energy efficiency certifications/standards
- Energy audits
- Specialized, third-party operations and maintenance
- System-specific design/specification
- System-specific equipment

1.2 Economic Development Methodology

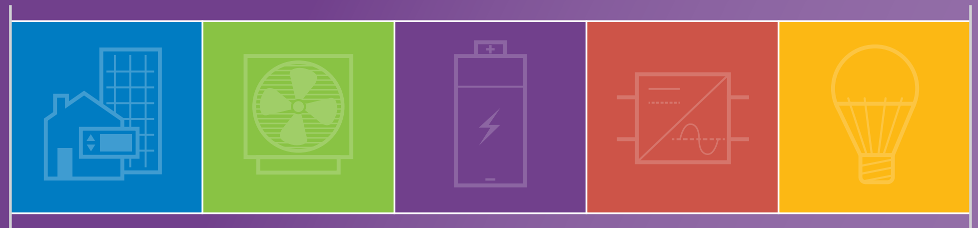
Building on information gained in the Market Research and Analysis stages, NextEnergy and Team NEO used a variety of targeted and industry-specific events to convene industry participants with the primary purpose of growing the sector. In certain instances, the Clean Energy Roadmap project created events with original content. In other situations, the project leveraged events already occurring in the market place. For example, NextEnergy organized the Michigan Advanced Lighting Conference and used it as a platform to grow the lighting sector. However, NextEnergy also attended events hosted by the Michigan Energy Innovation Business Council to gauge current activity in the market. The combination of these events were used to 1) inform the project of current market activity, trends, and ecosystem components and 2) communicate information to the sector that would be useful for constituents.

The information identified during the Market Research and Analysis stages allowed NextEnergy and Team NEO to communicate specific matchmaking opportunities with stakeholders during events. Matchmaking opportunities often occurred organically (e.g., two companies attended an event and realized a partnership opportunity was possible) or they occurred through a formal introduction. A few examples of these partnerships involved matchmaking that occurred through the Michigan Advanced Lighting Conference or the LED Lighting in Northeast Ohio event. In addition, a lighting technology challenge created opportunities for collaboration, matchmaking, new IP and product development, business opportunities, and market creation for the region. This project is only the start of a foundation that will continue to facilitate relationships.

Figure 4: Events

Year	EVENT	HOST
2015	MI Commercial & Industrial Conference (2)	Efficiency United
2015	Manufacturing in America	Electro-Matic Products, Inc.
2015	Michigan Advanced Lighting Conference	NextEnergy
2015	Building Technology Office (BTO) Peer Review	DOE Office of Efficiency & Renewable Energy Building Technology
2015	Energy Conference & Exhibition	DTE Energy / Engineering Society of Detroit
2015	LED Lighting in Northeast Ohio	Team NEO
2015	Midwest Energy Efficiency Alliance Annual Meeting	Midwest Energy Efficiency Alliance
2015	Michigan Advanced Lighting Community Event	NextEnergy
2015	Michigan CHP Conference	Michigan Energy Innovation Business Council / Oakland University
2015	Midwest Energy Solutions Conference	Midwest Energy Efficiency Alliance
2015	Northeast Ohio Stakeholders Meeting	Team NEO
2015	Northern Ohio Energy Storage & Integration Workshop	Team NEO / NASA
2015	Battery Seminar	PlugVolt
2015	Smart Energy Summit	Parks Associates
2015	V2B Mashup	NextEnergy
2015	Western Michigan University Sustainable Energy Future	Western Michigan University
2014	MI Commercial & Industrial Conference - (2)	Efficiency United
2014	Energy Conference & Exhibition	DTE Energy / Engineering Society of Detroit
2014	Metro Detroit Advanced Energy Business Networking Event	Michigan Energy Innovation Business Council
2014	Michigan Advanced Lighting Conference	NextEnergy
2014	Michigan Energy Efficiency Expo	Midwest Energy Efficiency Alliance Michigan Energy Efficiency Contractors Association Michigan Energy Innovation Business Council

Source: NextEnergy



Clean Energy Market Drivers

Overall, the global energy efficiency industry is experiencing significant growth within the last decade, increasing from a $61.8 billion industry in 2005, to an estimated $311.7 billion in 2015 according to a BCC Research estimate from 2011.[5] In 2012, the Massachusetts Institute of Technology determined the economic opportunity for building energy efficiency retrofits to be $279 billion in the United States alone.[6] While encouraging, these broad figures are often the culmination of more specific technology and market trends.

For example, the HVAC industry is experiencing growth on the back of new construction[7] and remodeling[8] growth. New housing starts in Michigan have increased by 24% in the first four months of 2015 compared to the same time period in 2014. In 2014, a total of 15,933 new houses (both single-family and multi-family buildings) and 19,872 new houses were started in Michigan and Ohio respectively according to the National Association of Homebuilders.[9]

Likewise, Statista is forecasting that the North American LED market is growing from a $1.1 billion market in 2011 to $10.9 billion in 2020,[10] and global revenue in the building automation market is expected to grow from $58 billion in 2013 to $91.9 billion by 2023.[11] These trends indicate a strong market for increased energy efficiency.

Other market drivers, including market maturity, consumer awareness and behavior, and marketing-related activities, are more subjective and vary substantially by technology making their impact harder to calculate. While some of these issues were discussed during qualitative interviews, an attempt to quantify these market drivers for each technology sector was outside the scope of this research and is not included in this report.

5 Green Technologies and Global Markets-BCC Research-Accessed Oct. 2015
6 United States Building Energy Efficiency Retrofits-Rockefeller Foundation and DB Climate Change Advisors-Accessed Oct. 2015
7 Continued Construction Industry Growth Predicted for 2015-Associated Builders and Contractors Inc.-Accessed Oct. 2015
8 Remodeling Activity Rose Again in 1Q, RRI Shows-Remodeling-Accessed Oct. 2015
9 Building Permits: State and Metro MSAs-National Association of Home Builders-Accessed Oct. 2015
10 North American LED lighting market size from 2011 to 2020-Statista-Accessed Oct. 2015
11 Commercial Building Automation Systems-Navigant Research-Accessed Oct. 2015

But what factors stimulate demand and create an environment ripe for adopting clean energy products and services? Clean energy market drivers are difficult to characterize overall because there are a number of different industries in both energy efficiency as well as renewable energy that are identified as "clean energy assets" coupled with the many forces contributing to it. However, there are three factors that appear to be driving demand in the EEBT market, including:

- Energy efficiency return on investment (ROI),
- The overall clean energy ecosystem—policies and trends—increasing clean energy activity and deployment; and
- Financial incentives supporting deployment of EEBTs or renewable energy systems.

Energy Efficiency and ROI

In business decisions that consider incorporating new technologies into building operations, the decision inevitably weighs heavily on investors' expected ROI. There are several methods for calculating ROI. In the case of energy efficiency ROI calculations, a simple payback calculation—dividing the initial cost of implementation divided by the annual savings—simply does not fully calculate the true cost and benefits of a project. While upfront costs are readily recognized, many factors are not considered, such as long-term maintenance costs, financial value (i.e., accounting for the fact that money changes value over time), productivity, or performance gains. Attempts to quantify the exact ROI are challenging because some benefits are difficult to quantify. To ease this burden, ENERGY STAR® administered by the Environmental Protection Agency (EPA) offers resources that reflect the avoided costs and potential benefits of an EEBT investment and guide financial decisions. Such tools help to recognize the true financial value of energy efficiency.

Policies and Trends Shaping the Clean Energy Environment

Regulations and trends in the marketplace are effective tools for driving the EEBT markets. Building codes that require efficiency and environmental emissions regulations that push buildings to reduce emissions or energy usage are just two regulatory examples. The forecasted doubling of urban populations by 2050 is a trend driving cities to critically consider how this increased population will impact energy consumption, emissions related to energy generation and use, and quality of life for urban communities.

The Clean Power Plan is a body of policy anticipated to drive states to strategize development and deployment of clean energy technologies. The EPA released the plan in 2015 (under Section 111d from the Clean Air Act). The Clean Power Plan requires states to reduce carbon emissions from fossil fuel-fired electric generating units by 2030. To ensure states are able to meet the requirement of the Clean Power Plan without experiencing an energy shortfall, states will need to identify solutions that reduce dependencies on fossil fuels including increased adoption of renewables, cleaner natural gas-fired power plants, and increased energy efficiency. By their very nature, EEBTs reduce energy usage, resulting in a potential reduction of generation assets needed to ensure the energy load is met. Thus, energy efficiency is more cost-effective than creating new generation assets. For these reasons, the Clean Power Plan may have a positive impact on EEBT manufacturers as these technologies will assist in complying with the plan.

Many states and communities use building codes to drive energy efficiency for buildings, and among the most energy efficient of those are Net Zero Energy (NZE) buildings, a trend in construction beginning to gain traction. As their name indicates, NZE buildings are defined by their ability to consume less than or equal to the energy as they generate. California is on the leading edge of NZE buildings with Title 24 building codes. Title 24 requires new residential buildings and commercial buildings be NZE by 2020 and 2030, respectively. NZE buildings benefit from a combination of distributed energy generation and highly energy efficient systems. This requirement is pushing growth in multiple technologies by, in essence, legislating a market in the coming years. The biggest evidence of this comes in the home and building automation market, where companies and technologies that tie buildings into connected services and devices (the internet of things, or "IoT") have been growing. Although NZE regulations in the United States are isolated, international mandates, such as those in the European Union, are calling for NZE compliance by the end of 2018. Thus, it may not be long before such requirements become more readily adopted across the United States.

Beyond the legal requirements of building codes, Leadership in Energy & Environmental Design (LEED) certification is another driver that contributes to the clean energy market. Developed by the U.S. Green Building Council in 1998, LEED is one of the most widely used green building certification programs. LEED certification involves a number of different building systems, including building materials, HVAC, water consumption, indoor air quality, and smart grid integration. With lower operating costs and better indoor environmental quality, LEED certified buildings are attractive to building owners as well as prospective tenants. The number of cumulative LEED certified projects grew from 11 in 2000 to 10,553 in 2008, and accelerated significantly to 60,727 projects at the end of 2014.[12]

Clean Energy Financial Tools

Historically, a key barrier to implementing clean energy technologies has been upfront cost. As a result, stakeholders from government, industry, and non-governmental organizations and institutions are developing numerous financial tools and mechanisms to drive investment in clean energy by offering incentives that make adopting energy efficiency technologies more affordable. One of the most comprehensive resources to find financial incentives for clean energy projects is the Database of State Incentives for Renewables & Efficiency (DSIRE), which is administered by North Carolina State University and funded by the DOE. Through the DSIRE website, anyone may seek information about policies and incentives for renewables and energy efficiency. Tools, like the Financing Program Decision Tool offered by the EPA, help state and local governments to identify financing opportunities based on each project's individual scope and need.

2.1 Advancing the Clean Energy Cluster

Unique characteristics in each state help to transform the clean energy ecosystem. The following section examines the elements and the entities (state and local government, industry, and nonprofit organizations) that contribute to an increased level of clean energy services and manufacturing in each state.

12 LEED Overview Green Building Information Gateway-LEED Overview-gbig.org-Accessed Oct. 2015

Michigan

In May 2015, the state restructured the agencies related to energy, resulting in one overarching agency: the MAE. Housed within the Michigan Department of Licensing and Regulatory Affairs (LARA), the new entity brings together the Air Policy Director and the Retired Engineers Technical Assistance Program from the Michigan Department of Environmental Quality, the Michigan Energy Office from the MEDC, and the Michigan Public Service Commission (MPSC) to develop and implement energy-related solutions. One of the pressing orders of business that the new MAE must immediately address is the Midwest Independent Service Operator (MISO) prediction that Michigan capacity will be 3,000 megawatts below where it is recommended to be for peak demand in 2016.[13]

Policies

Michigan's most extensive set of regulations regarding clean energy comes in the form of Public Act 295 of 2015 (PA 295), the "Clean, Renewable, and Efficient Energy Act", which addresses energy efficiency in both the private and public sectors of Michigan. The new law aims to diversify energy supply portfolio and encourage private investment. The law set the goal of reducing the state's grid based energy purchases by 25%, from 2008 through 2015, and established two instrumental standards:

- **Energy Optimization (EO)** requires natural gas and electric utility providers to implement programs that reduce energy use, with specific targets of up to 1% of retail annual sales for electric providers.
- **Renewable Portfolio Standard (RPS)** requires utility companies to generate 10% of electricity production from renewable energy sources by 2015.

One way the state addressed this measure was to mandate that energy efficient equipment be purchased and used in state-owned building operations whenever possible. The law seems to have achieved its intention to increase energy efficiency and investment in the state. In 2015, the MPSC reported the RPS has secured $3 billion in private sector investment in Michigan and it is widely anticipated that utility companies will meet RPS requirements (Michigan generation was at 8.1% from renewable sources at the end of 2014).[14]

In 2015, Governor Rick Snyder proposed changes to the energy policies in Michigan. The Governor proposed the goal of meeting 40% of Michigan's energy needs through a combination of renewable energy and increased energy efficiency by 2025.[15] The platform for achieving the state's energy goals of reducing energy waste will be based on policies rooted in three pillars: reliability, affordability, and a protected environment. Currently, MAE is developing a compliance strategy for the Clean Power Plan to be completed in 2016 that will help meet its goals of reducing state carbon dioxide emissions by 39% and retiring twenty-five Michigan-based coal-fired power plants.[16] At the same time, the Michigan legislature is proposing legislation that will replace PA 295, which mandated requirements be met by 2015, thus offering the opportunity to enact new energy efficiency laws in the state.

13 Long Term Resource Adequacy Update-MISO-Oct. 22, 2014.
14 Report on the Implementation of the PA 295 Renewable Energy Standard and the Cost-Effectiveness of the Energy Standards-Michigan Public Service Commission-February 13, 2015-Accessed Oct. 2015
15 A Special Message from Gov. Rick Snyder Ensuring Affordable, Reliable, and Environmentally Protective Energy for Michigan's Future-Michigan Executive Office-March 13, 2015-Accessed Oct. 2015
16 25 Michigan coal plants are set to retire by 2020-Detroit Free Press–October 10, 2015-Accessed Oct. 2015

While Michigan's policy environment is currently in a period of transition, there are a variety of public and private-based tools that create opportunities to ensure the three pillars and energy shortfall will be addressed.

Utility Energy Optimization Programs

Under PA 295, EO programs successfully drive energy efficiency, have reduced consumer energy use, and have proven to be cost-effective for the state and its customers. In 2014, a total of 65 electric and natural gas utilities—14 investor-owned natural gas, electric, or natural gas and electric combined utility providers, 10 electric cooperatives, and 41 municipal electric utilities—administered EO Plans throughout the state. In the 2015 report, MPSC reported overall program expenditures of $1.1 billion from 2010 to 2014 are estimated to achieve lifetime savings to all customers of $4.2 billion.[17] And from 2009 through 2014, program savings achieved for electric and natural gas utility providers were 131% and 130% of the target, respectively.[18]

The EO programs are broken down into two main focus areas—residential and commercial & industrial—and also include incentives for pilot programs and may be tailored for specific customer groups (e.g., the agricultural sector). Energy efficiency programs and devices are cataloged in the Michigan Energy Measures Database (MEMD) that provides a basis for energy efficiency savings. The MEMD is maintained by the MPSC and allows utilities to calculate how much energy savings they can claim from programs and devices when trying to meet PA 295 requirements.

Residential programs consist of five major categories:

- Lighting
- HVAC
- Weatherization
- Energy education
- Pilot programs

Commercial & Industrial programs consist of two categories:

- Prescriptive (rebates for energy efficient equipment)
- Custom (based on projected savings, incentives are based on a per kilowatt and kilowatt hour schedule)

Technology Incubators/SmartZones

Michigan is home to a robust network of technology incubators and accelerators that supports entrepreneurs, spurs clean energy innovation and boosts local economies. By supporting solution providers, the network creates an environment for success. The following offers a description of the ecosystem that supports clean energy cluster growth.

The MEDC has designated a total of 15 **SmartZones**[19] and 10 regional economic development zones (or service areas) across the state. A **SmartZone** designation

17 Report on the Implementation of the PA 295 Renewable Energy Standard and the Cost-Effectiveness of the Energy Standards-Michigan Public Service Commission-February 13, 2015-Accessed Oct. 2015
18 ibid.
19 Michigan SmartZones - www.michiganbusiness.org/cm/files/fact-sheets/mismartzonefactsheet.pdf - Accessed Dec. 2015

reflects a distinct geographical area where technology cluster development thrives. The SmartZones foster collaboration among innovators, academics, government, and industry, and provide the resources to accelerate development and commercialization of products and ideas.

Pure Michigan Business Connect is a program administered by the MEDC that creates business-to-business opportunities to promote business growth through:

- *Business services* - connections to capital, talent, and business planning services;
- *Matchmaking summits* - creating partnerships among Michigan businesses; and
- *Purchasing requests* - creating opportunity for Michigan–based companies to fulfill procurement needs.

Within Michigan's community college ecosystem, the state has created the **Michigan Technical Education Centers (M-TEC)** ecosystem, focusing on workforce development. The 18 centers offer training and services to clients ranging from Michigan businesses seeking employees to individuals seeking employment in technical fields.

What is an accelerator vs. an incubator?

An accelerator offers a variety of services including mentorship, training, and seed funding in exchange for small amounts of equity in the company.

An incubator provides a path to important networking opportunities and may operate virtually or in an actual physical space. Services range from providing a business space to supplying equipment to business planning services.

Financing Programs

Financing support for Michigan-based manufacturers, installers, and building owners is generated from a variety of public and private investment sources. For businesses in any stage of product or idea development, the MEDC offers the capital funding locator[20] to help identify capital through the technical or financial support of one or more of the following: venture capital firms, commercial banking resources, state and federal programs, business planning competitions, and business services.

The Michigan Energy Office administers the **Energy Efficiency and Renewable Energy Fund** that offers companies seeking to manufacture, install, or upgrade commercially ready EEBT or renewables from $50,000 to $350,000 with terms up to four years and fixed interest rates not more than 6%.[21]

Installers and building owners seeking to take advantage of the savings generated from implementing EEBT have options whether in the commercial or residential sector.

Michigan Saves[22] administers energy financing programs for the residential and commercial markets. The nonprofit offers low interest loans for the following entities:

20 Capital Funding Locator-Michigan Economic Development Corporation-Accessed Oct. 2015
21 Energy Efficiency and Renewable Energy Loans for Michigan Businesses- Michigan Economic Development Corporation-July 14, 2014-Accessed Oct. 2015
22 Michigan Saves-michigansaves.org-Accessed Oct. 2015

- Homeowners may receive up to $30,000, with up to a 10-year repayment term and fixed APR no more than 7%.
- Commercial and multi-family unit building owners with up to $250,000 with standard finance terms of 24, 36, 48 and 60 months and rates from 5.9%.
- Institutions in the public sector with up to $1 million for installment purchase agreements in terms of 2-5 years.

Property Assessed Clean Energy (PACE)[23] administered by Lean & Green Michigan helps to finance clean energy projects for building owners in the commercial multi-family and industrial sectors in areas where the city, county, or township has signed on to participate. This resource enables financing on projects in commercial, industrial, multi-family, and nonprofit property that save energy, save water, or install renewable energy through a special property tax assessment with the local government. Through PACE's special assessment obligation a property owner can sell the property and the new owner takes over the payments as the owner begins to pay property tax. Loan terms range from 10–20 years and can cover up to 100% of the project costs.

Although there are many options for financing, discussions during events and interviews uncovered that a lack of awareness and understanding about the programs from manufacturers, installers, and building owners may contribute to a lack of participation.

Trade Ally Programs

Trade ally programs offer contractors the opportunity to work with utilities and industry to save money and optimize energy usage for their customers. Contractors benefit from participating in the programs because they increase visibility to new customers and increase legitimacy with current customers, which in turn, increases revenue potential. Exclusive opportunities to participate in training programs keep participants apprised of the latest incentives and technologies, and offer access to tools, such as marketing and branding resources, to help grow one's business, and auditing calculators to be most effective in identifying energy efficiency needs. Most of the trade ally programs administered in Michigan were established as a direct result after PA 295 was passed into law to ensure requirements under the law would be met.

Many trade ally programs are administered by utilities, but Michigan has a few unique associations and nonprofits helping to advance energy efficiency measures through trade ally networks.

Michigan Saves offers a program for contractors to apply to become authorized Michigan Saves contractors. Applicants must meet qualifications that ensure each contractor has the applicable licenses, credentials and insurance, as well as understanding of the financial process. Clients interested in saving money in home or business improvements find this vetted process attractive as it provides access to professionals knowledgeable in such incentives. Further, being registered as a vetted contractor offers increased visibility to new customers that have a vested interest in energy efficiency improvements.

The **Michigan Energy Efficiency Contractors Association (MEECA)** is a nonprofit industry association working to influence policy, provide a unified voice for advising on issues important to contractors, and support education, training and professional development for energy efficiency contractors and workers.

23 Lean and Green Michigan-leanandgreenmi.com-Accessed Oct. 2015

International Brotherhood of Electrical Workers Local 58 and **National Electrical Contractors Association** through the **Electrical Industry Training Center** offer state of the art demonstration facilities, subsidized apprenticeship opportunities, and training programs. Its Michigan Advanced Lighting Controls Training Program is modeled after the California Advanced Lighting Controls Training Program and offers licensed electricians, electrical contractors, and specifiers training in the proper programming, testing, installation, commissioning, and maintenance of advanced lighting control systems.

Ohio

In 2011, Ohio Gov. John Kasich and his staff began working with energy stakeholders—from energy producers to environmentalists and energy consumers—to develop a comprehensive energy policy for Ohio that would encourage economic growth. The Governor's 21st Century Energy and Economic Summit was held in September 2011, and out of that summit came ideas and strategies the Governor's policy team used to build a comprehensive energy policy that rests on 10 pillars. The pillars comprise the Governor's energy policy for Ohio—ideas to support a diverse mix of reliable, low-cost energy sources that meet Ohio's continuing job-creation needs. The following pillars address maximizing energy resources or using clean or renewable energy to create efficiencies:

- **Pillar 2**—Generation: Ensuring Ohio's Generation Capacity and Investing in New Technologies
- **Pillar 4**—Cogeneration/Waste Heat Recovery: Capturing Waste Heat to Make Green Energy
- **Pillar 7**—Energy Efficiency: Promoting Efficiency to Save Resources
- **Pillar 10**—Renewables: Promoting Renewables for a Balanced Energy Portfolio

Policies

Ohio's Energy Efficiency Resource Standard (EERS), enacted through Ohio Senate Bill (SB) 221 in 2008, requires electric utilities to meet a portion of their customer demand through energy efficiency. The EERS sets annual energy reduction targets for Ohio's electric utilities starting with 0.3% in the first year and increasing to 2% of base retail sales. The standard aims to reduce 22.5% of Ohio's electric energy use by the year 2025. In 2014, Governor Kasich signed SB 310, which pauses the annually-increasing energy mandates at 2014 levels until the year 2017, at which point, the automatic levels are to be restored.

With the EERS frozen, the renewable-energy mandates stand at 2.5%, and the energy efficiency requirements stay at 4.2% compared to 2009 levels.

Tax Programs

The Conversion Facilities Tax Exemption, administered by the Ohio Department of Taxation, may provide an exemption for certain property state sales and use taxes for property used in energy conservation, thermal-efficiency improvements, and the conversion of solid waste to energy. The OERD provides technical review of the energy equipment utilized in the projects to verify it fulfills the intent of the Ohio Revised Code. An opinion is then issued to Ohio Department of Taxation, where the commissioner makes a final determination on certification of the property.

The Qualified Energy Project Tax Exemption promotes the deployment of alternative energy sources in Ohio by exempting the public utility tangible personal property tax and the real property tax for "energy facilities" in favor of an affordable, fixed annual payment in lieu of taxes for the life of the facility.

Utility Energy Optimization Programs (Serving Northeast Ohio)

Ohio's action in 2014 to freeze and evaluate energy efficiency mandates over a two-year period resulted in amendments to some utilities' energy efficiency plans. Ohio also began permitting its larger industries to make self-directed efficiency improvements, rather than participating in utility-run programs.

Typically, Northeast Ohio's utility EO programs include rewards programs, energy evaluations and audits, discounts and rebates for residential, and a focus on energy efficient IT equipment, HVAC, lighting, and power management for commercial customers.

First Energy, including its Ohio utilities (The Illuminating Company, Ohio Edison), amended their energy efficiency plan in 2014 to reduce customers' costs while aligning with the state's action to freeze and evaluate energy efficiency mandates. As part of the amended plan, a number of energy efficiency programs were suspended on December 31, 2014. A number of programs, however, remain available to consumers, such as the installation of programmable thermostats, in-home energy evaluations, and customized energy efficiency programs to meet specific customers' needs.

American Electric Power Ohio (AEP Ohio) serves the southernmost counties of Northeast Ohio, including Wayne and Stark counties. The energy efficiency programs to business customers are focused on LED lighting, space cooling – chillers, HVAC, building energy management systems (EMS), variable frequency drives; office equipment-network power management, refrigeration (LED case lighting and controls), uninterruptable power supplies, servers, ventilation, data rooms-power management. Residential customers can also receive discounts on ENERGY STAR® products and in-home energy audits, as well as participate in other energy efficiency incentive programs.

Technology Incubators

Northeast Ohio is home to several technology incubators and accelerators that impact the discovery, growth, and commercialization of energy efficiency innovations. These resources offer startups different, specialized services such as low-cost laboratory and office space, networking support, mentoring services, access to capital, and management guidance. However, their overarching goal is to help businesses obtain the crucial development services they need to be successful.

The Manufacturing Advocacy & Growth Network's (MAGNET) High Tech Business Incubation Program in Cleveland provides a comprehensive package of business assistance services to support the growth of technology-oriented companies. Also, on a fee-for-service basis, entrepreneurs can gain assistance with product development from highly-skilled individuals experienced in design engineering and prototyping, market testing, validation and product roll-out. The 85,000-square-foot MAGNET Innovation Center offers affordable space with 24-hour access (manufacturing and lab space, conference and presentation rooms, and more) to allow young companies to focus their limited cash and time on their priorities.

The Akron Global Business Accelerator is the longest-running business incubator program in Ohio. The Accelerator pays particular attention to new tech-based companies focused on biomedical, information technology, advanced materials, advanced energy, and instruments controls equipment. Since 2010, the Accelerator has assisted clients to secure $90.5 million in investment, create over 626 new high-paying jobs, generate $182.5 million in sales, and $89.9 million in payroll.

The Great Lakes Innovation and Development Enterprise (GLIDE) is a comprehensive regional innovation center, resource hub, and business incubator that supports all facets of the growth of enterprises. Based in Lorain County, GLIDE was created as a partnership of the Lorain County Commissioners, Lorain County Community College, and the Ohio Department of Development. GLIDE is an Edison Technology Incubator, which allows entrepreneurs, often with limited resources, to develop their product or service by drawing upon the proven expertise of GLIDE advisors. In fact, because GLIDE is publicly funded, its seasoned entrepreneurs and business executives provide assessments of businesses and business ideas at no charge to any individual or company requesting this service.

JumpStart, based in Cleveland, provides intensive business assistance to early stage tech-based Northeast Ohio companies in the sectors of healthcare, IT, clean technology, and business and consumer products. The nonprofit venture development organization has a deep commitment to diversity, with a special focus on providing specialized resources to accelerate the successes of women, minority, and inner-city entrepreneurs.

The Tech Belt Energy Innovation Center (TBEIC) in Warren, Ohio, is designed to cultivate research and technical potential, with the overarching goal of developing and commercializing early stage clean technology, energy, and natural resource technologies.

Youngstown Business Incubator helps accelerate emerging businesses by providing an array of resources critical to successful business development including facilities, equipment, entrepreneurial counseling, and networking opportunities.

Financing and Funding Programs

The Ohio Development Services Agency works to grow the economy of the state by connecting companies and communities to financial and technical resources through the following advanced energy and efficiency programs:

The Energy Efficiency Program for Manufacturers is a multi-phase energy efficiency program that helps Ohio manufacturers to reduce their costs through facilitation services and financial assistance that diagnose, plan, and implement cost-effective energy improvements at their facilities. Funding is made available through the DOE's State Energy Program and Ohio's Advanced Energy Fund. To date, the program has invested more than $24 million in Ohio's manufacturing sector to reduce energy usage for a combined annual savings of 1,112,109 British Thermal Units (BTU) (gas, oil, other) and 79,256 megawatt hours. These savings translate into a greenhouse gas emission reduction of 110,256 metric tons per year. In addition, the OERD, along with Ohio technical assistance providers, provides a portfolio of tools and services for Ohio manufacturers to use as a resource bank in developing the technical answers to the energy management plan.

The Energy Loan Fund is a program that provides low-cost financing to small businesses, manufacturers, nonprofits, and public entities for energy improvements that reduce energy usage and associated costs, reduce fossil fuel emissions, and/or create or retain jobs. Funding is provided through the Advanced Energy Fund and federal State Energy Program and American Recovery and Reinvestment Act. Eligible activities include energy retrofits, energy distribution technologies, and renewable energy technologies. Projects must achieve 15% reduction in energy usage, demonstrate economic and environmental impacts, and be included within a long-term energy strategy of the community served.[24]

The Loan Loss Reserve Program offers credit enhancement to eligible Ohio Port Authorities as they originate loans for projects that make businesses' and nonprofits' facilities more energy efficient. The Ohio Development Services Agency is partnering with eight Ohio port authorities for this program.[25]

ECO-Link is a partnership between the State Treasurer of Ohio and participating state banks that provides a 3% interest rate reduction for five or seven years on bank loans when completing energy-efficient upgrades in your home; the maximum loan amount the interest rate reduction can be applied to is $50,000. A homeowner can opt for a seven-year rate reduction if the loan is greater than $25,000.

The Energy Conservation Program (HB 264) allows school districts to make energy efficiency improvements to their buildings and use the cost savings to pay for those improvements. Passed in 1985, House Bill 264 enables school districts, in this one limited instance, to borrow funds without having to pass a ballot issue for the authority to borrow. This limited borrowing authority has given districts the ability to save millions in utility bills and operating costs, and all at no additional taxpayer expense.

The OERD works in partnership with the Ohio Schools Facilities Commission in administering this program and provides technical evaluation of applications submitted by school districts.

Trade Ally Programs

AEP Ohio's Solution Provider Network connects business customers with contractors, engineers, ESCOs, architects, suppliers, distributors, and other vendors who have been trained on AEP Ohio's energy efficiency programs for business customers. Participating solution providers are outreach partners. They have agreed to follow the program rules and processes, and can assist AEP Ohio business customers with energy efficiency upgrades and provide support on program applications, including:

- Requirements for installations,
- Selecting equipment that will qualify, and
- Completing the application process to receive the incentive payment.

24 Energy Loan Fund-Ohio Development Services Agency-Accessed Oct. 2015
25 Loan Loss Reserve Program- Ohio Development Services Agency-Accessed Oct. 2015

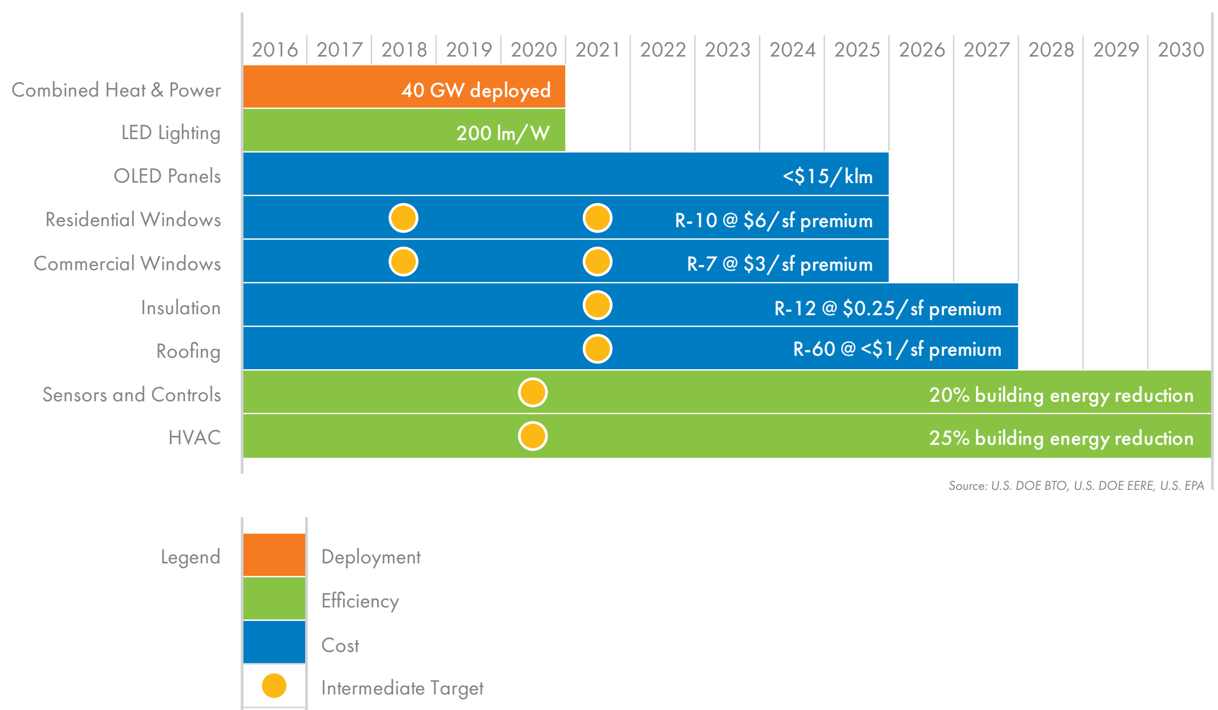
2.2 Technology Roadmapping Forecasts

NextEnergy reviewed the technology roadmaps that have been produced by the DOE within the Building Technology Office (BTO) and the Office of Energy Efficiency and Renewable Energy (EERE). The goal of the review was to identify which technologies are being targeted by federal programs for growth and are also applicable to the EEBT work within this report. Seven technology roadmaps were identified in the process for:

- Home and Building Energy Management Systems (HEMS/BEMS)
- Direct Current (DC)-Powered HVAC for Solar Photovoltaic (PV) Integration
- Separate Sensible and Latent Heat Management
- Combined Heat and Power
- Solid State Lighting Manufacturing
- Highly Insulating Windows
- Building Envelope Materials

Figure 5 highlights the technologies identified by the DOE in the technology roadmaps:

Figure 5: Technology Roadmap Target Timeline



Home and Building Energy Management Transaction Based Control Measures

HEMS/BEMS (which can be used in home and building automation systems) ensures the connectivity of all controllable device/loads/data inputs in a building or a system while also allowing for an overarching logic to more simply govern the interaction and interoperability of the various components of a system as complex as a building. The DOE has defined the HEMS/BEMS by identifying the technology as Transaction Based Control Measures. This lays the groundwork for the software to then make decisions based on specific data received from connected devices.

