CHP

ROADMAP FOR MICHIGAN

Prepared for the Michigan Energy Office on behalf of the Michigan Agency for Energy and the US Department of Energy

February 2018

Project Team

The **Michigan Energy Office** (MEO) is within the **Michigan Agency for Energy** (MAE). 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. The MEO is a recognized State Energy Office by the federal Department of Energy. MEO encourages and informs energy policy and technology and program development by facilitating partnerships, administering grant funds, and providing statewide education, outreach opportunities and stakeholder collaboratives.

5 Lakes Energy (5LE) is a Michigan-based policy consulting firm dedicated to advancing policies and programs that promote clean energy, sustainability and the environment. The team has decades of experience in research, modeling and analysis. From public policy design to reviewing policy implementation around the country and world, 5 Lakes Energy has the deep knowledge base necessary to review, analyze, and recommend models for optimizing the deployment of clean energy.

Sustainable Partners LLC (SPART) was formed in 2011 to develop and finance alternative and renewable energy projects and provide related consulting services to major industrial and commercial energy users. SPART excels at building consensus among stakeholders, leading cross-functional teams, and ensuring accountability, while helping clients thoroughly evaluate energy options and implement sustainable projects through advisory services and direct capital investment.

The **Energy Resources Center** (ERC), established in 1973 at the University of Illinois at Chicago, is an interdisciplinary public research center bringing experts from across the fields of electric, mechanical and environmental engineering, in addition to economics, public policy, and bioenergy. The ERC manages the U.S. Department of Energy's Midwest CHP Technical Assistance Partnership (TAP), which provides services to twelve Midwest states, including Michigan.

NextEnergy is one of the nation's leading accelerators of advanced energy and transportation technologies, businesses and industries. NextEnergy drives technology demonstration and commercialization, delivers industry and venture development services, and provides an authoritative voice in the public sector. Founded in 2002 as 501(c)(3) nonprofit organization, NextEnergy has helped attract more than $1.6 billion of new investment, including programs in excess of $160 million in which NextEnergy has directly participated.

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About the Report

The Combined Heat and Power (CHP) Roadmap for Michigan is a collaborative effort to accelerate the adoption of CHP in Michigan through three objectives:

1. Identify and evaluate CHP technologies and applications with a potential for adoption in Michigan;
2. Assess, measure, and determine the cost and value of CHP in Michigan's future energy mix;
3. Listen, educate, and advocate for the inclusion of CHP based upon economic, environmental, and system benefits.

Project partners worked to identify strategies to remove transactional, market, finance and policy barriers to CHP deployment. Project partners also worked to leverage proven methodology to map and engage the Michigan-specific CHP supply chain. This report shares results and recommendations that can be utilized to accelerate the adoption of CHP in Michigan and achieve the resulting economic benefits.

Acknowledgements

This report and the work described were supported by the U.S. Department of Energy and the Michigan Agency for Energy through the Michigan Energy Office under Award No. DE-EE0006226.

The authors gratefully acknowledge the assistance of the stakeholders in the CHP ecosystem who generously shared their time and expertise in completing surveys, participating in interviews, attending events, and providing other related information.

Glossary of Acronyms

5LE – 5 Lakes Energy, LLC

CHP – Combined heat and power

CI – Commercial/industrial

CIBO – Council of Industrial Boiler Owners

CODE2 – Cogeneration Observatory and Dissemination Europe

CPM – Continuous process manufacturing

CPP – Clean Power Plan

DE – Digital economy

DOE – United States Department of Energy

DTE – DTE Electric Company (formerly Detroit Edison)

EIA – United States Energy Information Administration

EPA – United States Environmental Protection Agency

EPRI – Electric Power Research Institute

ERC – Energy Resources Center

EWR – Energy Waste Reduction

F&ES – Fabrication and essential services

GDP – Gross domestic product

GW – Gigawatt

HHV – Higher heating value

IEI – Institute for Energy Innovation

IRP – Integrated Resource Plan

ITC – Investment tax credit

kW – Kilowatt

kWh – Kilowatt-hour

LHV – Lower heating value

Michigan EIBC – Michigan Energy Innovation Business Council

MISO – Midcontinent Independent System Operator

MMBtu – Million British thermal units

MPSC – Michigan Public Service Commission

MW – Megawatt

MWh – Megawatt-hour

NEP – New Energy Policy

NREL – National Renewable Energy Laboratory

NYSERDA – New York State Energy Research and Development Authority

PACE – Property Assessed Clean Energy

PURPA – Public Utilities Regulatory Policies Act

RAP – The Regulatory Assistance Project

REC – Renewable energy credit

RPS – Renewable Portfolio Standard

SPART – Sustainable Partners, LLC

STEER – State Tool for Electricity Emissions Reduction

TAP – Technical Assistance Partnership

WHP – Waste heat to power

WMAEE – West Michigan Association of Energy Engineers

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Executive Summary

Michigan has the opportunity to capture enormous benefits by embracing optimal levels of combined heat and power (CHP) generation in its future energy mix. CHP provides a path to make Michigan businesses more competitive by lowering and stabilizing energy costs, reducing strain on the electric grid, improving on-site reliability and resiliency, and lowering harmful greenhouse gas emissions. Yet many studies have shown that CHP is a vastly underutilized energy resource across the country due to a combination of policy barriers, market impediments, and other factors. Michigan intends to be a leader in advancing CHP deployment and this CHP Roadmap is a significant initial step in that effort.

CHP is *the* most fuel-efficient way to produce and utilize both electric and thermal energy from a single fuel source. CHP adoption across Michigan offers a low-cost approach to new electricity generation and uses highly skilled Michigan labor and technology to develop, implement, and operate projects.

Governor Snyder has made smart energy policy a top priority for Michigan, emphasizing the need to reduce energy waste and increase reliability. A confluence of executive and legislative interest in energy policy, coupled with recognition of the potential of CHP to participate in meeting Michigan's energy needs, means the time is right to accelerate CHP deployment in Michigan.

The CHP Roadmap for Michigan differs from previous projects by applying a cutting-edge integrated resource modeling tool to determine least-cost deployment of CHP resources. This model – the State Tool for Electricity Emissions Reduction (STEER) – calculates the least-cost resource portfolio to satisfy electricity demand and various reliability and environmental constraints based on projections of demand, fuel prices, technology price and performance, taxes, and other factors. Depending on natural gas prices and the availability of renewable energy resources, STEER recommended an optimal level of additional CHP deployment in Michigan ranging from 722 MW to 1,014 MW by 2030.

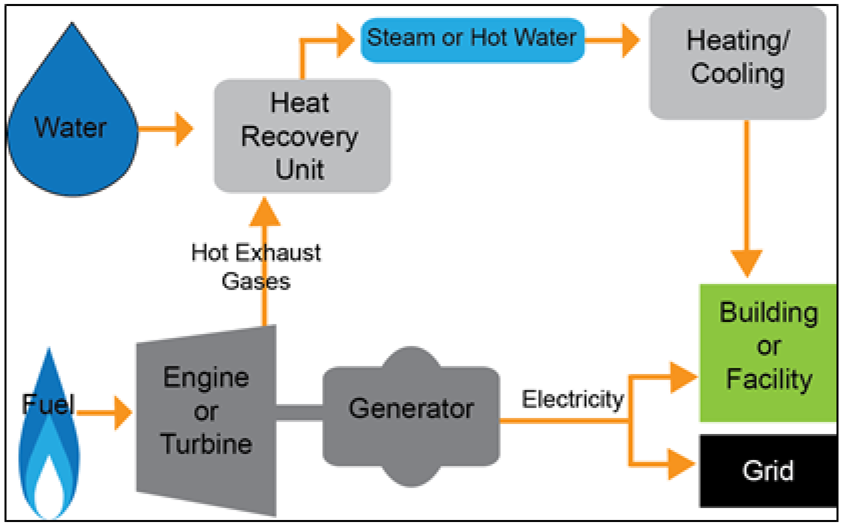
Parallel to this modeling effort, an intensive analysis of Michigan's CHP-related supply and value chains provides insight to support state-level policy analyses and recommendations. Michigan firms have a robust ability to participate throughout the CHP value chain with the majority of economic impact being realized by using the pool of talent based in Michigan companies to design and implement CHP projects.

Finally, the Michigan CHP Roadmap provides a series of prioritized public policy recommendations that will put Michigan on a path to a CHP-friendly future, including recommendations to:

- Offer financing and incentives for CHP in order to reduce the payback period for CHP projects;
- Promote Property Assessed Clean Energy (PACE) financing and on-bill financing for CHP;
- Consider best practices in utility standby rates and PURPA avoided cost/buyback rates;
- Fully value CHP when considering the costs and benefits of distributed energy resources;
- Update interconnection standards to better align with new technologies and best practices;
- Incorporate CHP as a resource in Michigan utility energy waste reduction (EWR) plans;
- Require utility integrated resource plans (IRPs) to consider CHP as both a supply-side and demand-side resource;
- Collaborate closely with expert organizations, such as the Midwest CHP Technical Assistance Program (TAP), to promote CHP assistance.

Background

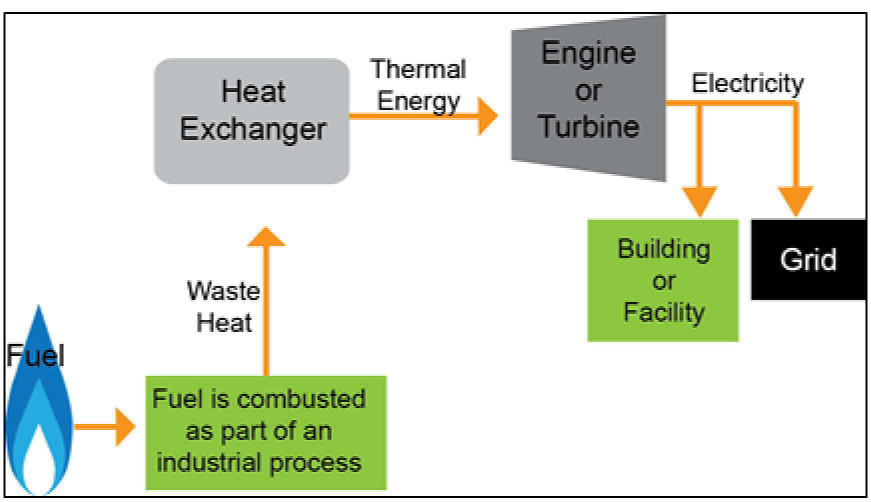
CHP is the simultaneous generation of electricity and useful thermal energy from a single source of fuel, located at or near the point of energy use. Electricity is primarily used on site as a substitute for utility-provided power, with any excess generation potentially sold onto the grid. The thermal energy can be used to support process applications or human comfort through the production of steam, hot water, hot air, refrigeration, or chilled water.



CHP Topping Cycle

Installed CHP systems typically achieve total energy efficiencies of 65% to 80%, compared to a weighted average of only about 45% to 60% for conventional separate heat (via boilers/furnaces) and power generation (via central utility plants). By avoiding electric line losses and utilizing much of the thermal energy normally wasted in power generation, CHP significantly reduces the total primary fuel needed to supply energy services, reducing greenhouse gas emissions and saving fuel and money. CHP systems can range in size from 5 kilowatts (kW; the demand of a typical single-family home) to several hundred Megawatts (MW; the demand of a very large industrial plant).

CHP technology can be deployed quickly, with few geographic limitations, and can utilize a variety of fuels, both fossil and renewable. CHP may not be widely recognized outside industrial, commercial, institutional, and utility circles, but it has quietly been providing highly efficient electricity and process heat throughout the United States for decades to vital industries, large employers, urban centers, critical infrastructure like hospitals and wastewater treatment plants, and university campuses.



CHP Bottoming Cycle: Waste Heat to Power (WHP)

Methodology

The methodology employed throughout the Roadmap was developed with the objective of replicability in other states. To achieve this objective, project partners relied on:

- U.S. Department of Energy (DOE) state-by-state CHP technical potential projections,
- U.S. Environmental Protection Agency (EPA) data on CHP economics and performance across a range of technologies and generating capacities, and
- U.S. Energy Information Administration (EIA) data for Michigan's existing power plant portfolio

According to DOE, Michigan has nearly 5 GW of CHP technical potential at more than 10,000 sites across 17 industrial and 24 commercial sectors. This potential, on a capacity basis, is roughly evenly split between industrial candidates in the transportation equipment, chemicals, primary metals, paper and food sectors; and commercial candidates in the commercial office building, higher education, hospital, retail location, and multifamily housing sectors.

The EPA provides cost and performance data for the five CHP technologies which comprise 99% of existing installations: reciprocating engines, steam turbines, combustion turbines, microturbines and fuel cells. Data from DOE, EPA and EIA serve as a major proportion of the input required for the STEER model to dynamically identify which CHP configurations are economically viable across a wide variety of scenarios. This analysis narrows the scope of Michigan's technical potential to only include those projects that are economically viable given Michigan's overall power generation portfolio.

Mapping of the Michigan CHP supply and value chain utilized methodology previously developed to support creation of the Michigan "Clean Energy Roadmap." Boundaries for supply and value chain mapping were determined through market research and market analysis based on likely economic impact to the state of Michigan arising from deployment of CHP projects. Market segments where Michigan companies are currently participating in the CHP supply or value chain were given principal consideration for surveys and interviews. A directory of Michigan supply and value chain firms has been created and will be distributed to foster collaboration and promote CHP deployment.

In customizing and prioritizing proposed solutions for Michigan, project partners considered the estimated proportion of potential projects affected, perception of barrier magnitude by stakeholders, and the ease/practicality of achieving change in the short term. Focus was placed on those barriers that are most significant to restricting deployment of CHP across Michigan and to which attainable solutions exist. These include 1) a lack of access to low-cost capital; 2) prohibitive utility rates; 3) failure to fully embrace CHP in energy waste reduction and integrated resource planning; and (4) a lack of awareness or familiarity with CHP. For the most part, solutions take the form of legislative change or regulatory relief, modification of utility rate structures, and financial incentives.

Finally, deployment of the Roadmap involves the ongoing effort to educate CHP stakeholders, and especially end-users, on the merits of CHP. Project partners engaged with over 300 individuals through outreach and education efforts related to the development of the Roadmap. Project partners are working with the Michigan Agency for Energy to expand outreach and assistance over the next several years as a critical step toward achieving the goal of accelerating the deployment of CHP in Michigan.

State Tool for Electricity Emissions Reduction (STEER)

The STEER model was used to assess, measure, and determine the cost and value of CHP as one of multiple resources in Michigan's future energy mix. In our primary application of STEER, we considered the net value of CHP to the economy by considering the cost of installing and operating various CHP systems, the value of the heat produced by CHP measured as the cost of supplying heat in the least-cost way other than CHP, and the value of electricity produced by the CHP system measured as the marginal cost of producing electricity absent the CHP system.

Because we determined that standby rates are one of the principal barriers to CHP adoption and may be amenable to policy adjustments, we also used STEER to evaluate the effect of standby rates on the economic potential for CHP in Michigan. Further, because resilience of CHP site host operations is an important benefit of CHP that is not reflected in standard electric power system evaluations, we also used STEER to evaluate the additional economic potential for CHP in Michigan if site hosts would not otherwise choose to build CHP but sufficiently valued resilience to enable them to build CHP. Consideration of resilience value increases the potential deployment of CHP in sectors where loss of power is most consequential and can significantly increase CHP potential beyond the levels that would be supported only by power sector value. Based on our analysis of Michigan potential, resilience value could increase CHP potential by around 60%. Standby rates, on the other hand, substantially reduce the profitability of CHP ownership and thereby reduce potential CHP deployment by 50% or more.

STEER modeling indicates that steam turbines, gas combustion turbines, and reciprocating engines appear profitable above some size threshold size in each scenario. Conversely, microturbines and fuel cells do not appear economically viable.

Scenarios with higher natural gas prices and higher cost of renewable resources in the future both tend to lower the minimum size threshold for the more viable CHP technologies, thereby expanding the number of potential installation sites in Michigan.

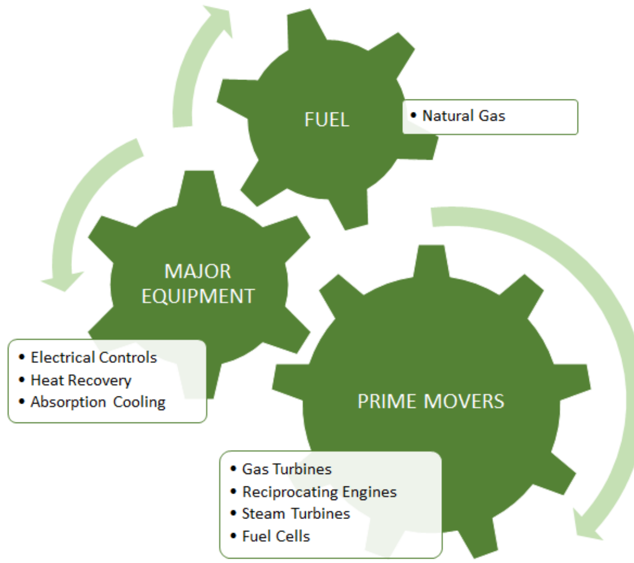
About half the sites where steam turbines are economically feasible are colleges and universities, confirming that this sector should be an important part of end-user outreach and education. We also note that this result does not necessarily mean that combustion turbines and reciprocating engines would not be suitable for many of these applications.

In our reference scenario, economic potential for CHP in Michigan is about 1,014 MW electric generation capacity with direct investment of about $865.6 million, annual direct O&M activity of about $67.6 million, annual economic profit of about $109.5 million, annual fuel cost savings of $94.7 million, and annual air emissions reductions of 662 tons CO_2 per year, 379 tons NO_x per year, and 39 tons SO_x per year.

In various scenarios, assuming various fuel and technology costs, the economic potential for new installed CHP in Michigan varies from 722 MW to 2,360 MW.

Michigan Supply and Value Chain

Demand for CHP projects in both the private and public sector is primarily driven by an economic comparison of the costs and benefits of CHP versus the costs and benefits of current operations. This status quo typically entails electric generation at a utility-owned power plant and thermal energy generation on-site by end-user-owned boilers or furnaces.

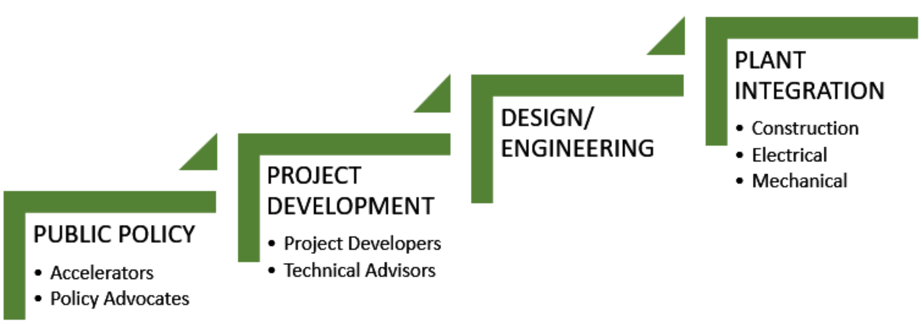


The **CHP supply chain** consists of the physical equipment and fuel required for the CHP system to operate. The major sectors of the CHP supply chain include CHP end-user applications, prime mover manufacturers and distributors, major equipment manufacturers and distributors, and fuel suppliers and brokers.

While Michigan manufacturers cannot realistically tap into prime mover manufacturing, there are a handful of Michigan companies that manufacture some of the major ancillary equipment that may be found in CHP projects but are not part of the prime mover systems. And manufacturers of both prime movers and other equipment execute sales, engineering, and service functions through Micihgan-based distributors.

Fuel supply and price can be controlled via 5 to 10 year contracts in most industrial and commercial locations, with costs currently near historic lows. This ability to control commodity costs significantly mitigates investment risk. In some regions of the state, particularly rural areas and the Upper Peninsula, the infrastructure for handling large volumes of natural gas is inadequate or nonexistent. Biomass-based fuel sources may be utilized but require significant additional effort on the part of the project developer. In the Upper Peninsula, unless a potential CHP project is located in one of the few major cities or along the east-west natural gas transmission corridor, fuel supply may be an impossible hurdle to overcome.

Michigan firms have a robust ability to participate throughout the **CHP value chain**, which consists of the intellectual capital and skilled trades required to develop, design, engineer, finance, install, and integrate CHP systems. The major sectors of the value chain include policy advocates and accelerators, project developers and technical advisors, design/engineering firms, and plant integration contractors. The majority of the economic impact of CHP will be realized by using this pool of talent based in Michigan companies to design and implement projects.



Barriers to CHP in Michigan

CHP has the potential to be a significant, reliable, cost-effective, and environmentally protective contributor to Michigan's energy mix. However, those interested in installing CHP projects face a number of obstacles. In order to fulfill the promise of energy waste reduction (EWR) in Michigan through optimal deployment of CHP, these barriers should be examined and understood in general, and in light of the unique circumstances facing Michigan energy users.

While CHP can save a system owner money in the long run, there are a few economic barriers that could prevent a CHP project from moving forward in the first place. The relatively high upfront cost of installing a CHP system can be a barrier in itself. Additionally, a lack of sufficient access to financing options can prevent otherwise cost-effective installations. CHP developers must navigate a complex landscape of project financing alternatives and provide detailed project information in order to attract investors. Inadequate information can cause project delays, leading investors to offer less favorable financial terms, or even decline a CHP investment opportunity all together.

Regulatory barriers can dramatically affect a CHP project's bottom line and projected payback period. An overarching barrier that affects the valuation of CHP throughout regulatory and policy discussions stems from the failure to account for the full value of CHP, including qualities such as resilience. Ignoring grid-wide and societal benefits affects how CHP is portrayed in standby rates, avoided cost rates, energy waste reduction standards and integrated resource planning. Standby rates, or charges a utility customer pays for the utility to provide backup service in case of a scheduled or unscheduled CHP system outage, can be so high as to completely undermine the economic viability of a proposed CHP system. Beyond standby rates, avoided cost or buyback rates under the Public Utility Regulatory Policies Act of 1978 (PURPA) may be insufficient to make a CHP project worthwhile. Interconnection processes can be lengthy, cumbersome and costly. Where states have embraced energy waste reduction (EWR) goals or standards, a failure to incorporate CHP, or to properly calculate energy savings from participating CHP systems, will lead to less than ideal deployment numbers. Finally, even as regulators and utilities embrace a longer-term resource planning approach, integrated resource planning (IRP) models often fail to recognize the value of CHP as both a supply side and demand side resource, resulting in CHP being overlooked in utility long-range resource plans.

Each of these barriers – which are often dependent on geography, project size and technology, utility constraints, and the prevailing regulatory climate – adds to the risk and cost associated with a potential CHP project. And since CHP is not regarded as part of most end-users' core business focus, it is often subject to higher investment hurdle rates than competing internal options.

Given the substantial capital investment involved in developing a CHP project, and in light of the benefits offered by more robust deployment of CHP, it is vitally important that these risks and costs be mitigated through thoughtful policies and incentives to avoid preventing CHP projects that would otherwise make good sense for Michigan businesses and the state's future energy mix.