This technology is typically cloud-based software that combines with needed connectivity hardware to allow for the potential for two-way communication between all connected (or "smart") devices and a distributed control system (or the "brain"). The operative technology is the integration of various device protocols as well as the addition of an overarching "self-configuring, self-commissioning, and self-learning" brain to govern the many transactions taking place to benefit all stakeholders. Therefore, the technology is a combination of both software and hardware in the system.

The software and hardware needed to round out a fully functional transaction-based control system are being developed in parallel. The open source software platform "VOLTTRON" is being developed at a number of national labs as the software solution to govern transactions. The goal of VOLTTRON is to establish a cost-effective platform for managing a large number of smart, interconnected appliances and devices.

Private industry is also developing a number of different software platforms in both the home and commercial building markets. "Connected hardware" like wireless sensors and controls are expected to come down in price as consumer appetite for connected home and building technology drives development in this space. The DOE is estimating that wireless sensors are coming down from $150-$300 per node to $1-$10 per node. As a result, the cost of connectivity varies by device.[26]

The barriers to growth in the market are a multi-stakeholder problem: third party connected devices often have their own proprietary controls and may be unwilling to surrender control even to a system that is not part of the proprietary system. The result is often disparate systems with a control layer laid over top, and compromising features or functionality. The VOLTTRON system is an attempt to help alleviate this problem.

The DOE has published goals for building automation that are focused on reducing energy consumption. The target is to use sensors and controls to help reduce building energy consumption by 10% by 2020 relative to 2010 consumption, and by 20% in 2030. The DOE is using two main mechanisms to meet these targets:

- Utilizing R&D and technology development out of the national labs (including development of VOLTTRON)
- Funding specific R&D programs, targeting a variety of sensor-related technology to help reduce costs

Within Michigan and Northeast Ohio, a number of building automation companies such as Hepta, Smart Building Systems, and Keweenaw Automation integrate and implement building automation systems, while other companies such as WiSuite (hotel room automation) are targeting more specific niches within the automation market.

26 S&C Peer Review-Joseph Hagerman, U.S. Department of Energy-Accessed Oct. 2015

DC-Powered HVAC for Solar PV Integration

The DOE has set a target of reducing energy consumption from HVAC systems by 10% in 2020 relative to 2010 and by 25% in 2030. To achieve this goal, there are a number of paths that could be followed, but one strategy is to target development of HVAC systems that run on DC power and can thus plug into microgrids or buildings' renewable generation sources, thereby minimizing efficiency and alternating current conversion losses.

Since both solar (photovoltaic or "PV") generation and energy storage technologies need to convert their DC-generated power to alternating current (AC), a DC-powered HVAC system would allow one of the building's largest loads to draw power from DC-powered generation assets like batteries and solar without conversion losses. An additional attractive feature is that the time of day when air conditioning loads are highest coincides with times of high solar power generation, furthering the value proposition.

The BTO ranks DC-powered HVAC as its number one priority for HVAC technology due to its potential energy savings. The DOE EERE has acknowledged that DC-powered HVAC systems are already used in specialized markets such as telecommunications, electronics, and in transportation applications (including recreational vehicles, trucks, and trains), but DC-powered HVAC for buildings remains extremely rare.

Much of the challenge in developing this system relates to the ecosystem surrounding the technology and is not specific to the DC-powered HVAC system itself. The electric generation system would likely require energy storage to take full advantage of the DC-powered HVAC system benefits and energy storage for commercial buildings is a nascent market. Additionally, the incorporation of DC-powered HVAC would require new training for installers and stakeholders (such as utilities and energy storage companies) to be involved in the installation process. The focus of the roadmapping efforts is therefore more focused on developing a prototype that can then be tested in a microgrid. These tests will "develop, test, and identify the role of DC-enabled HVAC systems as part of larger microgrid energy systems for residential and commercial buildings".[27] Ultimately, the inclusion of DC-powered HVAC systems are likely to help meet the 25% reduced consumption goal. However, Navigant Consulting research on the technology found that current energy efficiency metrics do not account for the type of savings that would be gained thereby limiting their potential impact.

Current market pricing for DC-powered HVAC units is close to three times the price of a traditional AC-powered unit for small residential wall units. In reviewing prices online (in August 2015), an 11,500 BTU cooling/13,000 BTU heating DC-powered unit retails for approximately $1,700 compared to a comparable AC-powered unit which can cost as low as $600.[28] These price comparisons should be considered cautiously as the DC-powered HVAC unit is based on mobile HVAC technology and only offers a directional indication of how the costs may vary between the two systems.

27 Roadmap for Emerging HVAC Technologies-Navigant Consulting-U.S. Department of Energy-October 2014
28 In a comparison of three units priced on hotspotenergy.com, homedepot.com, livingdirect.com

Heat Pumps/HVAC: Separate Sensible and Latent Heat Management

Traditional air conditioning cooling systems accumulate inefficiencies in the way they reheat cooled air to make it more comfortable. Losses also occur in the process by which energy is used to cool the air. To mitigate these losses, the DOE's BTO has compiled design decisions that together can have a significant impact on efficiency of air conditioner units. Separate Sensible and Latent Cooling (SSLC) mitigates these losses.

SSLC includes a number of tools. The BTO describes a few of these methods: "using multiple vapor compression cycles (e.g., dehumidifier), lowering supply airflow for moisture removal, solid or liquid desiccant materials that capture water vapor, selectively permeable membranes that transport water molecules across their surface, heat pipes, and other methods."[29] To develop the technology to address these methods, the BTO also identified near term (1-3 years), mid-term (3-5 years), and long term (5-7 years) R&D roadmaps for the technologies with milestones that are largely focused on developing both commercially viable technology as well as a best practices guide for those that wish to compete in the market.

The market is not yet ready for SSLC for the most part because the technology requires advanced building automation systems and there are currently few (if any) design guidelines for the technologies involved in the systems. Additional market challenges lie in the wide range of costs and potential solutions. Costs could range from minimal for aftermarket solutions, or may be significant for a new, state-of-the-art HVAC infrastructure upgrade with extra installation, building automation integration, and new ducting.

Interestingly, some of the requirements of SSLC HVAC coincide with constraints on automotive heating and cooling, pointing to the potential for overlap in manufacturing and design best practices for these technologies in Michigan and Northeast Ohio. Michigan's strength in commercial and industrial HVAC companies could also help push technology development within the R&D ecosystem in the state.

Combined Heat and Power

Combined heat and power (CHP) is not a new technology. The technology was developed in the late 1970s as a response to higher energy costs and grew 54 gigawatts (GW) between 1980 and 2000 according to the DOE. The CHP market slowed dramatically starting in 2001 as low energy costs made the ROI on CHP less attractive to investors.[30]

In CHP systems, a turbine, typically running on natural gas or biomass, generates electricity, and the waste heat is used to heat a facility. This combination therefore allows the secondary use of a wasted byproduct, and therefore, doubles the efficiency of the system overall. CHP is estimated to have overall efficiency of 80%, compared to 45% for electricity generation alone.

A CHP system is comprised of four main components: an engine or turbine, a generator driven by that engine or turbine, a boiler or heat recovery device, and a hot water system. The effort to improve efficiency in the system overall is generally

29 Research and Development Roadmap for Emerging HVAC Technologies-Navigant Consulting-U.S. Department of Energy-October 2014
30 Combined Heat and Power: A Clean Energy Solution-U.S. Department of Energy, U.S. Environmental Protection Agency-August 2012

focused on improved burners for heating the water or improved turbines or engines that will make the use of the primary fuel more efficient. While many companies are focused on improving the efficiency of fuel consumption in CHP systems, most of the innovations in the market are focused on business model innovations. The effort to grow the CHP market is focused on awareness improvements and new policies to encourage growth of this distributed energy generation system.

CHP was identified as a target technology for lower emissions energy production by President Obama who pushed the DOE and EPA to develop a strategy for reaching 40 GW of new CHP installations by 2020. In 2012, the DOE established a roadmap for the technology that is largely focused on three primary drivers:

1. Improving outlook for natural gas supply and price with increased domestic production
2. Growing state policymaker support
3. Changing market conditions for power producers and industrial sectors with increased regulations on fossil fuel emissions at central power plants and industrial boilers

The shift to CHP is far from certain though, with significant barriers identified by the DOE as well, including:

- An unclear value proposition for electric utilities to participate or support the CHP market
- Limited equipment manufacturers and infrastructure for CHP sales and installation
- Uncertainties in the CHP market, including project economics, emissions regulations, government financial incentives, and electricity sales for excess production
- End-user awareness and economic decision making which tends to provide greater weight to risks than the economic benefits CHP
- Local permitting and siting issues

Looking specifically at the Michigan and Northeast Ohio markets, the states are well-positioned for CHP growth because of the strong industrial base, the availability of natural gas, and a potential supply chain already in the state. In 2012, the DOE estimated that 87% of CHP installations are at industrial locations. Interviews conducted for the Clean Energy Roadmap included a small number of companies that compete in the CHP industry, and these interviews directionally confirmed that industrial and institutional campuses are the target market for CHP. Additionally, the 2015 Michigan CHP Conference—unrelated to the Clean Energy Roadmap—fostered cluster growth in industrial and institutional (hospital and education) sectors.

The strong industrial and institutional base in both Michigan and Northeast Ohio make the states good candidates for additional CHP sales. In addition to strong potential demand, Michigan has several companies that compete in the CHP market already. The cost of natural gas also contributes to the CHP opportunity, particularly in Ohio. Ohio's price for natural gas when used in electricity generation ($4.31 per thousand cubic feet in 2014) is lower than the national average and significantly lower than that of Michigan ($5.19 and $6.78 per thousand cubic feet, respectively).[31]

31 2014 Annual Natural Gas data from the U.S. Energy Information Agency-eia.gov/naturalgas/-Accessed September 25, 2015

Solid State Lighting Manufacturing Roadmap

The Solid State Lighting industry is split into two primary types of technologies: LEDs and OLEDs. While the LED market is marching towards maturity and has near-term targets for production costs, the OLED market is still nascent and has long-term production expectations with significant assumptions to make that production viable. The technology roadmapping for Solid State Lighting is therefore challenging to characterize as the targets for technology development remain within specific components in the market and not overall component costs. For the most part, the companies operating in the Michigan and Northeast Ohio markets are focused on LEDs, while some advanced research is occurring in the OLED market in the states' universities.

The LED lighting market is still small, but growing rapidly, with Strategies Unlimited estimating for the DOE that LED lighting commanded 5% market share in 2014, but is expected to grow to 42% by 2020.[32] Similar to a number of technology markets, the LED lighting market is global with significant production volume occurring outside the United States. As a result of the market forces and the opportunities, the DOE has identified six key R&D targets[33] for LED lighting:

1. *Emitter materials* - addressing current density and thermal droop, green and red efficiency, and red thermal stability
2. *Down-converter materials* - developing efficient, stable, and narrow linewidth materials
3. *Encapsulation materials* - targeting high refractive index and improved thermal stability
4. *Novel emitter architectures* - developing advanced device architectures for enhanced performance
5. *Higher integration levels* - investigating flexible integration of package, driver, and optics elements
6. *Novel luminaires* - developing luminaire concepts to achieve enhanced light distribution control, improved building integration, intuitive control, and enhanced lighting performance

In Michigan, the Michigan Saves energy efficiency financing program reports that as of January 2014, 56% of the 5,263 lighting projects in the Business Energy Financing programs[34] were LED retrofits. This points to the growth of LED lighting in the Michigan market. Similar data was not available for Northeast Ohio. In addition, the robust LED sector supply chain that has developed in Michigan and in Ohio is likely to continue the focus on product R&D to meet DOE cost targets.

Highly Insulating Windows

Current windows provide relatively poor insulation compared to the rest of the building. The goal of highly insulating windows R&D is to create windows that have significantly improved insulating properties through innovative materials, coatings, and manufacturing processes. Currently, residential windows, on average, have

32 Solid State Lighting R&D Plan-U.S. Department of Energy-May 2015.
33 Solid State Lighting R&D Plan-U.S. Department of Energy-May 2015
34 Strengthening Building Retrofit Markets, Final Report-Michigan Saves-April 15, 2014-Accessed Oct. 2015

an R-value of 1-2. The target is to create windows that have an R-value of 7 for commercial buildings and R-value of 10 for residential windows at a cost of $6 per square foot and $3/square foot, respectively, by 2025.[35]

The BTO has identified the following technical barriers that must be overcome to develop highly insulating windows:

- Low-cost inert gases for multilayer glazing - Currently, Krypton is used for insulated window glazings, but is not cost efficient for mass adoption.
- Improved performance of vacuum insulated glass - The thermal properties of vacuum insulated glass need to be improved for increased durability.
- New materials and designs for windows and films that control glare, but allow for light to pass through as aesthetically desired - Multilayer reflections need to be reduced while maintaining glare control.
- Improved performance framing materials - Need materials and mechanisms to increase R-value at window/frame junction.

However, given that this technology is more expensive, there is very little market push from consumers wanting to adopt these new technologies. One of the major reasons for this is that consumers do not know the long-term benefits of installing energy efficient windows. If the payback period makes sense and that information can be conveyed to consumers effectively, it would allow for increased adoption. Alternatively, increased adoption can come from stricter building codes and enforcement of those codes.

To support the work in highly insulated windows, the DOE offers several programs to encourage research and investment. The Building Energy Efficiency Frontiers and Innovations Technologies (BENEFIT) initiative awarded eight projects totaling $8 million in advanced windows, building thermal insulation, and advanced clothes dryers last year (the funding announcement for 2015 non-vapor compression HVAC technologies and advanced vapor compression HVAC technologies). In addition, the Building Technologies Innovations Program offers awards of about $500,000 per project.

Michigan and Northeast Ohio are both well-positioned for strength in the highly insulating window supply chain. The roadmap only identified two window manufacturers, Guardian and Pleotint (both in Michigan). However, due to the region's strengths in manufacturing and chemicals, the states are poised to be a competitor in the supply chain for advanced windows.

Building Envelope Technologies

To improve the energy efficiency of existing and newly constructed buildings, the DOE's BTO has a roadmap for improving the materials that make up the physical envelope of the building. This includes building envelope insulating materials, air-sealing materials, and roofing materials. Combined, the BTO has determined that the building envelope has a large potential for energy savings. The goal is to reach an R-value of 12 per inch of thickness for envelope materials and to double the R-value of existing roofs.

35 BTO Window and Envelope Technologies Emerging Technologies R&D Program-Karma Sawyer, U.S. Department of Energy- Accessed Oct. 2015

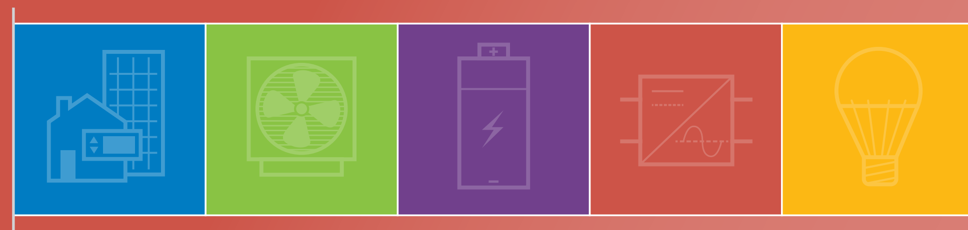
In order to meet the cost and R-value targets set by the BTO, the technology roadmap is focusing on developing low-cost materials that have:

- High R-values with pore sizes that are less than the mean free path of air
- Exceptional moisture/mold control
- Low pressure alternate filler gas with reliable long-term performance
- Ability to reflect thermal radiation

While building envelope insulating and air-sealing materials are given the highest priority in the BTO's roadmap, the improved roofing technology is also given aggressive cost targets of less than $1 per square foot of incremental cost for doubling roofing R-values by 2027. Beyond just making advancements in the specifications for the building envelope technology, the BTO is also hoping to gain a better understanding of failure modes and develop long-term testing protocols.

However, the BTO does recognize that there are significant barriers to the technology. The improved envelope materials need to fit into existing fabrication methods in order to limit incremental costs. They will require third-party verification of the gains. They need standardized sizes that will contribute to the ability to retrofit the material into existing buildings.

Despite these barriers, Michigan and Northeast Ohio both have manufacturers that are currently competing in the building envelope market. Both states also could help bolster the consumer demand for the products by working with the sizable installer base in each state for consumer education and education on technology ROI.



Energy Efficient Building Technologies

This analysis and cluster development was in response to a specific request from the DOE to develop "Clean-Energy Economic Opportunity Roadmaps [that] will assist States with regional clean-energy economic strategic planning." NextEnergy and Team NEO worked with their respective states to develop focused strategies for advancement of the EEBT cluster, based on asset mapping, value/supply chain analysis and technology roadmapping, that connect gaps in the cluster to specific interventions. In the following value chain assessment, the net was cast wide across a number of different potential technologies, and the supply chain analysis was completed on technology clusters where it was felt Michigan and Northeast Ohio had significant opportunities for economic development.

3.1 Technology Overview

As discussed in the Methodology section, the technology clusters that are targeted in this section have been vetted through an iterative process of identifying, assessing, and assigning companies to supply chain and value chain positions. The result was the ability to identify either strong EEBT clusters or EEBT clusters that are poised for strength. These clusters are measured in terms of either industry participation or potential economic opportunities identified during technology roadmapping and interviewing.

As a result of this analysis:

- The **LED lighting cluster** was chosen due to strength of the industry participation in both Michigan and Northeast Ohio, as measured by the number of companies, interest in LEDs from stakeholders and industry players, and number of employees in the states.
- The **building automation cluster** was chosen in Michigan because of significant knowledge about the software, sensors and controls that go into automation, and the interest expressed in the industry by both potential participating companies and a handful of potential customers (large building owners).

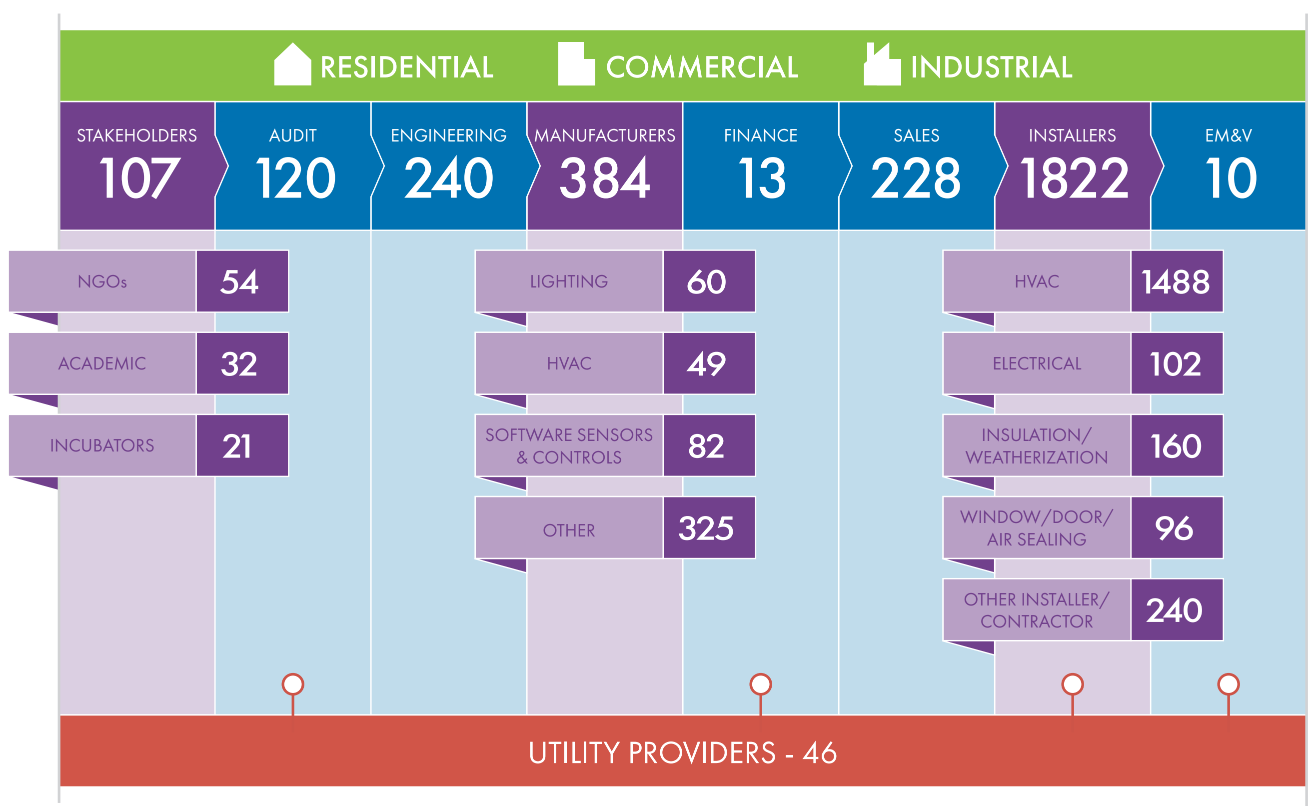
- The **HVAC cluster** was chosen in Michigan because of the number of commercial and industrial companies in the cluster and the large potential impact on energy efficiency of buildings.
- Building envelope and window technology clusters were not chosen as part of this focus because the other technology clusters were seen as a better opportunity for growth based on supply chain participation and interest in Michigan and Ohio.

3.2 Michigan

Value Chain Analysis

There have been nine key roles identified in the EEBT value chain. These include industry stakeholders; energy auditors; engineering; manufacturers; financers; sales and distribution; installers; evaluation, measurement, and validation (EM&V) services; and utilities. The largest role in the value chain, from a number of entities standpoint, is the installer role. The combination of localized services and a robust, competitive marketplace supports the large number of entities in comparison to other roles in the value chain.

Figure 6: Michigan's Energy Efficiency Value Chain

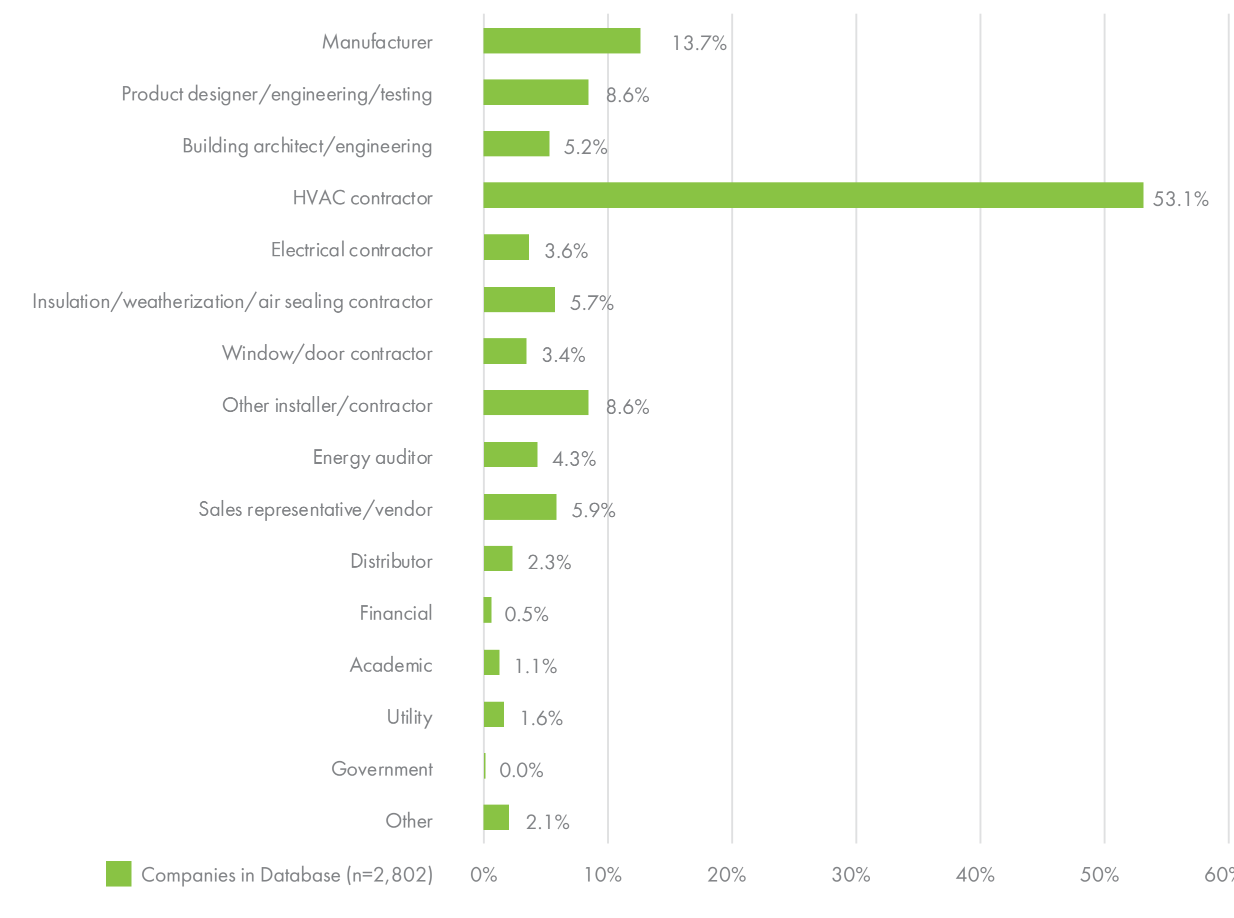


Overall Industry Profile

The database of companies that participate in the EEBT market in Michigan include companies at each stage of the value chain, though Michigan has a large number of installers of different technologies. This is not surprising since the installer market can be expected to serve local customers, and therefore, operates in many different cities and SmartZones around the state.

NextEnergy has identified a total of 2,802 unique companies, academic organizations, utilities, government, and non-government organizations that participate in the EEBT market in Michigan. Figure 7 shows the breakdown of the types of entities in the database of EEBT participants. These are entities that have either self-identified as participating in the energy efficiency markets or NextEnergy has identified as a participant. To generate this list, NextEnergy relied on four key sources of data: NextEnergy and Michigan Energy Office database of companies, utilities' trade allies programs, events, and trade associations including the MSSLA, MEECA, and the Michigan Energy Innovation Business Council (EIBC). Several of the entities claim to offer products in multiple categories in the EEBT, such as an insulation/weatherization/air-sealing contractor that also has energy auditing services.

Figure 7: Michigan Energy Efficiency Building Technology Entities (2014)



Stakeholders

Stakeholders identified in the value chain have a unique role because these entities often act as promoters that help foster growth of an emerging sector such as the EEBT industry. NextEnergy has identified 108 stakeholder organizations consisting of seven types of entities.

Figure 8: Energy Efficiency Building Technology Stakeholders Overview

VALUE CHAIN ROLE	COUNT IN VALUE CHAIN	INTEREST IN EEBT
Government Entity	1	Regulatory
Michigan SmartZone	15	Economic development
Community Action Agency	25	Energy efficiency and weatherization assistance to low income
Non-Government Organization	14	Energy efficiency ecosystem support and education
Small Business Incubator	21	Growth of energy and energy efficiency businesses
Private Training Centers	7	Energy efficiency technical training
Community Colleges, Colleges, and Universities	25	Academic organizations with specific energy efficiency or renewable energy programs

Source: NextEnergy

The EEBT ecosystem is well-served by the stakeholder community. The combination of non-governmental organizations and Community Action Agencies across the state of Michigan serves to support the programs for weatherization and other energy-related services for low income residents. The SmartZones and incubators often work in close collaboration to support economic growth in the EEBT industry. The education system has a combination of both private training centers and community colleges tend to focus on vocational training often covering the EEBT ecosystem, while colleges and universities are finding demand for energy and energy efficiency programs from their students.

The government entity identified in the asset map covering the EEBT value chain is the MAE. There are a few local communities that have stakes in the energy efficiency ecosystem as well, notably the cities of Ann Arbor[36], Grand Rapids, and Holland have programs that drive energy efficiency (typically serviced through their respective public works departments) regulations or citywide energy strategies.[37] These local programs tend to focus on local government energy efficiency and are outside the scope of this program.

Energy Auditors

Energy auditors are sometimes a first step for residential, commercial, or industrial customers wanting to make energy efficiency improvements to their facilities. Within the Clean Energy Roadmap database, NextEnergy has identified 120 auditors. Of those identifying with the auditor role in the value chain, almost 70% are affiliated with another role in the value chain.

Energy auditors affiliated with other roles are primarily installers (37%) or building architects/engineers (21%). This implies that the energy auditor role is not likely a service that can support itself and needs additional services to make a viable business. Additionally, energy auditing is a value-added service that other roles can offer to help make the case for other products or services. During the recent economic recession, energy auditing was increasingly relied upon as a way for architects and engineers to survive in the marketplace. Energy auditing may be an "easy" service to add to existing product offerings for companies whose primary business lies within other value chain roles.

Architects/Building Engineers

The architect and building engineer role within the EEBT value chain is a challenging one because EEBTs are not a mainstay of the architect and building engineer product offerings. This is not to say that the overall architects/building engineers industry is challenged (the American Institute of Architects is forecasting a 7.7% increase in construction spending in 2015 and an 8.2% increase in 2016[38]). However, engaging a building engineer or architect is often a very necessary step in navigating the energy efficiency process. Indeed, the database NextEnergy developed shows that about half (56%) of architects and building engineering firms compete in the residential market only, while 16% compete in the commercial market only, and the remainder serve either multiple markets or do not have a specific market identified.

This implies that residential and commercial markets to some degree use EEBT services as a differentiation tool in service offering. Many of the residential contractors are smaller firms, and therefore, more of them exist. Conversely, commercial A/E firms are usually larger and service a larger client base. Additional competitive pressure likely comes from outside Michigan as many national architecture firms compete for commercial and industrial buildings in Michigan.

Manufacturers

The manufacturers in the value chain cover a number of key technologies in the EEBT space. These include technologies that this report focuses on, including LED lighting, HVAC, and building automation that is included in the software sensors and controls category of manufacturers. The other technologies identified during research include insulation, windows and doors, gas processing, food processing and other technologies.