Michigan businesses interested in CHP have access to the U.S. DOE's Midwest CHP Technical Assistance Partnership (TAP), managed by the Energy Resources Center and based in Chicago, Illinois. The Midwest CHP TAP promotes greater adoption of clean and efficient energy generation and use through CHP, district energy, and waste heat recovery. The Midwest CHP TAP provides a number of resources to potential CHP end-users including free or low-cost technical advisory services.

Roadmap for CHP Deployment

There is strong interest and capability for Michigan to move closer to optimal levels of CHP deployment. Currently, Michigan is home to over 3,300 MW of installed CHP capacity, and STEER indicates that ideal levels of CHP in Michigan include between 722 MW to 2,360 MW of new installed capacity. In order to pursue a greater role for CHP in Michigan's future energy mix, these recommendations reflect lessons learned from stakeholder surveys, interviews, Midwest CHP TAP experience and expertise, and best practices from other states.

1. **Offer financial incentives for CHP.** Payback period is critical to the development of a CHP project. Efforts to reduce the payback period of CHP by either defraying some of the initial upfront cost through a grant or offering a production incentive would be beneficial in addressing this barrier.
2. **Promote Property Assessed Clean Energy (PACE) financing and On-Bill Financing (OBF) for CHP.** PACE financing eliminates the high upfront cost and spreads the repayment over a long enough term that the annual savings generated from the CHP project exceed the PACE payments starting in the very first year. With OBF, the customer's costs of energy waste reduction retrofits or equipment are amortized and added to savings resulting from the measures on the customer's utility bill.
3. **Consider best practices in utility standby rates and PURPA avoided cost/buyback rates.** Standby rates are difficult are to interpret and navigate and negatively impact a CHP project's bottom line. The need for a revised approach to standby rates in Michigan stands as a prime example of a barrier to CHP that can be readily reduced or eliminated.
4. **Fully value CHP when considering the costs and benefits of distributed energy resources.** Michigan's current distributed generation program is targeted at small installations and does not include CHP. Future consideration of the costs and benefits of distributed energy resources should include CHP and attempt to capture its full value, including the value of resilience.
5. **Update interconnection standards to better align with new technologies and best practices.** Michigan's new energy law (passed in December 2016, PA341 and PA342) gives the MPSC authority to revisit and update the interconnection technical standards. Other states in the Midwest have recently revised their interconnection standards for small electrical generations to follow best practices and reflect the proposed standards in FERC Orders 792 and 792-A.
6. **Incorporate CHP as a resource in Michigan utility energy waste reduction (EWR) plans.** When allowed as an eligible measure, CHP can improve a utility's ability to meet energy reduction goals and further increase CHP deployment.
7. **Require utility IRP's to consider CHP as both a supply-side and demand-side resource.** This would help ensure that these complicated projects are allotted equivalent analyses as other resources.
8. **Collaborate closely with expert organizations (e.g. the Midwest CHP TAP) to promote CHP assistance.** These resources can be enormously helpful for those interested in developing CHP projects.

Moving Michigan Forward

Michigan is poised to move forward toward optimal levels of CHP development. According to the U.S. DOE, Michigan has nearly 5 GW of CHP technical potential at more than 10,000 sites across 17 industrial and 24 commercial sectors. STEER model results indicate that ideal levels of new CHP in Michigan, as a least-cost resource option, range between 722 MW to 2,360 MW.

This increase in CHP deployment will enhance Michigan's efforts to lead on energy waste reduction among other states. Currently, Michigan ranks 7th in the nation for potential annual CO_2 reductions from industrial energy efficiency and CHP and waste heat to power (WHP). In the 2017 American Council for an Energy Efficient Economy (ACEEE)Energy Efficiency Scorecard, Michigan was ranked 14th (tied with Arizona, Delaware, Iowa, New Jersey, New Mexico, Ohio, Texas, and Wisconsin) in the CHP category, slightly lower than its overall energy efficiency rank of 11th.

Demonstrating leadership in CHP development will serve to both reinforce and grow Michigan's demonstrated commitment to energy waste reduction. According to the Michigan Public Service Commission, regarding energy waste reduction overall, "For 2015, Michigan utility providers successfully complied with the energy savings targets laid out in PA 295. Providers met a combined average of 121 percent of their electric energy savings targets and 117 percent of their natural gas energy savings targets – one percent of retail sales for electric providers, and 0.75 percent of retail sales for gas providers. Energy Optimization programs across the state accounted for electric savings totaling over 1.1 million MWh (megawatt hours) and natural gas savings totaling over 4.58 million Mcf (thousand cubic feet) for program year 2015." CHP could be key to continuing to meet strong energy savings targets in the future. A single CHP system can offer the efficiency savings of many smaller energy efficiency projects. Given that some utilities are reporting a lower availability of cheap ("low hanging") energy efficiency savings opportunities in the commercial and industrial sector, CHP can offer deep savings at a very low cost, enhancing the overall cost-effectiveness of energy efficiency portfolios.

Execution of the Michigan CHP Roadmap will likely have significant impacts on the levels of CHP deployed in Michigan. For example, by addressing the CHP barrier of standby rates, STEER results using the EIA Reference Case indicate that Michigan could see an increase of 345 MW of CHP capacity built.

Additionally, CHP incentive programs in other states have seen dramatic results in additional CHP capacity coming online. The NYSERDA CHP incentive program has had an enormous market impact in New York. Between 2013 and 2016, the NYSERDA program has provided incentives to over 150 sites with a cumulative total capacity of over 70 MW. Similarly, in Illinois, the impact of the public sector CHP incentive was immediately felt, with the incentive program receiving 17 applications providing 31 MW of capacity. Through implementation of the Michigan CHP Roadmap, well-crafted CHP incentive programs could have similar positive effects on CHP development in Michigan.

Building on its strong commitment to energy waste reduction, Michigan is well-positioned to take advantage of the opportunities offered by increased CHP development in the state. By implementing the Michigan CHP Roadmap, the state can expand its energy waste reduction vision to include the many benefits of CHP, helping businesses to achieve their cost-savings and energy reliability goals. With key revisions to programs and policy, CHP has the potential to be a significant, reliable, cost-effective, and environmentally protective contributor to Michigan's energy mix.

1 Introduction

Michigan has the opportunity to capture enormous benefits by embracing optimal levels of combined heat and power (CHP) generation in the state's future energy mix. CHP provides a path to make Michigan businesses more competitive by lowering and stabilizing energy costs, reducing strain on the electric grid, improving on-site reliability and resiliency, and lowering harmful greenhouse gas emissions. Yet many studies have shown that CHP is a vastly underutilized energy resource across the country due to a combination of policy barriers, market impediments, and other factors. Michigan intends to be a leader in advancing CHP deployment and this Roadmap is a significant initial step in that effort.

Also known as cogeneration, CHP involves using one power system to generate both electricity and heat simultaneously from a single fuel source, and is the most fuel-efficient way to produce and utilize both electric and thermal energy. CHP systems typically reach fuel efficiencies of 65% to 80%, while the average efficiency of utility-scale electric generation has remained near 35% percent since the 1960s.[1]

CHP adoption across Michigan offers a low-cost approach to new electricity generation and uses highly skilled Michigan labor and technology to develop, implement, and operate projects. CHP is likely to enhance the competitiveness of Michigan's manufacturing, commercial, and institutional sectors, while lessening the need for new investments in utility transmission and distribution infrastructure.

Governor Snyder has made smart energy policy a top priority for Michigan, emphasizing the need to reduce energy waste and increase reliability. Through his leadership, the state remains focused on meeting its energy needs while protecting the environment and reducing customers' energy bills. Late in 2016, Governor Snyder signed into law an important package of energy legislation (MCL 460.6t(5)(g)), which accomplishes the following:

- Reduces energy waste by providing incentives for utilities to enhance current energy waste reduction programs;
- Ensures a reliable energy supply by requiring all electric providers to have adequate resources, using a market-driven approach;
- Allows customers to finance energy waste reduction projects through an itemized charge on utility bills; and
- Requires utilities' Integrated Resource Plans (IRPs) to include the projected energy and capacity purchased or produced by the utility from CHP resources, ensuring the use of reliable, cost-effective, and environmentally friendly energy.

This confluence of executive and legislative interest in formulating new energy policy, coupled with recognition of the potential of CHP to participate in meeting Michigan's energy needs, means the time is right to optimize and accelerate the deployment of CHP in Michigan.

This project differs from previous projects by applying cutting-edge integrated resource modeling tools to determine least-cost deployment options for CHP resources. The project team quantitatively modeled

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[1] U.S. EPA. 2017. *Methods for Calculating CHP Efficiency*. https://www.epa.gov/chp/methods-calculating-chp-efficiency.

the optimized deployment of CHP in Michigan using a modified version of the State Tool for Electricity Emissions Reduction (STEER) model. STEER is an integrated resource planning model that calculates the least-cost resource portfolio to satisfy electricity demand and various reliability and environmental constraints based on projections of demand, fuel prices, technology price and performance, taxes, and other factors. STEER was used to assess, measure, and determine the cost and value of CHP as one of multiple resources in Michigan's future energy mix. Depending on natural gas prices and the availability of renewable energy resources, STEER recommended an optimal level of additional CHP deployment in Michigan ranging from 722 Megawatts (MW) to 1.014 Gigawatts (GW) by 2030.

In developing the Michigan CHP Roadmap, the STEER model was also customized to consider the impact of the value of resilience and standby rates on projected CHP deployment. Results showed that consideration of CHP's resilience value increases the potential deployment of CHP in sectors where loss of power is most consequential and can significantly increase CHP potential beyond the levels that would be supported by only the power sector value. According to STEER, resilience value could increase CHP potential by around 60%. On the other hand, standby rates, which apply to most grid-connected CHP projects, substantially reduce the profitability of CHP ownership and thereby reduce potential CHP deployment by 50% or more.

Parallel to this modeling effort, an intensive analysis of Michigan's CHP-related supply and value chains provides insight to support policy analyses and recommendations. Evaluation of the CHP supply and value chains in Michigan indicates a robust ability by Michigan firms to participate throughout the CHP value chain, with the majority of the economic impact of CHP being realized by using this pool of talent based in Michigan companies to design and implement CHP projects.

Finally, the Michigan CHP Roadmap provides a series of prioritized public policy recommendations that will put Michigan on a path to a CHP-friendly future, including recommendations to:

- Offer financial incentives for CHP in order to reduce the payback period for CHP projects;
- Promote Property Assessed Clean Energy (PACE) financing and encourage local communities to adopt PACE programs;
- Include CHP as eligible for on-bill financing;
- Include the full value of CHP (including the value of resilience) when considering the costs and benefits of distributed energy resources (DER), such as in a "Value of DER Study;"
- Consider best practices in utility standby rates and PURPA avoided cost/buyback rates;
- Update interconnection standards to better align with new technologies and best practices;
- Incorporate CHP as a resource in Michigan utility energy waste reduction (EWR) plans;
- Use a societal cost test for calculating energy savings from CHP in EWR plans;
- Require utilities to consider in integrated resource planning (IRP) the demand-side savings from utility-owned CHP and on-site CHP as both a supply-side and demand-side resource;
- Enable commercial and industrial property owners to utilize shared CHP assets under flexible terms;
- Collaborate closely with expert organizations, such as the Midwest CHP Technical Assistance Program (TAP), to promote CHP outreach and education in Michigan.

1.1 Project Goal

The goal of this project was to create a multifaceted, cohesive, replicable program that will help drive the adoption and deployment of CHP in Michigan. To do this, the project assessed the full range of CHP technologies and applications and used recently developed analytical capabilities to model the energy and cost savings derived from integrating CHP technologies into Michigan's power system. This project enlisted and mobilized the primary CHP supply and value chain constituencies – engineering, procurement, construction, and supply– to educate policymakers, legislators, utilities, and potential industrial and commercial end-users on the economic and environmental benefits of CHP technologies.

The actions steps completed during 2016 and 2017 to achieve this goal were:

- Model least-cost, optimized deployment of CHP as a clean, reliable, and fuel efficient energy resource in Michigan;
- Conduct field research, surveys and interviews, to obtain a complete picture of the economic development opportunity of CHP in Michigan, mapping both the supply and value chains;
- Use modeling results to explore and prioritize gaps and opportunities in the supply and value chains, while also using case studies and other data obtained from supply and value chain mapping effort to further refine data in modeling scenarios;
- Employ modeling results and supply and value chain maps to tell the complete story of CHP in Michigan, including key opportunities for how policymakers can eliminate barriers to help achieve the ideal level of cost-effective CHP deployment for the state;
- Engage with stakeholders throughout the state to build education and awareness among potential CHP end-users and value chain members who would be active during CHP project design, development, engineering, and construction stages.

2 Background

2.1 Combined Heat and Power (CHP)

CHP is the simultaneous generation of electricity and useful thermal energy from a single source of fuel, located at or near the point of energy use. Electricity is primarily used on-site as a substitute for utility-provided power. The thermal energy can be used to support process applications or human comfort through the production of steam, hot water, hot air, refrigeration, or chilled water.

Installed CHP systems typically achieve total energy efficiencies of 65% to 80%, compared to a weighted average of only about 45% to 60% for conventional separate heat (via boilers/furnaces) and power generation (via central utility plants).[2] By avoiding electric line losses and capturing much of the thermal energy normally wasted in power generation to provide heating and cooling to factories and businesses, CHP significantly reduces the total primary fuel needed to supply energy services, reducing air emissions and saving fuel and money.

[2] U.S. EPA. 2017. *Methods for Calculating CHP Efficiency*. https://www.epa.gov/chp/methods-calculating-chp-efficiency.

CHP systems can range in size from 5 kilowatts (kW; the demand of a typical single-family home) to several hundred MW (the demand of a very large industrial plant).[3] In general, the more efficiently the thermal energy can be utilized, the greater the net overall efficiency of the CHP system. Because fuel costs are the primary expenses for operational CHP systems, the more efficient the system is, the less fuel it consumes, and in turn, the less money the end-user likely spends on energy.

CHP technology can be deployed quickly, with few geographic limitations, and can be powered using a variety of fossil fuels and renewable resources. CHP may not be widely recognized outside industrial, commercial, institutional, and utility circles, but it has quietly been providing highly efficient electricity and process heat throughout the United States for decades to vital industries, large employers, urban centers, critical infrastructure like hospitals and wastewater treatment plants, and university campuses.

2.2 CHP Processes: Topping and Bottoming Cycle

There are two types of CHP processes -- topping cycle and bottoming cycle.[4] In a topping cycle CHP system, as depicted in **Figure 1**, fuel is consumed by a prime mover such as a gas turbine or reciprocating engine, generating electricity or mechanical power. Energy normally lost in the prime mover's hot exhaust or cooling systems is recovered to provide process heat, hot water, space heating, and/or cooling for the facility. Optimal topping CHP systems are typically designed and sized to meet a facility's baseload thermal demand. Heat production may offset energy requirements previously met with water heaters and steam boilers. The electric requirements of on-site air conditioning and refrigeration units may be offset by using absorption chiller technology to produce cold water or refrigerant.

[3] Cuttica, J. J. and Haefke C. May 14, 2009. U.S. DOE Industrial Technologies Program. *Combined Heat and Power: Is It Right For Your Facility?* Webcast Series. https://energy.gov/sites/prod/files/2013/11/f4/webcast_2009-0514_chp_in_facilities_2.pdf.

[4] U.S EPA. 2016. *What is CHP?* https://www.epa.gov/chp/what-chp.

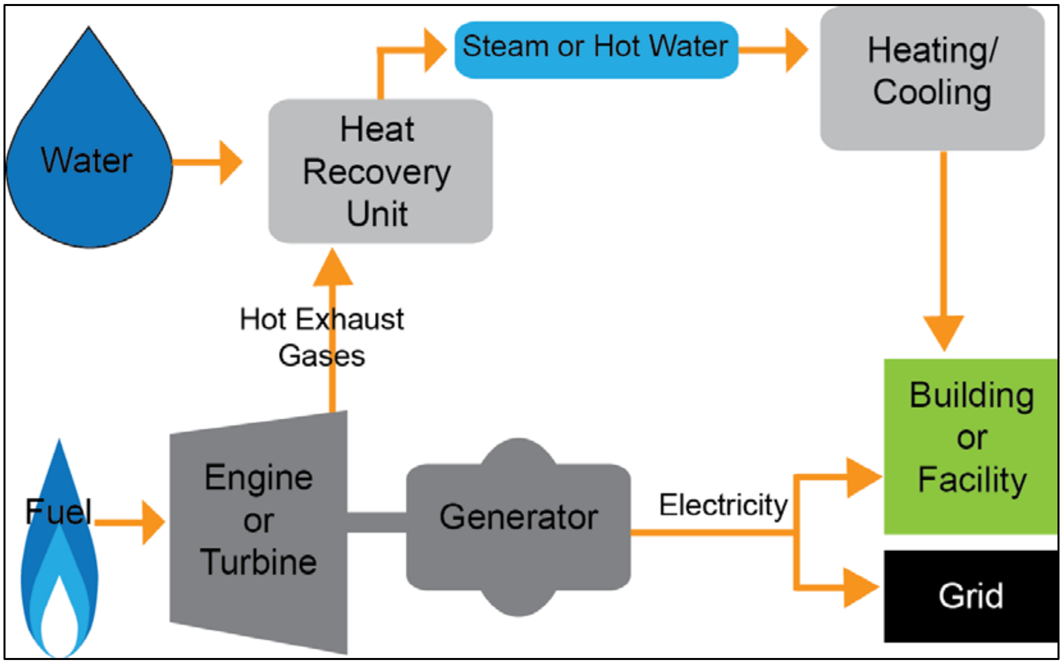

Figure 1: CHP Topping Cycle: Gas Turbine or Reciprocating Engine with Heat Recovery[5]

The bottoming cycle CHP process, which is alternatively known as waste heat to power (WHP), is depicted in **Figure 2**. In WHP, fuel is first used to provide thermal input to a furnace or other high temperature industrial process, and a portion of the heat rejected from the process is then recovered and used for power production, typically in a waste heat boiler/steam turbine system. WHP systems are a particularly beneficial form of CHP in that they utilize heat that would otherwise be wasted from an existing thermal process to produce electricity, without directly consuming additional fuel.

[5] Ibid.

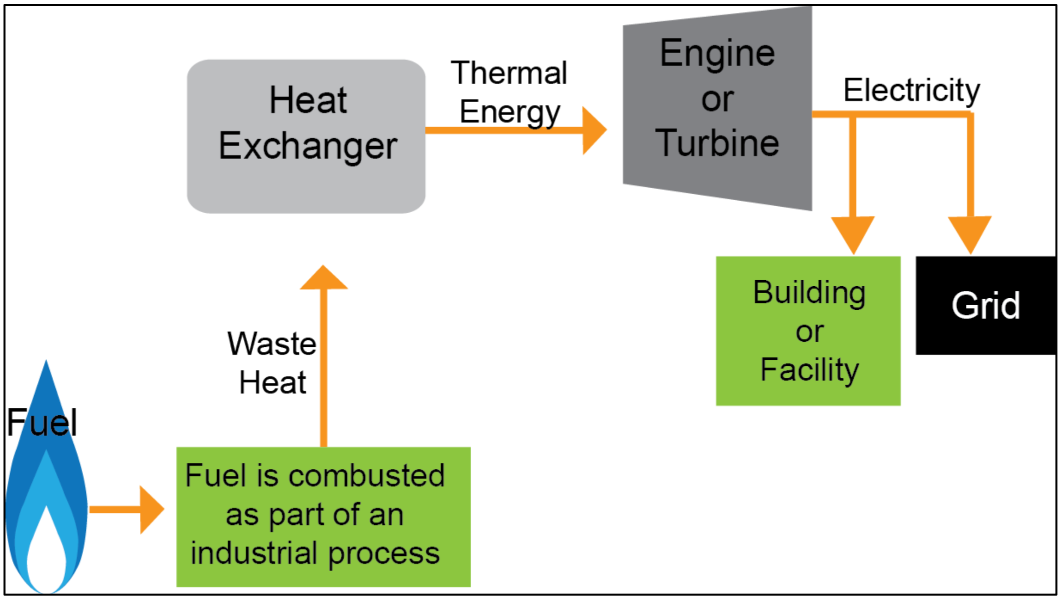

Figure 2: CHP Bottoming Cycle: Waste Heat to Power[6]

Topping cycle CHP installations may provide the local source of power generation around which microgrids can be designed. A microgrid is a group of interconnected power loads and distributed energy resources (DERs) such as CHP systems, solar panels, and batteries within clearly defined electrical boundaries that acts as a single controllable entity (micro-utility) with respect to the grid. A microgrid can connect and disconnect from the macro-utility grid to enable it to operate in both grid-connected or island-mode, providing distinct performance, resiliency, and economic benefits to energy users if managed and coordinated efficiently. Increased deployment of CHP in Michigan could present more opportunities for the development of microgrids, particularly in industrial parks or similar business clusters.[7]

[6] U.S EPA. 2016. *What is CHP?* https://www.epa.gov/chp/what-chp.
[7] Jones, D. and Tidball, R. ICF. 2016. *CHP for Microgrids: Resiliency Opportunities Through Locational Analysis*. https://www.icf.com/-/media/files/icf/white-papers/2016/energy-chp-microgrids.pdf.

2.3 Prime Mover Technologies

The United States Environmental Protection Agency (EPA) published a report in March 2015, which catalogs the various types of CHP technology.[8] According to the EPA, the five most common prime movers are fuel cells, gas turbines, micro gas turbines (microturbines), reciprocating engines, and steam turbines. Combined, these technologies comprised 97% of installations and 99% of CHP capacity installed in the U.S in 2016. **Table 1** provides a summary of the breakdown of prime movers for units under 100 MW – encompassing greater than 99.9% of all potential projects.

Fuel cells are the most recent of these innovations, and the least adopted, while steam turbines have been commonplace for over a century. Reciprocating engines, gas turbines, and microturbines comprise the bulk of new CHP installations.[9]

Prime Mover	Sites	Share of Sites	Capacity (MW)	Share of Capacity
Reciprocating Engine	2,194	51.9%	2,288	2.7%
Gas Turbine*	667	15.8%	53,320	64.0%
Boiler/Steam Turbine	734	17.4%	26,741	32.1%
Microturbine	355	8.4%	78	0.1%
Fuel Cell	155	3.7%	84	0.1%
Other	121	2.9%	806	1.0%
Total	**4,226**	**100.0%**	**83,317**	**100.0%**

Table 1: Economic Potential for CHP Units Less than 100 MW[10]

Installed capital costs for these technologies vary significantly depending on the scope of the plant equipment, geographical area, competitive market conditions, special site requirements, emissions control requirements, and prevailing labor rates. Prime mover packages themselves decline in cost, on an electrical capacity basis, only slightly as systems increase in scale. However, ancillary equipment such heat recovery steam generators (HRSG), gas compressors, water treatment systems, and electrical equipment achieve much lower costs per unit of electrical output as the systems become larger.

The description of each prime mover technology provided below is a summary of information provided in the EPA Catalog of CHP Technologies.[11] The U.S. Department of Energy (DOE) Midwest CHP TAP also describes the five prime mover technologies in additional detail.[12]

[8] U.S. EPA. 2017. *Catalog of CHP Technologies*. http://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf.
[9] Ibid.
[10] Ibid.
[11] Ibid.
[12] U.S. DOE Midwest CHP Technical Assistance Partnerships (TAP). http://www.midwestchptap.org.