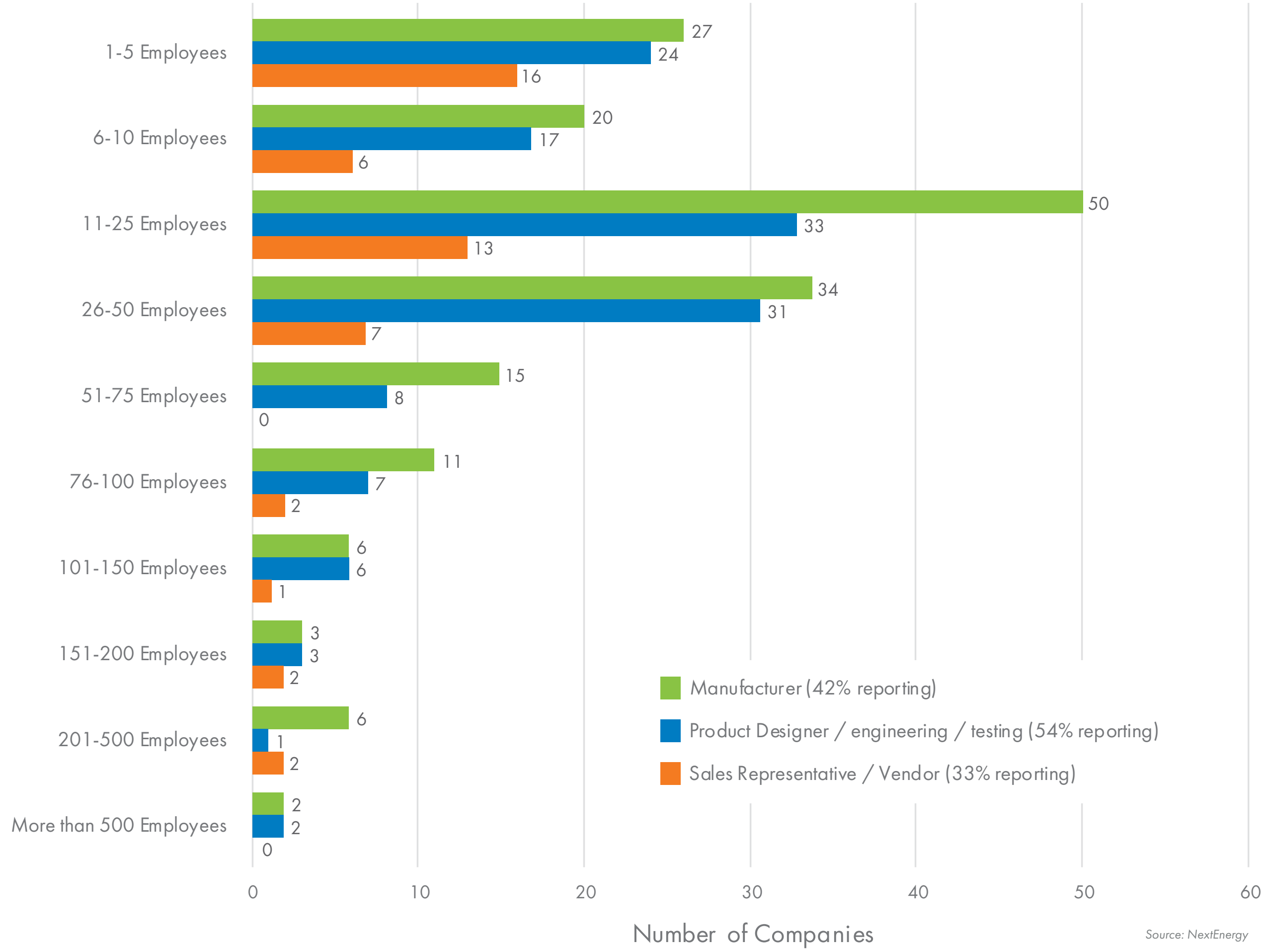
The database includes some data on the size of entities that are operating in the EEBT market as well, but this data is incomplete for many of the pieces of the value chain. While the focus of this report is all aspects of the value chain, there are parts where the data is more robust than others. One area with robust data is the NextEnergy database of manufacturers, which indicates that the EEBT manufacturers employ 59 people on average. This average is somewhat skewed by a small number of large manufacturers and the median size is 22 people. A similar story develops for firms like product designer/engineering/testing companies, which have an average of 49 employees, but two companies employ more than 1,000 people. The median number of employees in product designer/engineering/testing companies is 20. The database includes a total of 126 manufacturers, 70 product designer/engineering/testing companies, and 72 sales representative/vendors reporting employment data (or 42%, 54%, and 33% reporting employment figures, respectively).

36 "Michigan Cities Building a Sustainable Energy Platform: Focus on Grand Rapids", Triple Pundit, May 2, 2014, triplepundit.com - Accessed Oct. 2015.

37 "Michigan Cities Building a Sustainable Energy Platform: Holland, Ann Arbor and Beyond", Triple Pundit, May 3, 2014, triplepundit.com - Accessed Oct. 2015.

38 "AIA Forecasts Growth in Construction Spending in Next Two Years", Journal of the American Institute of Architects, January 2015, architectmagazine.com – Accessed Oct. 2015.

Figure 9: Number of Employees per Company



Among the many different EEBT manufacturers identified in Michigan, a handful of sectors stand out as being key economic interests for Michigan. Companies supplying process gas and electric equipment currently make up the largest faction of manufacturers in Michigan's EEBT industry. This sector is challenging to characterize because companies in this sector serve a wide variety of manufacturing and building processes and services and includes everything from pipe and tube manufacturers to valve and pump manufacturers.

Three sectors stand out as serving a significant need for EEBT products and offer unique offerings in the market: software, sensors, or control companies; LED lighting companies; and HVAC companies.

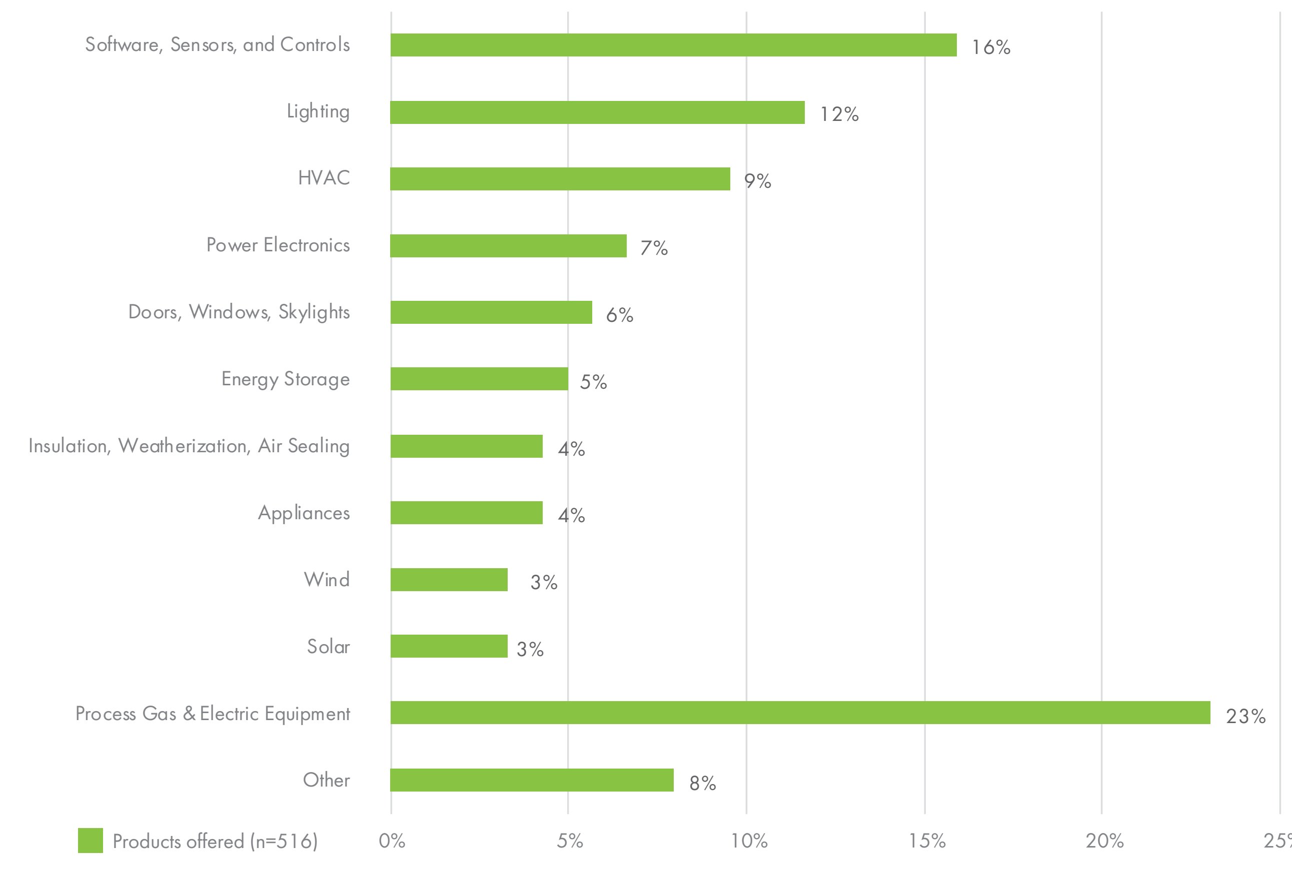
In the EEBT database, there are 82 software, sensors, or controls companies. This sector includes about 17 different sensor manufacturers, 14 factory automation suppliers, 12 electronics manufacturers, and 16 building automation companies. In addition, in this sector, it was found that there is a burgeoning software developer market. While many of these companies may not be doing energy work now, they potentially could be due to their strong foundational level of app and software development talents in other complex markets (automotive, health care, and transit).

The LED lighting sector has solid representation throughout the value chain with 60 companies identified in the EEBT database. These two sectors should be closely tied as the lighting industry is increasingly incorporating controls and daylighting sensors.

The third key sector identified serving Michigan's EEBT market is HVAC. There are 49 manufacturers that have been identified as serving the energy efficient HVAC market in Michigan. The bulk of these HVAC companies focus on components in the commercial or industrial HVAC market, including fans, controls, filters, specialty equipment such as boilers and chillers, and aluminum extrusions or extrusion painting. A few products included in the database are unique products in the market, including industrial filtration systems and air handling systems. The HVAC manufacturers in Michigan are facing distinct challenges as the residential and commercial HVAC brands or manufacturers that have significant national market share are manufactured outside the state; however, many of these organizations do compete heavily in Michigan for market share and have representation in other parts of the value chain (particularly in sales and installation).

There are a number of other manufacturers in the EEBT value chain, which includes a diverse array of technologies. These include energy-related technologies, such as energy storage (batteries), power electronics, and renewables, as well as building envelope companies, such as window/door or insulation manufacturers. Some of these technologies command significant capital resources without generating significant market players as of yet, and as a result these sectors were chosen as part of the clean energy manufacturing focus for this analysis (specifically, the energy storage and power electronics sectors). The building envelope clusters are small compared to other parts of the country, and while individual companies may have strength or unique opportunities in the marketplace, it may be challenging to grow the cluster overall.

Figure 10: Product Offerings of Energy Efficiency Manufacturers in Michigan



Finance

Due to the nature of financing products, the total number of entities in the State of Michigan is small (13 in total). However, Michigan has been nationally recognized for the product offerings that exist. Primarily, these include the Michigan Saves program and a statewide PACE offering, in addition to private sector offerings.

Sales/Distribution

Within the sales and distribution component, the value and supply chains are strong in the overall energy efficiency ecosystem. Within the sales and distribution role, there are two different levels at which the entities reside in the marketplace: the sales representatives that work as product representatives, distribution representatives calling on the manufacturers for different components in the manufacturers' supply chain, and those that represent the technology manufacturers and selling to the retailer or installer. The majority of those in the sales/distribution role are solely sales/distribution entities (73% are not active in any other value chain roles). Of the portion (27%) of sales/distribution entities that are also active in other roles in the value chain, the participation is varied across energy auditing, installers, and product designers/engineers. Within this smaller group, those that are sales/distribution entities and also installers are likely entities that either started as installers and added exclusive distribution rights to a particular product or have moved into installation to support the sales of a product line. This value chain role does not include retail sales stores, such as local hardware and big box retailers, though these were recognized during interviews as a viable sales channel for some EEBT products, particularly at the installer and residential customer level.

It is difficult to gauge the success or competitiveness of the sales/distribution role in the value chain because drawing a comparison to other industries or states is significantly difficult and potentially fraught with fallacy. However, during interviewing, NextEnergy was not made aware of a situation where products were commercially available, but inaccessible due to lack of sales representation. Anecdotally, manufacturers shared that there are a large number of sales representatives and distributors available.

> *"We started with 23 distributors, but terminated all these since they were not focused only on our product and now have all inside sales."*
>
> *- Building Automation Company*

Additionally, many companies discussed their efforts to vet and review the distributors and sales entities that represent their products in an effort to improve the sales channel or brand reputation of the products.

This points to two key issues within the sales/distribution role: a fragmented marketplace and an opportunity for increasing sophistication of the sales channels. In the fragmentation market, many of the builders or installer companies work with multiple sales and distribution roles for multiple technologies. In this case, retail stores may help address this challenge since retailers can provide contractors and installers access to many different technologies.

The value chain role also has a significant opportunity for increasing the potential product offerings, but would likely require some significant business model change for some companies. NextEnergy has interviewed a sample of sales and distribution companies that have made the shift to offer additional product design and engineering services, or additional manufacturing and assembly services, but these types of services are the exception. Energy auditing is another role that could be offered, but is currently not being added by participants in great numbers within this value chain role.

Installers

The installer role has the largest number of entities in the market with 1,822 identified as participating in the EEBT value chain. It is important to remember that the installers in this data are those companies that have self-identified as working in the energy efficiency industry. So, this is not an exhaustive list of installers or contractors in Michigan.

This self-identification also contributes to the dominance of HVAC installers. A vast majority of contractors, eight in ten, within the database are in the HVAC services market. This is likely due to the fact that many of the utilities' current incentive programs are designed to interact with HVAC contractors or the customer, so contractors are more likely to claim energy efficiency as a market they compete in to take advantage of these incentives. Beyond the HVAC installers, insulation/weatherization/air sealing contractors and electrical contractors make up the bulk of the remaining 20%. Other contractors, including homebuilders and general contractors, are a relatively small part of the installer role, likely due to few companies using energy efficiency as a marketing tool (in other words, it's a value-added benefit, not the primary driver).

The advantage to having a strong HVAC representation in the installer role of the value chain is that HVAC systems are most likely to be partnered with other systems. Whole Home Performance programs, such as the Home Performance with ENERGY STAR® program offered through Consumers Energy, require homeowners to conduct upgrades to multiple systems.[39] HVAC installers seem poised to be the most likely to pursue collaboration between different types of installation companies. In essence, to capture the incentives for Whole Home Performance, HVAC contractors will be forced to make the partnerships to get higher incentives for their customers.

Evaluation, Measurement, and Verification

A select number of companies are involved in the evaluation, measurement and verification of utility EO programs. Companies such as EMI Consulting or Navigant Consulting provide a third party evaluation of utility program performance and cost effectiveness, as mandated by the MPSC. The companies are predominantly national or multi-national companies that have a "Michigan presence."

Analysis of Michigan's Energy Efficiency Value Chain

An analysis was conducted of Michigan's energy efficiency value chain in order to identify opportunities and craft recommendations for work moving forward. Following are some key findings as well as the detailed analysis on the strengths, weaknesses, opportunities, and threats (SWOT).

39 2015 Consumers Energy's Home Performance with ENERGY STAR® program – Accessed Oct. 2015

Key Findings:

- **The unsettled politics of Michigan's energy policy are impacting value chain activity** – Currently, Michigan's EO programs are in flux as new laws, regulations, and policies are considered. This is creating an unstable environment for much of the energy efficiency value chain and will begin to compromise its economic impact.
- **Disparate energy efficiency programs** – Michigan has excellent and robust EO programs mandated by state law that are run through utility companies. However, these programs are disparate and produce a complicated situation for customers, contractors, and other service providers to navigate. For example, a customer will have different incentives, applications, and processes to follow if they have separate gas and electric providers.
- **Contractor community is strong** – A significant portion of the value chain is comprised of contractors. Regardless of public policy or new technologies that need to be deployed, the contractor community serves as a critical platform for deployment – and one that could be leveraged in greater capacity.
- **Awareness of customer financing is inconsistent** – It's not a secret that Michigan has excellent programs. However, the impact of financing is only effective if the customer awareness gap is minimized. Often, customers are unaware of financing options or don't elect to use financing.
- **Energy efficiency competes for capital** – Energy efficiency improvements compete for other capital priorities and often don't make it to the top of the list. In a manufacturing situation, a capital decision might be made to purchase a new piece of equipment. Or, in an office building, new computers, office furniture, or carpet might take priority. Overall, energy efficiency may be a tough sell when the ROI is ambiguous and investments for improvements are competing for other capital-intensive projects.
- **Strong innovation, engineering, and manufacturing base** – Building on deep expertise from the auto and manufacturing industries, Michigan can apply its wealth of human capital expertise and organizational knowledge to innovating and manufacturing just about any widget.
- **Michigan companies have a hard time selling in Michigan** – For many Michigan-based manufacturers, Michigan is not their biggest sales market because of a lack of access to sales channels or awareness within the sales channels. As a result, smaller Michigan-based companies compete with large national brands. Economic opportunity is likely being left on the table as mainstream brands from outside the state compete for awareness or mindshare with potential customers in the state.
- **Michigan companies compete with large national brands in out-of-state markets** – Michigan manufacturers are finding the market to be competitive and challenging in part due to greater sales focus out of state, resulting in competition with national and other regional brands which may impact profitability.
- **Emerging IT/software plays** – More and more EEBT devices are becoming connected through IT, unleashing more energy savings potential and value propositions. Emerging technology scenes in Detroit, Ann Arbor, and Grand Rapids are starting to apply software/IT skills in the EEBT space.
- **"Upstream" R&D, "downstream" deployment** – Michigan is unique in the sense that it has a really strong ecosystem (innovation, engineering, and manufacturing) of upstream R&D activity while also having a robust group of ecosystem components to deploy projects (auditors, project engineers, contractors, and A/E firms.

DTE Energy Residential Energy Management Application Case Study

INDUSTRY HIGHLIGHT

COMPANY:
DTE Energy

LOCATION:
Detroit, MI

PROJECT/SERVICE:
Residential energy management application

OVERVIEW:

Designed to help DTE Energy offer a home energy management experience to its customers, the DTE Insight App (and associated energy bridge hardware) offers customers with an interactive way of understanding energy use through a mobile application. The app's real-time energy insights make it easy for customers to track their energy consumption patterns, set goals, tackle energy-saving projects, and compare usage with similar homes in their neighborhood.

The DTE Insight app is an example of a new service that is affecting behavior through the use of data and is a great example of a Michigan-based software/IT firm, Vectorform, pivoting its expertise and applying it to an energy solution.

Figure 11:Energy Efficiency Value Chain SWOT Analysis

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
• PA 295 has driven adoption of energy efficiency • Utility EO programs push energy efficiency market • Michigan Saves and PACE provide path to financing • Strong contractor networks • Diverse ecosystem of energy efficiency assets in MI • Robust manufacturing, research, and engineering base • Strong supply chain has developed from automotive technology developers • Emerging IT and software ecosystem • Many Tier 1 auto suppliers have energy efficiency in their product portfolios, providing opportunity for global markets • Strong IP development channels • Solid education programs	• Energy efficiency programs fluctuation makes availability uncertain (on/off/on, etc.) • Disparate, uncoordinated public programs and processes are difficult for contractors and others to navigate • Customer awareness of energy efficiency technology, benefits, and financing options • Contractors often sell the status quo, in order to not lose or complicate a sale • Silos for energy efficiency, renewable energy, and demand response leads to inefficient programs • Major national and global energy efficiency brands are not located in MI, particularly in HVAC and renewable energy markets • IP development in MI, yet sales in MI are challenging	• Stronger/revised building codes could push energy efficiency • EPA Clean Power Plan provides opportunity to push new technologies (integrated energy efficiency, renewable energy, automated demand response, storage) • Incentivize and grow the contractor "army" of energy efficiency advocates - Sales training for contractors - Energy efficiency sales tools - Business model training and development support • Streamlined EO program and processes • Leverage partnership opportunities with innovators and manufacturers • Better Buy/Sell/Deploy financing options	• State EO and renewable energy policies and legislation are in flux and difficult to plan for • Energy efficiency improvements compete with other capital expenditures • Low energy prices mean energy efficiency ROI is less compelling on its own

Source: NextEnergy

Recommendations for Michigan's Energy Efficiency Value Chain

Given this analysis, the project team has developed the following recommendations to help grow Michigan's current EEBT value chain.

1. **Ongoing energy efficiency asset inventory and analysis** – Understanding the current assets of Michigan's energy efficiency economy and its economic impact is important to make informed decisions. An annual process should occur that surveys and interviews Michigan energy efficiency firms, generating economic impact data.

   Next Step:

   - Secure funding to continue annual survey of energy efficiency ecosystem

2. **Statewide energy efficiency program** – Currently, Michigan's EO programs are disparate and produce a complicated situation for customers, contractors, and other service providers to navigate. A cohesive, statewide program with extended duration to participate would create more of a true market situation and an easier situation for contractors and customers to navigate. For example, a streamlined application process, consistent incentives, and one call center would eliminate inefficiencies.

   Next Step:

   - Conduct analysis of other statewide energy efficiency programs to identify best practices that are most applicable to Michigan

3. **Customer energy efficiency awareness** – Although energy efficiency is important, it's often not top of mind, competes with other priorities, or a customer doesn't know what to do or who to turn to. A broader public awareness campaign and consistent statewide message combined with a toolset for end users would help achieve greater awareness.

   Next Step:

   - Conduct analysis of best methods to increase awareness of energy efficiency with customers

> *"As a state, we can innovate and manufacture the best technologies in the world, but if we don't have a local conduit for deployment and market development, huge opportunities are missed."*
>
> *- Michigan-based Lighting Company*

4. **Incentivize and educate contractors** – It's easy for a contractor to sell the status quo as opposed to more efficient equipment. They want the sale and often more efficient products come with a higher price tag. A program should be created and implemented that not only educates contractors on the benefits of energy efficiency equipment and provides them with sales tactics, but also has a considerable incentive available to move the conversation from "status quo" to the more efficient equipment.

   Next Step:

   - Conduct strategy sessions with contractor and trade associations regarding the development of new training modules

5. **Emerging technology forums** – There is a disconnect in the state between technology developers developing "what's next" and customers, architects/engineers, and contractors understanding what technologies are coming their way. Forums should be hosted on emerging technology areas in partnership with key end user groups such as the A/E and contractor communities.

   Next Step:

   - Identify opportunities to conduct emerging technology forums in partnership with A/E communities and contractors

6. **Connected systems training for contractors** – More and more "systems" in buildings are becoming connected. Whether these are lighting controls or building automation systems, contractors need to be trained appropriately so they can sell, install, and realize the energy savings value they present.

   Next Step:

   - Conduct strategy session with State of Michigan, the DOE, and local contractor groups to determine best solution for training

3.3 Northeast Ohio

Team NEO has worked with a number of Northeast Ohio's energy-related technology sectors to build an advanced energy cluster with the critical mass to accelerate development of emerging technologies and thereby grow the region's industrial base, physical and intellectual capital, revenues, and jobs.

The foundation of the advanced energy cluster was built on roadmapping exercises performed to identify the specific industry sectors and technology segments prevalent in Northeast Ohio. Furthermore, the energy efficiency roadmapping exercise helped identify those sectors that would benefit the most from cluster development work. The initial findings of the energy efficiency roadmapping work was highlighted in the 2012 report created by NorTech, entitled "Developing a Roadmap for Northeast Ohio's Energy Efficiency Sector."

Team NEO has continued to perform additional work to update its energy efficiency asset inventory and further refine its focus. Given the rapid global market growth and the proliferation of Northeast Ohio companies focused on LED technology, evident even within the last 24 months, Team NEO has concluded that the solid state lighting sector, with a focus on LED lighting within that sector, represents an emphasis for regional cluster development.

Value Chain Analysis

To identify the most promising technology segments within the sector, the roadmapping team analyzed each segment based on:

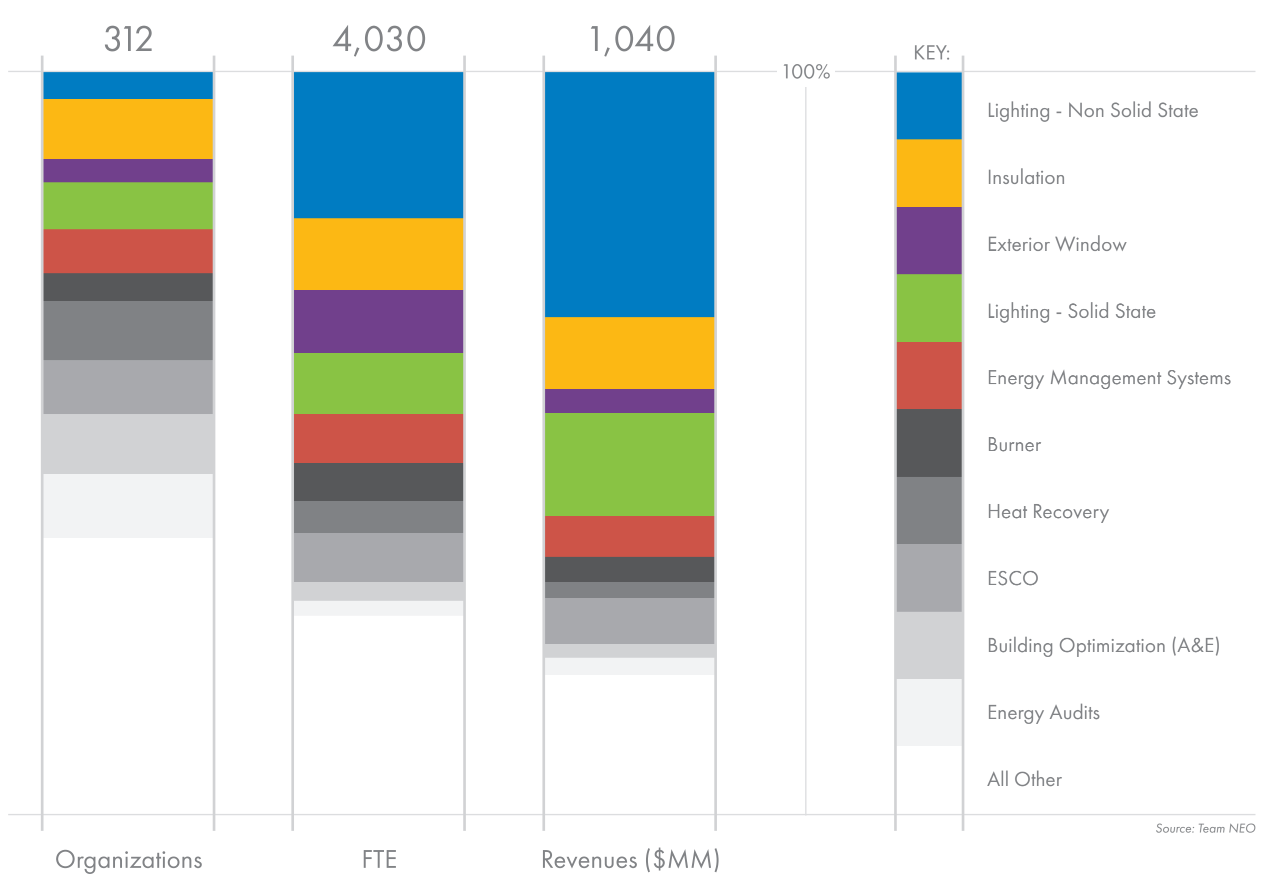
- The number of organizations and their revenue/funding and jobs
- Stage of development (R&D, pilot, commercial)
- Stage in the value chain (raw materials, components, sub-systems, systems, and end users)

Although this analysis helped identify priority potential focus areas with robust presence in Northeast Ohio, the focus areas for targeted action were not finalized until the market and competitive assessments were also completed. Based on all of these analyses, the team originally identified three energy efficiency focus areas with robust presence in Northeast Ohio, to then be analyzed for market growth opportunity and potential regional competitive advantage:

- Solid state lighting
- Non-fiberglass insulation
- Building efficiency services (value chain assets impacting all energy efficiency technology sectors)

Figure 12 categorizes these assets by key metrics: number of organizations, number of full-time equivalent (FTE), and total revenues.

Figure 12: Northeast Ohio's Energy Efficiency Assets, 2012



As of the Energy Efficiency Roadmap's original release, Northeast Ohio's assets included:

- 220 unique organizations (the slightly larger organization count in the diagrams considers the same organizations with activity in multiple different systems as multiple assets)
- 4,030 full-time equivalent workers
- $1.04 billion in revenue and funding

Industry Profile

The following section shares the market opportunity and regional competitive analysis for the following three sectors: solid state lighting, non-fiberglass insulation, building efficiency services.

Solid State Lighting Segment

Northeast Ohio is known for innovation in lighting technology, largely due to the presence of GE Lighting's headquarters. Consistent with this reputation, the region has a wide range of commercial and R&D activity in advanced lighting technology, also referred to as "solid state (LED)" in the Energy Efficiency Roadmap. The original roadmap identified seventeen companies, including GE Lighting, L.D. Kichler, Momentive Performance Materials, and others with operations in Northeast Ohio that span the value chain, with a heavy emphasis on fixtures and retrofits, and early-stage activity in the lamp sub-system. Regional R&D activities have attracted Third Frontier[40] and federal funding, and included the private resources of 6 different companies, as well as University of Akron and John Carroll University. As of the original roadmap development in 2012, most of the lamp supply chain was based in Asia.

Market Opportunity

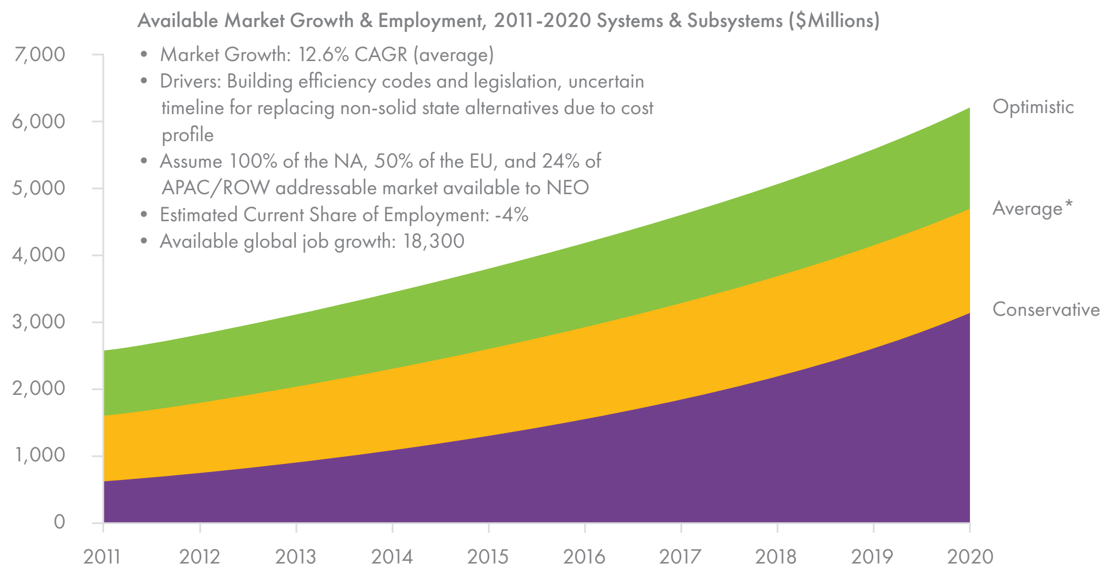
The LED lighting market is expected to grow significantly due to anticipated improvements in energy efficiency and lifespan vs. other lighting technologies. The market available to Northeast Ohio suppliers of LED lighting systems and sub-systems for space lighting was estimated between $0.6 and $2.5 billion (see Figure 13). Northeast Ohio's 2011 market share (based on employment) was estimated at nearly 4%.

The global market for solid state lamps, ballasts, and fixtures was expected to reach $5.3 to $13.7 billion in 2020, with $3 to $6 billion available to Northeast Ohio suppliers. Global adoption of LED lighting will be driven by technology and supply chain developments allowing cost competitiveness and more effective space-lighting application. The timeline for this advancement and the projected adoption in different global regions varies widely. Until then, non-solid state technologies for efficient lighting will remain very competitive with LED technologies for building lighting upgrades driven by regulations and cost savings opportunities for property owners. Using the average of the conservative and optimistic growth scenarios, market growth associated with these activities through 2020 translates to approximately 18,300 new jobs for which Northeast Ohio can compete.[41]

40 A statewide high tech business acceleration fund

41 Projections for both the 2011 and 2020 SSL market varied widely in the market studies consulted. Our understanding is that this difference derives from discrepancies in research methodologies and definitions for the solid state lighting market, even for the sizing of current markets. The optimistic estimate shown here is a Bush Consulting Group extrapolation of data from two published reports, validated by the Working Group.

Figure 13: Potential Solid State Lighting Market Opportunity for Northeast Ohio Suppliers, 2011-2020



*Average of the low and high estimates used to project employment growth, based on Freedonia, Pike, BCC Research, and Frost & Sullivan data

Source: Team NEO

Competitive Outlook

The San Francisco/San Jose and Los Angeles, California; Boston, Massachusetts; and Research Triangle in North Carolina areas are hotbeds of LED activity. Although most of these regions have more patents and unique inventors, Northeast Ohio's patents are cited most frequently in other patents, indicating a presence of foundational IP. Most of the other regions also show substantial federally funded research at companies, as well as universities. The California regions are clear competitors in terms of organizational concentration, with a variety of tech-based startups, while Cree, Osram Sylvania, and Philips Electronics represent some of the larger organizations located in the Research Triangle, Boston, and San Francisco areas, respectively. Factor costs are comparable, but higher workforce availability helps give the California regions and Boston an edge over Northeast Ohio. The Research Triangle area is overall on par.

Although Northeast Ohio's competitiveness is currently based on its technology development and system integration capabilities, opportunities to mitigate challenges associated with lamp and driver supply base in Asia (e.g., development cycle time for Northeast Ohio OEMs, supply chain complexity) would allow more cost-competitive manufacturing in the region. Northeast Ohio will be enabled to pursue these opportunities by leveraging what has been identified by other cluster assessments as a regional strength and focus in contract manufacturing.

Non-Fiberglass Insulation Segment

Northeast Ohio is home to a variety of specialized insulation manufacturers, as well as significant Owens Corning foam manufacturing and R&D. These 17 companies include providers of foamed plastic, mineral wool, and other non-fiberglass insulation products for a range of building envelope and HVAC applications, including two companies providing enabling spray-foam equipment. Also included in this segment is Bio100, with new technology to convert agricultural-based waste glycerin to a biopolyol for polyurethane foam insulation applications. All of this activity suggests innovation, even in an industry as mature as insulation, and complements Owens Corning, Johns Manville, and other insulation players' strong presence throughout the rest of Ohio.

Market Opportunity

Though insulation represents a relatively mature industry, its large base and overall growth rate following construction activity can still drive regional job and revenue growth. In 2011, the available insulation market was estimated between $10 and $11 billion. Relevant market segments include foamed plastics, mineral wool, and other materials (e.g., cellulose, aerogels, and bagasse, many of which offer environmental benefits beyond energy efficiency). Fiberglass insulation was excluded from this assessment due to the lack of manufacturers in Northeast Ohio. Northeast Ohio's share of the available non-fiberglass market in 2011 was estimated at 1 percent. By 2020, the global non-fiberglass insulation market is expected to reach $33 to $41 billion. Because the industry is lower-growth and cost competitive, unit volume is expected to drive growth with continued new construction and existing building retrofit activity.

Building Efficiency Services

Northeast Ohio has a wide range of organizations in building efficiency services, which include comprehensive ESCOs, A/E firms providing building optimization services, and standalone building auditors. Of the 29 ESCOs and A/E firms, most offer a range of services outside of energy efficiency activity, with Go Sustainable Energy as an exception focused on EO in both building and industrial contexts. These services are all classified as enabling to a range of building efficiency technologies, and typically serve regional or statewide markets. They typically face limited competition from service providers outside the region.

The market available to regional suppliers will reach $250 to $380 million by 2020, driven largely by regulations and building codes requiring increased building efficiency and cost savings opportunities from existing building retrofits. This investment will allow Northeast Ohio to capture employment growth of approximately 1,300 jobs over that time frame. Due to the nature of the services business, local companies or local offices of national firms will continue to hold a dominant market share.

Each of the main areas of focus in Northeast Ohio's energy efficiency sector represent substantial market opportunity. Together, they constitute a potential technology demand estimated to grow to $21billion in 2020, translating to 82,000 new full-time-equivalent jobs available to Northeast Ohio.

Energy Conservation Program: Mechanical System Upgrades and Water Conservation Case Study

INDUSTRY HIGHLIGHT	
COMPANY: The Brewer Garrett Company LOCATION: Middleburg Heights, Ohio PROJECT/SERVICE: Mechanical System Upgrades and Water Conservation	OVERVIEW: As the largest manufacturer of aluminum in the United States, Alcoa is also one of the largest consumers of electricity in North America. Over 25 percent of the company's primary aluminum production costs are from electricity alone. At Alcoa's request, The Brewer-Garrett Company performed an analysis of the Alcoa Cleveland Works facility. Based on this analysis, Brewer-Garrett provided turn-key implementation of facility wide infrastructure upgrades. These upgrades address the immediate needs of the facility's infrastructure while providing guaranteed results in performance and energy reduction. The water and sewer conservation project is expected to save the Alcoa Cleveland Works facility 70 million gallons of water and 72 million gallons of sewage per year. By implementing this project, Alcoa Cleveland will save over $1 million per year. Brewer-Garrett is also implementing a lighting project, improving equipment efficiency, to upgrade overall energy efficiency and save Alcoa an additional $120,000 per year in energy costs.

Recommendations for Northeast Ohio's Energy Efficiency Value Chain

Given the strengths of most promising technology segments – solid state lighting, non-fiberglass insulation, and building efficiency services – within the EEBT sector, the team and stakeholders outlined the following recommendations for continued development and support beyond the roadmapping effort. Since the following section will focus more specifically on solid state lighting and LED lighting, these recommendations are targeted towards the remaining strengths in Northeast Ohio's energy efficiency technology segments.

Non-Fiberglass Insulation:

1. Identify and engage representatives of insulation, window, and siding manufacturers and service providers

   Next Step:

   - Establish a working consortium and conduct regular consortium meetings

2. Agree on which deep retrofit markets offer the most significant overall economic impact

   Next Step:

   - Conduct economic impact analysis of retrofit markets

3. Organize cluster members to support relevant federal and state policy objectives for renewal or enactment

   Next Step:

   - Organize consortium meeting focused on federal and state policy objectives

Energy Efficiency Services:

1. Engage building optimization service providers (e.g., ESCOs, A/E firms, auditors)

   Next Step:

   - Identify opportunities and funding sources to engage service providers through networking and cluster development functions

2. Identify /clarify local buying provisions and barriers (e.g., interstate commerce, supplier diversity provisions)

   Next Step:

   - Conduct analysis of procurement barriers and requirements

3. Develop appropriate vetting process for assessing regional technologies

   Next Step:

   - Collaboratively establish standards/definition for "regionally sourced energy efficiency content" (i.e., locally manufactured vs. distributed through channels)

3.4 Regional Value Chain Strengths

Although there are plenty of opportunities to capitalize on strengths or to remove weaknesses for Michigan and Northeast Ohio, both states have strengths that align with each other. In order to create a stronger, multi-state region, it's important to focus on these synergistic strengths and exploit them. In the long run, following through on recommendations associated with the following regional strengths may create a truly powerful sector in the multi-state region.

- **Significant R&D activity** – Whether it is top research universities, accelerators, or private sector efforts, both Michigan and Northeast Ohio have significant activity taking place in an array of different clean energy sectors.
- **Engineering talent** – Due to a strong automotive, supplier presence and industrial base, both states have strong engineering capabilities.
- **Manufacturing know-how** – Michigan and Northeast Ohio are often referred to as the "manufacturing crosshairs of America". And, through this research, the project team came across a wealth of companies with solutions to assist with manufacturing a product. In short, plenty of service and hardware solutions, combined with generations of human capital know-how exist to help make just about any product.
- **Untapped deployment potential** – Since much of Michigan and Northeast Ohio experienced economic decline, there are many residential, commercial, and industrial buildings within the building stock that are poised for retrofit. Currently, untapped energy savings are on the table and ample opportunity exists for each state to deploy its own product.
- **Innovation and entrepreneur scene** – Both regions have a strong support network that fosters innovation within the entrepreneur scene. And, they have accolades to show for it. Using the lighting sector as an example, both states have successfully won federal funding such as SBIR grants and/or have obtained national innovation awards.

3.5 Sector Analysis

The sector analysis began by first completing a breakdown of the Michigan-made products in the chosen sectors (LED lighting, building automation and HVAC). The products were torn apart both literally, in the case of LED lighting, and figuratively during interviews to understand the system, sub-system, components, materials, and manufacturing processes used to build the products. This allowed for mapping different products from raw material through to finished product and helps define the supply chain for each of the different systems, sub-systems, components and materials.

Once the supply chain was mapped, it was vetted with industry experts to ensure that the supply chain maps and implications from them match real world experiences. The building automation and the HVAC industries in Michigan do not lend themselves well to a true supply chain map. In building automation, a large portion of the delivered product is software with a very shallow supply chain. The project team's approach to the supply chain in this sector was to consider the final product a fully-automated building and to include companies such as installers and integrators. Within the HVAC industry, the analysis became a breakdown of the HVAC industry overall, or an ecosystem analysis. Because the HVAC industry in Michigan is very diverse, the supply chain map would have needed to be completed for a number of different and potentially esoteric products. To reduce complexity and gain an understanding of HVAC products manufactured in Michigan, the analysis is focused on the overall ecosystem.

Michigan

LED Lighting Sector

Before initiating the Clean Energy Roadmap project, Michigan knew strong activity existed within the lighting industry. A significant sector of innovators, engineers, and manufacturers were generating new lighting innovations and, in 2009,the MSSLA was formed. Additionally, according to the Harvard Business School and U.S. Economic Development Administration cluster analysis, the number of companies competing in the lighting industry in Michigan was 205 in 2013: well above the national median of 59.[42] Within the Clean Energy Roadmap database, NextEnergy identified 150 companies that are specifically within the LED lighting ecosystem. Despite the existence of a lighting cluster in Michigan, the challenges, weaknesses, and full potential of the sector were not known. Through the methodology outlined in this report, the lighting sector was identified as an area of EEBT focus and, overall, economic opportunity exists to grow the sector.

Supply Chain Analysis

Through this project, NextEnergy conducted a detailed analysis of the lighting sector in Michigan by conducting interviews, hosting events, and analyzing the supply chain. The following supply chain analysis was produced, visualizing where certain companies provide an offering.

Within Michigan, the lighting industry has been shifting to focus on LEDs as that industry grows. NextEnergy has found that a number of companies in the LED lighting market have been able to capitalize on existing automotive innovation in lighting, strong electrical component contract manufacturers, engineering talent in the state, and strong supporting organizations including the MSSLA, Illuminating Engineering Society (IES), and events such as the Michigan Advanced Lighting Conference.

These advantages have helped to open opportunities and create partnerships for companies within and outside of the state. Certainly, the strength of the lighting ecosystem in Michigan has made innovation and increasing intellectual property a strength in the state. Much of this has developed from the connections that can easily be made within Michigan's ecosystem and presents an advantage over states without an existing lighting sector. Additionally, the robust engineering talent and experience in other areas of electronics points to the potential for Michigan to grow the LED driver and light engine capabilities. Most of this part of the supply chain is currently outside the U.S. Capitalizing on the growing ecosystem and partnering with other parts of the electronics supply chain are steps to ensure a viable economic cluster.

Much of the current industry is focused on the commercial and industrial sector, leaving the residential sector being covered by large brands and companies that are not located in Michigan, such as CREE and Phillips. One notable exception is TOGGLED, which has been able to carve out a niche in the florescent tube replacement market and is currently introducing product to all 2,900+ Home Depot stores. This can be used as evidence that another area of opportunity is within the small innovators in Michigan. These companies have a good track record of developing IP and innovative products.

42 U.S. Cluster Mapping for Lighting Cluster-Harvard Business School U.S. Cluster Mapping for Lighting Cluster-2013, Accessed Nov. 2015

Figure 14: LED Lighting Supply Chain in Michigan

MATERIALS
- Plastics - BASF
- Si - Dow Corning
- SiC - Dow Corning
- Epoxy - Dow Chemical
- Phosphors - Dow Chemical

ELECTRICAL COMPONENTS
CHIP DIODE EMS
- • •

PCB
- Adco Circuits
- Amptech
- Debron Industrial Electronics
- EBW Electronics
- Lumasmart
- Malibu
- Saline Lectronics
- Saturn Electronics

POWER DRIVER
- Bosch
- Flextronics
- Infineon
- Landmark Energy Development

LIGHT ENGINE
- BGM
- EBW Electronics
- Innotec

WIRING ASSEMBLY
- NewTech3
- SpecialTree

SMART LIGHTING
SENSORS
- AMF Nano
- Electro-Matic

CONTROLS/SOFTWARE
- AMF Nano
- Arborlight
- Arrow Electronics
- Electro-Matic
- Illuminating Concepts
- Kanepi
- Light Corp
- Limelight
- Nextek Power Solutions
- Qualite Sports Lighting, LLC
- Relume

LUMINAIRE ASSEMBLY
- Arborlight
- Best Lights, Inc
- Duo-Gard
- EBW Electronics
- Estrakon
- Everlast Lighting
- High Q Lighting
- Innotec
- Kimberly Lighting
- Kirlin
- Ledos
- Lumecon
- Light Corp
- Light-Speed USA
- Lumerica
- Lumecon
- Midwest Circuits
- Paramount
- Relume
- Solar Street Lights
- Solartonic
- The Straights Lighting Company
- TOGGLED
- Venntis Technologies

TESTING
- Intertek
- TUV

PRODUCT LIGHT DESIGN
- Arborlight
- Best Lights
- Bluecolt Lighting
- Bratic Enterprises
- Duo-Gard
- Earthtronics
- EBW Electronics
- Estrakon
- Everlast lighting
- High Q Lighting
- Illuminating Concepts
- Innotec
- Landscape Forms
- LEaDer Lights, LLC
- LED Optical Solutions
- Light-Speed USA
- Magwerks
- Midwest Circuits
- Paramount
- Solar Street Lights USA
- Solartonic
- The Straights Lighting Company
- Venntis Technologies

MECHANICAL COMPONENTS
OPTICAL LENSES
- CoreLED
- Lexa-Lite
- Lumenflow

THERMAL MGT
- Century Foundry

ACTIVE COOLING
- • •

HOUSINGS
- Port City Group

MOUNTS
- Flash Bridge Co. Inc.

POLES
- General Structures Inc.
- Lyte Poles
- Qualite

KEY:
• • • No companies present

Source: NextEnergy

LED Lighting Industry Highlights

INDUSTRY HIGHLIGHT

COMPANY: Innotec Group

LOCATION: Zeeland, MI

PROJECT/SERVICE: Electrical components and luminaire assembly

OVERVIEW:

As a tier two automotive supplier, Innotec Group has a long history of making lighting products for the automotive industry. More recently; however, the company applied its automotive manufacturing expertise to develop new LED lighting products for niche categories including retail and shop lights. Innotec has been able to combine its manufacturing efficiencies, product innovation, and optical knowledge to deliver truly innovative products for the built environment and other markets outside its original focus of automotive.

In fact, in 2014 Innotec won an SBIR grant to develop a flexible circuit board technology it calls "Board Free." This innovation, which was nationally recognized through the federal funding, allowed Innotec to further R&D activity and deliver a first for the industry. The board free technology allows the company to design luminaires into spaces and applications that would have otherwise been impossible.

INDUSTRY HIGHLIGHT

COMPANY: Arborlight

LOCATION: Ann Arbor, MI

PROJECT/SERVICE: Product Design/Smart Lighting/Luminaire assembly

OVERVIEW:

Initially a spin-off from the University of Michigan, Arborlight has successfully developed a new luminaire product category: daylight emulation. Its Lightwell product provides daylight on demand in the form of a skylight. Arborlight developed the idea, innovated their product, and has developed a control system that makes the skylight-looking luminaire act as if it was a traditional skylight throughout the day.

Arborlight's success engaging in early stage R&D and combining sophisticated hardware and software technologies has paid off– it is the 2014 Next Generation Luminaire winner.

In addition to the supply chain analysis, NextEnergy conducted an analysis to detail strengths, weaknesses, opportunities, and threats for companies and stakeholders in the cluster with the ultimate goal of identifying gaps and opportunities for the industry in Michigan – both of which are critical to recommendations focused on growing the sector.

Figure 15: SWOT Analysis of Michigan's LED Lighting Industry

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
• Abundance of extremely skilled contract manufacturers • Availability of third-party testing labs • Funding opportunities are readily available • Diverse SC eco-system • Downstream components • Industry working groups • Industry events / structure • Engineering talent and innovation • Leveraging automotive innovation • Solid upstream R&D activity • IP development • Electrical components	• No chip / diode manufacturing • Weak upstream activity in diodes and electrical components • Original sourcing for electrical components • The state is not home to any national brands • Too much manual assembly activity • Companies in local supply chain are often overlooked	• Eco-system connections • Residential sector penetration • Expand driver/engine • Expand mechanical components • Thermal management • Onshore assembly / production • Automation • Small innovators receive market share • Pursue niche markets • OLED R&D • Connected lighting systems	• Lots of components from local distributors, but sourced overseas • Technology is changing rapidly • LEDs are becoming a commodity • All chips / diodes are sourced overseas • Big companies are not located in Michigan

Source: NextEnergy

Current employment statistics

Again, the Harvard Business School Cluster Mapping analysis provides some employment data on Michigan's lighting cluster, showing that the lighting industry in Michigan employs 5,946 people,[43] compared to the national median of 4,146. Within the Clean Energy Roadmap database, few lighting companies are reporting employment data either through past interaction or through surveying. The database does indicate that among those companies reporting data, the average number of employees per company is 28.9. This would translate into estimated employment of 4,335 people within Michigan's LED lighting industry.

Key findings from LED Lighting Supply Chain Analysis

- **Robust and diverse supply chain** – Michigan has a robust and diverse supply chain. Most areas of the supply chain are occupied by Michigan companies and there are multiple companies in each category.
- **LED light engines** – Most of the light engine manufacturing occurs overseas.
- **Assembly and manufacturing** – Most companies in Michigan are offering downstream product assembly and manufacturing.
- **Michigan value add** – Many Michigan companies are conducting manufacturing and assembly – where most of the value add takes place.
- **Niche markets** – Many Michigan companies have the potential to pivot their expertise/product offering and enter new product categories and/or develop a strong presence in niche markets.
- **Major industry player** – No global lighting company has a Michigan headquarters – most Michigan companies are smaller industry players.
- **Commercial/Industrial/Outdoor** – Most (not all) companies offer products for commercial and industrial facilities, most offering outdoor applications.
- **Periphery supply chain potential** – A wealth of secondary supply chain companies exist that could easily add to and strengthen the overall supply chain. These are unique to Michigan and the industrial Midwest and include tool and die, paint, etc. due to auto manufacturing.
- **R&D is opportunity** – Michigan companies are great at innovating and developing intellectual property. Companies have potential to leverage the R&D/innovation pipeline by selling innovation into big lighting companies, participating in technology challenges and securing R&D from multiple sources.
- **Assembly and manufacturing automation** – Many of the companies either assembling or manufacturing product in Michigan have the opportunity to implement either more automation technology or smarter, connected automation technology.
- **Design and manufacturing** – Many companies and products throughout Michigan have the opportunity to apply the auto industry's manufacturing knowledge to produce smaller, lighter mechanical components, which could lead to competitive advantages for the cluster.
- **Lighting controls and Software as a Service (SAAS)** – A select (and growing) number of lighting companies have product offerings with fully integrated sensor and control hardware and/or software platforms that can be licensed on a subscription basis. An opportunity exists to leverage Michigan supply chain assets to help fill this gap.
- **Sales channels** – For smaller Michigan companies with product offers (most of them), it's difficult establishing sales channels due to size of national brands and entrenched sales channels.

Recommendations for Michigan's LED Lighting Sector

1. **Drive R&D activity** – Staying on the leading edge of developing products is difficult. It's expensive, it requires determination, and it's often easy to revert to selling a current product. However, intellectual property is often developed in the early R&D stage, a benefit for a company and for Michigan. Specific support should be provided to encourage Michigan's lighting ecosystem to engage in R&D activity. In addition, more focus should be given to extracting innovative ideas from small business innovators, both on the federal and state level. The DOE could focus more funds on SBIR efforts and the state could provide matching funds and advisor assistance to pursue funding.

   Next Step:

   - Capitalize on matching fund programs and advisors to support Michigan entities pursuing federal R&D programs. Additionally, communicate regional R&D needs and interests to help SBIR program managers identify opportunities to focus more funding on lighting innovations.

2. **Convene on connected lighting systems** – The convergence of hardware, sensor, software, and communication systems is driving activity globally. Regular convening and training of Michigan's ecosystem should occur to keep the industry abreast of connected lighting systems and to help them bring their own solutions to market.

43 U.S. Cluster Mapping for Lighting Cluster-Harvard Business School U.S. Cluster Mapping for Lighting Cluster-2013, accessed Nov. 2015

Next Step:

- Organize convening sessions that occur on a quarterly basis and have the ability to spur partnerships through product development and demonstration opportunities

3. **Develop sales channels + partnerships** – Competing with the entrenched lighting industry and developing sales channels for niche or small manufacturers can be difficult. Providing expert assistance to develop relationships with distributors and product reps is essential – and a very necessary step to help grow deployment both within the state and exports outside of the state. MAE could provide sales channel development advisors specifically for small businesses and leverage the MEDC Pure Michigan Business Connect, First Customer and Export programs to specifically assist the lighting ecosystem.

   Next Step:

   - Conduct strategy sessions to develop a broader sales channels implementation model that leverages the above recommendations

4. **Strengthen "Buy Michigan" program** – Having a strong stateside deployment conduit for many smaller Michigan companies is very important. Often, the entrenched sales channels mentioned above do not include or can out-market the smaller companies. Since the State of Michigan has a large building portfolio, highway system, and a range of other assets, a "Buy Michigan" program for lighting would provide companies a critical opportunity to establish market share and compete with out-of-state companies.

   Next Step:

   - Utilize research from the Clean Energy Roadmap to conduct more detailed analysis on current purchasing channels and develop strategy for a "Buy Michigan" program

5. **Encourage continued engineering innovation** – Michigan has a high concentration of engineering talent, manufacturing expertise, and automation solutions – much of which helped develop the original lighting sector. There is still significant room to help drive more innovation and product development in lighting systems. Through a mechanism such as technology challenges, we can encourage manufacturers to apply the same engineering and manufacturing rigor to a light fixture that typically gets applied to an automobile. MAE and/or the DOE could support ongoing lighting technology challenges to continue innovation development by small businesses and innovators.

   Next Step:

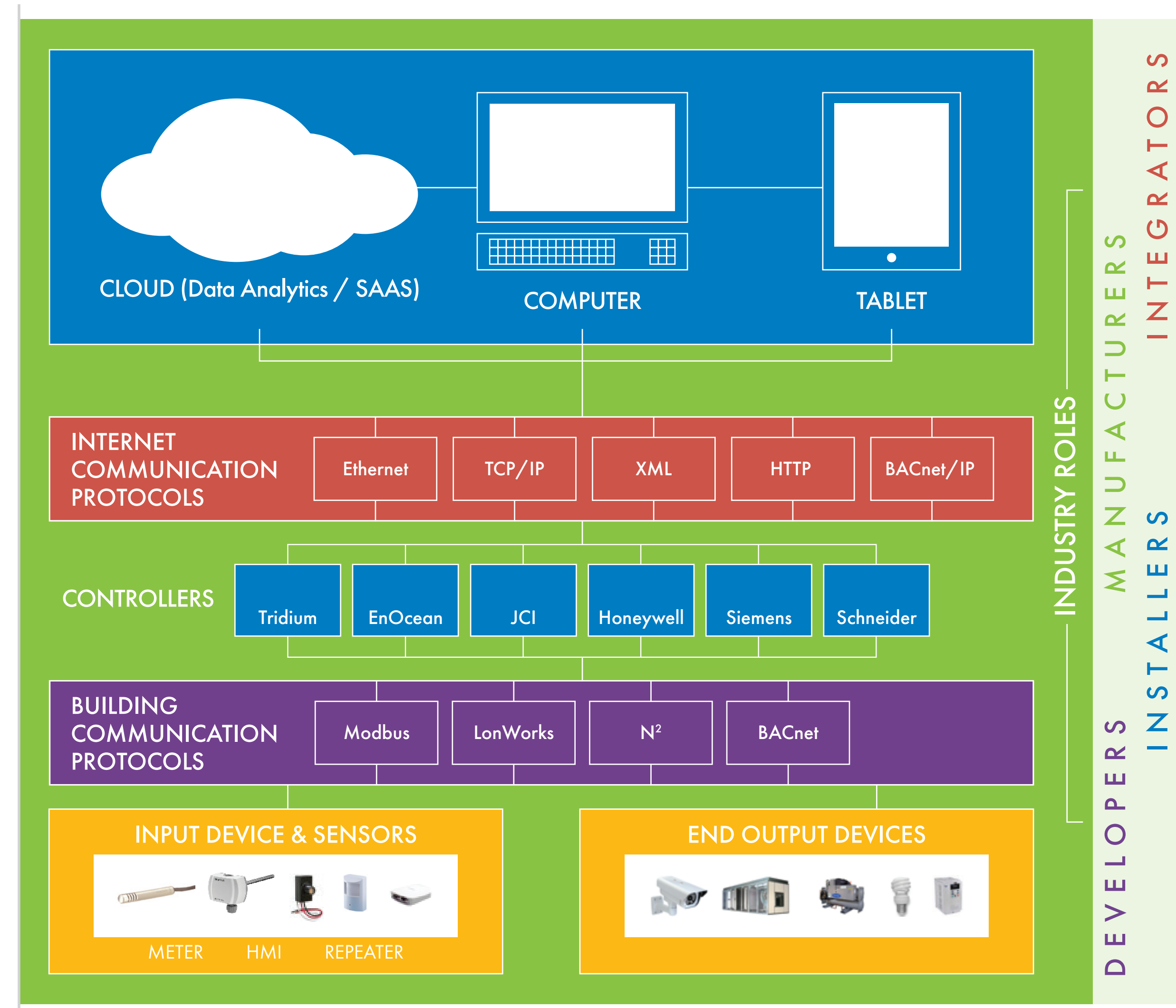
   - Develop strategy for technology challenge and secure funding to support program management and prize money

Building Automation Sector

Although the building automation sector has been well established by key industry strongholds such as Johnson Controls, Siemens, Honeywell, and others for a long time, a new wave of innovative products, wireless technology, and software platforms are challenging the status quo. A significant evolution is taking place that is unleashing the ability to capture great energy savings, provide more functionality for end users, and deliver price points that will help penetrate the 90%[44] of commercial building market that currently doesn't have building automation. Given the companies that were identified during the project's asset mapping, and the technology potential that was identified during technology roadmapping, building automation became a key focus area for a broader look at the supply chain.

44 Small- and Medium-Size Building Automation and Control System Needs: Scoping Study – U.S. Department of Energy – Accessed December 2015.

Figure 16: Key Building Automation Sector Components



Source: NextEnergy

Building Automation Supply Chain Analysis

End Output Devices and Sensors/Controls – Building automation systems are fairly simple. Looking at the lower portion of Figure 16, a variety of end devices exist in a building with some type of sensor and control system. In the past, these sensors and controls were wired into an end device. However, technology has advanced to a point where wireless sensing and control is possible. In addition, sensors are becoming more and more capable, smaller, and cheaper. The combination of increased capability, lower price points, and wireless connectivity is creating a much stronger value proposition for a building automation system through a combination of new features and a relatively quick return on investment.[45]

45 Based on WiSuite published information

Controller – Similar to a computer, the controller box is the "brains" of a building automation system and, traditionally, major industry companies such as Johnson Controls or Siemens have completely dominated this product space. However, due to a variety of reasons, some companies are starting to develop competitive products that are more capable and much cheaper. Controller boxes also communicate via a particular language (Modbus, LonWorks, BACnet) with the sensors and end devices. Over time, this has created some very entrenched industry alliances.

Installers – Traditionally, the HVAC and electrical installer community has implemented building automation systems (the combination of controllers and hardware). They are a critical element to deploying more systems. However, the advent of new sales channels, product offerings, and software platforms will change their typical "go to work" strategy.

Software/SAAS – Software and the services that surround them are emerging rapidly for building automation solutions. Whether it is attractive user interfaces that "bring to life" energy use and operational data or data analysis companies that help building owners optimize building performance remotely via SAAS, a wide range of services are entering the market. In short, these new solutions are unlocking new potential for existing hardware and sensor equipment.

Integrators – Contractors and installers that have a strong skill-set in the software space are able to integrate all of the equipment sensor nodes seamlessly with controllers and new software interfaces. This is an emerging category of service providers. Current integrators exist as a full-service operation and are able to offer all of the above software and hardware services with one phone call. Only a few exist in Michigan, but they are growing in numbers and remain busy. Establishing a more robust network of integrators will be essential to growing the building automation systems cluster.

Building Automation Industry Highlights

INDUSTRY HIGHLIGHT

COMPANY:
Smart Building Solutions

LOCATION:
Grand Rapids, MI

PROJECT/SERVICE:
Building Automation Integrator

OVERVIEW:
Smart Building Services is a full service provider (integrator) of efficiency solutions that leverage intelligent automation and technology to construct, operate and maintain high performance buildings. In addition to integrating energy-related equipment onto a single platform, Smart Building Services also incorporates other key systems such as security and fire/safety systems into a web-based platform. By bringing the multi-faceted solution to a building owner, they are able to break down traditional, siloed go-to-market strategies that more traditional companies are offering.

Smart Building Services is an example of a company that is creating the new role of a full service integrator. They offer a "turn-key" solution for building owners by combining the full design and installation of building automation hardware with custom software integration.

INDUSTRY HIGHLIGHT

COMPANY:
WiSuite

LOCATION:
Warren, MI

PROJECT/SERVICE:
Smart Thermostat (Sensor/Controller)

OVERVIEW:
WiSuite is an emerging provider of energy management solutions for the hospitality industry. Through WiSuite's Wifi enabled thermostat, WiSuite solves energy management challenges by giving hotel guests regulated comfort and provides hotel management with real-time guest room monitoring.

WiSuite is relatively unique in the hospitality market, with only a couple of large national competitors. WiSuite's innovation of a controllable HVAC thermostat, with an incorporated communication and software platform, has been proven in the market to provide hotels with improved energy efficiency for unoccupied hotel rooms.

In addition to the ecosystem analysis, NextEnergy utilized a SWOT analysis to detail strengths and weaknesses with the ultimate goal of identifying gaps and opportunities for the sector – both of which are critical to recommendations focused on growing the sector.

Figure 17: SWOT Analysis of Building Automation Sector in Michigan

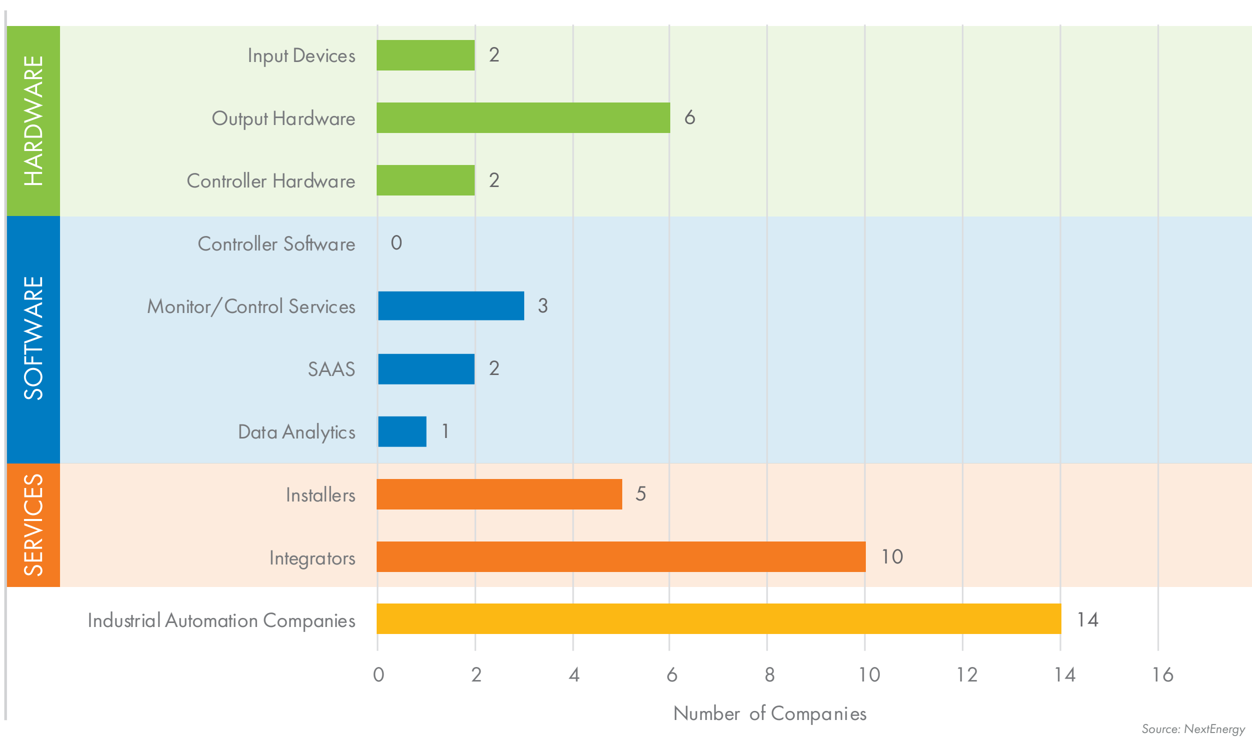
STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
• A few of Michigan's companies are considered leaders in this space either from a service or product offering • Michigan has deep electronics expertise and companies to produce product • Significant engineering presence • Emerging software / IT capabilities in Detroit, Ann Arbor, and Grand Rapids • Key "integrator" companies have won national awards	• No major industry company • Limited number of companies currently working in the space • Limited number of buildings in MI have a building automation system	• Encourage pivot of software expertise in Detroit, Ann Arbor, and Grand Rapids to be applied into the building automation space • Opportunity to cross-over deep knowledge of manufacturing automation into building automation space • Exploit engineering talent and the ability to develop advanced sensor technology • Leverage existing contractor community for more building automation installations • Encourage more partnership opportunities between electronics, software, and sensor companies • New service and product offerings may help establish market presence	• Entrenched industry and sales channels • Significant software plays emerging on US east and west coasts • Fully integrated building automation projects could be viewed as too difficult or complicated by both contractors and building owners • The building automation market is rapidly evolving • The new wave of technology is still evolving and price points are still dropping potentially eroding margins for cluster players • Cyber security concerns

Source: NextEnergy

Current employment statistics

The employment statistics for the building automation cluster in Michigan are difficult to come by because the market, while growing, is small with a comparatively few number of companies competing in the market. The Clean Energy Roadmap database has 47 companies reporting employment statistics with an average of 43 employees (20 median) in the Software, Sensors, and Controls sector. These are not all building automation companies, and therefore, the statistics are not specific to this sector. Within the Clean Energy Roadmap survey, 15 companies reported having energy management system products with a median number of employees of 11. Eight companies report offering building or lighting automation products with a median number of employees of 14. There is some crossover with these companies and factory automation (three companies report offering both). All of this points to the challenges of characterizing a sector that is still developing. Further research efforts to identify specific employment and economic impact of this burgeoning cluster are required.