Reciprocating Engines

Reciprocating internal combustion engines are the most widespread technology for power generation up to 5 MW. These engines start quickly, follow electric load well, and generally are highly reliable. They are effective in applications that require hot water or low-pressure steam as the heat carrier. Natural gas is the typical fuel, but propane, landfill gas, or biogas can also be used.

There are nearly 2,400 reciprocating engine CHP installations in the United States, accounting for 54% of the total number of installed CHP systems and nearly 2.4 GW, or 3%, of total capacity. Individual engine units range in size from less than 50 kW up to 10 MW. In Michigan, 30 sites utilize reciprocating engine technology, accounting for nearly 60 MW of capacity. Common applications for reciprocating engine CHP systems include universities, hospitals, water treatment facilities, industrial facilities, commercial buildings, and multi-family dwellings.

Routine maintenance of reciprocating engines is required after approximately 2,000 hours of operation to ensure optimal engine performance. Engine overhauls are required every 32,000 to 64,000 hours of operation, depending on service, and typically include a complete inspection and rebuild of components to restore the reciprocating engine to nearly original or current (upgraded) performance standards. Engine maintenance costs can vary significantly depending on the quality and diligence of the preventative maintenance program and operating conditions.

Gas Combustion Turbines

Gas combustion turbines (also referred to simply as gas turbines or combustion turbines) are available in sizes ranging from 1 MW to more than 300 MW. They produce high-quality heat that can be used to generate steam for on-site use. In large applications, typically above 40 MW, the steam can be used to drive a steam turbine, generating additional electricity, in an arrangement known as “combined cycle.”

In CHP applications, gas turbines typically have favorable economics for system sizes greater than 5 MW. Gas turbines account for 52 GW of installed CHP capacity in the United States, representing 64% of the total installed CHP capacity. Michigan features 19 gas turbine installations and an aggregate installed capacity of 2.8 GW, which represents over 80% of Michigan’s 3.4 GW of installed CHP capacity. Gas turbines are well suited for industrial CHP applications because the high temperature gas turbine exhaust can either be used to generate high pressure steam or used directly for heating or drying.

Routine maintenance practices include predictive maintenance, plotting trends, performance testing, vibration analysis, and preventive maintenance procedures. Typically, routine inspections are required every 4,000 hours of operation to ensure that the turbine is free of excessive vibration due to worn bearings and rotors or damaged blade tips. A gas turbine overhaul is needed every 25,000 to 50,000 hours of operation, depending on service, and typically includes a complete inspection and rebuild of components to restore the gas turbine to nearly original or current (upgraded) performance standards. Gas turbine maintenance costs can vary significantly depending on the quality and diligence of the preventative maintenance program and operating conditions and reliance on the turbine distributor to supply the required labor.

Steam Turbines

Steam turbines are a mature technology and have been used since the 1880s for electricity production. These systems burn fuel in a boiler to generate high-pressure steam that is transferred to a turbine that powers a generator. Steam turbine-based CHP systems are most often used in medium- and large-scale industrial or institutional facilities with high thermal loads, and where solid or waste fuels are readily available for combustion in the boiler.

Most of the electricity generated in the United States is produced by steam turbines in central station power plants. Steam turbines are also commonly used for CHP installations, of which there are 699 sites in the United States. These steam turbine CHP installations have an average capacity of 37 MW and a combined capacity of 26 GW, representing 32% of total installed CHP capacity. In Michigan, steam turbines are installed at 31 sites, accounting for 500 MW of capacity. The majority of these CHP steam turbines are at industrial plants, commercial buildings with high thermal loads, and district heating sites.

Microturbines

Microturbines are relatively small combustion turbines that can use gaseous or liquid fuels. They produce hot water or low-pressure steam for a variety of applications, including potable water heating, absorption chillers and desiccant dehumidification equipment, space heating, process heating, and other building uses.

Microturbines emerged as a CHP option in the 1990s, evolving from the technology used in turbochargers and auxiliary power units which are lightweight and have few moving parts. Individual microturbines range in size from 30 to 330 kW and can be integrated to provide modular packages with capacities exceeding 1,000 kW. There are over 360 sites in the United States that currently use microturbines for CHP, accounting for over 8% of the total number of CHP sites and 92 MW, or 0.1%, of aggregate capacity. In Michigan, 5 sites utilize an aggregate 1.6 MW of microturbine CHP technology.

Fuel Cells

Fuel cells use an electrochemical process similar to a battery to convert the chemical energy of hydrogen into water and electricity. In CHP applications, heat is generally recovered in the form of hot water or low-pressure steam.[13] The hydrogen can be obtained from natural gas, coal gas, methanol, and other hydrocarbon fuels. Fuel cells are highly efficient, quiet, and clean running.

There are 126 fuel cells installed in the United States that are configured for CHP operation, accounting for a combined capacity of 67 MW, or less than 0.1% of total US CHP capacity. None are currently installed in Michigan. The majority of these fuel cells are used in commercial and institutional buildings (such as universities, hospitals, nursing homes, hotels, and office buildings) where there is a relatively

[13] Rajalakshmi, N. and Dhathathreyan, K. S. 2008. *Present Trends in Fuel Cell Technology Development*. Nova Publishers, p. 104.

high coincident demand for electricity and thermal energy. Fuel cell capital costs have decreased in recent years, leading to an increase in the adoption of this technology in CHP projects. As in any CHP application, thermal load displacement can improve operating economies of a fuel cell system.

2.4 Reliability and Resiliency Benefits

Aging U.S. electricity infrastructure presents a significant concern to commercial and industrial (CI) facilities in meeting their power needs, as grid outages become increasingly frequent. The Electric Power Research Institute (EPRI) estimates that over $150 billion per year is lost by U.S. industries due to electric network (reliability) problems.[14]

When properly configured to operate independently from the grid, CHP systems can provide critical power reliability for businesses and critical infrastructure facilities while providing electric and thermal energy to the sites on a continuous basis, resulting in daily operating cost savings.[15] A more resilient energy supply also prevents lost business productivity and decreases the likelihood of crippling power outages. By installing properly sized and configured CHP systems, Michigan facilities can effectively insulate themselves from a grid failure, providing continuity of critical services and freeing power restoration efforts to focus on other facilities in periods of emergency.

There are a number of ways in which CHP systems can be configured to meet the specific reliability needs and risk profiles of various customers, and to offset the capital cost investment for traditional backup power measures. Most CI facilities and even some non-CI facilities have backup generators on-site to supply electricity in the case of an outage. While the presence of a CHP system may not override the necessity, or in some sectors the legal requirement to have a backup generator, CHP systems provide regular benefits to their host facilities, rather than just during emergencies. Some advantages that CHP systems have over backup generators include:[16]

- Backup generators are seldom used and can often be poorly maintained. This can result in operational problems during an actual emergency. Most CHP systems run daily and are typically better maintained.
- Backup generators rely on a finite supply of fuel on site, generally enough supply to last only a few hours or days, after which fuel deliveries are required. Most CHP systems have a permanent source of fuel on demand. For example, in the case of CHP systems powered by natural gas, most natural gas infrastructure is underground and rarely impacted by severe weather events.
- Backup generators may take time to start up after a grid failure. This lag time, even though it may be brief, can result in the shutdown of critical systems. In some cases, backup generators not permanently located on-site must be delivered to the sites where they are needed, leading to further delays.

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[14] Rouse, G. and Kelly, J. Galvin Electricity Initiative. 2011. *Electric Reliability: Problems, Progress, and Policy Solutions.* http://www.galvinpower.org/sites/default/files/Electricity_Reliability_031611.pdf.

[15] Hampson, A., et al. ICF International. Prepared for Oak Ridge National Laboratory. 2013. *Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities.* https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf.

[16] Ibid.

- Backup generators by and large typically rely on diesel fuel, a fuel which emits greater quantities of air pollutants compared to natural gas. The majority of CHP systems burn natural gas, thereby emitting less pollution in addition to significantly greater efficiencies and lower fuel costs.
- Backup generators only supply electricity; whereas, CHP systems supply thermal loads (heating, cooling, chilled water) as well as electricity to keep facilities operating as usual.

In a CHP system designed for reliability, the electric grid serves as the first level of backup to the CHP system. When the CHP system is down, the grid supplies the entire electricity load to the plant. In the unlikely event that both the CHP system and the grid are down at the same time, standby generators could be used to maintain critical loads. In certain applications, the value of this additional reliability can outweigh all other factors in the investment decision.

The requirements for a CHP system to deliver power reliability are straightforward. While CHP systems may or may not be designed to provide a facility's entire power demand, CHP can be configured to maintain critical loads in the event of a utility grid outage. To implement this capability, additional costs are often required including engineering, controls, labor and materials. The engineering required to analyze the existing electrical system, determine critical loads, provide a design and determine cost to provide back-up power from the system, may be extensive. A CHP system designed to supply the entire power needs of a facility during an outage may need to be oversized compared to the optimal design or require redundant units that would add to the cost.

2.5 CHP Market Summary

The DOE published a report in March 2016, which outlines the current status and technical potential for CHP for each state.[17] DOE data indicate that the U.S. currently has about 85 GW of CHP-based electric capacity installed, which represents nearly 9% of total installed electric capacity. Installed CHP systems generate about 505 million megawatt-hours (MWh) of electricity each year, or more than 12% of total U.S. 2016 generation. Compared to the average fossil-based electricity generation, this CHP portfolio eliminates 240 million metric tons of carbon dioxide emissions each year (equivalent to the emissions from 40 million cars).[18]

In Michigan, the total installed CHP capacity of 3.4 GW generates about 27 million MWh of electricity each year distributed among 87 locations and represents roughly 24% of total statewide generation. These CHP facilities provide power and thermal energy to users across a range of CI market sectors. The industrial chemicals sector is best represented, with 1,600+ MW of generation spread across 12 sites and is led by the state's largest CHP facility, Dow Corning's 1,370 MW plant in Midland.[19] Beyond

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[17] U.S. DOE. 2016. *Combined Heat and Power (CHP) Technical Potential in the United States*. https://www.energy.gov/eere/amo/downloads/new-release-us-doe-analysis-combined-heat-and-power-chp-technical-potential.

[18] State and Local Energy Efficiency Action Network. U.S. DOE. 2013. *Guide to the Successful Implementation of State Combined Heat and Power Policies*. p. 4. https://www4.eere.energy.gov/seeaction/system/files/documents/see_action_chp_policies_guide.pdf.

[19] We note that this facility is an extreme outlier in Michigan in terms of its size and scale.

industrial chemicals, the major users of CHP technology in Michigan are large public colleges and universities, pulp and paper mills, solid waste facilities, automotive factories, and agricultural processing plants.

The DOE Combined Heat and Power Installation Database, cataloging all operating CHP facilities in the nation, is publicly available online.[20] Nationwide investment in CHP declined in the early 2000s due to changes in the wholesale market for electricity and increasingly volatile natural gas prices. For example, in Michigan, from 2011 through 2015, only 10 CHP projects were commissioned, representing just 120 MW of capacity.

However, CHP's potential role as a clean energy source for the future is much greater than these recent market trends would indicate. Multiple factors point toward continued levels of CHP market penetration, including continued technological advancements reducing capital costs, new business and investment models, favorable incentives and policies, continued desire for low emissions profiles, and a recognition of the resiliency and reliability advantages of distributed energy.

Efficient on-site CHP represents a largely untapped resource that exists in a variety of energy-intensive industries and businesses. DOE estimates the technical potential for additional CHP at existing industrial facilities is slightly less than 65 GW and the technical potential for CHP at commercial and institutional facilities is slightly more than 65 GW, for a national total of about 130 GW.[21] A 2009 study by McKinsey & Company estimated that 50 GW of CHP in industrial and large commercial and institutional applications could be deployed at reasonable returns under then current equipment and energy prices.[22] These estimates of both technical and economic potential are likely greater today given the improved outlook in natural gas supply and pricing.

CHP deployment can also lead directly to greater deployment of renewable energy resources. Many renewable energy projects, such as biomass and solar, are often of an insufficient scale to be financially viable as stand-alone projects. Renewable fuels such as biogas or landfill gas can be co-fired with natural gas to enable larger scale, more cost-effective CHP installations than supply constraints of the renewable fuel might otherwise allow. A combined, larger-capacity solar/CHP project in some applications will yield an investment which is economically-viable, whereas neither solar nor CHP as smaller-capacity stand-alone projects are viable due to large fixed electrical grid interconnection costs.

The framework for a robust Michigan CHP industry is currently in place. As will be discussed in Section 5 of this Michigan CHP Roadmap, existing Michigan companies are well-positioned to supply the intellectual capital and skilled trades required to develop, design, finance, install/construct/integrate, operate, and maintain CHP systems. Economic value is primarily realized by employing the state's talent

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[20] U.S. DOE. 2016. *Combined Heat and Power Installation Database*. https://doe.icfwebservices.com/chpdb/.

[21] State and Local Energy Efficiency Action Network. U.S. DOE. 2013. *Guide to the Successful Implementation of State Combined Heat and Power Policies*. p. 4. https://www4.eere.energy.gov/seeaction/system/files/documents/see_action_chp_policies_guide.pdf.

[22] Granade, H. C., et al. McKinsey & Company. 2009. *Unlocking Energy Efficiency in the U.S. Economy*. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwipv7eB0-TYAhUEG6wKHet5DycQFggpMAA&url=https%3A%2F%2Fwww.mckinsey.com%2Fclient_service%2Felectric_power_and_natural_gas%2Flatest_thinking%2F~%2Fmedia%2F204463a4d27a419ba8d05a6c280a9.

pool and fuel suppliers throughout each project's 20- to 30-year useful lifecycle. Michigan companies are not particularly well-positioned to manufacture the principal energy equipment. But they will find opportunities in ancillary equipment manufacturing as well as in distribution and maintenance of both domestic and internationally-sourced CHP equipment.

2.6 Current Status of CHP Policy in Michigan

Historically, there have been a variety of policies and incentives in place to encourage the use of CHP. An enduring example is the DOE CHP TAPs, formerly called the Clean Energy Application Centers (CEACs), which promote and assist in transforming the market for CHP across the country. Services include market opportunity analyses, education and outreach, and technical assistance. Michigan is served by the Midwest CHP TAP, managed through the Energy Resources Center at the University of Illinois at Chicago.[23]

The federal Business Energy Investment Tax Credit (ITC) previously provided a non-refundable tax credit equal to 10% of expenditures related to CHP systems up to 50 MW in capacity that exceeded 60% energy efficiency. This credit expired at the end of 2016 and renewal is very unlikely.

At the state level, the Michigan legislature passed significant energy legislation at the end of 2016, including provisions affecting cogeneration. Public Act (PA) 341 of 2016 set criteria to be considered in an individual utility Integrated Resource Plan (IRP) filing with the Michigan Public Service Commission (MPSC). As of April 2017, CHP must be considered in a utility's IRP, which must be filed with the MPSC no later than April 2019. Specifically, a utility IRP must include the projected energy and capacity purchased or produced by the utility from a cogeneration resource (MCL 460.6t(5)(g)).

Also as part of this energy legislation, as of April 2017, renewable-fueled steam generation is included in the definition of "renewable energy."[24] However, PA 342 of 2016 also repealed Section 43 of PA 295, which provided that advanced cleaner energy credits could be created by cogeneration and Section 27, which provided the ability to substitute advanced cleaner energy credits for renewable energy credits. As a result, cogeneration does not qualify as renewable energy and can no longer be used to meet the requirements of the RPS under PA 342. [25] Despite their significance, these recent legislative changes are not expected to significantly affect the level of CHP deployment in Michigan.

One area of positive progress in Michigan is Property Assessed Clean Energy (PACE) financing, which is currently available in 23 Michigan counties and 2 large cities (Grand Rapids and Wyoming). PACE for CHP creates a system in which private sector loans are made to property owners to pay for up to 100% of

[23] U.S. DOE. Office of Energy Efficiency and Renewable Energy. 2017. *CHP Technical Assistance Partnerships (CHP TAPs)*. https://www.energy.gov/eere/amo/chp-technical-assistance-partnerships-chp-taps.

[24] According to PA 342 of 2016, one Renewable Energy Credit (REC) will be issued for each MWh of electricity generated, including the steam equivalent of a MWh of electricity. RECs are the currency of the Michigan Renewable Portfolio Standard (RPS).

[25] PA 295 of 2008, Section 27 generally limits the combined use of energy optimization credits and advanced cleaner energy credits to 10% of an electric provider's renewable energy credit standard. However, this limitation does not appear to have impacted the development of cogeneration based on electric provider's responses to this question as part of their annual reporting to the MPSC.

CHP investments, with repayment of those loans occurring through a "special assessment" on the site's property taxes. This mechanism allows for CHP investments without any up-front capital investment by the property owner, substantially mitigating financial risk while leveraging the return on investment. If the property is sold, the special assessment remains with the property. Additional information on PACE program attributes and participating local governments can be found in **Attachment A**.

2.7 Recent Efforts to Examine Standby Rates for CHP

From January 2016 through February 2017, the MPSC staff hosted a working group on standby rates. The Association of Businesses Advocating for Tariff Equity (ABATE), Michigan Energy Innovation Business Council (Michigan EIBC), Alliance for Industrial Efficiency, Electricity Consumers Resource Council, Midwest Cogeneration Association, Consumers Energy Company and DTE Energy Company all submitted comments to the MPSC staff to inform the final working group report, issued in June 2017.

In the MPSC staff's first standby rate working group report, published in August 2016, the purpose of the workgroup was described as the following:

> Ensuring that utility standby service tariffs are appropriately recovering only the costs attributable to the self-generation customer can result in complex analysis and billing. There is some concern in the self-generation community that standby rates in Michigan may not be set appropriately – particularly for small-scale CHP and intermittent resources such as solar and wind generation, but also in some cases for large-scale CHP. With the burgeoning interest in these types of projects by potential self-generation customers and project developers, greater understanding of these complicated standby service tariffs is essential. It is an opportune time to determine whether the current standby service tariffs reflect the cost of serving self-generation customers with CHP or solar and address concerns of the self-generation community.[26]

As part of the working group process, Michigan utility standby rates for CHP sites were analyzed and compared to the standby rates of other utilities in the Midwest.[27] The analysis found that standby charges experienced in Michigan are relatively high, potentially posing a barrier to CHP deployment.[28] Further, the analysis found that standby tariffs in Michigan can be confusing and difficult for customers to navigate.[29] While no formal requirements came out of the working group process, the MPSC staff issued several recommendations related to standby rate best practices.[30]

Coming out of the MPSC staff standby rate working group, engagement in the overall discussion of standby rates continued, and some interested parties went on to pursue formal intervention in utility general rate cases as a means of continuing to raise concerns about the effect of standby rates on CHP installations. Outside of formal intervention, businesses and associations have expressed their support

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[26] Michigan Public Service Commission Staff. 2016. *Standby Rate Working Group August 19, 2016 Report*. http://www.michigan.gov/mpsc/0,4639,7-159-16377_47107-376753--,00.html.
[27] 5 Lakes Energy. 2016. *Consumers Energy: Standby Rate Tariff Scenarios*. http://www.michigan.gov/documents/mpsc/5LE_Standby_Rate_Scenarios_10182016_538289_7.pdf.
[28] Ibid.
[29] Ibid.
[30] Michigan Public Service Commission Staff. 2017. *Standby Rate Working Group Supplemental Report June 2017*. http://www.michigan.gov/mpsc/0,4639,7-159-16377_47107-376753--,00.html.

for standby rate reform through comments and sign-on letters submitted to the MPSC.[31] As utilities continue to refine and develop the ways in which they interact with customers with CHP projects, there will likely continue to be attention paid to aligning standby rates with best practices, and making sure these rates reflect a utility's cost of service.

2.8 Roadmap Purpose

The purpose of the CHP Roadmap is to help drive the adoption and deployment of CHP in Michigan through an assessment of CHP technologies and applications, use of integrated resource planning (IRP) modeling to determine the energy and cost savings derived from integrating CHP technologies into Michigan's power system, identification and cataloging of CHP business constituencies, and education of policymakers, legislators, utilities, business, and industrial nd-users on the economic and environmental benefits of CHP technologies.

Against the backdrop of Michigan's energy legislation passed in December 2016, renewed interest in distributed generation such as CHP, and recent efforts to examine elements of rate design affecting distributed generation resources, there is a desire to better understand the opportunities and barriers to CHP deployment in Michigan, and to identify a path forward. In order to examine how CHP can contribute to Michigan's future energy mix on a least-cost basis, the STEER model is utilized, with the benefit of an enhanced CHP suite of technologies and applications. The results of this modeling effort show that CHP can play an important, cost-effective role in Michigan's future energy mix. In parallel with this modeling effort, the policy and regulatory barriers to greater CHP penetration are identified, along with recommended solutions to address these barriers in Michigan.

A strong stakeholder engagement process is key to optimizing deployment of CHP in Michigan. The development of the CHP Roadmap has involved state energy, environmental, economic development, and regulatory agencies, as well as participation from utilities, universities, trade associations, project developers, equipment suppliers, engineering firms, and current and prospective CHP end-users. These stakeholders have helped to refine the barriers, identify potential solutions, and recommend best practices most suitable for Michigan. The process of working closely with stakeholders on policy development and education also represents an important first step in increasing education and outreach about the benefits and opportunities offered by CHP. Building on this foundation, and with the aid of the information contained in the CHP Roadmap, Michigan's CHP education and outreach effort can continue into the future, encouraging and supporting optimized CHP deployment in the years to come.

[31] Michigan Public Service Commission Staff. 2017. Public comments. http://www.michigan.gov/mpsc/0,4639,7-159-16377_47107-376753--,00.html.

2.9 Prior Studies

A number of important CHP studies have been conducted. According to the DOE, "states, utilities, and non-governmental organizations across the country have commissioned analyses over the years to identify potential energy savings (typically for electricity) available within their jurisdictions. These studies can be used to fulfill a variety of needs, including energy efficiency program planning, state goal setting, utility resource planning, and other priorities."[32]

Among the most useful in identifying opportunities for both energy savings and economic development have been studies of CHP potential. These studies quantify the size of particular resource, such as MW of CHP development, under different scenarios and within a specific geography. According to the American Gas Association (AGA), "estimates on the untapped potential of CHP in the United States vary considerably depending on how 'potential' is defined and calculated. While investment in CHP applications has remained low since 2005, recent market activity suggests the potential for a rebound in CHP development powered by three critical drivers: 1) the changing outlook for natural gas supply and price; 2) environmental regulatory pressures on power plants and industrial boilers, and 3) growing federal and state policymaker support."[33]

CHP potential studies can be viewed as a subset of energy efficiency potential studies, which according to the American Council for an Energy-Efficient Economy (ACEEE), fall into three categories:

- Technical potential studies, which describe an ideal scenario that sums all energy efficiency measures that are feasible given technology limitations;
- Economic potential studies, which describe the fraction of the technical potential that is cost-effective;
- Achievable potential studies, which describe the fraction of the economic potential that is attainable given actual program infrastructure and both societal and market limitations.[34]

Importantly, according to the Alliance for Industrial Efficiency (AIE), "technical potential provides an estimation of market size constrained only by technological limits – the ability of CHP technologies to fit customer energy needs. It does not include economic or other considerations relevant to a decision to invest in CHP."[35]

In terms of CHP potential in the state of Michigan, there have been an array of different estimates throughout the years. In 2007, "Michigan's 21st Century Electric Energy Plan" – a study modeling technical and economic potential of a number of different energy resources, with a view toward evaluation of policy initiatives – examined Michigan's short and long term electric needs through 2025. The Plan utilized extensive modeling to enhance the understanding of Michigan's energy needs and to verify policy initiatives, and sought to advance the goals of supporting economic development,

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[32] U.S. DOE. Office of Energy Efficiency and Renewable Energy. 2017. *Energy Efficiency Potential Studies Catalog*. https://www.energy.gov/eere/slsc/energy-efficiency-potential-studies-catalog.

[33] ICF International, Inc. Prepared for the American Gas Association (AGA). 2013. *The Opportunity for CHP in the United States*. p. ES-1. https://www.aga.org/research/reports/the-opportunity-for-chp-in-the-us---may-2013/.

[34] American Council for an Energy Efficient Economy (ACEEE). *Efficiency Potential and Market Analysis*. https://aceee.org/topics/efficiency-potential-and-market-analysis.

[35] Alliance for Industrial Efficiency (AIE). 2015. *Combined Heat and Power (CHP) as a Compliance Option under the Clean Power Plan*. https://alliance4industrialefficiency.org/resources/chp-as-a-compliance-option-under-the-clean-power-plan/.

improving environmental quality and promoting resource diversity, while ensuring reliable electric power.[36] With regard to CHP potential, The Plan stated:

> Modeling indicates a potential for at least 1,100 MW, and up to 2,700 MW, of new electric power capacity development in Michigan from renewable resources with another 180 MW available from combined heat and power, or CHP. Forecasting in this area is particularly problematic, in light of the rapid pace of technological advancements and policy changes that will affect renewables. It is thus important to revisit renewable resource modeling on a regular basis and to expand the renewable portfolio when appropriate.[37]

In May 2013, ICF International, Inc. (ICF) prepared for the AGA a study titled "The Opportunity for CHP in the United States."[38] Table 2 illustrates the state-by-state economic potential for CHP units less than 100 MW in size. The study found that there was 803 MW of CHP potential in Michigan in the 5-10 year payback range, and 3605 MW of CHP potential in the >10 year time frame.[39]

State	Technical Potential by Payback Range, MW			Total Technical Potential	State	Technical Potential by Payback Range, MW			Total Technical Potential
	Minimal Potential, Payback >10 yrs	Moderate Potential, Payback 5-10 yrs	Strong Potential, Payback <5yrs			Minimal Potential, Payback >10 yrs	Moderate Potential, Payback 5-10 yrs	Strong Potential, Payback <5yrs	
Alabama	1,512	416	0	1,928	Missouri	2,532	0	0	2,532
Alaska	0	52	130	181	Montana	343	0	0	343
Arizona	1,561	134	0	1,695	Nebraska	718	26	0	744
Arkansas	1,384	0	0	1,384	Nevada	999	0	0	999
California	2,807	8,283	735	11,826	New Hampshire	0	497	74	571
Colorado	1,211	208	0	1,419	New Jersey	1,159	2,301	341	3,801
Connecticut	0	796	621	1,417	New Mexico	493	76	0	569
Delaware	254	144	0	398	New York	0	5,993	3,367	9,360
Dist of Columbia	321	0	0	321	North Carolina	3,726	632	0	4,358
Florida	2,541	2,098	104	4,744	North Dakota	324	0	0	324
Georgia	3,256	555	0	3,811	Ohio	5,951	0	0	5,951
Hawaii	77	212	86	376	Oklahoma	1,295	0	0	1,295
Idaho	469	0	0	469	Oregon	1,472	0	0	1,472
Illinois	4,626	727	0	5,354	Pennsylvania	4,972	1,143	0	6,115
Indiana	2,705	0	0	2,705	Rhode Island	203	198	35	436
Iowa	1,573	0	0	1,573	South Carolina	1,962	386	0	2,348
Kansas	1,126	96	0	1,222	South Dakota	332	0	0	332
Kentucky	1,607	932	0	2,539	Tennessee	2,143	594	0	2,737
Louisiana	1,864	658	0	2,523	Texas	5,716	1,836	384	7,935
Maine	582	237	0	820	Utah	881	0	0	881
Maryland	1,450	306	0	1,756	Vermont	0	282	12	293
Massachusetts	282	2,078	466	2,826	Virginia	2,570	490	0	3,060
Michigan	3,605	803	0	4,408	Washington	2,201	0	0	2,201
Minnesota	2,230	327	0	2,557	West Virginia	545	244	0	789
Mississippi	1,086	274	0	1,360	Wisconsin	2,859	1,114	0	3,973
					Wyoming	166	110	0	275
					U.S. Total	81,691	35,257	6,355	123,303

Table 2: Economic Potential for CHP Units Less than 100 MW[40]

[36] Lark, P. J. Michigan Public Service Commission. 2007. *Michigan's 21st Century Electric Energy Pl*an. p. 1. https://www.michigan.gov/documents/mpsc/21stcenturyenergyplan_185274_7.pdf.

[37] Ibid., p. 26.

[38] ICF International, Inc. Prepared for the American Gas Association (AGA). 2013. *The Opportunity for CHP in the United States*. p. ES-1. https://www.aga.org/research/reports/the-opportunity-for-chp-in-the-us---may-2013/.

[39] Ibid.

[40] Ibid.

According to the study, projects with greater than 10 year projected payback periods have minimal potential; the range of 5-10 years for payback represents moderate potential; and a project payback of less than 5 years is considered to have strong potential.[41] This finding underscores a major barrier to CHP deployment in Michigan the payback period, which is further discussed in Sections 6 and 7 of this report.

More recently, the U.S. DOE estimated that "Michigan has 4,987 MW of CHP technical potential capacity identified at 10,370 sites."[42] The DOE Technical Potential study notes that "the outlook for increased CHP use is bright as policymakers at the federal and state level are recognizing the potential benefits and the role that this technology could play in providing clean, reliable, cost-effective energy services to industry and businesses."[43]

Internationally, there is a major CHP roadmapping effort underway throughout the European Union. Pursuant to Cogeneration Directive (2004/8/EC) European Union member states have "identified their cogeneration potential out to 2020 but many have failed or are failing to make progress on cogeneration despite the wide range of support measures which are in place."[44] The CODE2 project aims to support the development of 27 National Cogeneration Roadmaps[45] and one European Cogeneration Roadmap. The project will also "develop 'How-to' guides focused on understanding the cogeneration legislation and business case to simplify first steps for new users."[46] A major goal of the CODE2 project is to recommend policy measures to increase the deployment of CHP in participating nations.[47] For example, as part of the CODE2 project, a study titled "Final CHP Roadmap Ireland" was published in November 2014. This Final CHP Roadmap Ireland draws from a previous study called "Cogeneration Potential in Ireland" published in 2009 by Sustainable Energy Authority of Ireland. This earlier study estimated CHP potential in 2020 across multiple scenarios using historic patterns of deployment and the effects of various policies. The 2014 "Final CHP Roadmap Ireland" was further updated in 2016 by a study titled "Combined Heat and Power in Ireland: 2016 Update," which provided an update on Ireland's installed CHP capacity and associated energy savings and carbon reductions.[48]

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[41] Lark, P. J. Michigan Public Service Commission. 2007. *Michigan's 21st Century Electric Energy Pl*an. p. ES-2. https://www.michigan.gov/documents/mpsc/21stcenturyenergyplan_185274_7.pdf.
[42] U.S. DOE. 2016. *Combined Heat and Power (CHP) Technical Potential in the United States*. p. 56. https://www.energy.gov/eere/amo/downloads/new-release-us-doe-analysis-combined-heat-and-power-chp-technical-potential.
[43] Ibid., p. 1.
[44] Cogeneration Observatory and Dissemination Europe. 2014. http://www.code2-project.eu/about/.
[45] Countries covered by the CODE2 Project include Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom. CHP Roadmaps are available at http://www.code2-project.eu/code-regions/.
[46] Cogeneration Observatory and Dissemination Europe. 2014. http://www.code2-project.eu/about/.
[47] Ibid.
[48] Howley, M. and Holland, M. Sustainable Energy Authority of Ireland. 2016. *Combined Heat and Power in Ireland: 2016 Updat*e. https://www.seai.ie/resources/publications/Combined%20Heat%20and%20Power%20in%20Ireland%20Update%202016.

The “Final CHP Roadmap Ireland” was developed to better understand market and policy factors affecting CHP penetration, map supply and value chain opportunities for manufacturers and project implementers, and determine ways to accelerate deployment. In this way, the “Final CHP Roadmap Ireland” is similar to this Michigan CHP Roadmap. A key difference, however, is that the Michigan CHP Roadmap benefits from the STEER model’s rigorous CHP technology and application suite, which allows for characterization of a range of CHP technologies and sizes, and dispatch of individual CHP units on an hourly basis. The Michigan CHP Roadmap also contains a substantial stakeholder outreach and education component.

Overall, the Michigan CHP Roadmap project builds upon these prior studies by adding a perspective that is specific to the challenges and opportunities of Michigan. The Michigan CHP Roadmap methodology makes use of the market-based perspective of private-sector project developers, and has the benefit of a quantitative modeling capability that differentiates among CHP technologies. Finally, the Michigan CHP Roadmap also makes initial strides toward educating a diverse array of stakeholders in order to effect long-term change, and lays the groundwork for this education and outreach to continue.

3 Methodology

The methodology employed throughout this study was developed with the objective of being replicable by other states. To achieve this objective, project partners relied on economic data provided by the U.S. EPA[49] and on technical potential data provided by the U.S. DOE[50] to evaluate CHP technologies and applications. Analytical modeling of this data within Michigan’s overall energy portfolio was achieved by leveraging the STEER model, which can be adapted by other states or developed independently. Mapping of the Michigan CHP supply and value chain utilized methodology previously developed to support creation of the Michigan “Clean Energy Roadmap.”[51] Recommendations to mitigate solutions are based on a quantitative assessment of the impact on CHP deployment under a variety of utility rate and public incentive scenarios. Finally, deployment of the CHP Roadmap involves the ongoing effort to educate CHP stakeholders, and especially end-users, on the merits of CHP, and to provide them with a directory of firms operating in the CHP space to facilitate project development with local partners. (A directory of Michigan CHP Supply/Value Chain Participants is contained in **Attachment B**.)

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[49] U.S. EPA. 2017. *Catalog of CHP Technologies*.
http://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf.
[50] U.S. DOE. 2016. *Combined Heat and Power (CHP) Technical Potential in the United States*.
https://www.energy.gov/eere/amo/downloads/new-release-us-doe-analysis-combined-heat-and-power-chp-technical-potential.
[51] Michigan Agency for Energy. 2016. Clean Energy Roadmap.
http://www.michigan.gov/documents/energy/2016-03-09_CER_Full_526941_7.pdf.

3.1 Technology Roadmapping

STEER can dynamically model Michigan's electricity system on an hourly basis by dispatching electricity resources based on lowest marginal cost, and has the advantage of representing a range of supply-side and demand-side resource options at the level of individual electric generating units (see Section 4). This modeling, which we will alternatively refer to as "technology roadmapping," provides a rigorous capability to quantify the optimal cost CHP potential in Michigan.

STEER is populated with U.S. Energy Information Administration (EIA) data of Michigan's existing portfolio of power plants and various modules of fossil-fueled and renewable generating units that can be deployed as needed to meet hourly energy and capacity requirements out to the year 2030. Modifications were made to include an expanded, more detailed suite of CHP prime mover technologies, system sizes, and operating characteristics.

STEER modifications required the establishment of criteria to evaluate prime mover technologies for the suite of CHP options. As discussed in Section 2.3, because 99% of total installed CHP capacity is comprised of reciprocating engines, combustion turbines, microturbines, steam turbines and fuel cells, the project team decided to limit its focus to just these five technologies.

Project partners identified and evaluated CHP technologies and applications as a prelude to modifying the STEER model in order to achieve the following goals:

- Quantify Michigan CHP technical potential by prime mover type;
- Quantify industry average cost and performance data for each prime mover type;
- Extrapolate these data to Michigan prime mover technical potential.

U.S. DOE defines technical potential as "an estimation of market size constrained only by technological limits – the ability of CHP technologies to fit customer energy needs without regard to economic or market factors." This provides a valid upper boundary of CHP deployment in Michigan, with actual deployment levels being lower due to economic factors that can be represented as inputs to the STEER model that act to constrain deployment below technical potential.

According to DOE, Michigan has nearly 5 GW of CHP technical potential at more than 10,000 sites across 17 industrial and 24 commercial sectors (specific identifying data for each of the 10,000 sites is not available from DOE).[52] This potential, on a capacity basis, is roughly evenly split between 17 industrial sectors and 24 commercial sectors, as depicted in **Figure 3**. However, nearly 80% of the 10,000 sites are commercial locations, which tend to have much lower CHP capacity potential than industrial sites.

According to DOE, there are 2.2 GW of industrial on-site CHP potential primarily in the transportation equipment, chemicals, primary metals, paper, and food sectors. Another 2.0 GW of commercial CHP technical potential exists primarily at commercial office buildings, colleges and universities, hospitals, retail locations, and multifamily housing sectors. Michigan also has 700 MW of CHP potential

[52] U.S. DOE. 2016. *Combined Heat and Power (CHP) Technical Potential in the United States*. https://www.energy.gov/eere/amo/downloads/new-release-us-doe-analysis-combined-heat-and-power-chp-technical-potential.

deployment at 2 district energy sites and 150 MW of waste heat to power (WHP) potential identified at 36 sites primarily in the oil and gas extraction, refining, stone/clay/glass, and primary metals sectors.[53]

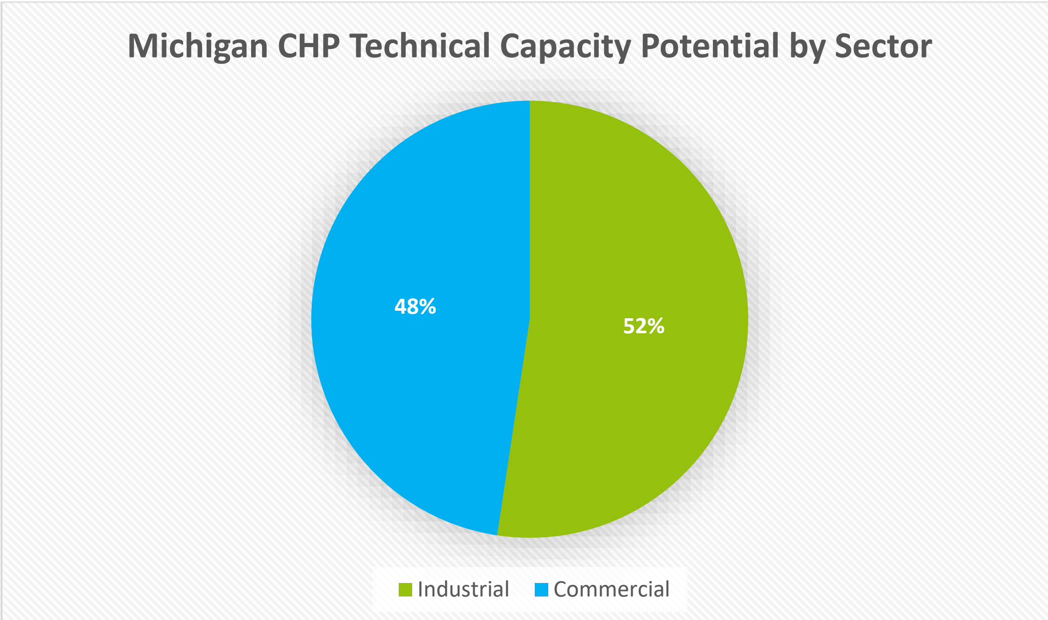

Figure 3: Michigan CHP Technical Capacity Potential by Sector[54]

Beyond commercial and industrial business types, the DOE database also quantifies the technical CHP potential in Michigan, by number of sites and capacity potential, according to annual operating hours (7,500 hours/full-time versus 4,500 hours/part-time) and project size classification (50 to 500 kW, 500 kW to 1 MW, 1 MW to 5 MW, 5 MW to 20 MW, and 20+ MW).[55]

For STEER customization, the DOE's CHP technical potential data for Michigan needed to be broken down one level further, from the total number of CHP sites and capacity (per project size range), to differentiate among the five prime mover types. To complete this task, the project team relied on EPA CHP cost and performance data for the prime movers across the spectrum of available capacities, along with project members' collective experience with public and private-sector CHP projects as necessary to make assumptions about market and pricing trends. Table 3 summarizes which prime movers were considered for CHP systems of various scale.

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[53] Ibid.
[54] Ibid.
[55] Ibid.

Table 3: Prime Mover Technologies by System Capacity[56]

Capacity	Fuel Cell	Microturbine	Reciprocating Engine	Combustion Turbine	Steam Turbine
50 kW – 500 KW	X	X	X		
500 kW – 1 MW		X	X		
1 MW – 5 MW		X	X	X	
5 MW – 20 MW			X	X	X
> 20 MW				X	X

In their "Catalog of CHP Technologies,"[57] the EPA compiled cost and performance data for twenty-four CHP technology and size combinations as indicated in Table 4.

Table 4. EPA Technology and System Size Combinations[58]

Prime Mover Technology	System Sizes (kW)	EPA Catalog Reference
Fuel Cell	0.7, 1.5, 300, 400, 1400	Table 6-3
Microturbine	30, 65, 200, 250, 333, 1000	Table 5-2
Reciprocating Engine	100, 633, 1121, 3326, 9341	Table 2-2
Combustion Turbine	3510, 7520, 10680, 21730, 45607	Table 3-5
Steam Turbine	500, 3000, 15000	Table 4-2

Project partners extrapolated, via simple regression modeling, the cost and performance data for the EPA's 24 technology/size combinations indicated in Table 4, to include an additional 33 technology/size combinations. These 33 reflect the average CHP system size based on DOE technical potential in Michigan, across each of the five technologies and five capacity categories indicated in Table 3.

Table 5 lists all 57 resource options that are now available in the STEER model's CHP suite. The extrapolated data in combination with the EPA provided data provide the basis for technical analysis of CHP in the STEER model.

[56] Ibid.
[57] U.S. EPA. 2017. *Catalog of CHP Technologies*. http://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf.
[58] Ibid.

Table 5. STEER Model CHP Resource Options

Prime Mover Technology	System Sizes (kW)
Fuel Cell	0.7, 1.5, 78, 124, 179, 300, 400, 1400
Microturbine	30, 65, 78, 124, 179, 200, 250, 333, 427, 597, 710, 1000, 1083
Reciprocating Engine	78, 100, 124, 179, 427, 597, 633, 710, 1083, 1121, 1800, 2093, 3326, 8000, 8758, 9341
Combustion Turbine	2093, 3510, 5000, 7520, 8000, 8758, 10680, 21730, 31000, 35867, 45607
Steam Turbine	500, 3000, 8000, 8758, 9091, 15000, 25000, 31000, 35867

Since STEER is a model of the electrical system and CHP provides heat-related benefits to the site host, STEER assumes that CHP systems will be sized to meet host thermal requirements. STEER treats the required capital and fuel costs for production of heat as the same with or without CHP. Thus, it can use the incremental capital and fuel costs associated with adding electricity production as the marginal cost of CHP generation of electricity.

This modified version of STEER containing these 57 CHP options can now dynamically identify which CHP configurations are economically viable across a wide variety of scenarios, narrowing the scope of Michigan's 5 GW/10,000 site technical potential to only include those projects that should be implemented based on economics and in consideration of Michigan's overall electricity generation portfolio.

3.2 Valuing Reliability and Resiliency

There have been many attempts to assess the cost of unreliable electricity. Reports by EPRI and DOE have estimated the cost of electricity outages at $30 to $400 billion per year.[59] According to the Lawrence Berkeley National Laboratory (LBNL), economic losses from unreliable electricity and power outages total approximately $80 billion per year.[60] However, even this figure is disputed as too low because it does not include the cost of food spoilage, dispatching police and fire personnel, evacuating and securing senior citizens and ancillary damage, such as the kind caused by sump pump failure.[61] While difficult to quantify, the full extent of power outage costs are undoubtedly quite large.

While everyone understands the value of power reliability and infrastructure resiliency, there are few, if any, proposed methodologies for monetizing that value. The data that exist regarding outage costs are largely aggregated between all customer classes among a wide geography and include economic loses as

[59] Primen. Submitted to the Electric Power Research Institute. 2001. *The Cost of Power Disturbances to Industrial and Digital Economy Companies*. http://www.energycollection.us/Energy-Reliability/Cost-Power-Disturbances.pdf.

[60] LaCommare, K. H., and Eto, J. H. Lawrence Berkeley National Laboratory. 2004. *Understanding the Cost of Power Interruptions to U.S. Electricity Consumer*s. https://emp.lbl.gov/sites/all/files/lbnl-55718.pdf.

[61] Rouse, G. and Kelly, J. Galvin Electricity Initiative. 2011. *Electric Reliability: Problems, Progress, and Policy Solutions.* http://www.galvinpower.org/sites/default/files/Electricity_Reliability_031611.pdf.

well as personal loses. Further complicating this effort is the fact that power resiliency creates both private and public benefits. In fact, there are three important categories when discussing resiliency costs and benefits:

- Private Resiliency for Private Benefit;
- Public Resiliency for Public Benefit;
- Private Resiliency for Public Benefit.

Public resiliency benefits are important specifically because of their relationship to maintaining critical infrastructure and the public well-being. However, it is difficult to monetize the value of resiliency in critical infrastructure where an outage may lead to human harm and even death. On the other hand, private benefits, such as reduced or eliminated economic loss can be easier and more ethical to monetize. Though public resiliency, especially as it relates to critical infrastructure, is very important, it was out of the scope of this project to attempt to create a methodology to monetize the value of public resiliency. Using existing research and literature, however, it is feasible to monetize the value of private benefits from private resiliency.

In 2001 and 2013, EPRI published studies that quantified the cost of power disturbances to industrial and digital economy firms using direct surveys. This report, titled “The Cost of Power Disturbances to Industrial & Digital Economy Companies,” provides the best available data to quantify the value of electric resiliency for private benefit. The report focuses on three economic sectors particularly sensitive to power outages within the U.S. economy:[62]

- **The digital economy (DE).** This sector includes firms that rely heavily on data storage and retrieval, data processing, or research and development operations. Specific industries include telecommunications, data storage and retrieval services (including collocation facilities or Internet hotels), biotechnology, electronics manufacturing, and the financial industry.
- **Continuous process manufacturing (CPM).** This sector includes manufacturing facilities that continuously feed raw materials, often at high temperatures, through an industrial process. Specific industries include paper, chemicals, petroleum, rubber and plastic, stone, clay, and glass, and primary metals.
- **Fabrication and essential services (F&ES).** This sector includes all other manufacturing industries, plus utilities and transportation facilities such as railroads and mass transit, water and wastewater treatment, and gas utilities and pipelines.