Figure 18: Overview of Companies in Building Automation Cluster



Key Findings from Building Automation Supply Chain Analysis

- **Established industry vs. newcomers** – Most "established" building automation companies such as Johnson Controls, Rockwell Automation, and Siemens are located in other states. Michigan will most likely not change the location of these companies through attraction. However, Michigan integrators have won national awards and some new technology developers are possibly poised to shake up the industry.
- **Emerging Technology** – Through the process of identifying companies and interviewing them, Michigan has a handful of emerging technology developers in the building automation space that are poised to help transform both the solutions delivered to customers and the go-to-market strategies within the industry.
- **Deployment potential** – As noted earlier in the report, Michigan has a robust installer base and a few, rather innovative, integrators. However, many of Michigan's contractors don't have the required software knowledge of building automation systems. Thus, scaling up any type of building automation effort will require pivoting contractors to focus on building automation systems and filling the education gap.
- **Greater need for integrators** – Only a few full-service integrators exist in Michigan and more are needed to reach the broad commercial and industrial building market in Michigan and to help encourage greater talent attraction in this burgeoning industry cluster.
- **Electronics/sensors/controls** – Throughout the project, a significant number of companies were identified that have expertise in manufacturing electronics, sensors, and controls – all critical components to advanced building automation systems.
- **Small commercial buildings** – Due to the fact that technology developers are bringing more capable, cheaper products to market and integrators are developing new go-to market strategies that may be counter to the traditional business models of larger building automation companies. An opportunity exists to penetrate the small and medium commercial building space – one that has often been underserved.
- **SAAS/data/web services emerging** – The software solutions that accompany traditional building automation hardware are flourishing and, some would argue, driving much of the activity in this ecosystem. Much of this software is developed on the east and west coast, but Michigan has a strong software/IT scene developing in Detroit, Ann Arbor, and Grand Rapids with a similar core skill set that could easily be pivoted to develop building automation solutions and data analysis dashboards.
- **Process automation strengths** – If you make a product in Michigan, there is a company to help you automate the process. Many of the same core elements – software, sensors, and controls – similarly exist in industrial automation as they do in building automation. Some of the talent and expertise could be leveraged.

Recommendations for Building Automation Sector

1. **Develop Michigan building automation demonstrations** – Building automation technology is developing rapidly, but it is not yet widely deployed, particularly in small- or medium-sized commercial buildings. Physical demonstration sites or software demonstrations of fully-integrated building automation systems that could be used as a means to promote building automation and educate end users, contractors, and architects would be valuable. Both the DOE and MAE could encourage building automation demonstrations through a dedicated source of funding.

   Next Step:

   - Conduct strategy session between the State of Michigan and the DOE on establishing building automation demonstrations
2. **Provide building automation sector support** – Michigan's building automation sector is disparate and still evolving. Companies are developing sensors; integrators are developing new models for deployment; software developers have the skill set for SAAS platforms; and technology companies are developing solutions to compete with mainstream providers. The sector in Michigan would be well-served to have regular support from MAE to foster its growth in terms of more robust understanding of potential Michigan supply chain players, Michigan market potential studies, and regular convening activities to encourage partnership development.

Next Step:

- Encourage matchmaking sessions and capitalize on existing state funding programs, such as the Michigan entrepreneurial support programs to support cluster companies

3. **Encourage software/IT development** – Michigan is fortunate to have a budding software/IT scene, predominately in Ann Arbor, Detroit, and Grand Rapids. Some companies such as Resolute and Vectorform, have applied their expertise into the energy arena. However, specific encouragement should be developed such as a technology challenge or app development event. The MEDC, in cooperation with regional entities such as Ann Arbor SPARK, should host industry gatherings to spur collaboration between the existing IT/software ecosystem and the budding building automation sector.

   Next Step:

   - Conduct matchmaking events through local technology accelerators

4. **Contractor education** – Deployment of advanced technologies, such as wireless sensor/control building automation systems, is dependent on a contractor/service provider knowing what to sell and how to sell it. A specific training program should be developed that teaches traditional HVAC, mechanical, and electrical contractors how to sell and install these low voltage, software based systems. This is a recommendation that could be adopted at a national scale by the DOE or at the state level by MAE.

   Next Step:

   - Conduct strategy session with the State of Michigan, the DOE and local contractor groups to determine best solution for training.

5. **Leverage existing automation strengths** – Since the core elements – software, sensors, and controls – share fundamental principles across software and integration applications, there is an opportunity to utilize existing automation expertise in Michigan to pivot into or grow new products for the building automation sector by convening automation and building automation experts through an annual event.

   Next Step:

   - Organize and conduct an annual building automation event that attracts existing industrial automation experts.

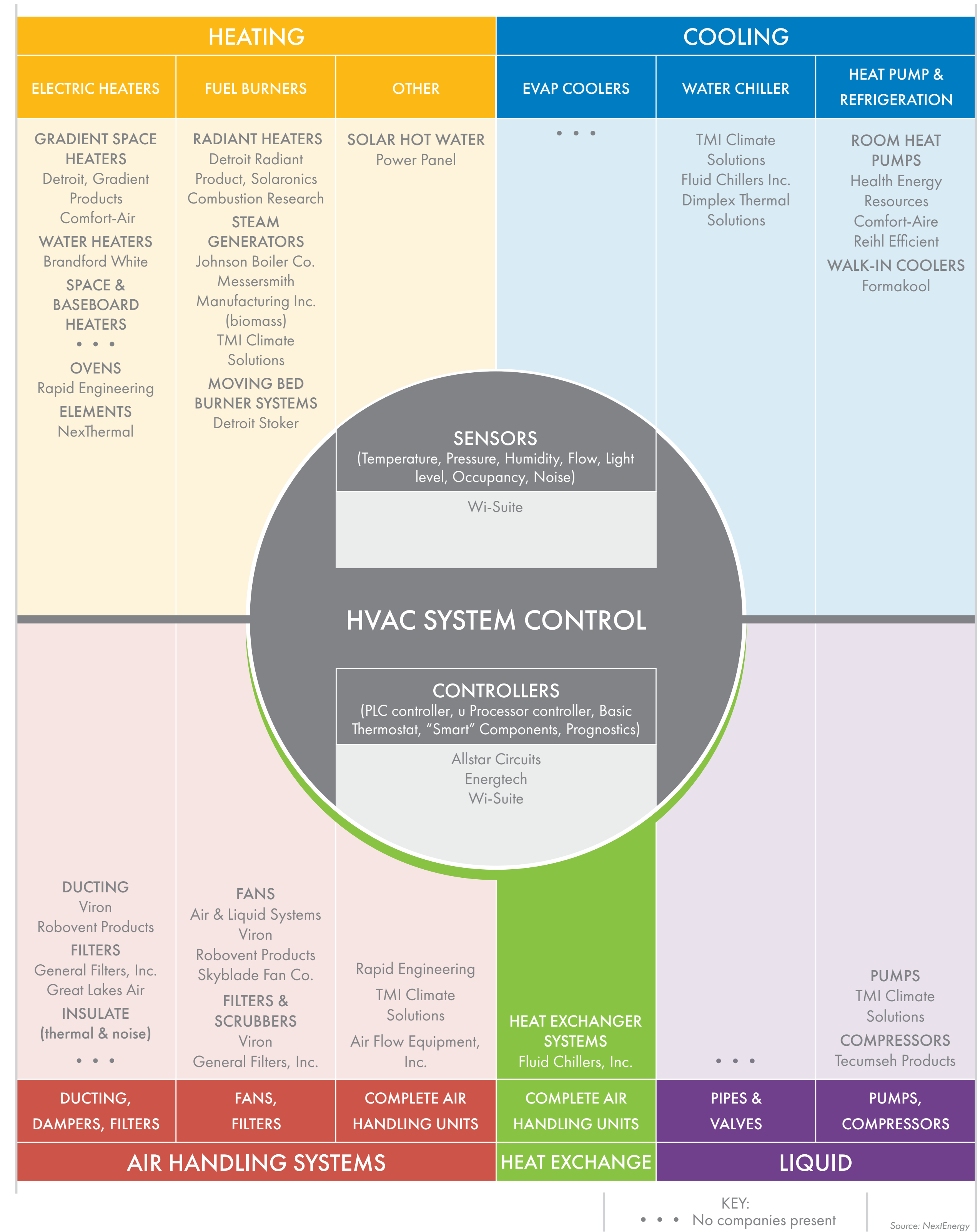
HVAC Sector

Of the energy consuming devices in buildings, HVAC systems are among the most consumptive. HVAC accounts for 31%[46] of commercial building energy use and 48%[47] of residential energy use according to the U.S. Energy Information Administration (EIA). This makes these different apparatuses prime targets for efforts to increase energy efficiency.

Within Michigan, the HVAC sector is focused in primarily two key parts of the value chain: installation and commercial and industrial system engineering. However, there are also a variety of companies manufacturing products in Michigan.

46 Commercial Buildings Energy Consumption Survey- EIA-2003-Accessed Oct. 2015
47 Residential Energy Consumption Survey-EIA-2009-Accessed Oct. 2015

Figure 19: HVAC Supply Chain in Michigan



HVAC Sector Analysis

Rather than analyzing the supply chain of a particular product, which would have excluded a number of sector participants, this section focuses on understanding the larger HVAC ecosystem that exists in Michigan. Since a plethora of products exists, focus was provided to the companies assembling and manufacturing product in Michigan. There are three main processes that are carried out by HVAC equipment: heating or cooling air or liquid, moving the heated/cooled air or liquid, and controlling the whole process. Within the heating/cooling process equipment (the top tier of Figure 19) includes the following:

- **Electric heaters** –Products ranging from radiant heating products to water heaters and electric heating elements
- **Fuel Burners** – A few companies in Michigan produce fuel burners that serve everything from boilers and steam generators to energy generation equipment
- **Heat pumps and refrigeration** –Some specialty products in this category may include room heat pumps for classrooms and refrigeration equipment for grocery stores
- **Water chillers** – TMI Climate Solutions produces a range of water chillers that can be used to provide cooling for air conditioning

Once something (air or liquid) is heated or cooled, it must be moved to eventually influence the temperature of the occupant. In this section, Michigan has companies producing the following items:

- **Air handling units** – A few companies in Michigan produce customer air handlers for commercial buildings
- **Ducting, dampers, and filters** – A variety of companies in Michigan focus on producing solutions for the larger commercial and industrial space
- **Fans** – A few companies in Michigan produce either destratification fans that eliminate hot or cold air layers in large commercial facilities or larger fans for industrial operations
- **Heat exchangers** – Essentially a coiled set of tubes for carrying hot or cold liquid that then heats or cools the air passing over them (or exchanges the heat with the air); there is one manufacturer (Fluid Chillers, Inc.) that manufactures industrial heat exchanges in Michigan
- **Pumps and compressors** – Most of these solutions are used to pump fluids through an HVAC system or to compress refrigerant; most companies in Michigan are serving the industrial market
- **Pipes and valves** – These components also serve an important role in the ecosystem, but the project did not specifically evaluate them

Once air or liquid is heated or cooled and moved, the last tier of the HVAC ecosystem involves utilizing sensors and controls to properly operate the system.

- **Sensors** – A variety of Michigan-based companies have sensor platforms. These range from large Michigan-based companies such as Bosch to smaller, innovative companies such as WiSuite, which has a new product for controlling the temperature in a hotel room
- **Electronics** – Due to the wealth of manufacturing activity in Michigan, there are a lot of companies that perform electronics assembly and manufacturing – all critical components for a sensor and controls system
- **Controls** –Similar to the electronics section above, manufacturers of controls systems are prevalent; these controls are often incorporated into a larger building automation system as described in the building automation section

HVAC Industry Highlights

INDUSTRY HIGHLIGHT	
COMPANY: SkyBlade Fans LOCATION: Warren, MI PROJECT/SERVICE: Fans	OVERVIEW: SkyBlade Fans manufactures High Volume Low Speed (HVLS) destratification fans. Their 12-24' fans assist heating and cooling systems by reducing run times, cycles, and improving overall comfort. SkyBlade Fans is an example of a Michigan-based manufacturer that is producing a niche HVAC product. Although destratification fans may not play as significant role in the market as larger HVAC components, SkyBlade's products still deliver proven energy savings in commercial/industrial facilities.

INDUSTRY HIGHLIGHT	
COMPANY: Johnston Boiler LOCATION: Ferrysburg, MI PROJECT/SERVICE: Boiler	OVERVIEW: Johnston Boiler Company manufactures large, custom firetube boilers to meet their diverse range of client needs. Johnston Boiler is focused on industrial applications where steam is used for electricity generation and heating and it pioneered the first water backed boiler over 100 years ago. The bulk of Johnston Boiler Company's capabilities includes large scale metal fabrication in their facility and application engineering for the CHP systems that their boilers serve. The company is an excellent example of a Michigan manufacturer that is conducting all of the upfront engineering and R&D in house while also carrying out 100% of the manufacturing process.

In addition to the ecosystem analysis, NextEnergy utilized a SWOT analysis to detail strengths and weaknesses with the ultimate goal of identifying gaps and opportunities for the sector – both of which are critical to recommendations focused on growing the sector.

Figure 20: SWOT Analysis of HVAC Sector in Michigan

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
• MI has strength in process and product engineering, including strength in combustion systems for industrial applications • All the parts of the supply chain exist in varying degrees • Most MI products are niche products positioning companies well against large competitors • Wealth of engineering and engineering education	• No one vertically integrated entity capitalizing on multiple parts of the supply chain • Limited residential market focused companies (almost no residential players) • Companies are often without well-established sales channels and are not sure of best path-to-market • Some companies have a relatively small geographic reach	• Well-positioned for CHP integration and engineering, leveraging large MI industrial base • Grow sales channels for niche product companies and establish greater supply chain relationships • Industrial niche products have potential to expand into commercial market as well • Opportunity for partnership or value chain activity in the market with numerous complementary products • Link sensors and controls with manufacturers to bring smart building tech to the market • Potential for growing exports (both out-of-state and country)	• Uncertainty around energy efficiency regulations and potential for new building codes impacts investment in energy efficiency technology • Supply chain not established to serve mainstream competitors in MI • Workforce and sales force is not currently focused on energy efficiency • Strong competitive threat from national/multi-national brands and other states

Source: NextEnergy

Current Employment Statistics

The employment figures in the HVAC sector are difficult to parse out because most of the databases that track HVAC are looking at the installer value chain level, rather than the manufacturer, and few HVAC manufacturers responded to the survey despite multiple invitations. For this reason, much of the employment data for HVAC manufacturers is from the existing NextEnergy data collected over several years. This data may be used as a general rule of thumb for sector comparison. The resulting Clean Energy Roadmap database contains 49 HVAC manufacturers, of which 24 have reported employment data over the years. Of these, the average number of employees is 48 and the median is 20. This would imply a potential sector impact of up to 2,352 in Michigan.

Key Findings from HVAC Sector Analysis

- **Regulatory environment** – Due to the fact that HVAC comprises a large percentage of energy use, these technologies are poised to provide significant solutions for energy efficiency requirements and assisting in meeting Clean Power Plan requirements. However, the current regulatory environment is "in flux" and presents an uncertain business environment in which to operate.
- **Manufacturing** – Companies in Michigan are engineering their products and often carrying out the entire manufacturing process.
- **Major industry** – Major industry players (Honeywell, UT, etc.) have a Michigan presence (usually a sales or service office), but headquarters are all out of state.
- **Niche products** – Most Michigan companies offer "niche" products, such as specific types of fans, heat exchangers, or boilers, and few complete commercial HVAC systems or significant portions of HVAC systems, such as complete air handling systems.
- **Sales Channels** – Most HVAC companies are smaller and offer niche products, making access to robust sales channels challenging or expensive to use.
- **Integrated system design** – Specialized integrators are rare and building A/E firms fill that role. Many larger A/E firms have a Michigan presence, but are not headquartered in Michigan.
- **Control systems** – Many current products offer an opportunity for integration of control systems, and many are likely to be included in control systems of some kind (even a simple thermostat can be considered a control "system").
- **CHP**– Michigan has a variety of assets, both manufactured hardware and services, that point to opportunity for CHP growth.
- **Industrial strength** – Michigan has both HVAC products that target the industrial building segment, as well as industrial plants that utilize the products. Additionally, automotive manufacturers and suppliers are often headquartered in Michigan with plants located throughout North America.

Recommendations for Michigan's HVAC Ecosystem

1. **Develop CHP cluster** – CHP systems present lots of potential and Michigan has a variety of hardware and service providers that are poised to deliver solutions in this space. The state should apply focus and funding to assess CHP-specific assets, organize the cluster through quarterly meetings, and generate customer education/awareness opportunities through system demonstrations.

   Next Step:

   - Assess existing CHP assets and conduct convening meetings

2. **Foster control system partnerships** – Many HVAC products being developed and manufactured in Michigan stand the opportunity to have control systems integrated. Either the products already have a control system and a new, Michigan partnership is possible, or the addition of a control system would create a competitive advantage for the product. The State of Michigan should consider providing assistance to develop partnerships between control system companies and HVAC manufacturers through advisors providing matchmaking strategy and assistance. Matchmaking with sensor and controls firms, hardware manufacturers, and system integrators could provide a more competitive position in industrial and commercial markets. Inviting these companies to participate in building automation matchmaking could further strengthen the market position of both the HVAC and building automation sector participants in Michigan.

   Next Step:

   - Develop strategy for initiating HVAC advisor program

3. **Develop sales channels + partnerships** – Competing with well-known, nationally-branded HVAC companies and developing sales channels for niche or small manufacturers can be difficult. Providing expert assistance to develop relationships with distributors and product reps is essential – and a very necessary step to help grow deployment both within the state and exports outside of the state. The state should develop an advisor program to help HVAC companies establish their sales channels while also leveraging the existing Pure Michigan Business Connect, First Customer, and Export programs to specifically assist HVAC companies.

   Next Step:

   - Conduct strategy sessions to develop a broader sales channels implementation model that leverages the above recommendations

4. **Create "Buy Michigan" program** – Having a strong state side deployment conduit for many smaller Michigan companies is very important. Since the State of Michigan has a large building portfolio, a special "Buy Michigan" program for HVAC equipment would provide companies a critical opportunity to establish market share and compete with out-of-state companies. The State of Michigan should establish a preferred vendor program or a preferred bidding process for Michigan companies.

   Next Step:

   - Utilize research from the Clean Energy Roadmap to conduct more detailed analysis on current purchasing channels and develop strategy for a "Buy Michigan" program

Northeast Ohio

Ongoing review of the roadmapping process resulted in the conclusion that solid state lighting, with a particular emphasis on LED lighting, represents an emphasis for regional cluster development. LED lighting plays to the region's strengths in contract manufacturing, technology development, and system integration capabilities. Patents originating in Northeast Ohio are cited frequently on other lighting patents, indicating strength in IP, and the growth rate of LED lighting in Northeast Ohio is projected to be substantially higher than originally forecasted in 2011.

LED Lighting Sector

The evidence of a rapidly growing global and U.S. LED market has mounted. Reports from Navigant Research,[48] Frost and Sullivan,[49] and Goldman Sachs[50] project compound annual growth rates of 24-40% for global LED lighting over the next 5-8 years, all of which are substantially steeper than the 12.6% projected in the original NorTech roadmap. These reports point to evidence that efficacy, quality, and pricing of LEDs are already noticeably improved, and being combined with more attractive service packages and warranties to speed adoption over traditional technologies. In May 2013, the DOE projected LEDs would account for 75% of lighting sales by 2030,[51] while Goldman Sachs projected 70 percent LED lighting market penetration may be possible by 2020.[52] While market definitions and current size estimates still vary, all of these reports, plus the 10-Ks of companies like Cree and Philips, suggest LED lighting technology is still in the early stages of a steep adoption curve in a highly competitive and rapidly consolidating space. In this context, there is no time to lose if Northeast Ohio wishes to establish a recognized market identity as a leading LED region.

In Northeast Ohio over the last 24 months, there has also been noticeable growth in the region's LED lighting assets. Some growth has come from already-established LED companies, while several other companies have joined the LED space since then – either as traditional lighting companies, non-lighting companies, or as new start-ups. A Chinese manufacturer has relocated substantial operations to Northeast Ohio. The updated asset inventory below illustrates this trend, representing valuable regional momentum on which to build.

Northeast Ohio has seen little recent movement toward cluster development around insulation technologies or building energy efficiency services. Given the insulation industry's maturity, it is less clear there is an effective role for collaborative activity to play in promoting revenue or job growth beyond what is already to be expected from market growth associated with new build activity. While working to promote local efficiency service providers is still a worthy goal – especially the role these service providers play in LED lighting – Team NEO's cluster development focus is on traded goods, given the inherent opportunity to draw revenues in from outside of the region, and promote associated job growth. Except to the extent that building efficiency service providers can enable the increase in sales of technologies such as LED lighting, the services industry specifically is no longer considered a focus for regional cluster development.

Northeast Ohio's LED-related growth has been led by existing global lighting manufacturers' shifting emphasis toward solid state products. These include GE Lighting, with global headquarters at Nela Park; Eye Lighting, the North American Division of Iwasaki Electric Company of Japan; and Technical Consumer Products, which was originally a compact fluorescent lighting manufacturer, but now focuses on LED products. Venture Lighting is the region's fourth major lighting manufacturer, but its migration to LED products has been limited so far.

48 LED Supply Chain Dynamics-Navigant Research-April 2013-Accessed Oct. 2015

49 Frost & Sullivan: Global LED Lighting Market is Ablaze-Shane Henderson, FMLink-February 7, 2014 Integrated Solutions Providers Gain Competitive Edge in the Global LED Lighting Markets, Finds Frost & Sullivan-Frost and Sullivan Press Release-January 21, 2014-Accessed Oct. 2015

50 "GOLDMAN: The 8 Extraordinary Technologies Forcing Businesses to Adapt or Die." Rob Wile, BusinessInsider.com-August 8, 2013-Accessed Oct. 2015

51 Adoption of Light-Emitting Diodes in Common Lighting Applications-U.S. Department of Energy-Revised May 2013-Accessed Oct. 2015

52 Goldman Sachs Optimistic about LED Growth in 2014-Judy Lin, LEDinside-October 1, 2013-Accessed Oct. 2015

Regional LED assets also comprise a range of subsystem and component manufacturers, as well as specialty material capabilities at Momentive Performance Materials, PolyOne, Ovation Polymers, Shin-Etsu Silicones, and GrafTech. Other core technology providers include STERIS, Intellitronix, and Darkside Scientific, which have developed niche LED products for specific industries. Furthermore, as noted in the original roadmap, companies such as Energy Focus and Momentive Performance Materials have continued to receive federal technology development grants focused on LED lighting.

Together with enabling service providers such as Valtronic, Rambus, AVID Technologies, SmartShape, and The Lighting Innovations Institute, these organizations characterize a region ripe for robust LED supply chain development. The first three of these enablers are leading electronics manufacturers who have only recently begun work on LED related projects; they represent some of the region's historic strengths adapted to meet the needs of this emerging industry. Specialized distributors, as well as lighting retrofit providers like Heirloom Energy, Carbon Vision, and Lighting Services, play enabling product specification roles to influence new technology development and commercialization as well.

Figure 21: Advanced Lighting Supply Chain in Ohio

MATERIALS
- Graftech
- Momentive Performance Materials
- OhVations
- Polyone
- Shin-Etsu Silicones

ELECTRICAL COMPONENTS
CHIP DIODE
- • • •

PCB
- Arrow Electronics
- Libra Industries
- RBB Systems
- RPC Electronics
- Techtron Systems, Inc.
- Valtronic Technologies USA, Inc.

POWER DRIVER
- Delta Systems
- Valtronic Technologies USA, Inc.
- Venture Lighting Int'l.
- Wireless Environment

LIGHT ENGINE
- • • •

WIRING ASSEMBLY
- SpecialTree
- Thermtrol, Inc.
- Tip Products
- Western Reserve Wire Products

PRODUCT LIGHT DESIGN
- Advanced Lighting Technologies, Inc.
- Arrow Electronics
- AVID Technologies Inc.
- Bluetronix
- Essential Research, Inc.
- Eye Lighting
- GE Lighting Solutions, LLC
- Lighting Innovations
- Lighting Services, Inc.
- Nottingham - Spirk
- Smart Shape
- Valtronic Technologies USA, Inc.
- Vincent Lighting Systems

LUMINAIRE ASSEMBLY
BUILT ENVIRONMENT
- Bock Lighting
- Cleanlife LED
- Energy Focus
- ETI Solid State Lighting
- Eye Lighting (Iwasaki Electric)
- GE Lighting Solutions LLC
- Global Lighting Technologies
- Green Rock Lighting
- Hinkley Lighting
- King Luminaire/StressCrete
- Lumination, Inc.
- Megalight, Inc.
- Rambus
- Starbright Lighting USA
- STERIS Inc.
- Technical Consumer Products, Inc.
- The L.D. Kichler Co.
- US Lighting Group
- Valtronic Technologies USA
- Wireless Environment LLC

TESTING/VALIDATION
- CSA Group
- Lighting Innovations
- Tech Belt Energy Innovation Center

MECHANICAL COMPONENTS
OPTICAL LENSES
- Global Lighting Technologies
- Kent Displays
- Lumitex
- Rambus Lighting
- Venture Lighting Int'l.

THERMAL MANAGEMENT
- Graftech

ACTIVE COOLING
- GE Lighting

HOUSINGS
- Aerolite Extrusion Company
- Astro Manufacturing
- Astro Shapes Inc.
- Automation Plastics
- Extrudex Aluminum
- General Extrusions Inc.
- GSH Industries
- J and O Plastics
- J&M Castings
- Jaco Manufacturing
- Lerner & Associates
- Magnode Corporation
- Mercury Plastics
- Middlefield Plastics
- Plastic Extrusion Technologies
- Steere Enterprises
- Technology House
- Thogus

SMART LIGHTING
SENSORS
- GE Lighting
- Greenrock Lighting
- Philips Lighting
- Rambus
- TCP Lighting

CONTROLS/SOFTWARE
- Arrow Electronics

COMMUNICATIONS/CAMERAS
- Green Rock Lighting

KEY:
• • • No companies present

Source: NextEnergy/Team NEO

As a result of the ongoing Northeast Ohio roadmap work in LED lighting, additional assets have been identified, signaling significant growth in the industry since 2011:

- 60 unique organizations in manufacturing (vs. 17 in 2011)
- 680 full-time equivalent workers (vs. 330 in 2011)
- $223 million in revenue and research funding (vs. $141 million in 2011)

The number of organizations and estimated employment focused on core LED technologies and enabling services has grown beyond what was estimated in the original roadmap work. This activity, which includes a mix of major lighting manufacturers, enabling electronics and materials capabilities, and funded R&D activity, indicates burgeoning regional momentum, well-positioned to capitalize on a rapidly growing global market. However, given the increasingly competitive global landscape, effort to bolster Northeast Ohio activities with targeted cluster development must be made promptly, before the opportunity to solidify a distinct regional identity has passed.

LED Lighting Industry Highlights

INDUSTRY HIGHLIGHT

COMPANY:
Energy Focus, Inc.

LOCATION:
Solon, Ohio

PROJECT/SERVICE:
LED building retrofit

OVERVIEW:
Corrpro is a leading provider of cathodic protection corrosion control systems and engineering services, as well as a leading supplier of corrosion protection services relating to coatings, pipeline integrity, and reinforced concrete structures. Corrpro's 50,000 square foot facility suffered from a variety of lighting issues that resulted in insuffcient light levels, increased maintenance costs, and high energy consumption.

At Corrpro's request, Energy Focus, Inc. performed upgrades to exclusive LED solutions throughout the building. Outdated T12 fluorescent lamps in the office were replaced with Energy Focus Series 100 LED Tubes, going from four lamps or 133W per fixture to only two lamps equaling 30W per fixture. The warehouse was originally lit with 400W metal Halide Highbays consuming 460W each. After the upgrade, the warehouse is now lit with six lamp linear Highbay fixtures using Energy Focus Series 100 LED Tubes bringing the energy consumption per fixture to only 90W, a reduction of 370W per fixture. Additionally, light sensors were installed throughout the facility to reduce lighting demands in areas where no one is present.

Replacing the existing inefficient lighting technology saved thousands of dollars in energy and improved the light quality throughout the facility. By reducing the kilowatt load from 188 to 22, Corrpro contributes greatly to our nation's desire to reduce energy consumption.

INDUSTRY HIGHLIGHT	
COMPANY: Green Rock Lighting **LOCATION:** Cleveland, Ohio **PROJECT/SERVICE:** ILLUMENOS MAX Series: LED Street Lights	**OVERVIEW:** The Roadway/Area Lighting ILLUMENOS MAX Series form of LED lights were developed by inventor, entrepreneur, owner and founder of Green Rock Lighting, Tina Haddad. These new efficient lights are part of a pilot project in Cleveland. The ILLUMENOS MAX Series, manufactured and assembled in the United States, contains no mercury or lead. Where the traditional light utilizes 400 watts of electricity to operate, the new ILLUMENOS MAX consumes only 174 watts. Other fixtures operating at 250 or 150 watts will only consume 117 and 83 watts. These efficiencies will cut a city's lighting bill by 43 to 65 percent Along with being highly efficient, they are durable with low maintenance that will stand up to the wide range of weather that even stands up to hurricane conditions. The project foresees replacing all of the Cleveland's roadway/area light with LEDs, reducing the city's power consumption by 50 million kilowatt hours a year and cutting carbon dioxide emissions by 25,282 tons annually. It would also shave millions from the city's utility and maintenance bills. Cleveland currently spends approximately $12 million a year to power streetlights. These 'Made in America' LED streetlights support the growth of the LED lighting industry in the U.S. and are creating quality green jobs in Cleveland.

Building off of the core and enabling services identified in the 2014 roadmap update, with additional input from regional LED subject matter expert Roger Buelow, the Clean Energy Roadmap teams aligned the Northeast Ohio LED lighting industry with NextEnergy's supply and value chain identifiers. This exercise offered a view of the Northeast Ohio LED Lighting industry through a wider lens and resulted in the identification of over 60 organizations involved directly in the manufacturing of LED Lighting components or sub-components, as identified in Figure 21.

The challenges for Northeast Ohio's LED lighting industry represent some universal threats experienced by all regions, including increasing commoditization and the challenge of competing with the cost savings of sourcing components from Asia. However, some challenges are inherent to the region, such as the lack of certification laboratories and the better understanding of potential local supply chain opportunities– all of which would benefit positively from cluster development activity. Despite these challenges, Northeast Ohio has manufacturing capabilities, such as contract manufacturing and integration, that eclipse the abilities of other regions, and evidence of a growing upstream LED lighting component capacity. Both factors make Northeast Ohio a standout region.