These three sectors account for roughly 2 million business establishments in the U.S. While this comprises only 17 percent of U.S. businesses by establishment, these same sectors comprise approximately 40 percent of U.S. gross domestic product (GDP). Disruptions in each of these sectors – but especially DE and F&ES – have an almost immediate effect on other sectors that depend on the services they provide. According to the EPRI report, the U.S. economy is losing between $104 billion and $164 billion a year to outages and another $15 billion to $24 billion to power quality phenomena.[63]

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[62] Primen. Submitted to the Electric Power Research Institute. 2001. *The Cost of Power Disturbances to Industrial and Digital Economy Companies*. http://www.energycollection.us/Energy-Reliability/Cost-Power-Disturbances.pdf.
[63] Ibid.

Michigan is estimated to be losing between $3.765 billion and $5.971 billion per year in annual outage costs for all sectors.

However, in relation to the total economic losses stemming from power outages these figures are most likely on the low end of the spectrum because they do not include the loses stemming from outages to critical infrastructure. These data only include business losses, which in general, do not include the cost of potential loss of life, loss of communications, loss of critical infrastructure, and loss of evacuation routes. No doubt the cost of these aspects would outweigh those from the business sector, but as previously stated, there is no data available monetizing the value of public resiliency benefits.

While it is relatively easy to approximate the annual outage cost by state or economic sector it is much more difficult to translate that monetary loss into a resiliency value. Certainly, DE, F&ES and CPM businesses with on-site generation such as CHP would benefit from the increased resiliency provided by such applications. Difficulty arises, however, when monetizing individual resiliency benefits using nationwide, aggregate numbers.

In order to include the benefits of CHP resiliency into the STEER model it was necessary to calculate a dollar value per kilowatt of CHP installed for power resiliency. Using the data provided in the EPRI report and summarized in Figure 4, an average annual cost was assigned to all businesses within the DE, CPM and F&ES sectors. It was only necessary, however, to consider the Standard Industrial Classification (SIC) codes within each economic category with any CHP technical potential. CHP technical potential was assigned to each SIC code using DOE data discussed in Section 2.5. This aggregate CHP potential was then divided by potential CHP sites per SIC code to arrive at the average capacity per potential site. Using average CHP capacity by SIC code it was possible to assign a technology type and corresponding duration before a major maintenance overhaul based on the EPA Catalog of CHP Technologies.[64] This lifespan duration is not equal to the equipment lifespan but, rather, the average duration before a major overhaul is required. Because the equipment overhaul costs are not included in the STEER model, we felt it best to calculate resiliency benefits over the average timespan before any major overhaul is required. Resiliency benefits beyond this original duration could be calculated using the cost of the overhaul and the anticipated longevity of the CHP system at that point.

[64] U.S. EPA. 2017. *Catalog of CHP Technologies*. http://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf.

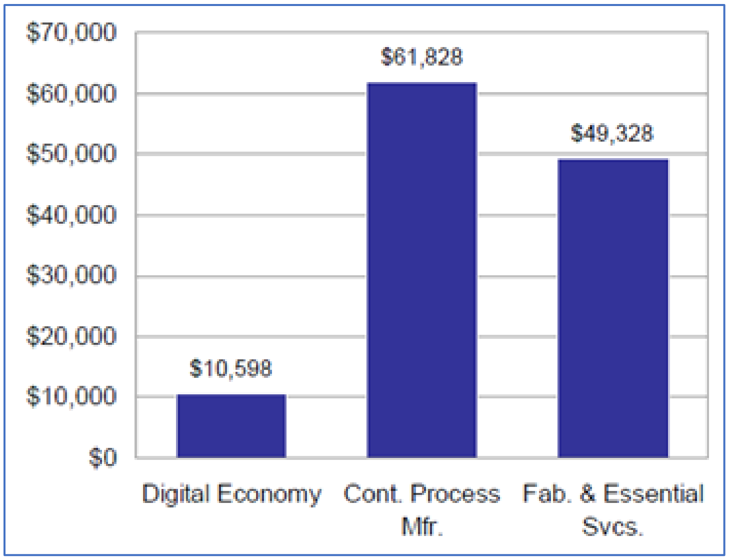


Figure 4: Average Annual Per-Establishment Cost of Outage by Sector

The value of resiliency was calculated by summing the annual outage costs over each CHP lifespan and using an 8% weighted average cost of capital[65] to determine the net present cost of outages. This net present cost was divided by the average CHP capacity per SIC code to arrive at a gross value of resiliency on a dollar per kW installed basis. As the CHP installed costs within the STEER model do not include additional costs related to resiliency (black start, islanding mode, etc.), an estimation of those costs was required. According to Oak Ridge National Laboratory, adding resiliency features to CHP installations costs approximately 10% of the total installed costs.[66]

The difference between these two figures is the net value of resiliency on a dollar per kW installed. Technically, this does not capture the value of resiliency, *per se.* Nevertheless, it does capture the costs of power outages per kW of CHP installed capacity on a net present value basis. However, absent other methodologies or guidelines, this approach best reflects an accurate monetization of the private resiliency benefits necessary to avoid costly power outages. The final results are presented in Table 6.

[65] While each SIC code might have an average weighted average cost of capital, 8% was used for simplicity.
[66] Hampson, A., et al. ICF International. Prepared for Oak Ridge National Laboratory. 2013. *Combined Heat and Power: Enabling Resilient Energy Infrastructure for Critical Facilities.* https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf.

Table 6. Value of CHP Resiliency

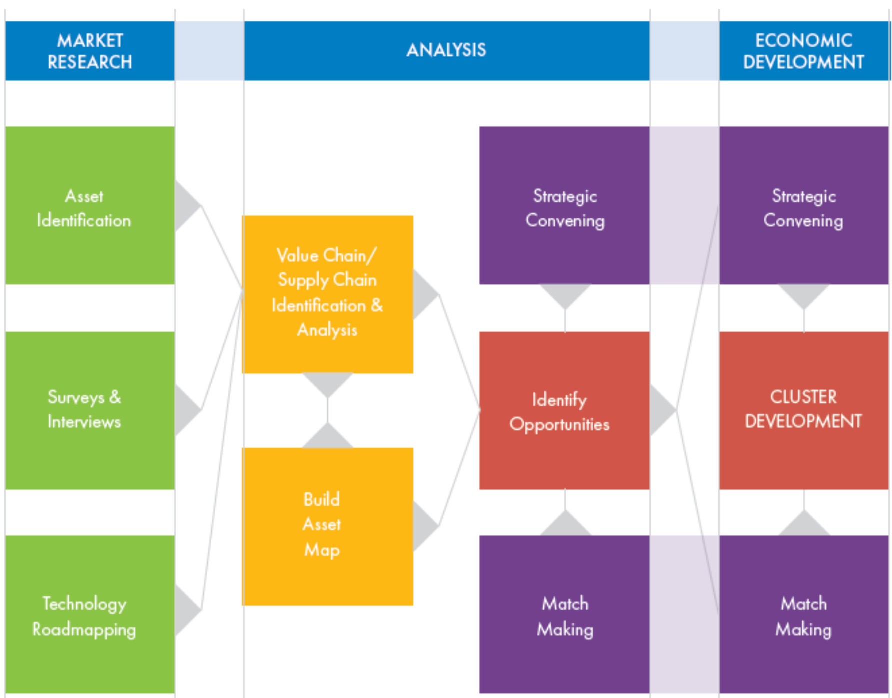
Sectors by SIC Code	Average Annual Outage Costs	CHP Technical Potential (kW)	CHP Technical Potential (Sites)	Average kW per Site	Technology Type	Average CHP Lifespan	Present Value of Outage costs per CHP lifespan	Gross value of resiliency $/kW Installed	Costs of Resiliency Equipment $/kW Installed	Net Value of Resiliency $/kW installed
Digital Economy	$ 10,598.00									
7374		27,948 kW	70	399 kW	RECIP	9	$66,204.52	$ 165.82	$ 230.00	$ (64.18)
38		915 kW	5	183 kW	MT	5	$42,314.74	$ 231.28	$ 230.00	$ 1.28
8051		42,672 kW	313	136 kW	MT	5	$42,314.74	$ 310.38	$ 230.00	$ 80.38
8062		193,064 kW	171	1,129 kW	RECIP	9	$66,204.52	$ 58.64	$ 160.00	$ (101.36)
Continuous Process Manufacturing	$ 61,828.00									
26		211,885 kW	104	2,037 kW	CT	6.25	$295,104.35	$ 144.85	$ 300.00	$ (155.15)
28		572,452 kW	284	2,016 kW	CT	6.25	$295,104.35	$ 146.40	$ 300.00	$ (153.60)
29		69,484 kW	20	3,474 kW	CT	6.25	$295,104.35	$ 84.94	$ 300.00	$ (215.06)
30		88,300 kW	333	265 kW	RECIP	9	$386,232.59	$ 1,456.57	$ 230.00	$ 1,226.57
32		16,923 kW	4	4,231 kW	CT	6.25	$295,104.35	$ 69.75	$ 300.00	$ (230.25)
33		255,213 kW	169	1,510 kW	CT	6.25	$295,104.35	$ 195.42	$ 300.00	$ (104.58)
Fabrication and Essential Services	$ 49,328.00									
43		2,344 kW	24	98 kW	MT	5	$196,952.40	$ 2,016.63	$ 230.00	$ 1,786.63
4581		6,977 kW	11	634 kW	RECIP	9	$308,146.49	$ 485.86	$ 180.00	$ 305.86
49		8,283 kW	16	518 kW	RECIP	9	$308,146.49	$ 595.20	$ 230.00	$ 365.20
20		186,019 kW	273	681 kW	RECIP	9	$308,146.49	$ 452.23	$ 180.00	$ 272.23
22		6,406 kW	23	279 kW	RECIP	9	$308,146.49	$ 1,106.40	$ 230.00	$ 876.40
25		662 kW	7	95 kW	MT	5	$196,952.40	$ 2,081.30	$ 230.00	$ 1,851.30
27		5,526 kW	38	145 kW	MT	5	$196,952.40	$ 1,354.34	$ 230.00	$ 1,124.34
34		18,129 kW	149	122 kW	MT	5	$196,952.40	$ 1,618.71	$ 230.00	$ 1,388.71
35		15,673 kW	17	922 kW	RECIP	9	$308,146.49	$ 334.25	$ 180.00	$ 154.25
37		618,436 kW	529	1,169 kW	RECIP	9	$308,146.49	$ 263.58	$ 160.00	$ 103.58
39		490 kW	6	82 kW	MT	5	$196,952.40	$ 2,411.02	$ 230.00	$ 2,181.02

3.3 Supply and Value Chain Mapping

Boundaries for the supply and value chain mapping component of this Michigan CHP Roadmap were determined through a combination of market research and market analysis. The primary criteria for setting boundaries were the significance to the state of Michigan in terms of economic activity arising from deployment of CHP projects and feasibility given the resources and timeframe of this project. Any market segments where Michigan companies are currently participating in the CHP supply or value chain were given principal consideration for surveys, interviews, and database development. Segments where Michigan companies are not competing but perhaps could compete, under the right value proposition, were also analyzed.

The supply and value chain mapping methodology was adapted from the approach used in developing the Michigan Agency for Energy's (MAE) "Clean Energy Roadmap" published in 2016.[67] That effort, focused on Michigan and Northeast Ohio, developed strategies for accelerating energy efficient or energy waste reduction technologies and developing technology roadmaps for several energy intensive, clean energy manufacturing processes to reduce the energy cost of these processes. The project was split into three components: market research, market analysis, and economic development, as depicted in **Figure 5**.

Figure 5: Clean Energy Roadmap Methodology[68]



[67] Michigan Agency for Energy. 2016. Clean Energy Roadmap. http://www.michigan.gov/documents/energy/2016-03-09_CER_Full_526941_7.pdf.
[68] Ibid.

Market Research

The first step of the mapping methodology -- market research -- included asset identification, surveying and interviewing market participants, and technology roadmapping.

Michigan companies – "assets" – that could potentially participate in the CHP supply and value chain, through a clear supply or value proposition, were identified by project partners through internet research, project partners' knowledge base, and aggregation of attendance lists from the 2015, 2016 and 2017 Michigan CHP Conferences, as well as via additional contacts obtained through Institute for Energy Innovation (IEI) industrial energy efficiency (IEE) roundtables. This baseline asset list was supplemented by attendee lists from other CHP-related events, such as the Smart Solutions for the Upper Peninsula event (July 14, 2016), the Combined Heat and Power Opportunities for Michigan Healthcare Providers Detroit Event (August 22, 2016), and referrals from those in the supply and value chain.

Survey and interview questions were developed by project partners based on prior survey and interview work that had been completed to support the MAE's "Clean Energy Roadmap." The project team conducted 21 detailed interviews with representatives of firms active in the various sectors of Michigan's CHP supply and value chain, and received detailed survey results from 107 individuals working at firms throughout these sectors. Many more information gathering conversations were conducted with supply and value chain participants by members of the project team throughout the course of this study.

Participants in the Michigan CHP supply and value chain who volunteered for interviews include the following, with their principal role in the CHP supply and value chain indicated:

- Michigan Caterpillar (prime mover distributor)
- W.W. Williams (prime mover distributor)
- Solar Turbines (prime mover distributor)
- Varnum Law (legal)
- CMS Enterprises (investor)
- Petros PACE Finance (investor)
- Ford Dearborn campus (end-user)
- Dow Chemical (end-user)
- Scenic View and Brook View dairy farms (end-user)
- Midland Cogeneration Venture (end-user)
- Opterra Energy (developer)
- Cogen Consultants (developer)
- DTE Gas (fuel supplier)
- Michigan Public Service Commission (regulators/policymakers)
- GEM Energy (design/engineering)
- Ghafari & Associates (design/engineering)
- Fishbeck, Thomson, Carr & Huber (design/engineering)
- Newkirk Electric/Theka (engineering/component supplier)

- Kendall Electric/Eaton (component supplier)
- Waukesha-Pierce (component supplier)
- EMP Corp (component supplier)

The project team also received 68 detailed survey responses from firm representatives who attended the annual Michigan CHP Conference in either 2015, 2016, or 2017. The survey was deployed on the following dates:

1. 9/14/2016 – First deployment sent to attendees of 2015 and 2016 CHP Conferences
2. 9/22/2016 – Survey reminder sent
3. 10/26/2016 – Survey link was shared with Michigan's New Energy Policy (NEP) stakeholder group
4. 7/24/2017 – Survey sent to attendees of 2015, 2016 and 2017 CHP Conferences
5. 8/14/2017 – Survey reminder sent

Digging deeper into potential opportunities for Michigan manufacturers to produce the high-value CHP equipment and/or prime mover components, further research was completed to ascertain whether there are any realistic economic opportunities for Michigan companies. This was pursued through:

1. Qualifying the market opportunity for a typical Michigan manufacturing firm;
2. Interviewing procurement gatekeepers at prime mover and major component manufacturers;
3. Identifying and qualifying the legal, regulatory, and financial barriers to market entry;
4. Assessing what Michigan could potentially do through state incentives or other mitigating strategies to help Michigan's manufacturing firms enter and compete in this market.

In aggregate, these market research efforts enabled the project team to better understand the full spectrum of challenges and opportunities facing CHP deployment in Michigan from a supply and value chain perspective and qualify the economic opportunities for Michigan businesses to participate.

Market Analysis

To identify likely gaps and opportunities for Michigan companies, the second step of the mapping methodology -- market analysis -- entailed identification of the specific industry segments within the CHP supply and value chains and classification of the Michigan CHP market participants into those sectors.

Project partners defined the **CHP supply chain** as the physical equipment and fuel required for the CHP system to operate. The CHP supply chain contains four major sectors of participants:

- CHP end-user applications;
- Prime mover manufacturers and distributors;
- Major equipment manufacturers and distributors;
- Fuel suppliers and brokers.

Project partners defined the **CHP value chain** as the intellectual capital and skilled trades required to develop, design, engineer, finance, install, and integrate CHP systems. The CHP value chain contains four major sectors of participants:

- Public policy advocates and accelerators;
- Project developers and technical advisors;
- Design/engineering firms;
- Plant integration contractors.

All firms identified as participating in the Michigan CHP supply and value chains were classified by project partners into one of these major sectors. Where a firm might participate across multiple sectors, preference was given to the sector in which it was deemed that the greatest impact would likely be realized for the business.

Economic Development

In the case of the MAE's "Clean Energy Roadmap," economic development was the third and final step of the mapping methodology and entailed strategic convening and match-making of Michigan companies who participate in the supply and value chains for the purpose of manufacturing new products. However, this approach is not well-suited for increasing the deployment of CHP energy projects, which are driven primarily by individual end-user interest, understanding, and their financial and technical ability to implement projects with the support of local and regional supply and value chain participants. For this reason, project partners expanded upon the economic development methodology used previously by MAE. For the Michigan CHP Roadmap, economic development includes not only the matchmaking component, which is accomplished through compiling, distributing, and periodically updating the directory of Michigan supply and value chain participants, but also proactive outreach to potential CHP end-users and their industry associations to discuss the merits of CHP.

End-users typically focus on their core business and take energy for granted. In project partners' experience, few have a clear understanding of CHP on both its technical and economic merits. End-users must be educated and engaged to explore CHP opportunities for their facilities, as it is their ultimate interest (or lack of interest) in the technology, coupled with their expectations for economic benefit that will drive (or stall) CHP project deployment.

The task of education has historically fallen on CHP equipment distributors who understand the technology well. However, these equipment distributors are often unable to accurately assess the economic impact of CHP systems on the end-user in an unbiased fashion. By helping prospective end-users fully recognize the range of benefits afforded by CHP, including implementation of projects and reinvestment of end-users' energy savings into growth or expansion of their core businesses, will create opportunities for economic development.

3.4 Barrier Identification

Project partners collected data through three approaches In order to recommend targeted solutions to mitigate barriers to CHP deployment:

1. The project team conducted detailed research to understand the barriers and market impediments, which in most cases are well-documented by prior studies;
2. The project team aggregated in-house data acquired through public- and private-sector technical assistance activities and project development experience;
3. The project team surveyed and interviewed the major market participants including CHP developers, equipment manufacturers, end-users, regulatory officials, and other invested stakeholders.

Throughout 2016 and 2017, Michigan stakeholders interested in CHP development were surveyed and interviewed as to their perceptions of the major barriers facing CHP in the state. As was described in Section 3.3, a comprehensive survey was deployed at five separate intervals between September 14, 2016 and August 14, 2017 to over 200 recipients. There were 107 survey respondents in total, representing the full spectrum of stakeholders including utilities, government officials, economic development specialists, CHP developers, engineering firms, advocates and end-users. Additionally, more than two dozen in-depth interviews took place with representatives from government, utilities, law firms, finance experts, CHP developers, engineering/design firms, and major energy users. Results from these survey and interview responses shed light on stakeholder perceptions regarding the major barriers impeding CHP development in Michigan. **Attachment C** contains survey and interview data reflecting respondents' perceptions as to the magnitude of potential barriers to CHP in Michigan.

Upon review of the survey and interview responses received from a broad array of Michigan stakeholders, key barriers to deployment of CHP in Michigan have been identified as: 1) a lack of access to low-cost capital; 2) utility rates; 3) failure by the electric utilities to fully embrace CHP in EWR and IRP programs; and (4) a lack of awareness/familiarity with CHP.

Identifying solutions to the barriers and market impediments of CHP adoption will help to enlarge the pool of CHP projects that meet minimum criteria for technical and economic viability within STEER, which models CHP as a least-cost resource in Michigan's future energy mix, and thereby enable increased CHP deployment. In customizing and prioritizing proposed solutions for Michigan, project partners considered the estimated proportion of potential projects affected, perception of barrier magnitude by stakeholders, and the ease/practicality of achieving change in the short term. Focus was placed on those barriers which are most significant to restricting deployment of CHP across Michigan and to which attainable solutions exist. For the most part, solutions take the form of legislative change or regulatory relief, modification of utility rate structures, and financial incentives.

3.5 Stakeholder Engagement in Roadmap Deployment

Project partners have engaged policymakers, utilities, state agencies, the MPSC, business and industrial trade associations, non-governmental organizations (NGOs), and end-users with regard to the development of this CHP roadmap, through presentations and engagement with, among others: the state's New Energy Policy (NEP) Stakeholder Group, the Michigan CHP Conferences at Oakland University (2016) and Grand Valley State University (2017), IEE roundtables hosted by IEI in Marquette, Kalamazoo, and Ann Arbor, an event focusing on CHP in healthcare in Detroit, and outreach to the state's Collaborative Development Council.

The 2016 Michigan CHP Conference took place at Oakland University on May 10, 2016. There were over 120 attendees representing component manufacturers, developers, end-users and potential end-users, and governmental leaders. This followed-up on the success of the first ever Michigan CHP Conference, held in Lansing in 2015, which drew nearly 200 attendees. Panel discussions at the 2016 conference focused on technology, case studies, project development, financing and policy.

On June 20, 2016, project partners presented at the NEP Stakeholder Group Meeting in Lansing. Stakeholders were asked to engage around the following questions: "What barriers are impeding the adoption of CHP technology in Michigan?" and "Where do you see the greatest opportunity for distributed CHP energy production?" A follow-up webinar was conducted on October 24, 2016 to gain further feedback on the project.

IEI hosted two roundtables focused on IEE and CHP: one in Marquette on July 15, 2016 and the other in Kalamazoo on August 22, 2016. These roundtables provided an opportunity for project partners to engage with current and potential end-users and policymakers, and provided a productive forum for education around a variety of aspects affecting CHP implementation in the state.

In August 2016, the Energy Resources Center organized an event focused on CHP in healthcare in Detroit. The workshop, titled "Combined Heat and Power Opportunities for Michigan Healthcare Providers," highlighted the steps necessary for end-users to implement a successful CHP project, from initial screening to equipment installation. The workshop also outlined the complimentary technical assistance provided by DOE CHP TAP to end-users interested in CHP solutions.

In December 2016, team members from Sustainable Partners, LLC (SPART) led a CHP presentation before the Collaborative Development Council, a group comprised of 18 economic development practitioners representing regions across the state. The purpose of the presentation was to provide general education about CHP, and also enlist the group's assistance in facilitating end-user outreach in 2017. Additionally, Douglas Jester of 5 Lakes Energy (5LE) presented to the Council of Industrial Boiler Owners (CIBO) on the potential challenges and opportunities surrounding CHP. The Energy Resource Center also presented on CHP to DTE Gas in November 2016, and to the West Michigan Association of Energy Engineers (WMAEE) in December 2016.

Proactive stakeholder engagement continued through year two of the project. On February 23, 2017 and April 25, 2017, Jamie Scripps of 5LE presented to the Alliance for Industrial Efficiency (AIE) and to the American Forest & Paper Association (AF&PA) on standby rates as a potential barrier to CHP deployment. In May 2017, project partners presented to MAE on the supply/value chain mapping aspects of the project. In the summer, project partners engaged with stakeholders through the 2017 Michigan CHP Conference held on June 28, 2017 in Grand Rapids.

In September 2017, Greg Northrup of SPART participated as an exhibitor on behalf of the CHP Roadmap Project at the Michigan Society for Healthcare Engineering (Mi-SHE) annual meeting in Traverse City. Also in September 2017, Jamie Scripps of 5LE presented to the Electricity Consumers Resource Council (ELCON) on standby rates as a potential barrier to CHP deployment. Additionally, in partnership with IEI, project partners presented on the CHP Roadmap and solicited feedback from stakeholders at a UP Energy Roundtable in Marquette on September 19, 2017, and at a CHP Roundtable in Ann Arbor on December 11, 2017.