Figure 22: SWOT Analysis of Solid State Lighting Industry in Ohio

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
• Several contract manufacturers, such as circuit board makers, with capabilities relevant to the LED supply chain in the region • Engineering talent as a result of the manufacturing ecosystem and high quality secondary education institutions in the region • Number of organizations and estimated employment focused on core LED technologies and enabling services has grown to more than double in the last five years • Regional assets comprise a range of subsystem and component manufacturers and specialty material capabilities that represent the region's historic strengths adapted to meet the needs of the emerging LED industry • A heavy emphasis on fixtures and retrofits, and early-stage activity in the lamp sub system • Regional R&D activities have attracted Ohio Third Frontier and federal funding, and included the private resources of 6 different companies, as well as University of Akron and John Carroll University	• Gap in regional capabilities for LED chips and semiconductors (Asia dominates) • Lack of "hard assets" such as physical laboratory and incubator space (though TBEIC is starting to change this environment) • Weak collaboration between companies; Lack of supply chain realization • Lack of knowledge or coordination of government incentives • Weak upstream activity in diodes and electrical components	• Potential for cluster development and coordinated, regional supply chain • Evidence of a rapidly growing global and U.S. LED market with projected compound of annual growth rates of 24-40 percent for global LED lighting over the next 5-8 years • Evidence that efficacy, quality, and pricing of LEDs are improving • Existing global lighting manufacturers' shifting emphasis toward solid state products • LED lighting technology is in the early stages of a steep adoption curve in a highly competitive and rapidly consolidating space • TBEIC introduction of lab assets	• Increasing competition from Asia/components (e.g. chips, diodes) sourced overseas • Only one big name company in Northeast OH: GE Lighting • Technology is changing rapidly • LEDs are becoming a commodity

Source: Team NEO

Current Employment Statistics

Northeast Ohio's LED lighting assets include:

- 60 component, sub component, and materials manufacturing organizations; and 17 lighting designers/engineering companies within the supply chain
- 680 full-time equivalent workers
- $223 million in revenue and research funding

Recommendations for Northeast Ohio's LED Lighting Industry

Recommendations to support and grow Northeast Ohio's LED lighting industry are specific to the vision, goals, and broader recommendations outlined in the implementation plan.

1. **Support the LED Lighting Ecosystem**

   Next Steps:

   - Explore the idea of developing a geographically accessible lighting certification lab in the region with the Tech Belt Energy Innovation Center

- Engage additional LED lighting and supply chain players, particularly contract electronics manufacturers, to build mutual understanding of regional lighting production needs and existing manufacturing capabilities
- Collaboratively identify specific manufacturing opportunities that incorporate or integrate LED sub systems, components, and/or services (e.g., PCB assembly, heat sink, controls) to improve cost-competitiveness

2. **Identify opportunities for further support of LED cluster R&D**

   Next Steps:

   - Work on developing specific business cases for presentation to the state administration: "this is what we found, this is how you can help us"

3. **Support attraction, retention and innovation**

   Next Steps:

   - Focus on pockets of strength to help grow companies in Northeast Ohio
   - Stimulate innovation for areas of focus where the region has future potential; specifically, in the OLED and advanced building controls space

4. **Improve Northeast Ohio LED lighting manufacturers' product deployment**

   Next Steps:

   - Work with utilities to develop and promote "Made in Ohio" initiatives, such as offering an additional 15% rebate to commercial and industrial customers on qualifying energy efficient products manufactured in Ohio
   - Gather cluster support for business case development that encourages government entities to buy only LED Lighting products manufactured in Ohio for installation and retrofit in government-owned facilities and properties

3.6 Regional Supply Chain Opportunities

After evaluating the previously discussed EEBT supply chains in both Michigan and Ohio, the greatest opportunity for regional collaboration is with the lighting cluster. Given there is focus from a federal R&D level, combined with the fact that significant activity is occurring in the market in both states, a variety of collaboration opportunities exist that could not only help strengthen the sector within each state, but will help create a more cohesive cluster in the Midwest.

After conducting analyses of the Michigan and Northeast Ohio LED supply chain, collaboration opportunities were brainstormed by NextEnergy and Team NEO and include the following:

Leverage R&D and Innovation Pipeline – The sectors of both states have strong R&D capabilities and activity, often focused in different areas. There is an opportunity to leverage these strengths and have more coordinated R&D activity, including the following:

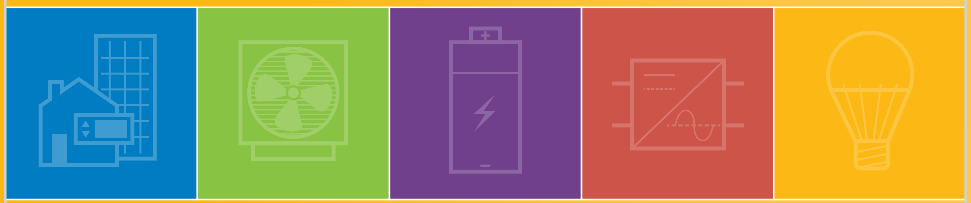
- *Pursue R&D funding opportunities* – A variety of funding opportunities exist, including SBIR, ARPA-E, and other federal funding. Ensure both regions are aware of these opportunities and form stronger partnerships to promote greater R&D activity benefitting the entire region.
- *Technology Challenges* – Building on the diverse LED ecosystem that exists in both states, technology challenges will drive innovation.
- *Sell innovation into big companies* – Often innovation occurs within the entrepreneur community, but the true path to commercialization and sales is with larger, multi-national companies. An effort should be undertaken to help facilitate relationships between these larger companies across both regions.
- *Connect private sector and academia* – Currently, awareness between R&D occurring in the private sector and R&D activity occurring in academic institutions is disjointed, especially across regions. Greater opportunity exists to socialize activity amongst the entire region. For example, it might make sense for a company conducting R&D in Northeast Ohio to partner with a Michigan-based academic institution.

Foster EEBT cluster development – Each geographic region (Michigan and Northeast Ohio) has an established cluster with a diverse set of supply chain assets. However, the individual regions have limited cluster support and do not have funded support to foster growth of the broader regional cluster. The following opportunities would help overcome this obstacle:

- *Regular convening events* – Holding regular convening meetings targeted toward supply chain companies in both regions would help foster better interaction, identify opportunities for partnership, and grow a stronger, multi-state region.
- *Capabilities matrix* – Currently, companies across both cluster regions are not aware of or do not understand the capabilities of other companies. In Michigan, the MSSLA has been successful in organizing companies and communicating technologies. However, many Michigan companies are not part of the MSSLA and Northeast Ohio does not have an organized industry associated with this sector. A capability matrix for both regions could help foster increased activity levels and success for the broader region.

Harness deployment potential – Since much of Michigan and Northeast Ohio experienced economic decline, there are many residential, commercial, and industrial buildings within the building stock that are poised for retrofit. The lighting sector has the ability to harness these untapped energy savings and will require the support of its professional and contractor community.

- *Midwest Advanced Lighting Conference* – Currently, the Michigan Advanced Lighting Conference has successfully gathered and educated not only manufacturers and lighting professionals, but also building owners. More opportunity exists to host a conference with a broader geographic footprint.
- *Combined contractor training* – New lighting systems are often associated with control systems and, in order to capture all of the available energy savings, engaging the contractor workforce on these new technologies will be necessary. Michigan already has the Advanced Lighting Controls Training Program, but expanding it in partnership with Ohio would help create more deployment potential across the entire region.
- *Coordinated professional memberships* – Michigan and Northeast Ohio both have professional Illumination Engineering Society (IES) associations. However, opportunity exists to host combined events, training opportunities, and industry days to create more synergy and paths to market for Michigan and Ohio products.



Clean Energy Manufacturing Process Roadmapping

Analysis of the Clean Energy Manufacturing processes followed five steps:

1. Identify existing sectors with strong clean energy manufacturing bases in the region
2. Develop a baseline industry asset list for the sectors to understand what is manufactured and assess the general level of energy consumption by the industry assets to narrow the sectors targeted
3. Map the manufacturing process flow
4. Identify energy intensive production processes
5. Develop state and regional implementation plans for energy reduction of specific products

These steps provided a framework for the analysis of each of the sectors. The methodology for conducting this analysis consisted largely of qualitative analysis of both primary in-depth interviews and secondary information sources, as detailed in the Market Research Methodology section. The analysis resulted in targeted implementation plans for the energy storage sector in Michigan and Northeast Ohio, the LED lighting sector in Michigan and Northeast Ohio, and the power electronics industry in Michigan.

4.1 General Assessment of Process Energy Use by Industry Segment

To identify areas of manufacturing in "clean energy" industries that offer potential areas of significant energy use improvement, NextEnergy started by analyzing their existing database of local and regional company contacts. We analyzed the database for companies that actually do manufacturing in the "clean energy" market segments, which include LED lighting, energy efficiency, energy storage, power electronics, solar generation, and wind generation. Next, based on the understanding of basic processes used by those companies, NextEnergy made a high level assessment of categorizing energy use.

From this analysis, it was determined that the energy storage and power electronics industries both have processes that have the potential to consume relatively high amounts of energy and have a Michigan presence, and therefore, should be investigated. Additionally, LED lighting was included because of its high growth rate as an industry and the fact that there are some energy intensive processes in some of the product designs in this area. At this point, NextEnergy analyzed the intensity of the processes used within each of these clean energy market segments.

It should be noted that manufacturing processes and device and materials technologies are all intimately and inextricably linked. Advances in materials or process capabilities enable new and advanced devices. New device concepts can simplify process concepts or reduce materials usage. Reduction in energy use in the production of a product can therefore come from improvements in any of these technology areas.

In the following sections, basic concepts for the function and manufacture of the components and sub systems that comprise products in the energy storage, LED lighting and power electronics segments are described. Special attention is given to areas of significant energy use and concepts that reduce or may potentially reduce energy use are highlighted.

4.2 Basic Manufacturing Processes and Supply Chain: Pb-A and Li-Ion Batteries

Pb-A Batteries

Energy Drivers

Energy is used in multiple stages of the battery manufacturing process including to melt the lead; mix, form, and dry the paste materials onto the electrodes; and during the formation process to initialize the chemistry and charge the battery. Refining the lead and other raw materials also requires energy and is typically done at a material supplier's facility, which is not located in Michigan, and therefore, these processes have not been analyzed as part of this specific report.

Description of Materials

Basic components of any battery include electrodes (or plates), electrolyte, separator, electrical connections and case. Each of these components is made up of specific materials unique to the chemistry of the battery.

For the current Pb-A battery configurations the electrodes basically consist of lead, lead oxide, and lead sulfate. Separators are made of glass fiber mat and the electrolyte is sulfuric acid. Case material is plastic and the connections and internal buss bars are lead.

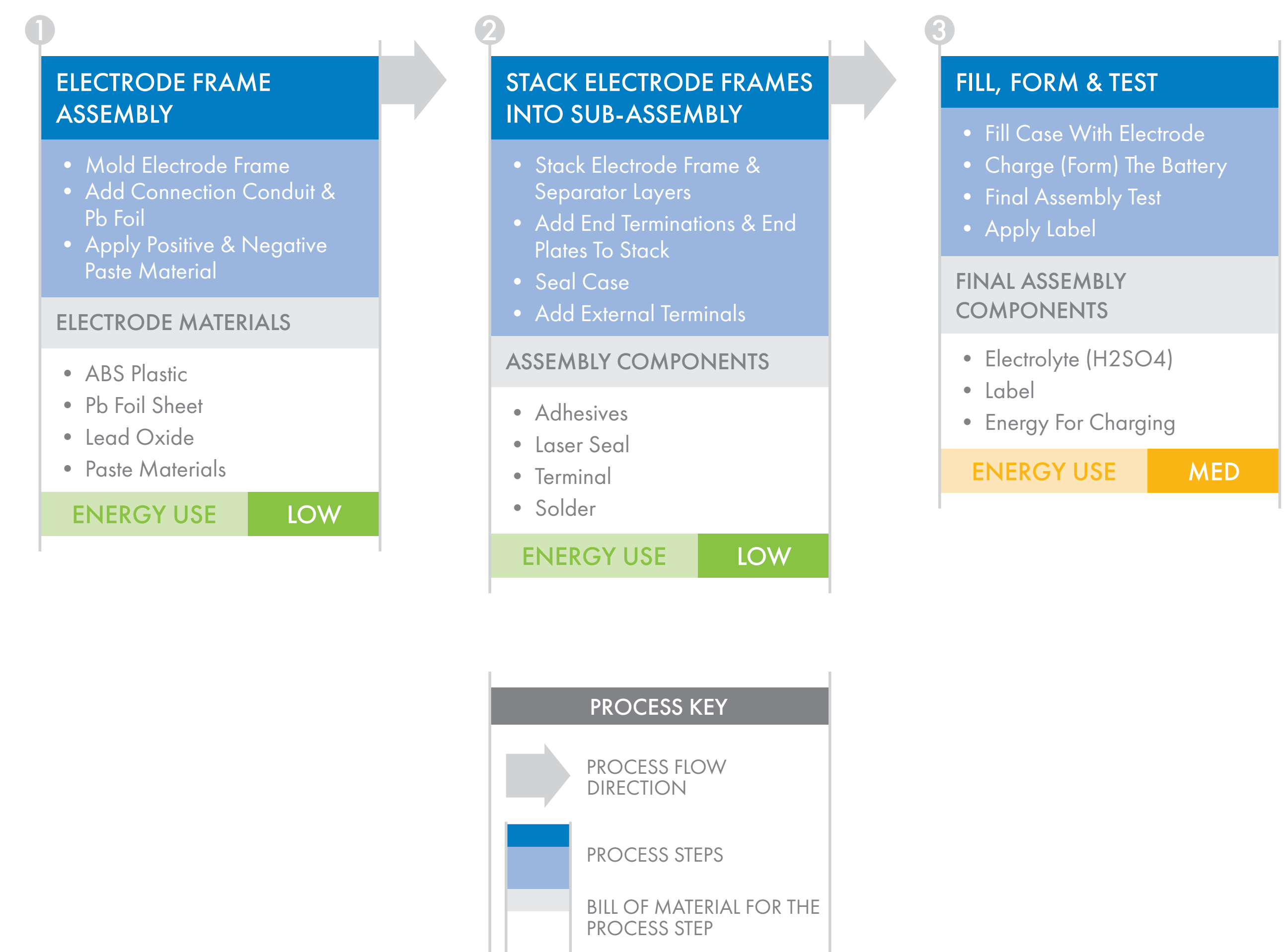
The material supply chain for Pb-A batteries is very well established and this industry employs a very comprehensive recycling infrastructure that utilizes over 95% of the materials returned from end-of-life batteries.

Description of Processes, Equipment, Testing, and Inspection

A simplified process flow for Pb-A battery production is shown in Figure 23.

For a traditional Pb-A battery, Pb is melted and formed into thin electrode carrier structures. Lead oxide is formed into a paste and pressed into a carrier, which becomes the cathode. Lead sulfate paste is pressed into a carrier, becoming the anode. Anodes, separator sheets, and cathodes are stacked, inserted into a case and connected electrically. The case is then filled with electrolyte and sealed. Batteries are charged during a "formation" process. End-of-line testing typically includes voltage and current delivery test, as well checking for leaks and a visual inspection.

Figure 23: Lead-Acid Battery Manufacturing Process



Source: NextEnergy

Potential Energy Use Mitigating Technologies

Energy reduction for processing is being achieved through more efficient use of the raw materials and improved designs utilize less material. Energy consumption is also mitigated by the high degree of recycling that is prevalent in manufacturing Pb-A batteries. Overall, energy consumption of processing these materials has not been identified as a major part of the cost structure. Advanced Pb-A battery designs are being developed, which have significantly improved cycle life, as well as increased energy and power densities while using less material. Reduced material usage inherently leads to reduced energy usage in the production of the requisite materials. Differences in advanced designs from conventional Pb-A batteries include bi-polar plate stacking configuration, carbon added to the anode, and microstructure changes to the electrodes. The manufacturing process for these advanced batteries, however, remains largely the same as the conventional implementation.

Global, U.S., and MI/Northeast OH Production Manufacturers

Figure 24: MI and Northeast OH Lead-Acid Battery Manufacturing Companies

Michigan and Northeast Ohio have some activity in the Pb-A manufacturing industry. Advanced Battery Concepts and Energy Power Systems are both advanced Pb-A development and manufacturing start-ups located Michigan.

Johnson Controls is a major battery producer that manufactures both Pb-A and Li-Ion batteries and operates an absorbent glass matt Pb-A battery manufacturing plant in Ohio. Wirtz Manufacturing makes manufacturing equipment for Pb-A battery production. Wirtz Manufacturing includes several subsidiaries and is headquartered in Port Huron, MI.

Li-Ion Batteries

Energy Drivers

Energy is used in the manufacturing process for area lighting, running motors to mill and mix the active materials, running the reel to reel process to apply the paste to the current collectors, operating heaters to dry the paste, and cutting, stacking, or rolling the electrode/separator assembly. Electricity is also required for charging the battery cells during the formation and test process. The formation process requires at least one closely-controlled charging process. The highest energy usage, however, is in running the air conditioning and circulating equipment. The air is maintained at a relative humidity of low single digit percent level, is maintained within a tight temperature range, and is cleaned to a class <1000 particulate level. Some manufacturers control the number of personnel allowed into the room at a time so as to strictly regulate moisture in the environment (a typical worker exhales approximately one pint of moisture during an eight hour shift). One manufacturer indicated that the energy requirement to maintain the clean room environment costs approximately $250,000 per month. This would represent a cost of more than $4.00/kWh of battery capacity manufactured in the plant with the plant operating at full capacity — far higher than the cost of the energy used during the formation process (approximately $0.12/kWh capacity/charge cycle).

Description of Materials

For Li-Ion batteries, chemistries and configurations are much more diverse than Pb-A batteries. Cathode active material chemistries include lithium cobalt oxide (LCO), lithium manganese oxide (LMO), lithium iron phosphate (LFP), nickel manganese cobalt (NMC), and nickel cobalt aluminum oxide (NCA). The cathode current collector is a very thin aluminum sheet. Anode active materials include carbon-based materials ranging from hard carbon to nano-phase carbon and lithium titanate. The anode current collector is a thin copper sheet. Electrolyte consists of lithium salts and various solvents. The separator can be made of polyethylene, polypropylene or other materials.

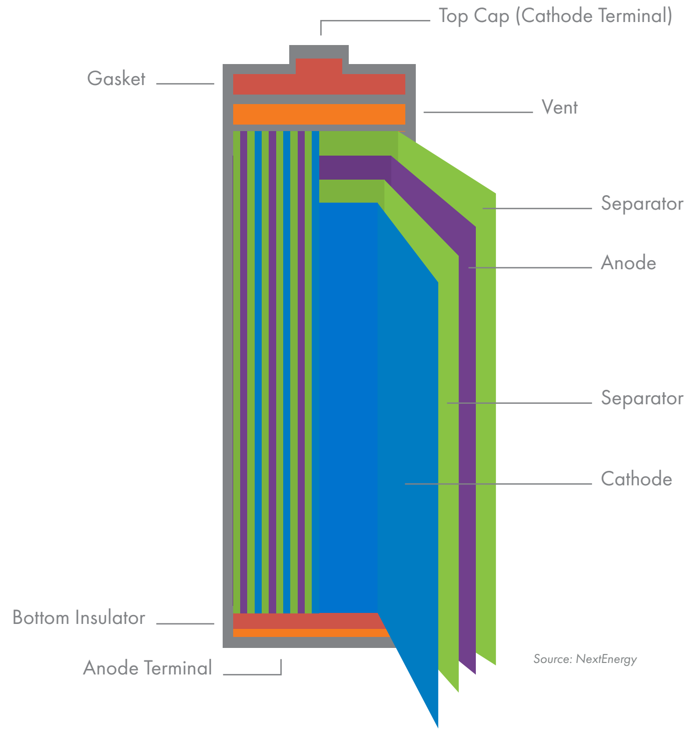
With the growing usage of lithium in battery applications, there has been some concern about supply for lithium. While the Li-Ion battery is poised to continue to grow, lithium accounts for less than 0.5% of the overall cost of a Li-Ion battery. Lithium can also be reclaimed from used batteries and there is a growing reclamation industry including at least one company (Sybesma's Electronics) in Michigan and one (Toxco) in Ohio (also Umicore in Sweden). Currently the cost of reclamation exceeds that of new production, but as the availability of used batteries increases, it is expected that the reclamation stream will also increase and the process will become more viable.

Cobalt, another element that is used in batteries, is expensive on a cost per weight basis. Cobalt is produced as a by-product from copper and tin mining and major sources are located in China, Finland, and Canada. The value of cobalt in a battery can exceed that of lithium, depending on the specific battery chemistry, but battery manufacturers are working to reduce the amount of cobalt used per battery to help contain cost. Cobalt can also be reclaimed and overall, there does not seem to be much concern about the availability of this element.

Other elements used in Li-Ion batteries include iron, aluminum, magnesium, and nickel, but these are commodity items for which supply is generally non-problematic.

Cases for rolled cylindrical or trapezoid styles are made of deep drawn steel or aluminum. Pouch style packaging uses metalized polymer film for the cell casing.

Figure 25: Lithium-Ion Battery Internal View



Description of Processes, Equipment, Testing, and Inspection

A simplified process flow for Li-Ion battery production that is typically used by Michigan manufacturers is shown in Figure 26. Note that there are two basic styles of construction, which are rolled as depicted in Figure 25 above and cut and stacked for pouch style cells.

Processing for Li-Ion batteries is more complex than that of the Pb-A battery. The process for both the cathode and anode electrodes begins with mixing finely ground and graded powders containing the active ingredients with a binder into a paste. The paste is applied in a thin layer to the electrode current collector sheet and then dried, calendared, and rolled or cut into sheets. The current collector material for the cathode is aluminum, and for the anode, it is copper. The anode and cathode sheets or ribbons are then rolled or stacked together with the separator into the desired configuration of "Jelly-Roll" or stack, inserted into a can or sealed into a pouch, filled with electrolyte and sealed. The electrical connections are made as part of the sealing process.

It is important to note that the entire Li-Ion production process from the preparation of the active material powders to the sealing of the cell assembly must be done in a very clean and extremely dry environment. Lithium reacts extremely readily with moisture, and any particle contamination can cause defects in the final product. Once sealed, the cell goes through a formation and charging process, taking several days or weeks.

Figure 26: Lithium-Ion Battery Manufacturing Process

While there are process control parameters throughout the manufacturing process, performance testing of the cell (parameters include output voltage, energy capacity, and internal resistance) cannot be accomplished until during or after the formation process. At this point, cells can be characterized according to their performance and matched with cells of similar characteristics into a module. As process controls improve, the need for this matching diminishes. Ultimately, modules are integrated into a complete battery pack, which has charge, discharge, and module balancing controls. Cells that are found to be deficient after formation must be discarded, and it is impossible to rework a deficient cell into an acceptable one. Deficient cells are typically sent to a materials recycler where some of the elements can be reclaimed, primarily lithium, cobalt, nickel, and magnesium.

Potential Energy Use Mitigating Technologies

Advancements are continuously being made in the formulation of the active materials, electrolyte composition, separator material, and structure and packaging. These advancements are improving the effectiveness of the materials being used in the function of storing energy and are therefore driving down material usage requirements and costs. Additionally, manufacturing yields are continuously improving, resulting in reduced scrap, which drives reduced material and energy usage and reduced cost.

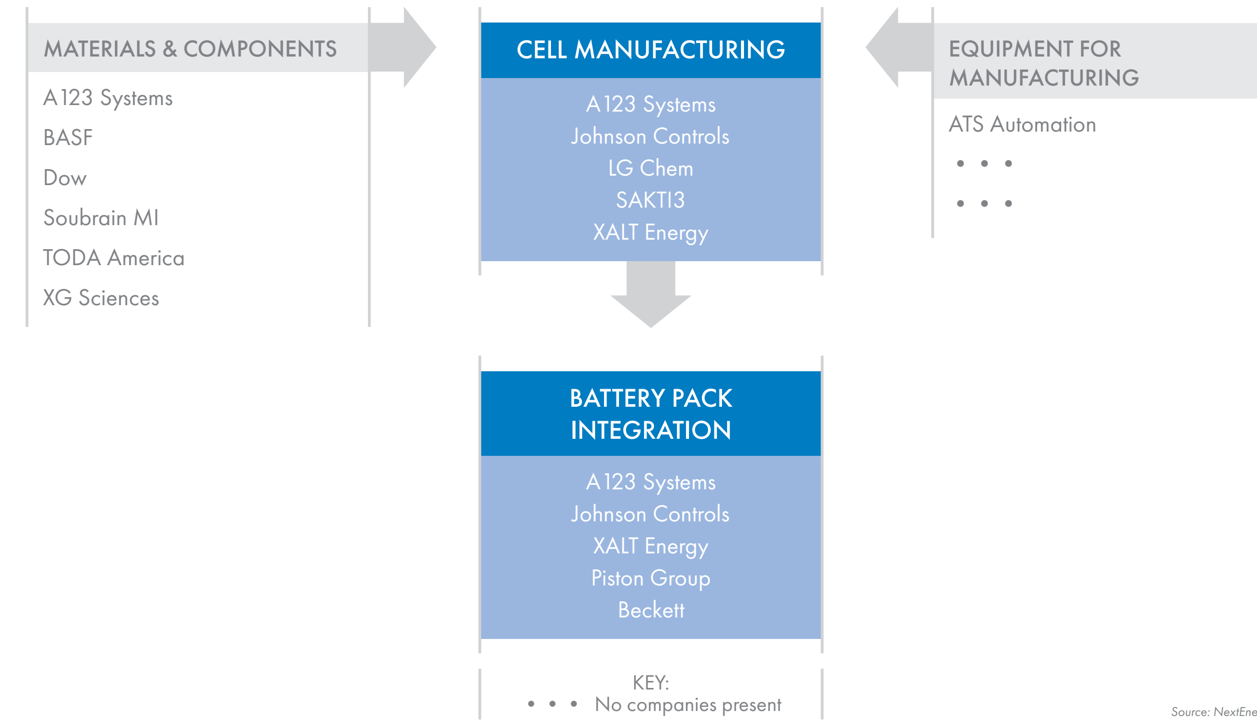
Solid state electrolyte implementations are being developed and represent a much more significant change in performance than just evolution of current materials. Solid state cells employ a significantly different manufacturing process that does not require the clean and dry environment of the conventional Li-Ion manufacturing process and at the same time offer the possibility of significantly improved power and energy storage densities. Development of solid state Li batteries is being done in Michigan at the University of Michigan and by start-up Sakti3 (Acquired by Dyson in October 2015).

Global, U.S., and MI/Northeast OH Production Manufacturers

Michigan has significant activity in the Li-Ion industry as a result of American Recovery and Reinvestment Act funding initiatives and MEDC tax incentives that have totaled over $2 billion. These incentives resulted in four major cell and module manufacturing plants and a strong supply chain presence. Additionally, there is significant R&D activity in the state, including Navitas and start-ups like Satki3. R&D activities in Li-Ion are very active at University of Michigan, Michigan State University, and Wayne State University.

The initial focus of the industry expansion in Michigan was to build a supply of Li-Ion batteries to meet the electric vehicle demand. Unfortunately, the electric vehicle industry has not accelerated at the rate that some hoped, and the cell plants within the state are currently running at only about 20% of capacity. However, markets and applications are expanding into stationary applications including grid, commercial, and residential applications.

Figure 27: Lithium-Ion Battery Manufacturing Companies in MI and Northeast OH



Source: NextEnergy

4.3 Basic Manufacturing Processes and Supply Chain: LED Lighting

Markets considered include residential, commercial, and industrial lighting, as well as street and parking lot lighting. Not included are vehicle (automotive) lighting, accent lighting, or indicator lighting. Within the markets considered, there is an enormously large variety of styles and fixtures included. High Bay, panel, grow, tube and tube replacement, recessed fixture, bulb, flood, and exterior illumination are some of the marketing categories into which the industry is supplying lighting products. These devices can require anywhere from one or two watts to several hundred watts, and light output varies from a few lumens to several thousand lumens. Other major characteristics of the light output include wavelength, diffusivity, distribution, viewing angle, and glare.

For all of these categories, however, the basic structure is similar. There is a "light engine" which consists of a light-emitting chip or die mounted on a circuit substrate that supplies the requisite electrical connection and thermal management characteristics. There is usually a phosphor material coating or over-layer that modifies the wavelength of the light that is emitted from the die to that which is ultimately desired and may also introduce some diffusion. This die and circuit assembly is mounted in a structure of the desired size, shape and ruggedness to fulfill the intended function in the intended environment for the required life. This structure includes light management which may include a lens, reflector, diffuser, or other device to make sure the light goes where it is intended with the proper characteristics. This may include an electrical power driver, and there may be ancillary thermal management equipment including heat sink, fan, coolant circulating pump or other thermal management equipment.

Figure 28 shows a basic flow diagram of the various materials and sub-components of a typical LED fixture and how they are processed into a complete assembly.

Figure 28: LED Light Engine Manufacturing Process

The overall manufacturing process for building a LED lighting fixture and a power electronics converter are very similar. Basic electronic components including active and passive devices are populated onto a circuit board assembly which is then packaged into a final assembly. For each application, attention must be paid to the ambient environment, thermal management, electrical connections external to the assembly, mounting of the assembly etc. The discussion regarding packaging that follows applies to both the LED luminaire and the power electronic packaging. Production and packaging of the base semiconductor die will be handled in the Power Electronic Active Device section.

Energy Drivers

Energy drivers for the assembly and packaging of lighting fixtures and power electronics devices are largely driven by the energy use in producing the basic materials used in the packaging. Assembly and test operations use some energy in the pick-and-place operations, solder re-flow, metal bending and driving screws, but it is small compared to that used to produce the materials. More detailed information on energy requirements to produce the basic die and assemble the circuitry are shown in the Power Electronics section of this report.

Embedded energy for the materials listed below used in housings, heat sinks, and light management elements are approximately: steel 25 MJ/kg, plastic 100 MJ/kg, aluminum 110 MJ/kg, magnesium 200 MJ/kg. These values are for producing primary materials directly from ore or the basic feedstock for the material. It is interesting to note that the energy requirements for the refining processes for both iron and aluminum have been steadily improving. Energy requirements to produce iron have reduced by almost an order of magnitude over the last two centuries while aluminum has shown a reduction to about one-fifth in about a century.[53]

Aluminum, steel, and plastic can all be recycled to some degree. Energy use to produce recycled aluminum, or secondary aluminum is about 10% of that for primary, and for steel it is about 50%, which brings the embedded energy for steel and aluminum to approximately equal values for recycled or secondary materials.

It is more difficult to recycle plastic due to the many types of plastic and the need for sorting, but it is being done.

Description of Materials

Housing and Thermal Management Materials

Materials for the housing of the final assembly vary with application, but consist mainly of various types of plastic, aluminum, magnesium, and fabricated steel. The basic function of the housing is to serve as a mounting structure and to protect the circuitry and light engine from the environment. Often, in addition to those basic functions, the housing serves additional purposes, such as acting as a heat sink for thermal management of the heat produced in the drive electronics.

Aluminum works very well as a housing material and has the added advantage of being an excellent heat sink material because of its high thermal conductivity and relatively high specific heat values. Manufacturing processes to form aluminum including sand casting, die casting, molding, forging, extruding, and machining are ubiquitous and cost effective. Aluminum can be treated or painted to reduce corrosion and can, therefore, serve in most environments.

53 "The Energy Required to Produce Materials: Constraints on Energy-Intensity Improvements, Parameters of Demand," Philosophical Transactions of The Royal Society, (Published online 28 January 2013)

Magnesium also works well as a housing for reasons similar to that of aluminum. Magnesium is lighter than aluminum, and its specific heat is similar to that of aluminum and thermal conductivity is good, but slightly less. Forming processes include die-casting and thixotropic forming.

Steel housings are often fabricated. Steel is easily stamped, bent, crimped, welded and coated and is cost effective. Steel also has some thermal capabilities, but the conductivity is only about one-fifth that of aluminum and the specific heat is about one-half.

Various plastics can be very cost effective, are easily formed into the desired shape by molding or extruding, and generally are resistant to corrosion. Plastics have poor thermal conduction, so, are not very useful as a heat sink in their basic formulation. It is possible, however, to add thermally conductive materials to the plastic to improve the thermal characteristics.

Light Management Materials

Light management functions are basically as a lens, diffuser, and reflector. The function of these elements is to direct the light produced by the light engine onto the desired surface with the desired characteristics (e.g., evenly distributed and without glare) and to prevent the light from going in unwanted directions.

Lenses require that the refractive index of the material be different from that of air. In this industry, two materials are generally used and they are polycarbonate and acrylic glass (Polymethyl methacrylate or PMMA, also known as Lucite and Perspex). Both have attractive refractive index values, can be easily formed by molding or extruding, and are readily available. Both are widely used in eyeglass, as well as other lens applications. Polycarbonate is more impact resistant, but less scratch resistant. It should be noted that the base feedstock for acrylic glass is petroleum, while polycarbonate is produced by the reaction of bisphenol A (BPA) and phosgene $COCl_2$. Polycarbonate base material is more expensive than acrylic, but does have some very attractive properties for many applications.

Reflectors can be made from polished aluminum, polished stainless steel, and metalized plastics. Often, reflector materials are not flat, so the base material must be able to be formed into the desired shape.

Phosphors

Phosphor materials (also known as fluorescent materials) are used to shift the wavelength or color temperature of some of the light produced by the LED die to a different value. For example, the blue light produced by a InGaN LED is shifted by a phosphor material containing Cerium (III)-doped YAG ($YAG{:}Ce^{3+}$, or $Y_3Al_5O_{12}{:}Ce^{3+}$) to produce red, green, and yellow wavelengths. The red, green, and yellow wavelengths together with the blue produce a white LED light engine.

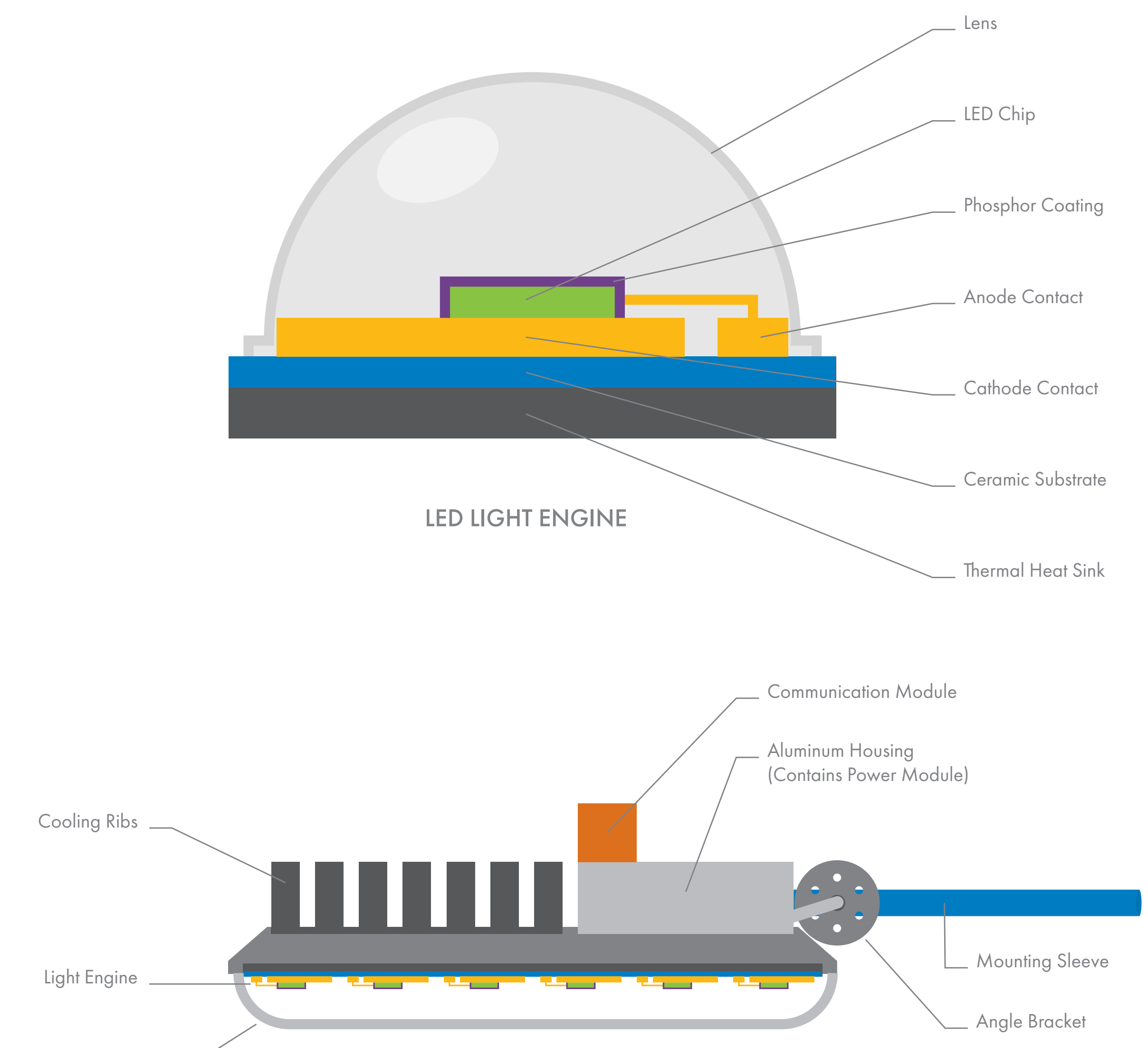
Miscellaneous Hardware, Fasteners, and Sealants

There is a wide range of miscellaneous hardware, fasteners, sealants, coatings, and other bits that are used in the assembly and application of LED lighting. These tend to be commodity items, and as such, the LED industry represents a very small percentage of their market.

Description of Processes, Equipment, Testing, and Inspection

Once the design engineering has been done so that the final product meets all the operational performance requirements, and the sub-components and sub-assemblies have been produced, final assembly and test can be completed. Testing can include verifying the quality of the light produced and level of power consumed.

Figure 29: LED Internal View



Source: NextEnergy

The initial process steps in producing an LED light engine assembly are to assemble the light engine similar to that of any electronic circuit board. The term "light engine" is used to describe the light-producing sub-component as shown Figure 29. The basic white LED die is an electronic component, constructed with an Indium Gallium Nitride semi-conductor, a layer of phosphor that converts blue to yellow light, and a package that manages the electrical, mechanical, and thermal connections to the device. Sometimes, there is an additional lens placed directly over the LED die to manage the distribution of the emitted light. Almost all LEDs and LED luminaires are made in Asia, with China, Taiwan, and Korea accounting for over 80% of the world production. Michigan and Northeast Ohio have no LED die production.

The "controller and driver" sub-assembly is used to regulate the current to the LED. This is a power conversion device that ensures that the amount of current delivered to the LED remains stable and safe. The driver in LED lighting is analogous to the ballast used in other efficient lighting constructs, and they often have similar construction. Drivers are made by basically the same process as any electronic device: by assembling electronic components onto a PC Board. This process typically involves robots to place the components, ovens to melt solder, and end-of-line testing equipment. Some configurations include the basic LED die and associated materials on the same substrate as the drive electronics.

The final step is to assemble all of the sub-components into an integrated assembly. There are many design concepts and methods to accomplish this. Basically, the light engine and controller board are mounted into the structure in such a way as to manage the electrical connections to the power supply, manage the heat flow to the outside environment, protect the electronics from that environment, and control the light produced. Sometimes the basic circuit board also functions as a heat sink.

Potential Energy Use Mitigating Technologies

For the circuit board and light engine portion, more highly-integrated designs can make components smaller, require fewer assembly steps, and make the electronics more efficient in use. Much work is going on in developing integrated driver designs, new die connection methods, and improved thermal management techniques.

Clearly, recycled materials offer reduced energy usage potential. It should be noted, however, that secondary materials can exhibit degraded material properties, so depending on the specific application, they may or may not be appropriate for use. Housings for lighting fixtures would not generally represent a very demanding application for material properties as compared to other applications (e.g., aircraft structures), so secondary materials would normally be functional. Light management applications or lenses, however, would probably require very well controlled characteristics so primary materials would be advantageous.

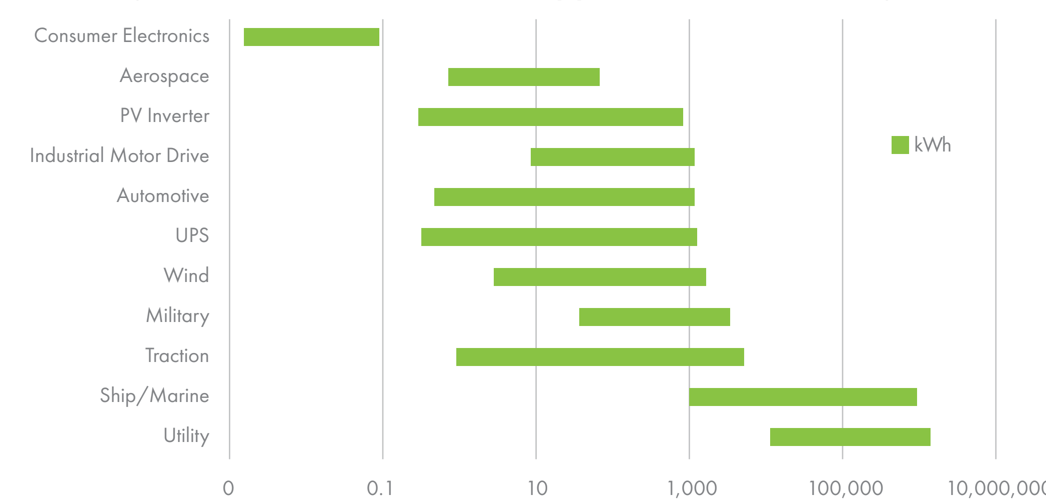
Material substitution offers another possible energy reduction strategy. Substituting plastic that is lighter, coated with a reflective coating, or filled with thermally conductive additives for aluminum may reduce energy use even though the embedded energy for plastic is higher per kilogram than that of aluminum. Careful engineering analysis would yield the optimal material usage. Not surprisingly, there is a very strong correlation between the cost of a material and the energy required to produce it. It follows then that in choosing materials, often the most cost effective is also the lowest energy use choice.

Life Cycle Analysis (LCA) of the energy used to produce a given amount of light includes both the energy used to produce the lighting fixture and the energy used by that fixture to actually produce the light. Several LCAs comparing conventional incandescent, compact fluorescent (CFL), and LED lamps show that the energy used by the fixture to produce light far outweighs the energy used to produce the fixture. Implementing lighting controls, integrating "smart" lighting controls to use the fixture only during appropriate times and conditions could be an effective strategy to save overall energy use. This functionality for control of lighting is being integrated into the basic circuit board for some products and will affect ultimate energy use of the fixture. Note that this concept overlaps with building energy efficiency initiatives and is discussed in more detail in that section of the report.[54]

4.4 Basic Manufacturing Processes and Supply Chain: Power Electronics

The term "power electronics" generally refers to a piece of equipment or apparatus that performs the function of converting electrical power from one form to another. Examples of this conversion include AC to DC (rectifier), DC to AC (inverter) and voltage and frequency conversions. Power electronics are used in a wide range of functions and applications and consist of a wide range of sub-components and devices. For purposes of this report, NextEnergy defines the scope of power electronics to include power levels of approximately 25 watts to over 1 megawatt. As can be seen in Figure 30, this will include applications utilizing voltages between about 12 and 2,000 volts and between about 2 and 2,000 amps. This will include most applications for the transportation, energy efficiency, and alternative energy application markets. Power conversion devices or systems at levels less than this are often integrated directly into the final product at the chip level. Power conversion devices or systems over this range are typically built for a specific application in a specific location and are often of a specific design.

Figure 30: Power Electronics Applications Market Segments



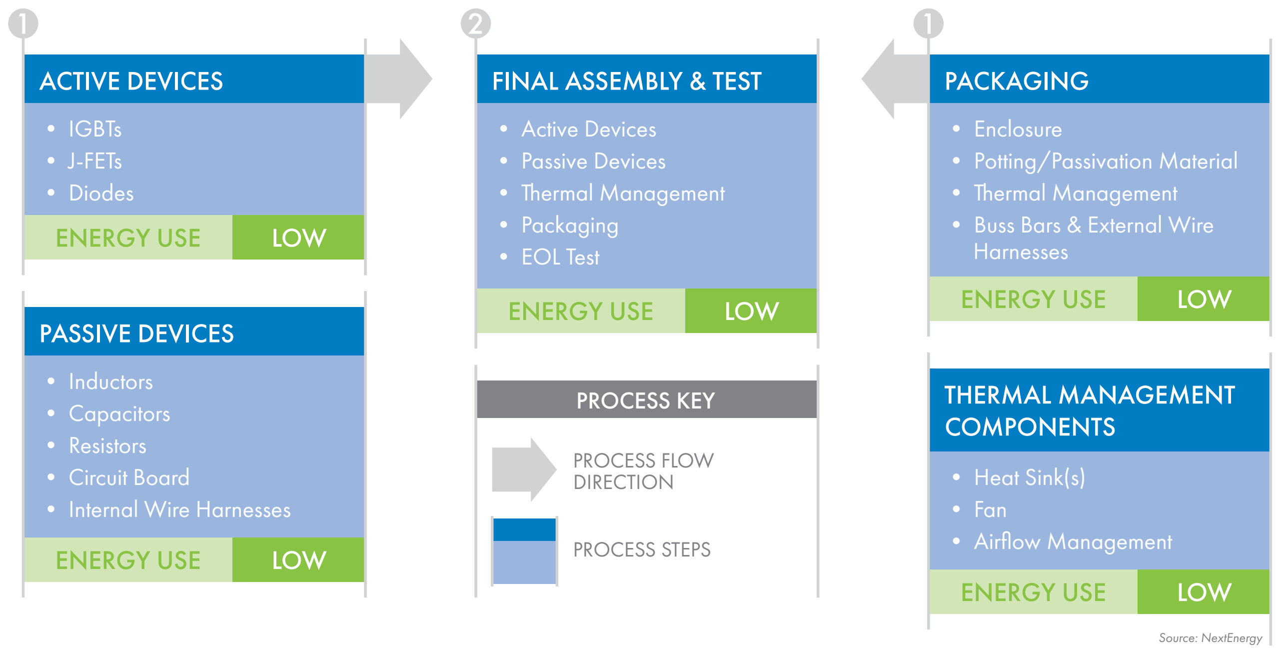
Source: Power Electronics Industry Collaborative

54 Developing Sector Roadmaps for the Advanced Energy Cluster in Northeast Ohio, NorTech, 2012

Package sizes and configurations for the power conversion products in the range of interest will vary significantly ranging from small LED drivers to large stand-alone boxes supplying power conversion for various applications.

Major components and sub-components of a power electronic converter will include specific electrical devices that are either active or passive electrically as well as packaging and thermal management hardware.

Figure 31: Overview of Power Electronic Converter Manufacturing Process



Active devices are semiconductors that perform the function of controlling current or voltage and include diodes and various forms of switching devices. Base semiconductor device materials include Silicon (Si), Silicon Carbide (SiC), and Gallium Nitride (GaN). Microprocessor chips are also required within the power conversion equipment to control the switch timing of the power devices, but these chips belong more to the signal processing and control family of devices and are not considered in this analysis.

Passive devices include inductive (magnetic) devices, capacitors, resistors, and circuit boards, including conductor traces and some internal wire jumpers. In each case, there can be a wide range of materials and types of devices that are utilized depending on the requisite voltage, current, temperature, frequency, and other requirements.

Packaging and thermal management consists of the hardware that is required to mount, protect, cool, heat, and otherwise make the equipment connect to and survive in the real world application.

Active Semiconductor Devices for Power Electronics and LEDs

Energy Drivers

Silicon and graphite both use energy in the purification steps required to make a usable product from the naturally occurring state of the material. Graphite processing uses progressively higher temperatures in the refining, coking, calcining, and graphitization processes, where the graphitization process can run in the 2,600°C to 3,300°C range. The final step in silicon processing to polysilicon is a Chemical Vapor Deposition (CVD) process called the "Siemens Process" which runs at high temperature and consumes a lot of electrical energy in heating the rods during the deposition process.

SiC crystal growth is done by a seeded sublimation process, which runs at a high temperature (2,100°C to 2,500°C) under very tightly controlled conditions. Crystal growth is slow and can take several days with the temperature being carefully maintained for the entire time. It should be noted, however, that energy cost is not a significant part of the cost of production and, according to one estimate, accounts for <5% of the total cost of SiC wafer production. Those high temperature chambers that are on for a long time are very well insulated due to the tight control required for processing and, therefore, lose relatively little energy to the environment.

GaN heteroepitaxy layer growth is most often done on a silicon substrate wafer although other substrates include sapphire, SiC, and GaN itself. As mentioned earlier, this Epi-Deposition is most often done by metal organic chemical vapor deposition (MOCVD). This CVD process runs at a high temperature (900°C to 1,100°C) and may offer an area for energy savings. Both the chamber and the gases entering the chamber must be heated to this temperature range. However, energy is not a significant cost driver in this process. The most significant costs at this step are the precursor materials, which include ammonia (NH_3), trimethyl-gallium (TMG), and nitrogen and hydrogen as carrier gases, all of which must be in a very pure state.

Device fabrication, as mentioned above, requires many different processes, some of which run at elevated temperature (ion implantation, diffusion, annealing). These processes, however, involve relatively small work pieces and heated volumes, and are very well-controlled thermally. The entire process does run in a very stringently controlled clean room environment and the energy cost for cleaning, temperature conditioning, and drying the air could be significant as seen in the Li-Ion battery example cited earlier.

A 2012 report titled "Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products" published by the DOE looked at a LCA for a GaN on Sapphire die for lighting at that time. A quick summary of the energy used to produce a GaN on Sapphire die is as follows:

Table 3: LED Lamp Production Energy Use - Three Inch Wafer, 2012

WAFERS	kWh/Wafer	DIES	kWh/Die
Sapphire Wafer (3in. Dia.)	18.24	2,438/wafer	0.0249
EPI Deposition	32.74	Packaging	0.0300
Die Fabrication	9.83		
TOTAL	60.81	TOTAL	0.0549

Source: DOE, NextEnergy

The energy content represented here is only for the production of the die and mounting it onto the initial ceramic carrier. The cost calculates to ≈ .6 ¢ per die in 2012. Additionally, this cost per die is falling, as the DOE is forecasting increased die yields per wafers (totaling 3,250 dies) in 2017 resulting in the energy usage per die decreasing to 0.0187 kWh/units. While this is specifically for GaN on Sapphire, it is instructive for other materials as well.

Description of Materials, Processes, Equipment, Testing, and Inspection

A simplified overall process flow diagram for producing active semiconductor devices is shown in Figure 32. The basic processing step sequence is similar for Si, SiC, and GaN devices, and as noted earlier, these basic process steps also apply to the production of LED dies.

The basic building block material that makes up the majority of the semiconductor die in a silicon active device is the element silicon. Silicon is also a basic material for SiC devices, and is the substrate for the most commercially available power GaN devices. Purified polysilicon for use in making single crystal wafers used in device die production is processed starting with quartz.

Basic quartz (sand) goes through a series of refining steps as shown. Each step increases the purity level of the Si until it reaches the Polysilicon state with a purity level of up to "6-9s" (meaning purity of 99.9999%). Hemlock Semiconductor in Michigan advertises that their CVD process can reach "11-9s" purity in their polysilicon product. In addition to being used as a feedstock for single crystal silicon wafer production, pure silicon metal is used as a feedstock for SiC production.

High purity graphite for use in SiC production is basically pure carbon. Processing graphite consists of several steps, starting with high quality liquid petroleum. The petroleum is refined, which removes the shorter carbon chain length molecules; run through a coking process, which produces a coal-like product called petroleum coke; calcined to further remove impurities, including water and volatiles; and finally turned into graphite in a process that further purifies the material and crystallizes the carbon molecules called graphitization.

Figure 32: Active Power Device Manufacturing Process

Source: NextEnergy

Wafer production for basic Si power devices utilizes polysilicon, which is melted in a crucible. A single Si crystal ingot is "pulled" from the molten polysilicon as the molecules attach onto the crystal in a freezing process forming a crystal structure. This step also effects a further purification of the material. The single crystal ingot is then sawed into thin slices and polished to produce wafers. These wafers can then be used to form Si semiconductor power devices or as the base substrate for GaN epi-deposition.

For SiC wafer production, a typical process is a "seeded sublimation" process in which high purity graphite and high purity silicon metal are placed into a sublimation furnace where they are inductively heated and vaporized. The vapor then condenses onto a seed that has the desired SiC crystal structure (typically 4H) forming a boule. The boule is then sawed at the appropriate thickness and angle and then polished creating a wafer. An additional layer of slightly doped SiC is applied during an Epitaxial (epi) Deposition process. This layer has the characteristic of having either positive (p-type) or negative (n-type) charge carriers depending on the dopant element used. Aluminum and boron are used for p-type, and nitrogen and phosphorous for n-type.

For GaN on Si devices, Si base wafers receive a layer of GaN material that is deposited via epi-deposition typically using a Metal Organic Chemical Vapor Deposition (MOCVD) technique or molecular beam epitaxy (MBE) deposition technique. Precursor materials for this deposition process are ammonia and trimethyl-gallium.

Two basic materials that have been discussed so far, Si and Carbon (C), are very common and available in abundance. Gallium (Ga) is produced as a byproduct from aluminum ore (bauxite) or zinc ore. It is estimated that only about 10% of the available Ga in bauxite ore is retrieved during refining, meaning that there is a very large potential for increased production. Ga is mainly used in the electronics industry in the production of devices, but it is also used in pharmaceuticals and, along with Indium (In), in the production of thin film PV solar panels.

A critical inspection point in this process flow is at the polished wafer stage. While there are process control parameters and checkpoints at every step, the first time that the wafer can really be inspected is after polishing. Defects can include crystal structure defects, contamination particles, cracks, chips, scratches, and warped surface. It is critical to reject any defective wafers prior to epi-deposition or initiation of device fabrication, as these follow-on steps are very expensive. Inspection techniques for Si wafers is very well developed in the industry and can be done optically and at high speed. Inspection of SiC wafers are made much more difficult by the transparent nature of the material. Techniques including interference contrast microscopy and photoluminescence are being used and developed, but currently are slow and expensive.

Once the wafer is complete, it is taken to a device fabrication facility, also referred to as a silicon foundry. Device fabrication consists of dozens or even hundreds of individual steps. These steps include activities like washing, etching, photolithography masking, oxidation, dopant ion implantation, annealing, grinding, and metallization. All of the steps in this device fabrication process are carried out in a clean room environment over a period of several days. Multiple devices are created on the wafer simultaneously with the exact number being a function of the size of the individual die, the size (diameter) of the wafer and the yield. Each functional device is tested while still in the wafer for electrical functionality by connecting to the device electrically with a probing fixture and running the requisite electrical tests. Yield rates can vary widely and depend on the defect rate in the initial basic wafer material, number of steps required, and complexity of the circuitry.

The final step is to package the functional die into a saleable package. A more detailed discussion of packaging is in following sections.

Potential Energy Use Mitigating Technologies

The study referenced above continued to project costs and energy use for 2017. Several energy mitigating effects are expected, including use of larger diameter wafers for LED die production; significantly improved yield on those wafers; improved light output per die, therefore, requiring fewer LED dies and less drive electronics; smaller and simpler drive electronics; and smaller overall packaging. In addition to GaN on Sapphire, advancements are being made in substrate material including use of GaN on silicon, GaN on GaN, or GaN on silicon carbide. GaN on silicon represents a significant cost reduction and energy savings when compared to the GaN on sapphire reference case. Energy requirements for GaN or SiC substrate materials will vary from the reference case, but will remain a small percentage of the overall cost of the final product.

As mentioned above, Silicon represents a cost and energy savings compared to sapphire, but cost reduction work is occurring in this area as well. RECSilicon Company has developed a fluidized bed reactor for polysilicon production for solar-grade silicon product, which operates at a lower temperature and claims an energy reduction of 80-90 percent compared to the Siemens process for silicon wafer production. It should be noted, however, that solar-grade is "only" six-or-seven nines pure and is not adequate for electronics grade applications so additional work will be required in this area.

Inductive Devices

Energy Drivers

Processing cores requires energy for mixing and milling, and heat energy is used in heating the material for the steps of calcining (≈950°C) and sintering (≈1,350°C). The spray drying process also uses energy to vaporize the water. All of these processes have been in general industrial use for a long time. Energy savings might be achieved by paying attention to the basic motor efficiencies, heat transfer and insulation features of the specific individual processes utilized, and material handling methodologies, but these are the basic "blocking and tackling" attention to detail techniques that might be applied to any process or processing system.

Materials

Inductors are passive magnetic devices that store energy in a magnetic field or "B Field." Energy stored =½ LI2, where L is the inductive value of the device and I is the current passing through the device. An inductor consists of a conductor that carries the current and a core that carries and shapes the magnetic field. Core materials for inductors are referred to as "soft" because they need to be able to allow the direction of the magnetic field to change readily, or have low hysteresis and, therefore, exhibit low loss during field switching. ("Hard" cores are used in magnets and are designed to retain a magnetic field direction.) Conductors are usually copper, but can be any conductive material including aluminum. The core can be silicon steel, fused alloy powders, ferrites, or ceramic.

Effectiveness of the inductor can be improved by optimizing the characteristics of L, which is accomplished by optimizing the characteristics of the core shape and material. Flux density, permeability, reluctance, resistivity, and saturation are all characteristics that are of importance and must be controlled in the core.

Silicon Steel is a type of steel formulated specifically for use in magnetic devices and displays specific magnetic properties including small hysteresis and high permeability. It is typically used in laminate stacks in low frequency applications like 60Hz transformers. The base material is steel containing silicon and processed to produce the desired grain structure.

Fused Alloy Powder core materials are basically iron alloy (metal) powers that are mixed in a binder and formed into the desired shape. Small particle size helps to reduce magnetic losses and can be used at higher frequencies.

Ferrites (metal oxides) make up a significant percentage of core material in inductors for power electronic applications. Ferrite core production process flow is shown in Figure 33. Iron makes up most of the basic element that is used, but other elements are added, including calcium, manganese, lithium, titanium, nickel, and zinc.

Ceramic or air core materials have essentially no enhanced magnetic characteristics beyond that of air, which is desirable for this application. Ceramic materials are sometimes used just for mechanical shape characteristics.

Description of Processes, Equipment, Testing, and Inspection

For inductors, the conductor component is basically wire, which is highly commoditized. Wire conductor material is most often copper and the insulation is chosen to meet the requirements of the environment in which it will be applied, mainly temperature. The core, however, must be more specifically designed for power electronics applications.

Silicon steel core material process is similar to most any steel sheet and is again highly commoditized. Fused alloy powder cores and ferrite cores, however, are more specific to application in power electronics applications.

Basic processing steps for producing ferrite cores are shown in Figure 33.

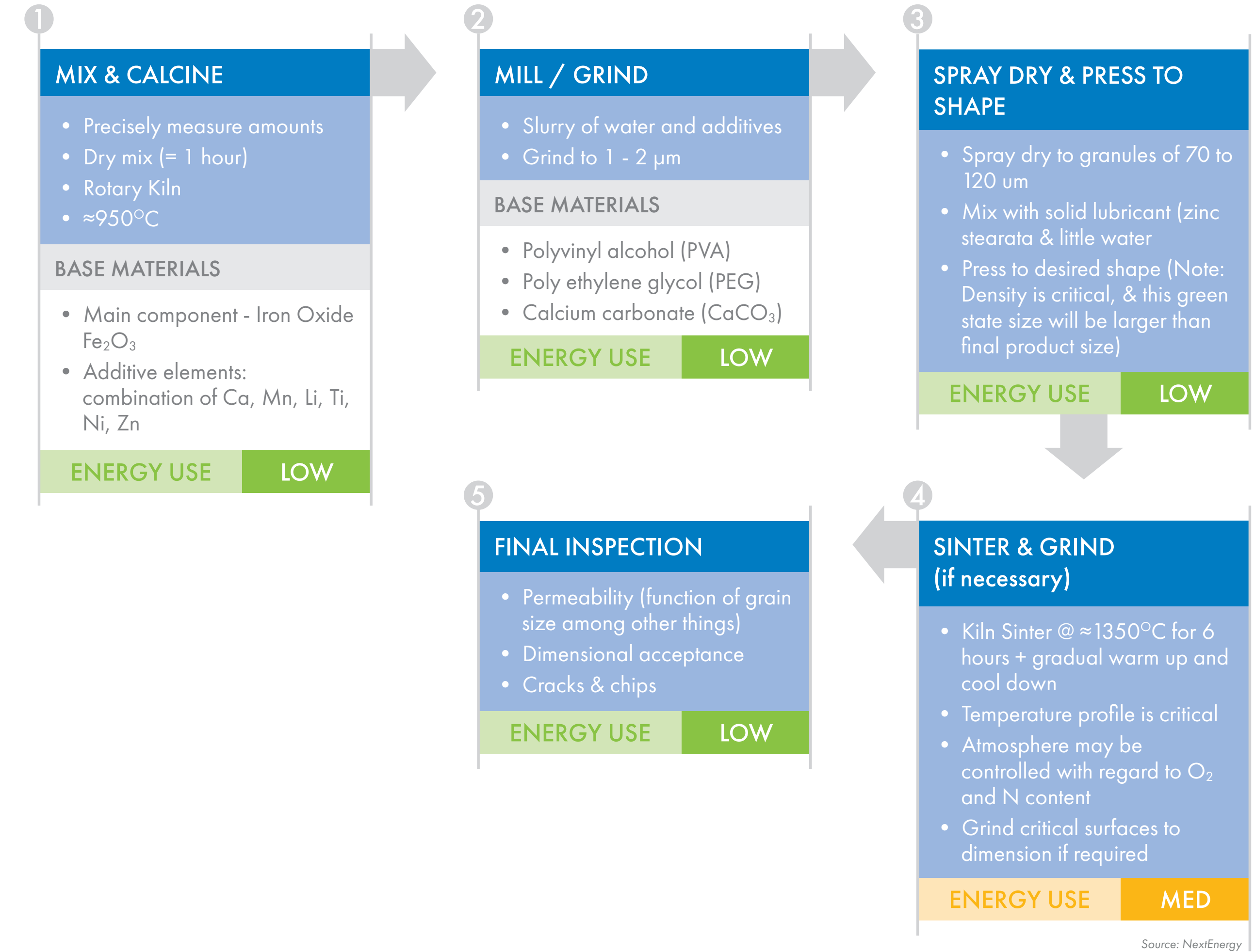
The first steps in the process of mixing, calcining, and milling/grinding are aimed at getting the correct constituents in the correct amounts into the correct particle size. Spray drying creates a kind of powder, which is mixed with a lubricant/binder making a mixture that can be pressed into a desired shape. Sintering removes the volatiles, develops the desired grain structure in the small particles, and fuses the particles together forming a solid structure. Finally, grinding of some surfaces may be required to achieve the final dimensional requirements.

The final magnetic properties of the ferrite core material including permeability and hysteresis will be directly affected by the structural characteristics of the material including composition, grain size, crystal structure, and density. These characteristics are monitored throughout the process. Final dimensions of the core, as well as the absence of cracks in the core material are also critical and are checked at the end of the process.

Processing steps for fused alloy powder core materials are similar to ferrite cores and include mixing, molding, sintering, and machining. A basic difference is that powdered metal cores are just that, powdered metal alloys, not metal oxides as in ferrites.

The final step in producing an inductor is to wrap the conductor around the core in the desired manner, apply any potting material or external package and make the electrical connections to the conductor. As can be seen in Figure 33, there is a wide range of types, shapes, and sizes of inductors.

Figure 33: Ferrite Core Manufacturing Process



Potential Energy Use Mitigating Technologies

Recently, the demand for higher efficiency power conditioning devices has driven a demand for higher switching frequencies in the power converters. For the inductors in the circuit, higher frequencies means lower inductance values which leads to smaller parts, but it also means the core materials must work at higher frequencies with low loss. Metal powder and ferrites are capable of frequencies of up to several MHz, but work is needed in developing high frequency cores. Ultimately, this will lead to smaller and less energy-costly devices.

Capacitive Devices

Energy Drivers

Energy usage in the manufacture of capacitors begins with the processing of the base materials. High purity aluminum is used in the vacuum metalizing of the plastic film for film caps and as the material for the foil in the electrolytic caps. The purity requirement for the anode in the electrolytic capacitor, for example, is 99.99%. Energy is used in the vacuum metallization process, the anodizing process, to drive the winding and slitting processes and in the packaging and curing processes. It should be noted, however, that all of these processes are widely used in many industries and have been practiced for many decades. The cost of energy per part for these capacitors is very low. Additionally, these components are made in highly automated high volume facilities that are usually located overseas.

Materials

Capacitors are passive energy storage devices that store the energy in an electric or "E" field. Energy storage =½ C V2 where C is the capacitive value of the device. Three basic types of capacitors classified according to the type of dielectric used are film, electrolytic, and ceramic. Each type has its specific performance features and usage will depend on the application.

For power electronics, the two types most often used are film and aluminum electrolytic. Film capacitors typically have values in the 10's of µfs (micro farads), are used in parts of the circuit where AC is present, and are used as snubbers, filter caps in conjunction with resistors, and as de-coupling caps. Electrolytic capacitors have values in the 1000's of µfs, are used as DC input caps and DC link caps.

Capacitors consist of conducting layers separated by a dielectric layer. Capacity is determined by the area of the conductive layers, distance between the layers and the "K" value of the dielectric. Larger area, less separation distance, and higher K all increase the capacity. Breakdown voltage, frequency characteristics, internal resistance, polarity requirements, sensitivity to temperature, and durability are other major considerations of a capacitor.