Project partners engaged with over 300 unique individuals through outreach and education efforts related to the development of the CHP Roadmap.[69] Through this outreach process, in addition to receiving valuable insight, the project team has increased awareness in CHP and built a network of stakeholders interested in participating the future of CHP in Michigan.

4 State Tool for Electricity Emissions Reduction (STEER)

One objective of this project was to identify and evaluate CHP technologies and applications with a potential for adoption in Michigan. In support of this objective, the project team quantitatively modeled the optimized deployment of CHP in Michigan using a modified version of the STEER model. Because CHP simultaneously provides heat and power, the potential for CHP adoption is partly determined by the number and size of sites that have heat requirements that can be met by CHP.

STEER was used to assess, measure, and determine the cost and value of CHP as one of multiple resources in Michigan's future energy mix. In the primary application of STEER, the model considered the net value of CHP in the economy by considering the cost of installing and operating various CHP systems, the value of the heat produced by CHP measured as the cost of supplying heat in the least-cost way other than CHP, and the value of electricity produced by the CHP system measured as the marginal cost of producing electricity absent the CHP system. Determining the value of CHP in the electric power system is the province of STEER. Thus, the selection of CHP technologies by STEER is a projection of the economic potential for CHP in Michigan. The actual division of costs and benefits amongst CHP site hosts and utilities depends on policy and particularly on utility rates as applied to customers with CHP.

Because we determined that standby rates are one of the principal barriers to CHP adoption that may be amenable to policy adjustments, STEER was used to evaluate the effect of standby rates on the economic potential for CHP in Michigan. Further, because resilience of CHP site host operations is an important benefit of CHP that is not reflected in standard electric power system evaluations, STEER was used to evaluate the additional economic potential for CHP in Michigan if site hosts would not otherwise choose to build CHP but sufficiently valued resilience to do so. Consideration of resilience value increases the potential deployment of CHP in sectors where loss of power is most consequential and can significantly increase CHP potential beyond the levels that would be supported only by power sector value. Based on STEER analysis of Michigan potential, resilience value could increase CHP potential by

[69] Total calculated through aggregation and removal of duplicates from attendance lists for 2015, 2016 and 2017 Michigan CHP Conferences, and 2016 and 2017 IEI roundtables. This total is conservative and does not include anonymous survey respondents.

around 60%. Standby rates, on the other hand, substantially reduce the profitability of CHP ownership and thereby reduce potential CHP deployment by 50% or more.

As described in detail in the following sections, STEER modeling indicates that steam turbines, gas combustion turbines, and reciprocating engines appear profitable above some size threshold size in each scenario. Conversely, microturbines and fuel cells do not appear economically viable. In addition, STEER indicates that higher natural gas prices and higher cost of renewable resources in the future both tend to lower the minimum size threshold for the more viable CHP technologies, thereby expanding the number of potential installation sites in Michigan.

Furthermore, approximately half of sites where steam turbines are economically feasible are on college and university campuses, confirming that this sector should be an important part of end-user outreach and education. However, this result does not necessarily mean that combustion turbines and reciprocating engines would also not be suitable for these facilities.

In the STEEER reference scenario, economic potential for CHP in Michigan is about 1,014 MW electric generation capacity with direct investment of about $865.6 million, annual direct O&M activity of about $67.6 million, annual economic profit of about $109.5 million, annual fuel cost savings of $94.7 million, and annual air emissions reductions of 662 tons carbon dioxide (CO_2) per year, 379 tons nitrous oxide (NO_x) per year, and 39 tons sulfur oxide (SO_x) per year. In other STEER scenarios, assuming different fuel and technology costs, the economic potential for CHP in Michigan varies from 722 MW to 1,014 MW.

4.1 Model Overview

STEER is an integrated resource planning model that calculates the least-cost resource portfolio to satisfy electricity demand and various reliability and environmental constraints based on projections of demand, fuel prices, technology price and performance, taxes, and other factors.

To give state lawmakers, regulators, and stakeholders the ability to evaluate Clean Power Plan compliance approaches with the benefit of reliable integrated resource planning data, 5LE, in collaboration with the University of Michigan, originally developed the STEER model with funding from the Energy Foundation and Advanced Energy Economy Institute. The principal purpose of theSTEER model is to facilitate stakeholder access to data and integrated resource planning analysis. The STEER model automatically calculates the least-cost compliance and implementation strategies to serve forecast demand and comply with reliability and environmental standards, along with projected cost to electricity users, given certain policy options and electricity demand and price forecasts. All data, inputs, and formulae are visible to and changeable by the user. The Michigan version of the STEER model is available for download online.[70]

STEER is based on hourly load data for 24 representative days of the year and forecasts future loads out to 2030, considering changes in load profile that result from selected energy efficiency/EWR programs.

[70] Advanced Energy Economy. 2017. *State Tool for Electricity Reduction (*STEER). https://info.aee.net/steer.

STEER builds on a trend forecast of load with adjustments to accommodate forecasted adoption of electric vehicles and demand response, storage, and smart grid programs.

STEER contains performance data for each utility-scale electric generating unit in Michigan, including the multiple units in each power plant, and for aggregated small-scale generation either "behind-the meter" or integrated to the distribution system. It calculates the least-cost dispatch of these generating units to satisfy load for each hour, then calculates coal usage, natural gas usage, variable costs, carbon emissions, sulfur oxide emissions, nitrous oxide emissions, and mercury emissions based on that dispatch plan.

The STEER dispatch model also derives locational marginal prices for selection of least-cost resource additions. These locational marginal prices have been verified by comparisons to historical data. If an environmental policy (such as annual CO_2 emissions limits or NO_x limits to reduce summer ozone levels) is applied to dispatch, the model calculates dispatch, locational marginal price, and incremental cost of operating the power system accordingly.

STEER adds generation resources when needed to satisfy load, meet capacity reserve margin standards, or to satisfy a constraint on emissions. When adding generation resources, the STEER model considers technologies including natural gas combustion turbines and combined cycle plants, nuclear electricity generation, biomass co-firing in existing coal plants, hydropower, wind power, utility-scale and distributed solar photovoltaic generation, biomass combustion, and cogeneration. Required revenue to recover investment costs and operating expenses, as well as capacity and energy value of new generation resources is considered when those are chosen for addition to the generation portfolio. STEER follows the standard utility planning practice of valuing capacity at the cost of new entry of a natural gas combustion turbine, when capacity is needed. In utility operations, energy production is planned from a generating unit only when the output from all units that are cheaper to operate is insufficient to meet demand. The value of energy from each generating unit is the cost of electricity from the marginal generating unit at each time a generating unit operates.

To address capacity limitations, if the model finds that capacity requirements to satisfy the forecasted load, plus necessary reserve requirements, are not being met based on economic selection of another resource, it adds new natural gas combustion turbine capacity to the generation fleet. This occurs because, of the available generation technologies, such combustion turbines require the lowest capital investment per unit capacity. Economic selection of another technology occurs when the higher investment in the technology is offset by lower operating costs or emissions compliance. This method assures adequate capacity at least-cost even if the combustion turbine capacity itself is not "profitable" as a power system resource.

STEER allows for improvements in the fuel efficiency of existing generation plants, often referred to as "heat rate improvements." Costs and effects of heat rate improvements at existing plants default to the assumptions made by EPA in developing the draft Clean Power Plan. However, a STEER user is free to make plant-specific assumptions.

STEER does not automatically retire power plants, but allows the user to specify plant retirements and to attribute these retirements as due to compliance with environmental regulations or as retirements that would occur anyway. STEER facilitates user decisions about plant retirements by providing the capacity factors, dispatch order, air pollutant emissions, and other information that a user might consider in making retirement decisions. Upon retirement, the STEER model reflects the avoided fixed and variable cost of plant operations and the costs of replacement capacity and energy. Remaining book value is assumed to be securitized and accounted for in utility revenue and rate forecasts.

Since utility practices and regulation rarely lead to capacity additions based purely on economic value, if additional capacity is not needed, STEER does not add capacity unless capacity is needed. However, a user can quickly determine such economic additions by retiring plants that do not "earn" their fixed and operating costs and allowing STEER to select the best available demand-side or generation option.

Renewable resource options are based on inventories of renewable resource potentials developed by the National Renewable Energy Laboratory (NREL). Wind and solar generation are based on hourly site-specific data from NREL's Eastern Wind Integration Transmission Study and System Advisory Model, respectively. Capacity factors, capacity credits, and hence power system value of wind and solar generation are the result of calculations using site-specific data rather than general assumptions. Hydropower resources are representative of small hydropower facilities operated run-of-river using typical Michigan streamflow. Biomass resources are grouped into eight categories running from municipal waste and landfill gas through timber residuals.

Energy efficiency or energy waste reduction measures included in the model, their costs, and their achievable potential are taken from the Michigan Energy Efficiency Potential Study performed by GDS Associates in 2013 and released as part of Governor Snyder's "Ensuring Michigan's Future" report series in November 2013.[71] These measures include 190 applications used by residential, commercial, and industrial customers. For purposes of modeling effects on load profiles, we classified each measure as affecting all load or peak load. In STEER, the user can specify whether the model should consider all achievable cost-effective energy efficiency or constrain these programs to a spending cap of 2% of utility revenues, as was evaluated by GDS.

In addition to these features of Michigan's power system, the STEER model also incorporates the operation of the Ludington Pumped Storage Plant and the possibility of power imports and exports subject to current transmission limitations established by the regional transmission organizations. A STEER user can make changes to the import and export capacity limits.

4.2 Strengths and Weaknesses

By utilizing STEER, the project team was able to take advantage of an existing, Excel-based tool designed for use by anyone with a standard laptop or desktop computer. Also, STEER provides an appropriate granularity of analysis for this project because it represents Michigan's electricity system at the level of individual generating units dispatched hourly. This level of detail is well suited for capturing the different

[71] GDS Associates, Inc. Prepared for the Michigan Public Service Commission. 2013. *Michigan Electric and Natural Gas Energy Efficiency Potential Study*. http://www.michigan.gov/documents/mpsc/mi_ee_potential_study_rep_v29_439270_7.pdf.

sizes, operating characteristics, and costs of a range of CHP technologies. Finally, STEER's existing suite of cogeneration units provided a framework that could be readily expanded to include multiple prime mover technologies and system sizes to yield a more realistic set of CHP options for the model to deploy.

As with any model, simplifications have been made. STEER assumes there are no binding transmission constraints within Michigan. The model might replace generation from a fossil fuel plant with, for example, renewables located in an area that lacks adequate transmission interconnections, requiring additional transmission. New natural gas and biomass plants are not assigned to specific locations, so their locations can also reflect transmission availability and support requirements. That said, model results do not appear to be distorted as a result of this simplification.

In addition, the model calculates the least-cost plan for the single year, chosen by the user, and does not aggregate year-by-year results over a period of time. For example, the model might calculate that the least-cost plan uses a new natural gas combined cycle plant based on projected conditions in 2020. However, based on projected conditions in 2030, the model may calculate that a combination of wind generation and cogeneration is more cost-effective. The model does not attempt to resolve these differences by solving the dynamic programming problem of how best to act over the full life-cycle of each generator although that analysis can be performed by using the model to analyze results year-by-year and evaluating the life-cycle results. As such, the results of the model from any given year should be viewed in the context of long-term utility and regulatory planning, including underlying changes in the cost of fossil fuels used for generation and the desirability of hedging against volatility in fossil fuel prices.

With these simplifications in mind, STEER represents a useful strategic planning tool for regulators and stakeholders alike, enabling consideration of a wide range of alternatives and providing transparency as to the model's calculations in a particular scenario. STEER users may rely on the existing publicly available data that is included in the model or the data can be replaced with more granular information if desired. Stakeholders can use this tool for analysis and comparison with analyses produced by utility companies and other stakeholders.

4.3 Model Adaptation

The original version of STEER already included a limited selection of natural gas-fired, combustion turbine cogeneration systems available for deployment. As described in Section 3.1, for this project, this existing suite of CHP options was expanded to reflect a wider range of prime mover technologies, system sizes, and fuel types. This enables the ability to run more sophisticated modeling scenarios that consider the characteristics of different types of CHP applications. The result is a more realistic picture of the scale of CHP deployment that is possible in Michigan, subject to various factors such as future fuel prices, policy decisions such as the structure of standby rates, and other elements that affect the overall cost of building and operating CHP systems. The results presented throughout this report are based on the modified version of STEER.

During activities related to the customization of the STEER Model as described in detail within the technology roadmapping methodology in Section 3.1, project partners incorporated CHP technologies for inclusion in Michigan's generation portfolio based on the performance characteristics and costs published by EPA with potential deployment numbers and capacities published by DOE. These included various sizes of reciprocating engines, gas turbines, steam turbines, microturbines and fuel cells. In order to evaluate CHP's value to the electric power system, we found the "electric-only" costs of each CHP application by subtracting from both the investment cost and the operating cost of CHP the cost of producing a comparable amount of heat from an efficient natural gas boiler.

STEER evaluates the potential deployment of each CHP technology in the same way that it evaluates all new generation options. First, it computes the required annual revenue for investment per unit of the technology based on the investment cost, depreciation schedule, cost and shares of debt and equity, property and use taxation, and income taxation using rates that are representative of Michigan utilities. Second, STEER calculates the capacity and energy value of each generation option when placed into dispatch competition with all existing or previously selected generation resources. This allows calculation of "unmet required revenue," which is the required annual revenue for investment less the capacity and energy value the resource would provide if built. In principle, this is the same as determining whether the new resource would be profitable in a wholesale power supply market. If "unmet required revenue" is negative, then the plant would be profitable based solely on wholesale power market revenues and capacity values. If "unmet required revenue" is positive, then it would fail to recover its costs with a reasonable return on investment from its power output and would only be built if it provided additional value, such as resilience benefits to its host. Third, STEER calculates avoided emissions of CO_2, NO_x and SO_x by calculating the reduced use of the marginal generating unit in each hour due to deployment of a potential new resource and the consequent reduction of emissions from that marginal unit, offset by any emissions from the potential new resource. Finally, STEER chooses which generation resources to deploy by ranking them in order from the lowest to highest "unmet required revenue" per unit environmental mitigation and going as far down this list as necessary to both meet required load and satisfy the aggregate statewide environmental constraints established by the user. If the environmental constraints are lax, this produces essentially the same result as ranking them from lowest to highest "unmet required revenue" per unit of power generation.

Because new generation resources are only added when needed, in deference to the existing generation resources, it is possible that options with a negative (profitable) "unmet revenue requirement" will not be chosen by STEER. STEER might choose a resource that has a positive (unprofitable) "unmet revenue requirement" if necessary to meet the emissions constraints. For purposes of CHP deployment, any technology with a negative "unmet revenue requirement" would be viable in the marketplace absent discriminatory utility policy and without an emissions constraint.

4.4 Assumptions

As with all integrated resource planning, assumptions or projections about future conditions are the bases for analysis. The STEER model provides means to determine an optimum course of action given those projections, but the projections of future conditions are determined external to the model. Projections of conditions such as load growth, fuel prices, and technology prices are provided to the model as independent parameters but are not actually independent. Best practice when using a model is therefore to use multiple scenarios reflecting possible "states of the world" in order to understand the variation of modeling results and the risks associated with a potential course of action. Because of the large number of parameters that are incorporated into STEER, it is possible to construct many scenarios.

Because any investment in CHP will need to be viable for an extended period, we evaluated the role of CHP in 2030. For purposes of preliminary evaluation of the viability of CHP technologies in Michigan, we constructed and used several scenarios. In each case, we assume current law including Michigan's EWR resource standard and Renewable Portfolio Standard (RPS), the availability of federal production or investment tax credits, tax rates, etc. We also assumed announced plans to retire power plants, consistent with the retirements used by MAE in its modeling of Clean Power Plan compliance.[72]

"Spark spread" – the difference between the price of electricity and the cost of fuel to produce electricity – is widely understood to be one of the most critical factors in the economic viability of CHP projects. In order to evaluate this factor in a logically consistent way, we used natural gas price forecasts from three scenarios provided in the U.S. DOE Energy Information Administration (EIA) 2016 Annual Energy Outlook.[73]

In preparing the annual outlook, EIA uses econometric models that statistically identify the "linkages between the prices of various fuels." Their scenarios, designed principally to identify the effects of variation in natural gas supply, are the Reference Case, the High Oil and Gas Resource Case ("High Resource Case"), and the Low Oil and Gas Resource Case ("Low Resource Case"). The High Resource Case produces lower fuel price forecasts and the Low Resource Case produces higher fuel price forecasts than the Reference Case. These forecasts, in 2016 dollars per Million British thermal units (MMBtu) of heat content, are shown through 2030 in Table 7.

The other principal non-policy factor besides fuel prices that would be likely to materially affect "spark spread" and hence CHP project economics, is the price of electricity. STEER forecasts the hourly wholesale price of electricity given fuel prices, existing generation resources, and the least-cost selection of new generation resources. STEER projects the price of electricity using the embedded costs of legacy generation, projected costs of new generation resources, and projected costs of fuel used in either existing or new generation resources. The assumptions used in STEER, other than fuel prices, that are most likely to affect the future price of electricity are the costs of renewable generation technologies. In order to assess the effects of these projections, we used each of the fuel price scenarios noted above in combination with two alternative assumptions about renewable technology. One alternative assumes that renewable generation costs continue to decline at the rates that have occurred over the last five years, while the second alternative simply excludes new renewables from the STEER analysis, simulating that they are not economically competitive. This range of scenarios provides a corresponding range of CHP deployment outcomes, reflecting appropriate uncertainty about the future.

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[72] These retirements were not based on requirements of the Clean Power Plan. Rather they reflected the knowledge and opinions of staff of the Michigan Public Service Commission and Michigan Agency for Energy about expected retirements of existing generating units based on age and other environmental requirements.
[73] U.S. EIA. 2016. *Annual Energy Outlook 2016 with projections to 2040*. https://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf.

Table 7. EIA Price Forecasts through 2030[74]

	Reference Case Fuel Forecast (2016$/MMBtu)				High Gas and Oil Resource Case Fuel Forecast (2016$/MMBtu)				Low Oil and Gas Resource Case Fuel Forecast (2016$/MMBtu)			
Year	Distillate Fuel Oil	Residual Fuel Oil	Natural Gas	Steam Coal	Distillate Fuel Oil	Residual Fuel Oil	Natural Gas	Steam Coal	Distillate Fuel Oil	Residual Fuel Oil	Natural Gas	Steam Coal
2014	$ 23.19	$ 20.00	$ 5.04	$ 2.27	$ 23.19	$ 20.01	$ 4.93	$ 2.27	$ 23.19	$ 20.01	$ 5.00	$ 2.27
2015	$ 15.26	$ 10.13	$ 3.29	$ 2.28	$ 15.26	$ 10.13	$ 3.29	$ 2.28	$ 15.26	$ 10.13	$ 3.29	$ 2.28
2016	$ 11.95	$ 8.09	$ 3.02	$ 2.14	$ 11.95	$ 8.09	$ 2.93	$ 2.15	$ 11.95	$ 8.09	$ 3.05	$ 2.13
2017	$ 14.33	$ 9.30	$ 3.53	$ 2.18	$ 14.58	$ 9.39	$ 3.32	$ 2.18	$ 14.17	$ 9.20	$ 3.65	$ 2.17
2018	$ 16.22	$ 10.57	$ 3.81	$ 2.23	$ 15.94	$ 10.40	$ 3.58	$ 2.20	$ 15.81	$ 9.89	$ 4.03	$ 2.26
2019	$ 17.26	$ 12.65	$ 4.18	$ 2.28	$ 16.96	$ 12.47	$ 3.81	$ 2.23	$ 17.22	$ 12.40	$ 4.55	$ 2.31
2020	$ 17.75	$ 13.25	$ 4.54	$ 2.31	$ 17.44	$ 13.00	$ 3.83	$ 2.24	$ 17.86	$ 13.14	$ 5.15	$ 2.36
2021	$ 18.10	$ 13.74	$ 4.57	$ 2.31	$ 17.76	$ 13.44	$ 3.68	$ 2.22	$ 18.52	$ 13.94	$ 5.48	$ 2.38
2022	$ 18.36	$ 14.12	$ 4.53	$ 2.32	$ 18.06	$ 13.93	$ 3.58	$ 2.23	$ 18.87	$ 14.45	$ 5.99	$ 2.39
2023	$ 18.69	$ 14.52	$ 4.56	$ 2.33	$ 18.55	$ 14.39	$ 3.60	$ 2.23	$ 19.27	$ 14.83	$ 6.32	$ 2.40
2024	$ 19.00	$ 14.78	$ 4.68	$ 2.33	$ 19.08	$ 14.87	$ 3.69	$ 2.24	$ 19.60	$ 15.22	$ 6.82	$ 2.40
2025	$ 19.48	$ 15.41	$ 4.81	$ 2.33	$ 19.47	$ 15.48	$ 3.76	$ 2.24	$ 20.07	$ 15.86	$ 7.34	$ 2.41
2026	$ 19.84	$ 15.95	$ 4.93	$ 2.33	$ 20.06	$ 16.41	$ 3.85	$ 2.25	$ 20.52	$ 16.49	$ 7.69	$ 2.41
2027	$ 20.04	$ 16.05	$ 5.05	$ 2.32	$ 20.07	$ 16.24	$ 3.97	$ 2.24	$ 20.74	$ 16.62	$ 8.00	$ 2.41
2028	$ 20.06	$ 16.09	$ 5.16	$ 2.31	$ 20.30	$ 16.60	$ 4.10	$ 2.23	$ 20.95	$ 16.77	$ 8.17	$ 2.42
2029	$ 20.31	$ 16.32	$ 5.25	$ 2.30	$ 20.64	$ 17.11	$ 4.14	$ 2.23	$ 21.28	$ 17.01	$ 8.33	$ 2.42
2030	$ 20.75	$ 16.63	$ 5.29	$ 2.30	$ 21.25	$ 17.42	$ 4.07	$ 2.22	$ 21.77	$ 17.41	$ 8.37	$ 2.42

[74] U.S. EIA. 2016. *Annual Energy Outlook 2016 with projections to 2040.* https://www.eia.gov/outlooks/aeo/pdf/0383(2016).pdf.

4.5 Power System Modeling Results

Using the EIA 2016 Annual Energy Outlook Reference Case and allowing STEER to choose renewables to meet generation requirements, STEER produced the results for the various CHP technologies that are shown in **Attachment D**. In this scenario, steam turbines of any size, combustion turbines larger than 20 MW capacity, and reciprocating engines larger than 3 MW capacity are profitable. Michigan technical potential for these CHP technologies totals 1.014 GW but only 722 MW at 70 sites are built because the additional capacity was not required.

Using the EIA 2016 Annual Energy Outlook Reference Case without allowing STEER to choose renewables to meet generation requirements, STEER produced the results for the various CHP technologies that are shown in **Attachment E**. In this scenario, the same CHP technologies as in the scenario with renewables are profitable, but because renewable capacity was not allowed to be chosen by STEER, all 1.014 GW of profitable CHP technologies at 103 sites are chosen.

Using the EIA 2016 Annual Energy Outlook High Resource Case and allowing STEER to choose renewables to meet generation requirements, STEER produced the results for the various CHP technologies that are shown in **Attachment F**. Natural gas prices are lower in this scenario, but CHP is generally competing with combined cycle natural gas in the dispatch order, so that the price of electricity is also lower. As a result, the same technologies are profitable as in the Reference Case: steam turbines of any size, combustion turbines larger than 20 MW capacity, and reciprocating engines larger than 3 MW capacity. However, because the price of natural gas is lower in this scenario, fewer renewables are selected and more of the profitable CHP capacity is built. Just like the Reference case, the profitable CHP technologies have Michigan potential totaling 1.014 GW at 103 sites, but in this case all 1.014 GW are chosen.

Using the EIA 2016 Annual Energy Outlook High Resource Case without allowing STEER to choose renewables to meet generation requirements, STEER produced the results for the various CHP technologies that are shown in **Attachment G**. In this scenario, the same CHP technologies are profitable as in the preceding scenario and are chosen as in the High Resource Case but with renewables excluded, primarily because with the low natural gas prices projected in this case, incremental renewables are not chosen.

Using the EIA 2016 Annual Energy Outlook Low Resource Case and allowing STEER to choose renewables to meet generation requirements, STEER Michigan CHP produced the results for the various CHP technologies that are shown in **Attachment H**. With the higher natural gas prices used in this scenario, the relative fuel efficiency of CHP generation as compared to combined cycle and electricity-only combustion turbines causes a wider range of CHP technologies to be profitable, including steam turbines of any size, combustion turbines 8 MW capacity and larger, and reciprocating engines 1 MW capacity and larger. Michigan technical potential for these profitable technologies totals 2.36 GW at 816 sites. However, with higher natural gas prices, substantial renewables are chosen and the selected amount of cogeneration is still only 1.014 GW.

Using the EIA 2016 Annual Energy Outlook Low Resource Case without allowing STEER to choose renewables to meet generation requirements, STEER produced the results for the various CHP technologies that are shown in **Attachment I**. As is generally true, the same set of CHP technologies is profitable in this scenario as in the previous scenario. Without renewables available in this scenario, STEER builds the entire 2.36 GW of profitable CHP generation technologies at 816 sites. This scenario results in the most amount of CHP being chosen by the STEER model.

Across a fairly broad range of scenarios, neither microturbines nor fuel cells appear economically viable for broad application in Michigan. Steam turbines, combustion turbines, and reciprocating engines above some threshold size appear profitable in each scenario with the minimum size threshold being lower under higher natural gas pricing and when renewables aren't available.

The CHP technologies that appear viable based on STEER modeling results based solely on their value to the power system have potential in specific economic sectors. Table 8 summarizes the number of sites in each sector for which there appear to be viable technologies, where a range reflects the results in the various scenarios described above.

Table 8. STEER CHP Evaluation Results

Sector	**Steam Turbine**		**Combustion Turbine**		**Reciprocating Engine**	
	MW	**Sites**	**MW**	**Sites**	**MW**	**Sites**
Food/Beverages	8	1	25	3	24-90	3-36
Lumber/Wood	-	-	7	1	6-36	1-16
Paper/Pulp	40	1	79-87	2-3	8-50	1-21
Chemicals	64	3	88-194	2-13	108-244	11-66
Petroleum Refining	-	-	-	-	0-16	0-8
Rubber/Plastics	-	-	-	-	0-17	0-9
Stone/Clay/Glass	-	-	5	1	5-12	1-3
Primary Metals	39	1	58-71	2-3	13-67	1-26
Machinery/Comp Equip	-	-	-	-	0-3	0-2
Transportation Equip	25	3	101-182	4-14	80-231	10-87
Gas Processing	-	-	-	-	0-6	0-2
Refrigerated Warehouses	-	-	-	-	1	1
Wastewater Treatment	-	-	-	-	2	1
Commercial Office Bldgs	-	-	-	-	0-172	0-284
Multifamily Housing	-	-	-	-	0-17	0-16
Hotels	-	-	-	-	0-24	0-15
Data Centers	-	-	-	-	0-13	0-8
Hospitals	-	-	0-21	0-3	7-131	1-57
Colleges/Universities	101	8	31-70	1-6	41-128	5-37
Prisons	-	-	-	-	0-50	0-34
Military Facilities	-	-	-	-	0-7	0-3
Airports	-	-	-	-	0-4	0-2
Museums	-	-	-	-	0-2	0-1
Government Buildings	-	-	5	1	0-30	0-16

4.6 Resilience

The preceding analysis using STEER does not assign any value to the potential contribution of CHP to site or community resilience in case of an extended grid outage, nor to the avoidance of costs related to outages of any length. For some CHP host sites, this resilience value can be decisive. We therefore extended STEER to account for the additional CHP potential associated with the resilience value of CHP.

Resilience value does not lead to increased deployment of a CHP technology that would be developed anyway based on only its power system value. Thus incremental CHP potential due to resilience value will result when CHP is not profitable based purely on the avoided cost of electricity. In these cases, the profitability gap is overcome by the value of resilience to the CHP host. Since resilience value varies amongst potential hosts, our extension of STEER to address resilience value was conducted primarily to include calculations of the minimum resilience value that would lead a potential CHP host to build a CHP resource that is otherwise not profitable, identify the application sectors likely to have resilience value at least as large as the threshold, and estimate the additional potential for CHP in those sectors.

The results of resilience calculations based on the EIA 2016 Annual Energy Outlook Reference Case fuel prices and considering additional use of renewables in the power system (corresponding to the assumptions in Attachment D) are shown in **Attachment J**. Consideration of CHP resilience value enables the potential use of smaller combustion turbines and reciprocating engines than would be profitable based solely on heat and power system value, and also enables the potential use of some microturbines.

Under the assumptions of Attachments D and J, consideration of resilience value increases CHP potential by 591 MW above the 1,014 MW that would be profitable without consideration of resilience value.

4.7 Standby Rates

The primary analysis using STEER examined the fundamental value of CHP in Michigan's power supply. Host decisions to adopt CHP, however, are often determined by the terms of utility tariffs rather than by power system value. The principal difference between these is the application of standby rates, which is one of the primary barriers to CHP adoption. We therefore extended our analysis using STEER to examine the effect of standby rate tariffs on CHP potential.

In order to incorporate the economic effects of standby rates on CHP potential, it was necessary to model the avoided costs as created by Michigan standby rates. The avoided cost assesses the financial relationship between the aggregate price of electricity before and after the installation of customer-sited CHP.

As a metric for evaluation, we used the guidelines and methodology presented by the EPA CHP partnership in the paper "Standby Rates for Customer-sited Resources: Issues, Considerations, and the Elements of Model Tariffs"; specifically, the EPA's concept and application of the avoided rate.[75] This

[75] Regulatory Assistance Project. Prepared for the U.S. EPA. Office of Atmospheric Programs, Climate Protection Partnerships Division. 2009. *Standby Rates for Customer-Sited Resources: Issues, Considerations, and the Elements of Model Tariffs*. https://www.epa.gov/sites/production/files/2015-10/documents/standby_rates.pdf.

metric is useful because it reduces the economic and financial impact created by standby rates to a simple percentage figure that can easily be incorporated into the STEER model.

The concept of avoided rate evaluates the financial impacts of standby rates on distributed generation systems by comparing the per kWh cost of full-requirements customers to that of otherwise comparable standby customers. Ideally, a decrease in electricity purchased from the utility would be commensurate with a decrease in monthly electric costs. If a customer reduces their purchased electricity by 50% they would expect their bill to decrease by a similar amount. However, there are some utility system costs appropriately billed to the customer that are not reduced by the same percentage and limit the bill reduction. These manifest as standby charges and the question of whether or not they are reasonable is beginning to be the subject of rate cases before the MPSC.

Standby rates can increase electric demand charges even when a customer decreases overall electric consumption, thus negating many economic benefits to the customer. The avoided rate is a metric that measures the amount of savings per kWh a distributed generation customer receives when not purchasing electricity from the utility. In essence, it compares the value of a purchased kWh to the value of an avoided kWh. This rate requires the comparison between the electricity costs to a facility when on a full-requirements rate and the electricity costs to a facility when on a standby rate.

The avoided rate model analyzes the extent that standby rates allow distributed generation customers to avoid electric charges. After modeling each facility's usage during one year it is possible to aggregate all charges into a simple cost per kWh. This aggregate cost includes the cost of generation, transmission, distribution, demand, taxes and all applicable riders for both full-requirements and standby rates. The avoided rate is calculated by dividing the money not paid to the utility by the electricity not purchased from the utility. When the avoided rate closely matches the full-requirements rate, the user experiences increased savings.

For example, if a hypothetical facility purchases 1,000,000 kWh of electricity per year from the utility at an aggregate cost of $0.10 per kWh, the facility will pay a total cost of $100,000. If this same facility installs a CHP system that reduces their need for purchased electricity to 500,000 kWh per year, in an ideal economic situation, the annual bill would be half the normal bill, or $50,000. Under this ideally constructed scenario, the avoided rate from the 500,000 kWh *not* purchased would be $0.10 ($50,000/500,000 kWh). Thus, this situation would have an avoided rate equivalent to the full requirement rate.

There are limitations in using the avoided rate metric, however. Though simple to calculate and communicate, the avoided rate metric can over-simplify situations. The economic effect of standby rates is largely related to the specific attributes and operating schedules of a customer's generator. Given the diversity of potential CHP hosts in Michigan, the avoided rate represents a simplified generalization for these actual CHP hosts. A more specific calculation would be needed to assess an individual CHP project.

Project partners modeled the avoided rates of Consumers Energy and DTE Energy using energy usage data provided during a March 14, 2016 workshop on standby rates. Based on these data, Consumers Energy's standby rate results in an avoided rate between 81%-85% depending on the size of the CHP customer while DTE Energy's standby rate results in an avoided rate between 71%-77%. According to the EPA, avoided rates below 90% may pose an economic barrier to otherwise financially feasible CHP implementation. The results of this modelling are shown in Table 9.

Since standby rates primarily apply to the capacity of the CHP system, the ratio of the cost of standby rates to CHP system capacity is an appropriate measure of the effect of standby rates on the profitability of a CHP system. Based on the avoided rates of DTE Energy and Consumers Energy, STEER projected that standby rates in 2030 would impose costs of about $88,000 per MW capacity of a CHP system. In STEER, this additional cost of capacity reduced the profitability of all CHP technologies. Some CHP technologies were still profitable, despite the standby rate cost, while more marginal CHP technologies became unprofitable. The technologies that became unprofitable in the face of standby rates depend on the scenario under which they are evaluated.

The effect of standby rates on STEER Michigan CHP potential results using the EIA 2016 Annual Energy Outlook Reference Case and allowing STEER to choose renewables to meet generation requirements (corresponding to the assumptions of Attachment D) is shown in **Attachment K**. Standby charges had the effect of making combustion turbines below 40 MW and reciprocating engines below 9 MW unprofitable, thereby reducing CHP potential by 669 MW from the 1,014 MW that would be available under the same scenario but without standby charges.

Table 9. Utility Standby Rate Impact

Utility	Site Peak Load	CHP Capacity	Total Required kWh	Generated kWh	Full Requirements Bill	Standby Bill	Full Requirements $/kWh	Avoided Rate $/kWh	Avoided Rate Percentage
Consumers	7,000 kW	3,500 kW	44,623,000 kWh	27,594,000 kWh	$ 3,128,000.00	$ 1,489,000.00	$ 0.070	$ 0.059	85%
	1,000 kW	450 kW	5,889,000 kWh	3,548,000 kWh	$ 503,000.00	$ 259,000.00	$ 0.085	$ 0.069	81%
DTE Energy	8,000 kW	5,000 kW	51,544,000 kWh	30,926,400 kWh	$ 3,280,000.00	$ 1,756,000.00	$ 0.064	$ 0.049	77%
	1,000 kW	282 kW	3,917,000 kWh	2,350,200 kWh	$ 318,000.00	$ 183,000.00	$ 0.081	$ 0.057	71%

4.8 Analysis

As noted previously, STEER modeling indicated that steam turbines, gas combustion turbines, and reciprocating engines appear profitable above some size threshold size in each scenario. Conversely, microturbines and fuel cells do not appear economically viable. Assuming higher natural gas prices and higher cost of renewable resources in the future both tend to lower the minimum size threshold for the more viable CHP technologies, thereby expanding the number of potential installation sites in Michigan.

Consideration of resilience value increases the potential deployment of CHP in sectors where loss of power is most consequential and can significantly increase CHP potential beyond the levels that would be supported only by power sector value. Based on STEER analysis of Michigan potential, resilience value could increase CHP potential by around 60%. Standby rates, on the other hand, substantially reduce the profitability of CHP ownership and thereby reduce potential CHP deployment by 50% or more.

Developing CHP to its economic potential will provide a number of benefits to Michigan. Since economic potential varies with projections of technology and fuel costs, and other factors, STEER estimated the primary benefits using the EIA 2016 Annual Energy Outlook Reference Case for fuel prices and was allowed to choose renewables to meet generation requirements (corresponding to assumptions of Attachment D). If built, these CHP installations would produce about $109.5 million per year in profit above the level required to recover cost of capital. Such profit due to outperforming the marginal unit in the economy is considered a significant benefit to society and, if accruing to CHP hosts, increases the likelihood that they remain in their primary business in Michigan.

STEER estimates building 1,014 MW CHP of the types chosen in this scenario would require direct investment of about $865.7 million and annual non-fuel operations and maintenance of about $67.6 million. These expenditures are themselves costs to the site host but are income to suppliers and generate additional economic activity in Michigan. The amount of direct and indirect economic activity in Michigan and the consequent employment depends on the degree to which Michigan-based businesses are able to participate in the supply and value chains for CHP systems.

Fuel efficiency of CHP systems, in contrast to separately produced heat and electricity using natural gas as a fuel is a benefit to Michigan. STEER estimates building and operating 1,014 MW CHP of the types chosen in this scenario would save about 11.3 million MMBtus per year, representing a net cost savings to Michigan's economy of about $94.7 million per year. This reduction in fuel usage would also reduce air emissions by 662 tons of CO_2 per year, 379 tons of NO_x per year, and 39 tons of SO_x per year.

5 Michigan Supply and Value Chain

The primary objectives of mapping the Michigan CHP supply and value chains were to:

1. Identify the companies who are positioned to facilitate Michigan CHP projects – these firms are members of the Michigan supply and value chains;
2. Develop a digital directory of the identified companies and distribute to potential end-users to market CHP and expedite project discovery and implementation;
3. Evaluate segments of the supply and value chains where there may be barriers to CHP deployment due to a lack of Michigan firms operating in that space;
4. Assess the economic impact to Michigan arising from CHP deployment.

Mapping efforts built on the results of technology roadmapping presented in Section 3.1 and the conclusions of STEER modeling discussed in Section 4.8. Mapping utilized stakeholder engagement activities to assess end-user appetite for CHP and the supply and value chain enthusiasm for participating in CHP projects, with the goal of ultimately driving CHP education, project development, and implementation.

Demand for CHP projects in both the private and public sector is primarily driven by an economic comparison of the costs and benefits of CHP versus the costs and benefits of end-user current operations. This status quo typically entails electric generation at a utility-owned power plant and thermal energy generation on-site by end-user-owned boilers or furnaces. Thus, in order for demand for CHP to increase, the economics must become more favorable than the status quo. Market economics are affected by a number of factors, including:

- Delivered energy cost trends
- End-user energy efficiency or energy waste reduction targets
- Technological performance or cost improvements
- Fuel resource supply and pricing trends
- Utility regulations and incentives
- Government legislation and incentives

5.1 Supply Chain Mapping

As discussed in Section 3.4, project partners have defined the **CHP supply chain** as the physical equipment and fuel required for the CHP system to operate. The major sectors of the CHP supply chain include CHP end-user applications, prime mover manufacturers and distributors, major equipment manufacturers and distributors, and fuel suppliers and brokers.

Prime movers include gas turbines, reciprocating engines, steam turbines, and fuel cells. Project partners have confirmed that there are businesses operating in Michigan that manufacture, distribute, or provide maintenance services to each of these four types of prime movers.

Major equipment was grouped into three subsectors: electrical controls, heat recovery, and absorption cooling. Electrical controls and heat recovery are common to nearly all CHP applications, although the implementation may vary considerably. Absorption cooling is utilized in projects where there is demand for chilled water or refrigeration, but limited demand for heat.

Finally, natural gas was the only fuel identified to realistically supply most CHP projects. Although other types of fuel such as woody biomass, biogas, and landfill gas are available in some locations, unless a potential CHP user is located at an adjacent site, guaranteeing supply and transportation of these fuels is likely to be risky and cost prohibitive, respectively.

The major and minor sectors of the Michigan CHP supply chain are summarized in **Figure 6**.

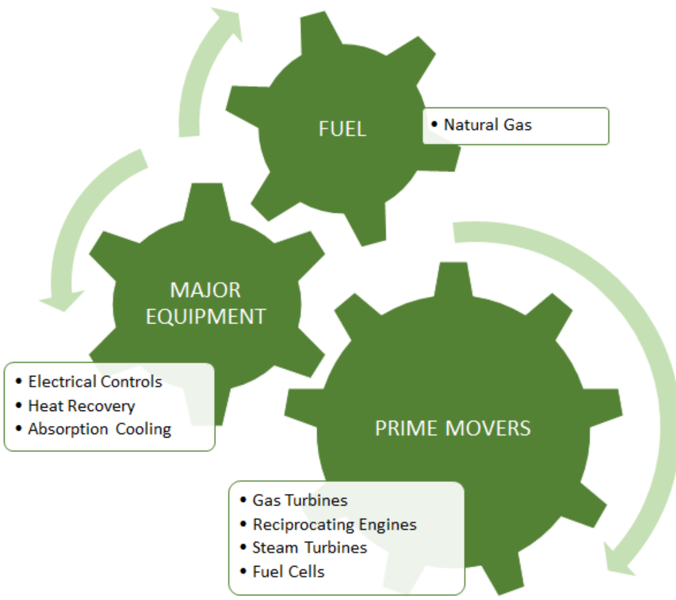

Figure 6: CHP Supply Chain (excluding end-users)

The majority of turbine and reciprocating engine prime movers – the highest value components in the supply chain – are designed and manufactured in a small geographic region in Germany and Austria. The firms operating in that region compete for the same engineering talent, which further encourages new CHP engineers to move there, much in the same manner as Silicon Valley has become the dominant location where computer engineers and their employees locate in the U.S.. Caterpillar is a notable exception as they manufacture reciprocating engines at a plant in Lafayette, Indiana and gas turbines at a plant in San Diego, California. Michigan prime mover manufacturers and distributors are identified in **Figure 7.**

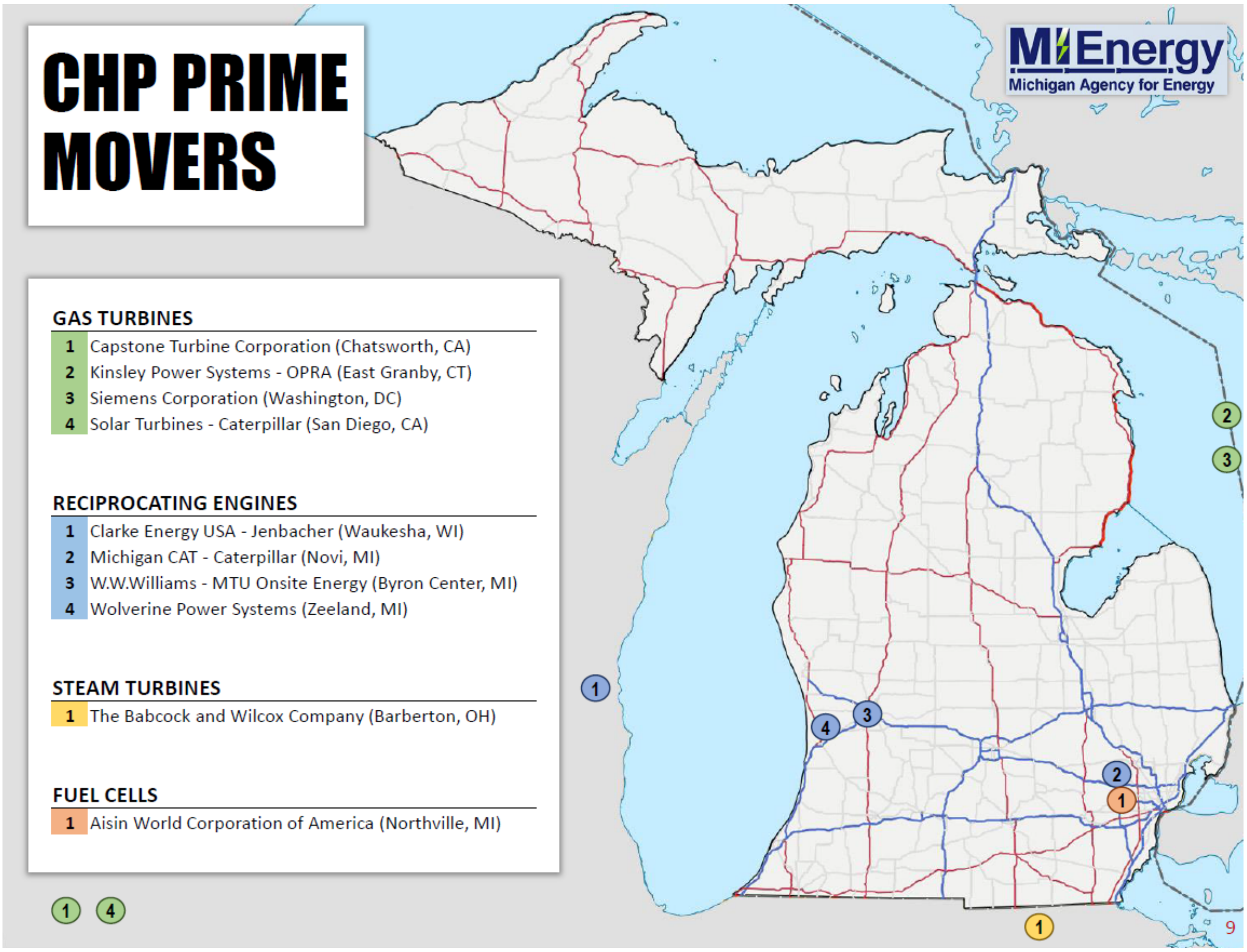

Figure 7: CHP Prime Movers

Project partners interviewed distributors from the companies MTU On-site Energy and Caterpillar serving the Michigan market. These distributors could not identify any companies in Michigan that currently manufacture any of the components found within the prime movers. These components are readily sourced from a well-developed domestic and international marketplace, with high economic, technical, and regulatory barriers to entry. Existing major equipment is sold based on decades of successful performance history which would be rendered invalid if any significant changes were made to the design of the equipment or sourcing of components. It is unlikely that Michigan manufacturers could someday tap into this market due to the unwillingness of prime mover and major component manufacturers to even entertain the possibility. From their perspective, sourcing components from Michigan manufacturers has insignificant upside potential and is fraught with considerable potential downside risks.