Film capacitors are formed from either alternating layers of thin metal foil and dielectric material or metalized plastic films. Metals used can be aluminum or zinc and the film materials typically include polyester, polypropylene, polystyrene and polycarbonate. Film caps have capacity values ranging from about 1 ηF (nano farad) to 100 µF and voltage ratings up to 2,000 volts. Film caps also exhibit good frequency capabilities, and reliability and durability characteristics, but are limited in high temperature capability to usually less than 125°C. Development work is progressing to raise the temperature capability.

Electrolytic capacitors are formed from a thin aluminum sheet with a surface oxidized layer that forms the electrodes, and thin paper spacer that is saturated with an electrolyte material. Typical electrolyte materials are ammonium chloride or amidine chloride. Electrolytic caps have capacity values ranging from 100 µF up to approaching 1 F (farad), and voltage ratings up to several hundred volts. Electrolytic caps, however, are polarized and need to have the anode voltage always be positive with respect to the cathode voltage. Electrolytic capacitors are limited to temperature ranges that are similar to film caps, and can exhibit reduced durability due to the electrolyte drying out.

Description of Processes, Equipment, Testing, and Inspection

Both film and electrolytic capacitors are produced in high volume utilizing a roll-to-roll process. For film capacitors, a typical process starts with a large roll of the appropriate plastic film that undergoes a vacuum metallization process. The film is then slit into the desired width and wound together with another similarly metalized film to form the two electrodes. These two films are wound to the desired capacitance value by controlling the length of film wound together. For an axial terminal configuration, the films are also wound slightly offset so that electrical contact can be made on each edge. Subsequent steps complete the assembly by shaping the roll (flattening if desired), adding the contact layer to each edge, "healing" any internal shorts by burning them off, welding on the connector tabs, and coating the assembly with an external layer of film or lacquer. End of line testing can include checking for capacitance value, internal impedance or dissipation factor, and internal leakage.

Processing for an electrolytic starts with a roll of thin (50 to 100 µm thick) aluminum, which is etched on one surface to increase the surface area, then oxidized to form a thin layer of aluminum oxide in an anodizing process. This aluminum foil becomes the anode and the oxide layer becomes the dielectric. The cathode is also a thin sheet of aluminum foil. The cathode and anode are then rolled together separated by a thin spacer, usually of paper. For terminal configurations where the anode and cathode terminals are both on the same side or end of the device, terminal tabs are connected to the respective foils and brought out the same end of the roll. The roll is then impregnated with the electrolyte, inserted into a can usually made of aluminum, sealed, insulated, and tested.

Potential Energy Use Mitigating Technologies

Currently, the power electronics industry is pushing for improved operational performance characteristics in the areas of high temperature performance for film capacitors and improved durability for electrolytic capacitors. An improved volumetric density for capacitors is also desired. The advent of improved performance active devices through the use of wide band-gap substrate materials is driving these more stringent demands. Higher constant dielectric materials with higher temperature capabilities, thinner electrodes, and potentially more durable electrolytes will all reduce base material usage, and therefore, reduce the energy required to make these components. Examples of advanced dielectric materials that are being developed include very thin glass with a K value of ≈5, advanced polymer film materials that can be deposited in extremely thin layers and exhibit good high temperature performance and thin ceramic materials with K values up to 80. (K value for standard polymer films is around 2.)

Because there is not currently capacitor manufacturing occurring in Michigan or Northeast Ohio, the opportunity for the region rests in continued development of basic materials with improved properties for capacitor application along with their manufacturing processes offers an opportunity for R&D at universities located in Michigan and Ohio.

Packaging

Power electronics and power converters span a wide range of power levels.

Packaging discussion will be addressed for packaging of the active semiconductor device die into single die package and power module configurations. Packaging of the final power conversion device functional unit is similar to that of final product packaging for lighting, and packaging at that level is handled in more detail in the LED Lighting section. The package for each level of assembly is responsible for mechanically holding and protecting the contents, providing the electrical connections to the higher level circuitry or system and managing the heat energy that is generated from operating the die or circuits within the package.

Energy Drivers

Basic assembly of the active device die into a usable package consists mainly of assembly steps. Bonding the die to the substrate electrical attachment, usually by wire bonding, attaching a thermal management heat sink to the baseplate, if required, and then potting the assembly, make up the basic operations. These operations require a clean environment, but not to the degree that is required by die fabrication. Basic energy requirements for these steps are listed in the Table 3 in section 4.4 as the packaging of die and amount to 0.03 kWh / die, or about $0.003/die.

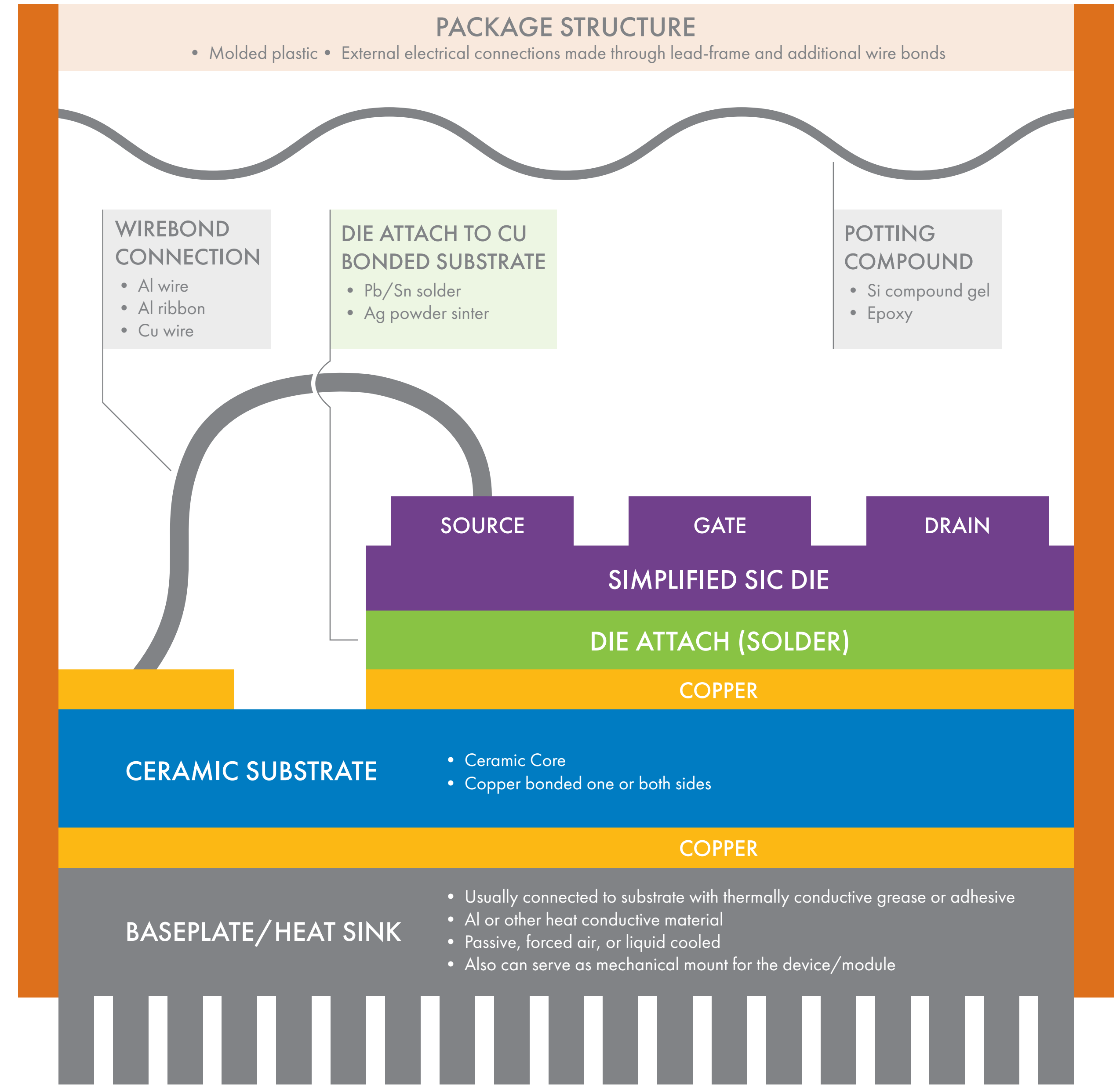
There is also embedded energy in the materials including copper, aluminum, ceramic and potting compound, but again these materials are commodities and the energy content represents a very small portion of the cost of the bill of materials.

Description of Materials, Processes, Equipment, Testing, and Inspection

There is a wide range of basic materials that are used in this phase of product assembly. Those materials can include aluminum and copper wire, copper for cladding and circuit traces, ceramics, plastic molding, adhesives, solder, aluminum extrusions, silicon potting compound, and others.

For the active semiconductor device, each package can contain a single functional die or several die connected together to increase functionality. Usually, the die is first attached to a substrate by adhesive or soldering, electrical connection is made by wire bond or attachment of an upper substrate connection, coated or potted into a package with a protective material to keep moisture and contaminants out, and finally sealed into a package. Often, there are specific thermal management features to the package, including heat sinks or liquid cooling passages. A diagram of a basic device package is shown in Figure 34.

Figure 34: Semiconductor Device Packaging

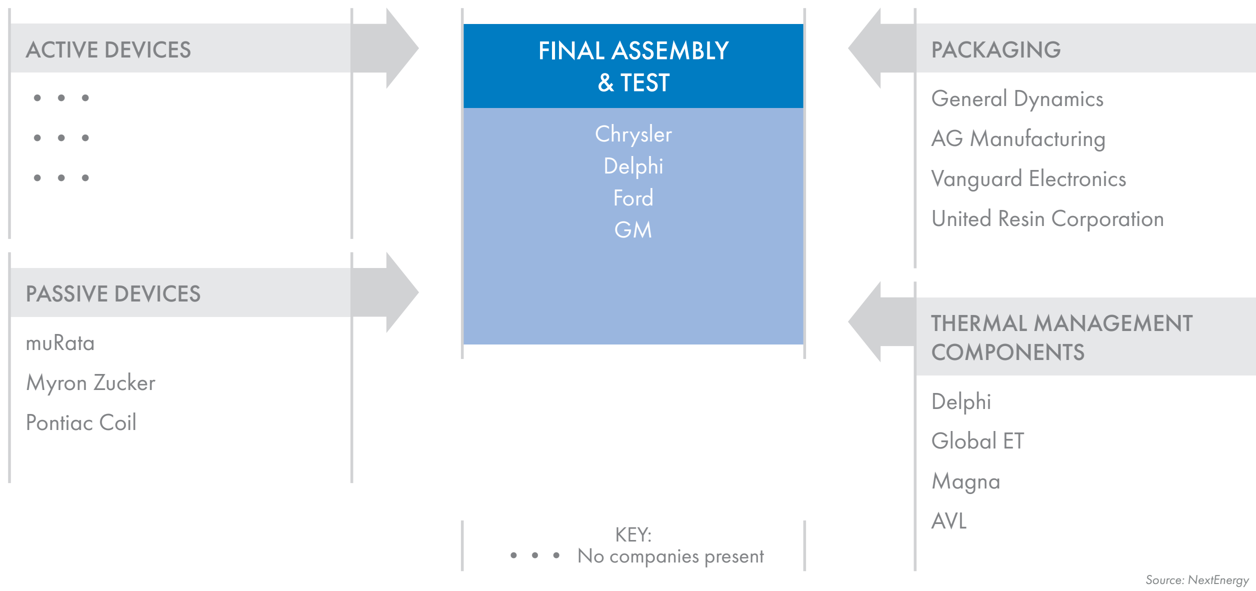


Source: NextEnergy

Potential Energy Use Mitigating Technologies

Shrinking package size by increasing power density capability of the device represents a viable way of reducing energy use of manufacture of these devices. Much R&D activity is taking place in this area. One possibility in this area includes integrating all of the components for the entire circuit on the same substrate as the active devices.

Figure 35: Power Electronics MI and Northeast OH Manufacturing Companies



4.5 Summary of Opportunities for Energy Use Mitigation

In summarizing the energy use mitigation possibilities, the technologies fell into three basic categories. Those categories are 1) evolutionary improvements in materials and designs, 2) revolutionary improvements in materials and designs, and 3) improvements in manufacturing techniques and processes. Categories 1) and 2) both result in the reduction of material use for a given performance level and, therefore, reduced energy usage. Category 3) results in improved yields, more efficient throughput in the manufacturing area, and lower fixed costs for equipment and HVAC requirements and, therefore, less waste and less energy use. Industry generally is continuously driving toward lower cost structures, which often results in reduced energy usage.

Evolutionary Improvements

Both Pb-A and Li-Ion batteries are experiencing improvement in material utilization through the development of improved materials and designs. For Pb-A batteries, the addition of carbon to the anode and implementing microstructure features to the electrodes are increasing the power and energy densities of these devices, as well as improving performance characteristics. Electronic packaging and lighting fixtures are implementing use of filled or coated plastics in place of metals, and improved thermal management designs. Generally, more compact designs lead to improved specific densities for all functions and reduced energy requirements for manufacture. Integrated drivers on the chip and improved thermal management materials are what enable these more compact designs.

Implementation of smart device controls such as on-board lighting controls is another area of evolutionary improvement. Technology is progressing from basic timers to motion detectors to much more sophisticated control algorithms.

Revolutionary Improvements

Pb-A batteries are being introduced with bi-polar construction designs and Li-Ion cells are reportedly close to production with solid state electrolytes. Both of these concepts significantly improve function with less material requirements. In the case of the solid state electrolyte Li-Ion cell, it also eliminates the need for the very costly clean and dry manufacturing environment.

In semiconductors, new substrate materials such as SiC and GaN for power electronics are proving to be very revolutionary in improving power handling efficiencies and reducing package size. The potential for revolutionary improvement in capacitors is in the area of the dialectric. New materials offer higher K value and improved temperature performance, both of which offer the possibility of reduced size and material usage.

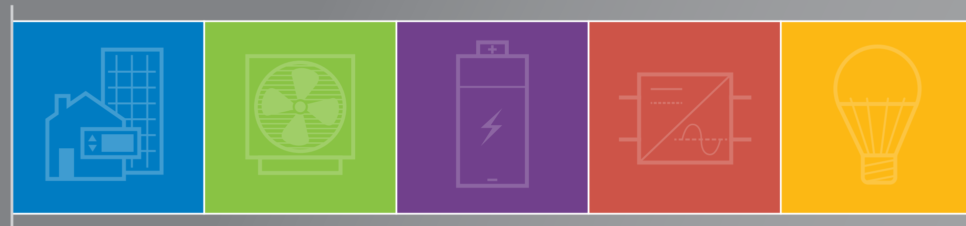
Manufacturing Improvements

Improvements in semiconductor device fabrication processes, including larger wafer diameters that improve process efficiencies and generally reduce defects, which improves process yields. For capacitors, new deposition processes are being developed, which will not only produce products with improved performance, but do it with less material.

Figure 36: Energy Use Mitigation Enabling Technologies Summary Discussion

AREA	EVOLUTIONARY	REVOLUTIONARY	MANUFACTURING
Pb-A Batteries	Carbon used in anode and improved electrode material structures	Bi-Polar plate construction	
Li-Ion Batteries	Improved chemistries and electrode material structures	Significant improvements in material usage via advanced designs (solid state, air electrode, Sulphur, or others)	Elimination of need for extremely clean and dry manufacturing space
Advanced Lighting	Increasingly intelligent lighting controls	Integrated light engine, drive & control circuitry	
Active Power		Wide Bandgap power device technologies allow improved efficiency and smaller ancillary components	Improved WBG device yields and larger wafer diameters for efficient manufacturing
Capacitive	Improved dialectric materials for "K" value, temperature and voltage	New dialectric materials with significantly improved "K" value, temperature and voltage capabilities	New manufacturing techniques enable and are required by new dialectric materials
Device Packaging	Engineered and thermally conductive plastics allow substitutions for metals	WBG power devices allow improved performance in much smaller packages requiring less material	

Source: NextEnergy



Summary

The Clean Energy Roadmap offers not only a detailed understanding of the current position of the clean energy ecosystem and its assets, but also discusses the current barriers, opportunities, and solutions that capitalize on opportunities moving forward in Michigan and Northeast Ohio.

Within the value chain, there are cross-cutting regional strengths including significant robust R&D activity, strong engineering and manufacturing talent, a strong network of entrepreneurs and innovation, as well as challenges such as untapped deployment potential. The tools recommended and needed to bridge the deployment gap may differ by state due to program preference and available opportunities

The analysis of specific energy efficient building technology supply chains reveals strength in the combined region of Michigan and Northeast Ohio LED lighting cluster. Focusing regional efforts on unique and complementary strengths to grow that cluster should pay dividends in both job and economic growth, and could be used as a model to foster growth in other sectors of importance. Both states can work together to position the region as a leader in the LED lighting sector by capitalizing on existing assets, better communicating industry capabilities, and fostering cluster development through private sector and academia matchmaking and convening.

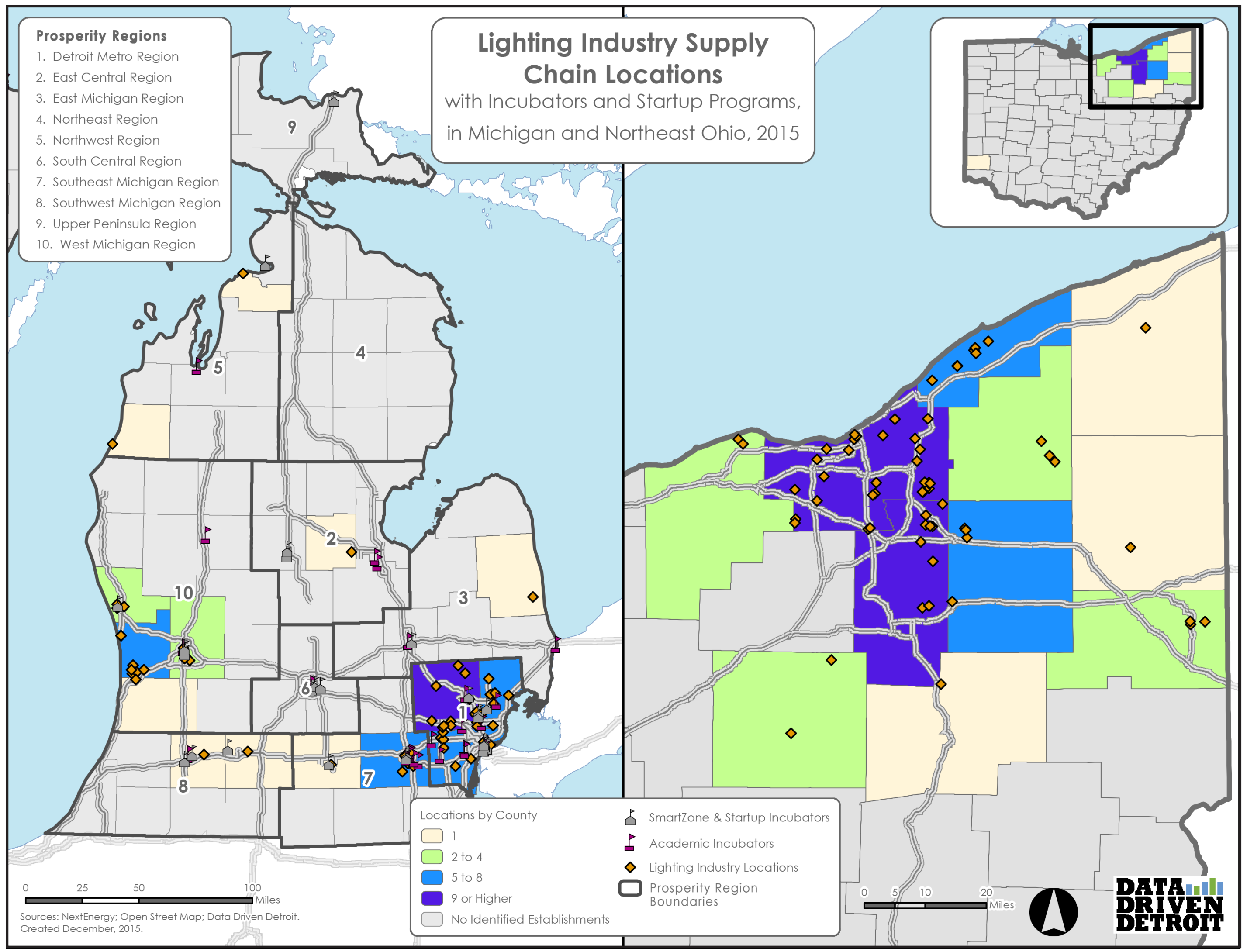
While these goals are applicable to each state and to their similar strengths in manufacturing processes, there are unique actions that could assist cluster growth in each state's specific ecosystem. In Northeast Ohio, this includes focusing on improving LED lighting investment attraction and business retention through funding assistance, collaboration, and potential customer engagement. In Michigan, this includes capitalizing on improved export opportunities and process improvements for improved design, reduction in costs, and improvements in yields through supply chain cross-pollination and matchmaking.

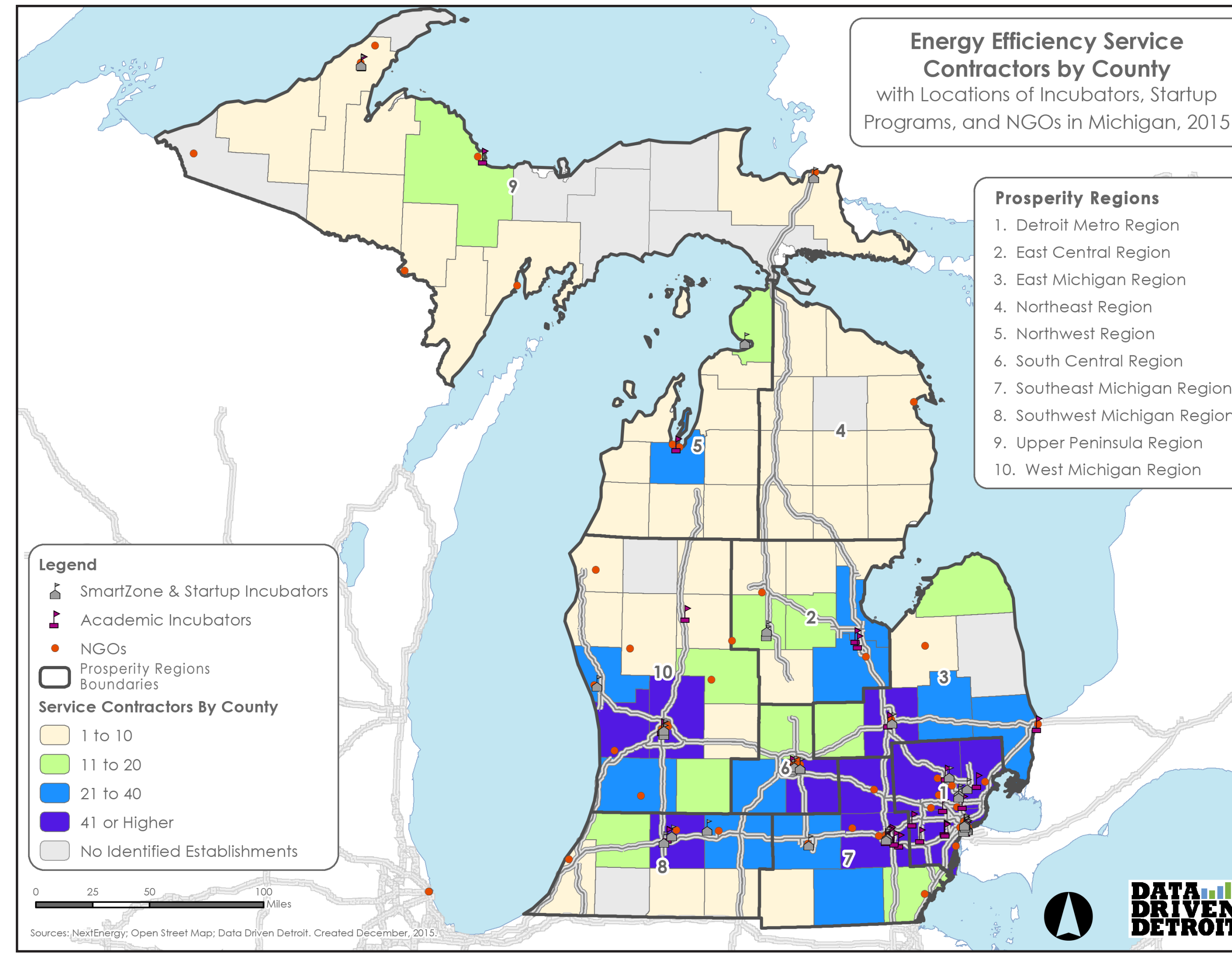
Furthermore, the growing building automation cluster in Michigan would benefit from developing technology demonstrations and from receiving regular cluster support and/or from forming an industry consortium. The cluster would also benefit from greater software development, as well as contractor training about the systems to help encourage adoption at the customer level. Additionally, the Michigan HVAC ecosystem faces challenges in developing sales channels. Tools to combat these challenges and grow the cluster overall include developing a CHP cluster, fostering control system partnerships, cultivating buy-sell relationships, and pushing existing "Buy Michigan" programs.

Finally, the analysis of potential opportunities to improve the energy efficiency in clean energy manufacturing processes reveals that energy drivers for clean energy manufacturing vary by the type of batteries being manufactured: within Li-Ion battery manufacturing controlling the temperature, humidity and dust uses a lot of energy; and, in Pb-A battery manufacturing, the melting, mixing and drying of lead is energy intensive. Within LED lighting and power electronics manufacturing processes, the energy use patterns are similar: basic materials, assembly, and testing drive energy use for facilities, but are small on a per unit basis. Therefore, mitigating energy use in these three applications will take significant effort to improve raw material efficiency, improve yield from production, or in the case of Li-Ion, leapfrog the technology to reduce clean room necessity.

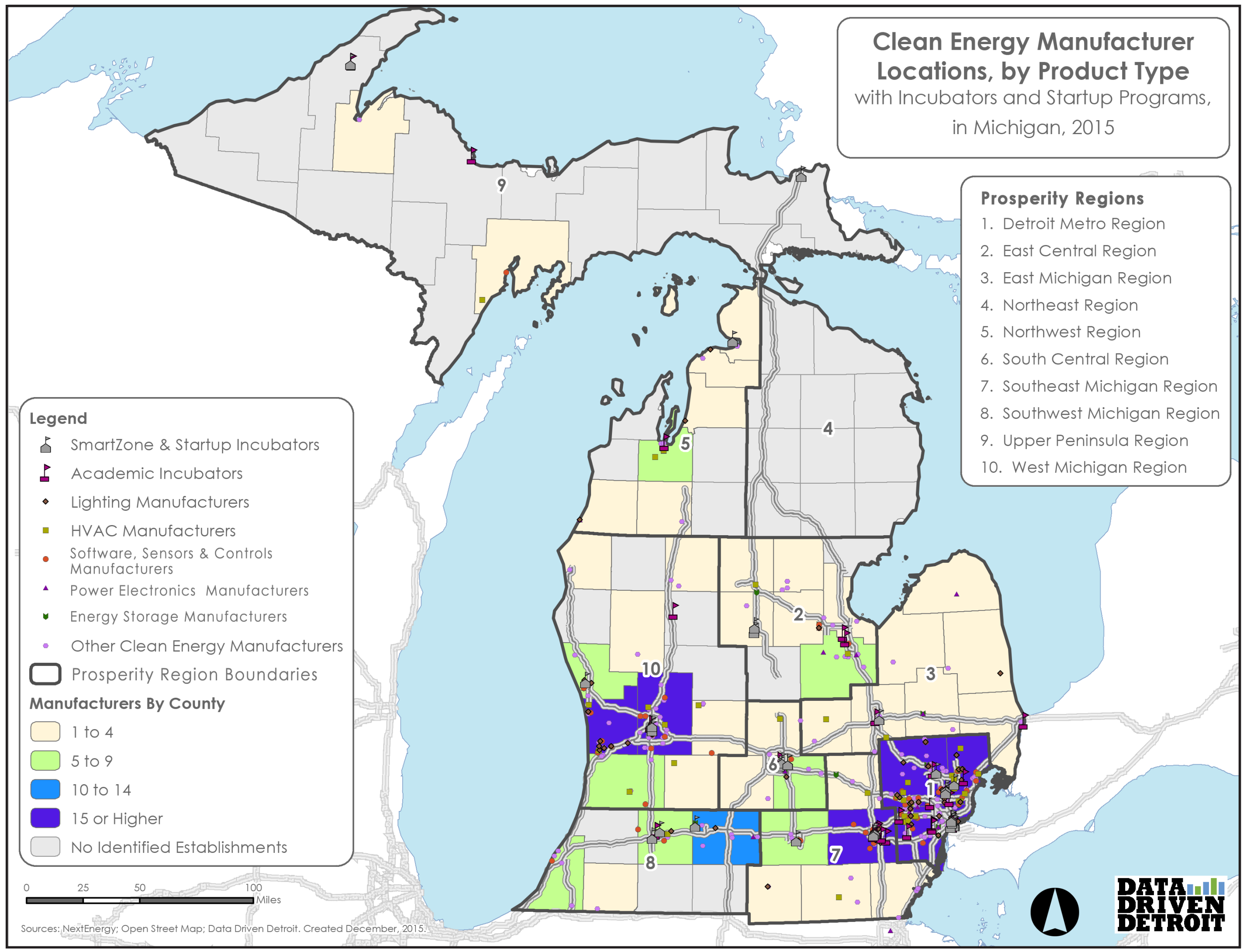
The implementation plan provides a roadmap for growing the clean energy and energy efficiency sectors in the region and will contribute to regional economic growth.

Appendix - Maps





Appendix - Maps Continued



Appendix - Acronyms

A/E............................architecture and engineering
AC..............................alternating current
AEP Ohio....................American Electric Power Ohio
Al................................aluminum
B2B............................business to business
BEMS.........................building energy management system
BENEFIT.....................Building Energy Efficiency Frontiers and Innovations Technology
BPA.............................bisphenol A
BTO............................Building Technology Office
BTU.............................British thermal unit
C..................................carbon
CFL.............................compact fluorescent lightbulb
CHP............................combined heat & power
CVD............................chemical vapor deposition
DC..............................direct current
DOE...........................Department of Energy
DSIRE.........................Database of State Incentives for Renewables & Efficiency
EEBT...........................energy efficient building technology
EERE...........................Office of Energy Efficiency and Renewable Energy
EERS...........................Energy Efficiency Resource Standard
EIBC...........................Michigan Energy Innovation Business Council
EMS............................energy management system
EO..............................energy optimization
EPA.............................Environmental Protection Agency
ESCO.........................energy service company
F..................................farad
GaN...........................gallium nitride
GLIDE.........................Great Lakes Innovation and Development Enterprise
HEMS.........................home energy management system
HVAC.........................heating, ventilating, and air conditioning
IES..............................Illuminating Engineering Society
IoT..............................internet of things
IP................................intellectual property
IR................................infrared
IT.................................information technology
JDA.............................joint development agreement
JV................................joint venture
kWh............................kilowatt hour
LCA.............................life cycle analysis
LCO............................lithium cobalt oxide
LED.............................light emitting diode
LEED...........................Leadership in Energy & Environmental Design
LFP..............................lithium iron phosphate
Li.................................lithium
Li-Ion..........................lithium ion

Appendix - Acronyms Continued

LMO............................lithium manganese oxide
M-TEC.........................Michigan Technical Education Centers
MAE............................Michigan Agency for Energy
MAGNET ....Manufacturing Advocacy & Growth Network
MEDC.........................Michigan Economic Development Corporation
MEECA.......................Michigan Energy Efficiency Contractors Association
MEMD........................Michigan Energy Measures Database
MI...............................Michigan
MISO..........................Midcontinent Independent System Operator, Inc.
MJ/kg.........................Megajoules per kilogram
MOCVD.....................metal organic chemical vapor deposition
MPSC.........................Michigan Public Service Commission
MSSLA.......................Michigan Solid State Lighting Association
NASA..........................National Aeronautics and Space Administration
NCA............................nickel cobalt aluminum oxide
NH_3............................ammonia
NMC...........................nickel manganese cobalt
NZE.............................net zero energy
OEM...........................original equipment manufacturer
OH..............................Ohio
OLED..........................organic light emitting diode
PACE..........................property assessed clean energy
Pb...............................lead
Pb-A...........................lead-acid
PCB............................printed circuit board
PMMA........................poly methyl methacylate
R&D............................research and development
ROI.............................return on investment
RPS.............................Renewable Portfolio Standard
SAAS..........................software as a service
SB...............................Senate Bill
SBIR............................Small Business Innovation Research
SC...............................supply chain
Si.................................silicon
SiC..............................siliconcarbide
SSLC...........................Separate Sensible and Latent Cooling
SWOT.........................strengths, weaknesses, opportunities and threats
TBEIC..........................Tech Belt Energy Innovation Center
TMG............................trimethyl-gallium
U.S. ....United States
ηF ....nano farad
μF ....micro farad

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