As identified in **Figure 8**, a handful of Michigan companies manufacture some of the major ancillary equipment that may be found in CHP projects but are not part of the prime mover systems. However, the vast majority of these firms' sales of these components are not to support CHP projects, but rather to support an array of traditional electric power and thermal energy processes. Broader deployment of

CHP would have a positive impact on the total economic activity generated by these firms, but the bulk of these firms' sales would still be expected to be for non-CHP purposes.

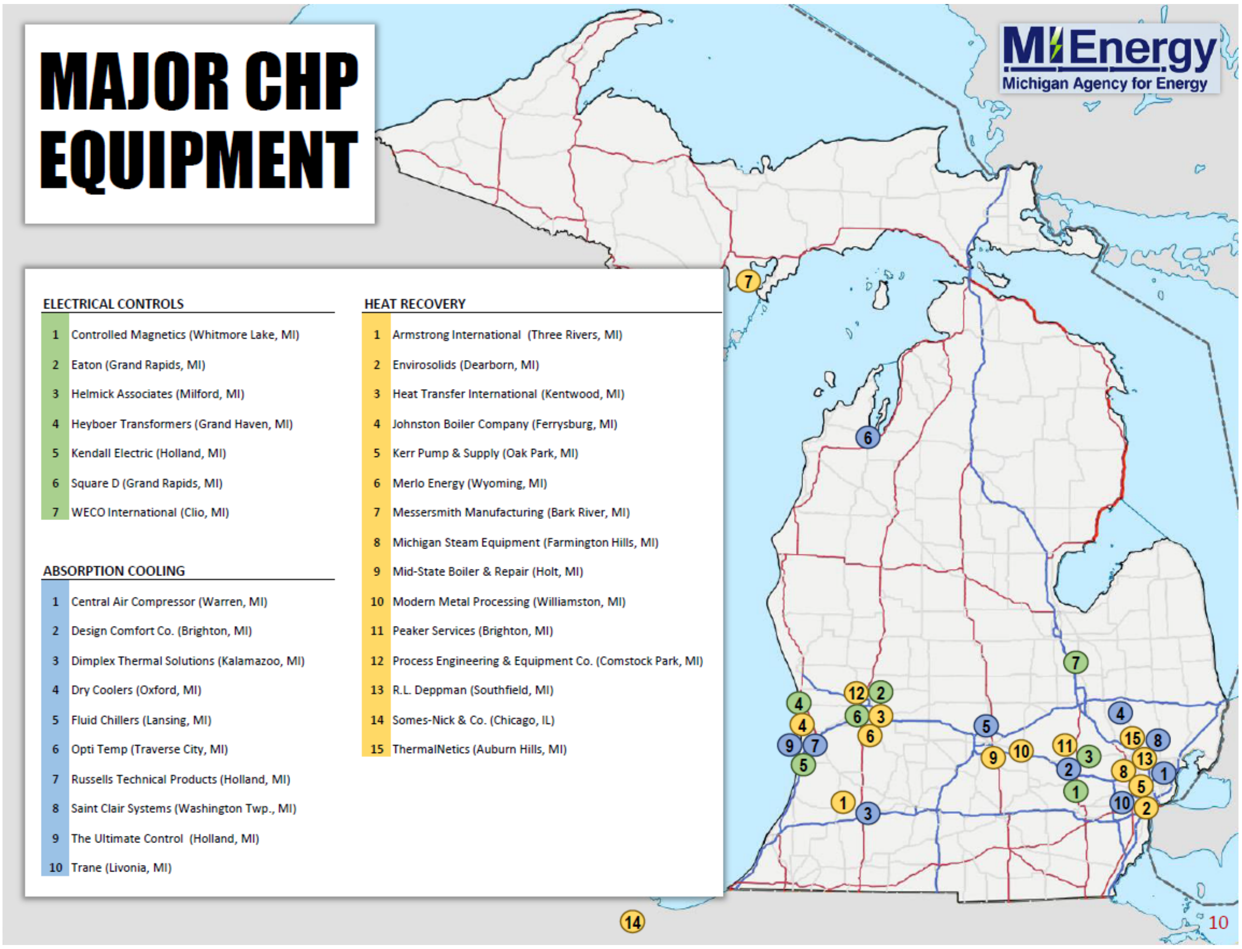

Figure 8: CHP Major Equipment

Fuel supply represents the largest ongoing expense for CHP projects. Natural gas, the most common fuel for CHP systems, is widely available in many parts of Michigan at cost near historical lows. Long-term contracts of 5 to 10 years are readily available through a large number of natural gas traders and brokers, allowing investors to control natural gas fuel supply and pricing during the project's payback period, significantly mitigating investment risk.

In some regions of the state, particularly rural areas and the Upper Peninsula, the infrastructure for transporting or receiving large volumes of natural gas is inadequate or nonexistent. Other fuel sources, such as woody biomass, biogas from anaerobic digesters, and landfill gas, may be utilized but are typically difficult to source, requiring significant additional effort on the part of the project developer to negotiate long-term project-specific supply agreements. Ultimately, this means that in the Upper Peninsula of Michigan, unless a potential CHP project is located in one of the few major cities or along the east-west gas pipeline corridor, fuel supply may be an impossible hurdle to overcome.

However, in general, and especially in the Lower Peninsula, instances where lack of access to appropriate fuel may prevent deployment of otherwise viable CHP projects will be rare. To be a candidate for CHP, one must have a significant existing thermal energy load, and in turn, existing access to a fuel source used to meet that load, which in most cases is natural gas which could be repurposed for a CHP application. Michigan natural gas suppliers and brokers are identified in **Figure 9**. A map of Michigan's natural gas transmission pipelines is available online.[76]

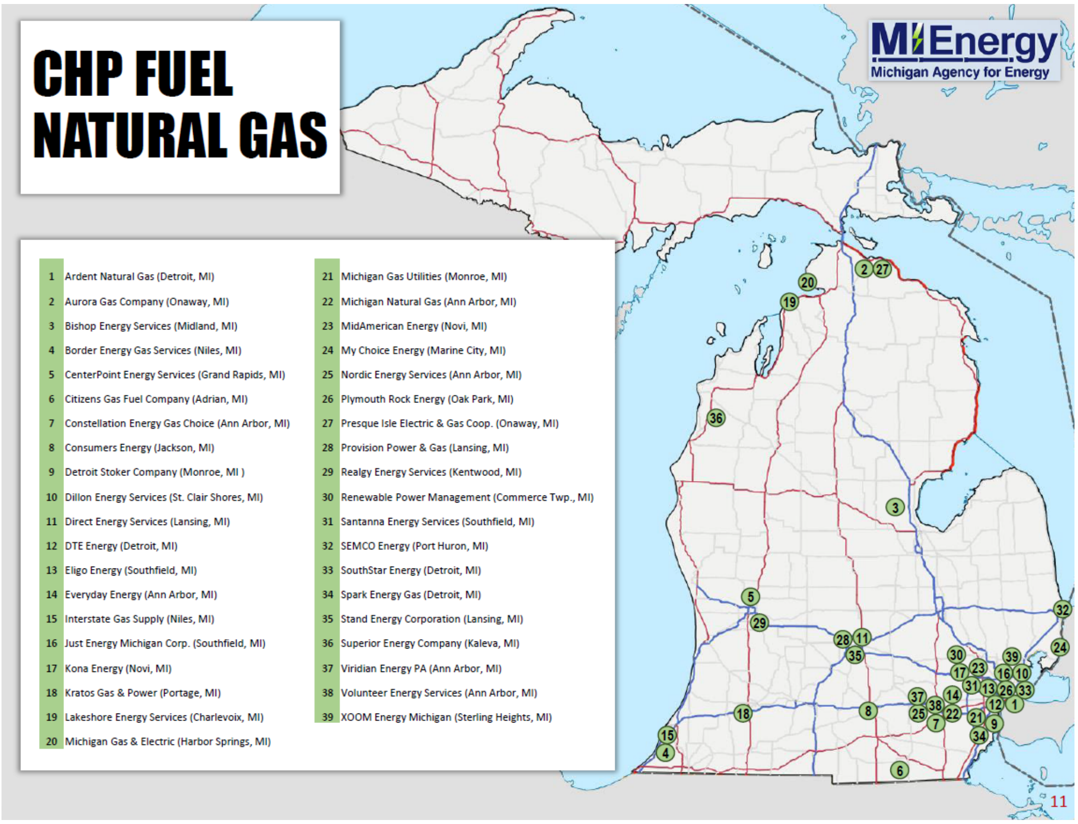

Figure 9: CHP Natural Gas Fuel Marketers

[76] Michigan Public Service Commission. 2002. *Natural Gas Transmission Pipeline and Storage Field Map*. http://www.michigan.gov/mpsc/0,4639,7-159-16385-413020--,00.html.

5.2 Value Chain Mapping

Limited opportunities for Michigan firms in the CHP supply chain are overcome by the robust ability of Michigan firms to participate throughout the value chain. As discussed in Section 3.4, project partners have defined the **CHP value chain** as the intellectual capital and skilled trades required to develop, design, engineer, finance, install, and integrate CHP systems. The major sectors of the value chain include public policy advocates and accelerators, project developers and technical advisors, design/engineering firms, and plant integration contractors.

CHP accelerators and public policy advocates play a critical role in developing the market for CHP applications through encouraging technological innovation, educating and lobbying policy-makers, and supporting end-users and industry organization. With the framework for CHP in place, project developers then identify and conceptually develop projects, assisted by valuable technical advisors and their specific expertise. Design/engineering firms bring the CHP projects from concept to a state of construction readiness. Finally, plant integration contractors, which may include construction management firms, electrical subcontractors, and mechanical subcontractors, install the CHP systems and ensure they operate as designed.

The major and minor sectors of the Michigan CHP value chain are summarized in **Figure 10.**

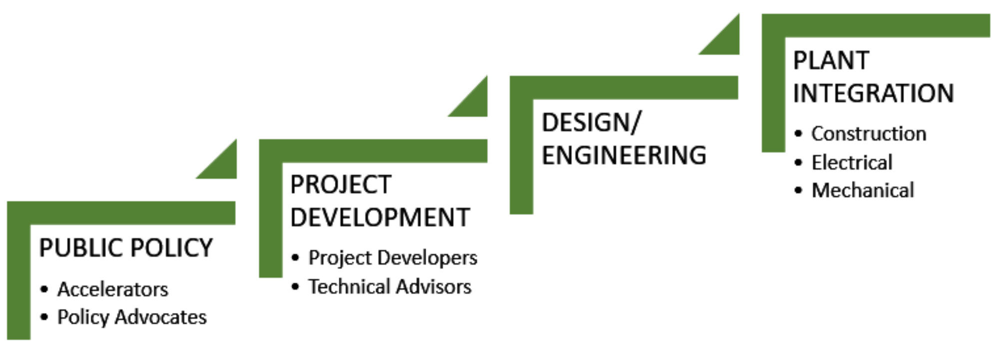

Figure 10: CHP Value Chain

The majority of the economic impact of CHP will be realized by using this pool of talent based in Michigan companies to design and implement projects. However, many value chain firms currently lack significant CHP experience due to the dearth of completed CHP projects in the state in recent years. This obstacle will be rapidly overcome as more projects are deployed throughout the state.

CHP accelerators and policy advocates in Michigan are identified in **Figure 11**. Not surprisingly, most of these firms are clustered around Lansing, Michigan and Washington, D.C., where regulatory policy and legislation are crafted at the statewide and national levels, respectively.

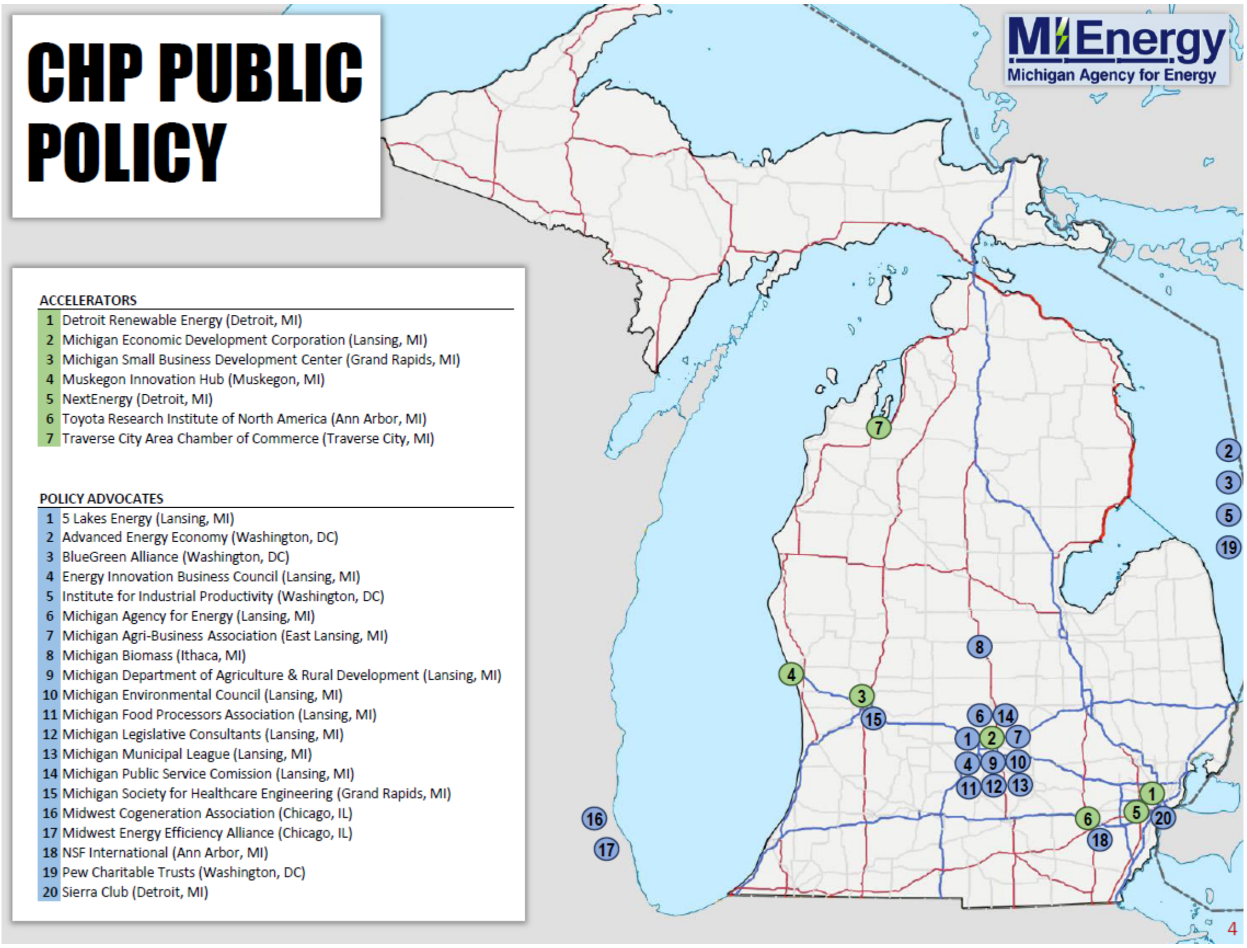

Figure 11: CHP Public Policy

CHP project developers and technical advisors are identified in **Figure 12**. In many cases, firms that principally develop projects also have some capabilities to provide technical expertise, and vice versa. One major difference may be in terms of the business model, where developers often take significant financial risk on developing and securing financing for projects, whereas technical advisors often have a clear fee structure and will only take minimal financial risk.

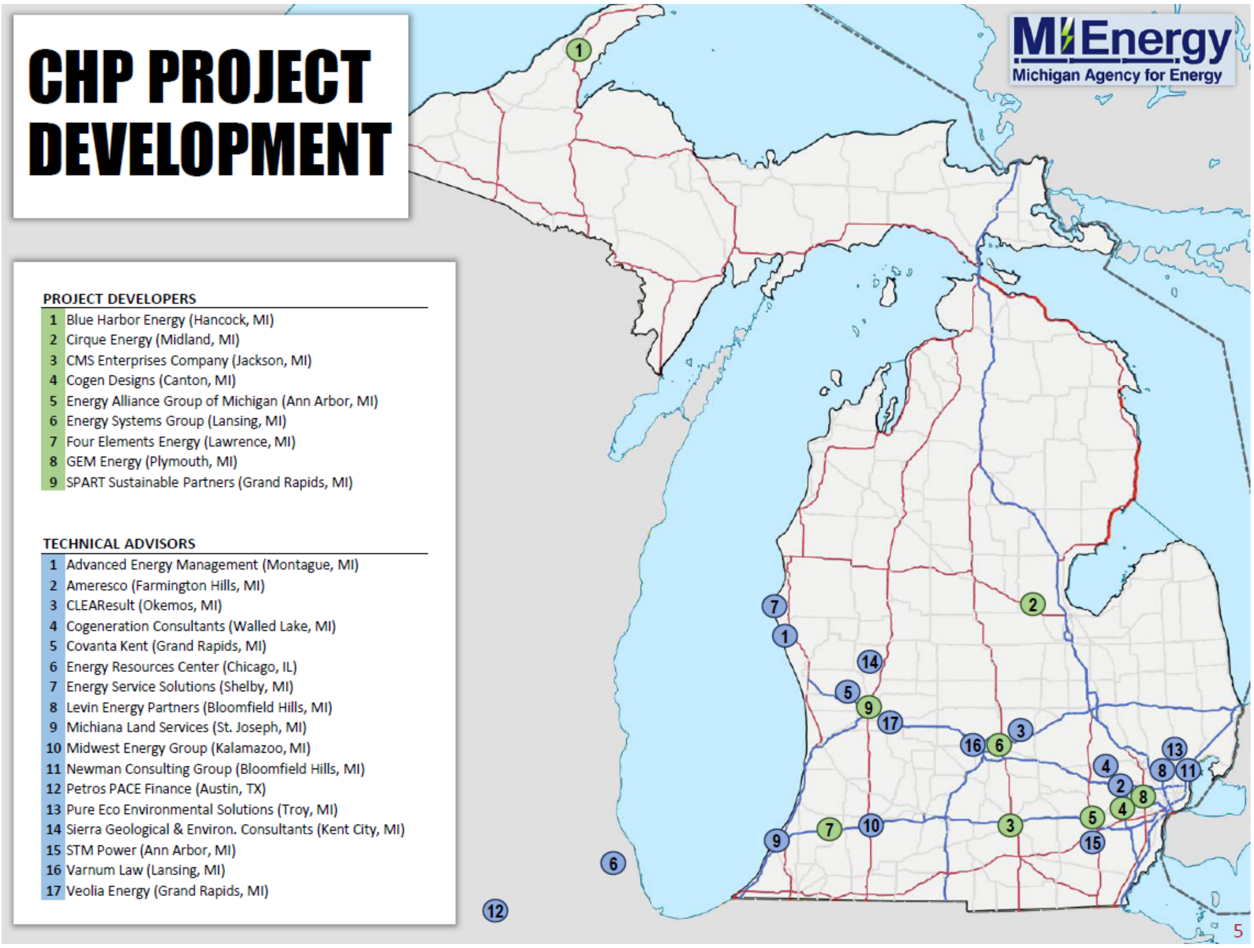

Figure 12: CHP Project Development

CHP design/engineering firms are identified in **Figure 13**. There are a great number of firms with the civil, electrical, and mechanical capabilities required to engineer CHP project in Michigan, and for simplicity many potential end-users may opt to work with the same firm that designed their existing electrical and thermal systems. Generally these firms are clustered around the state's major population centers.

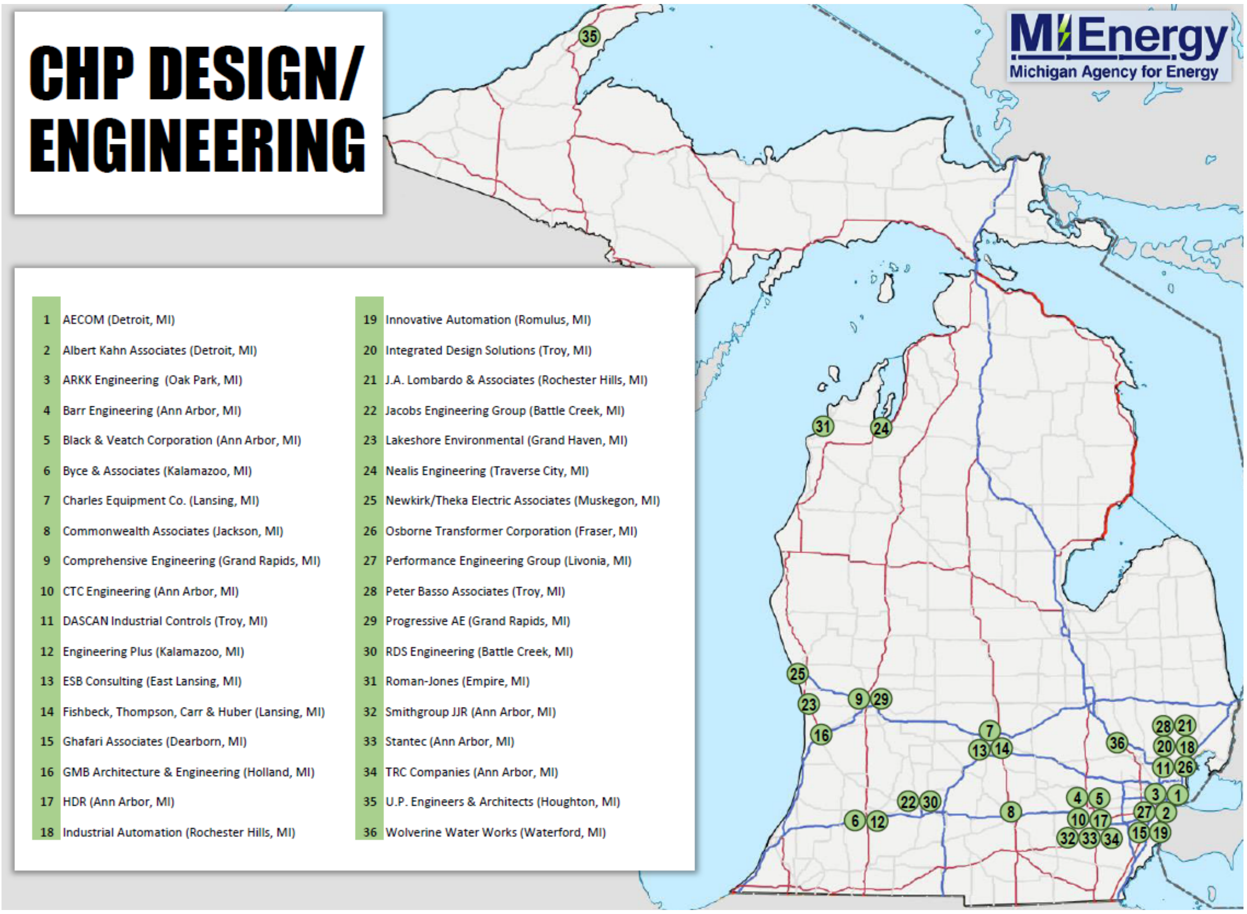

Figure 13: CHP Design/Engineering

CHP plant integration contractors are identified in **Figure 14**. These firms encompass the disciplines of construction management, electrical installation, and mechanical installation. Generally, these firms are clustered around the state's major population centers.

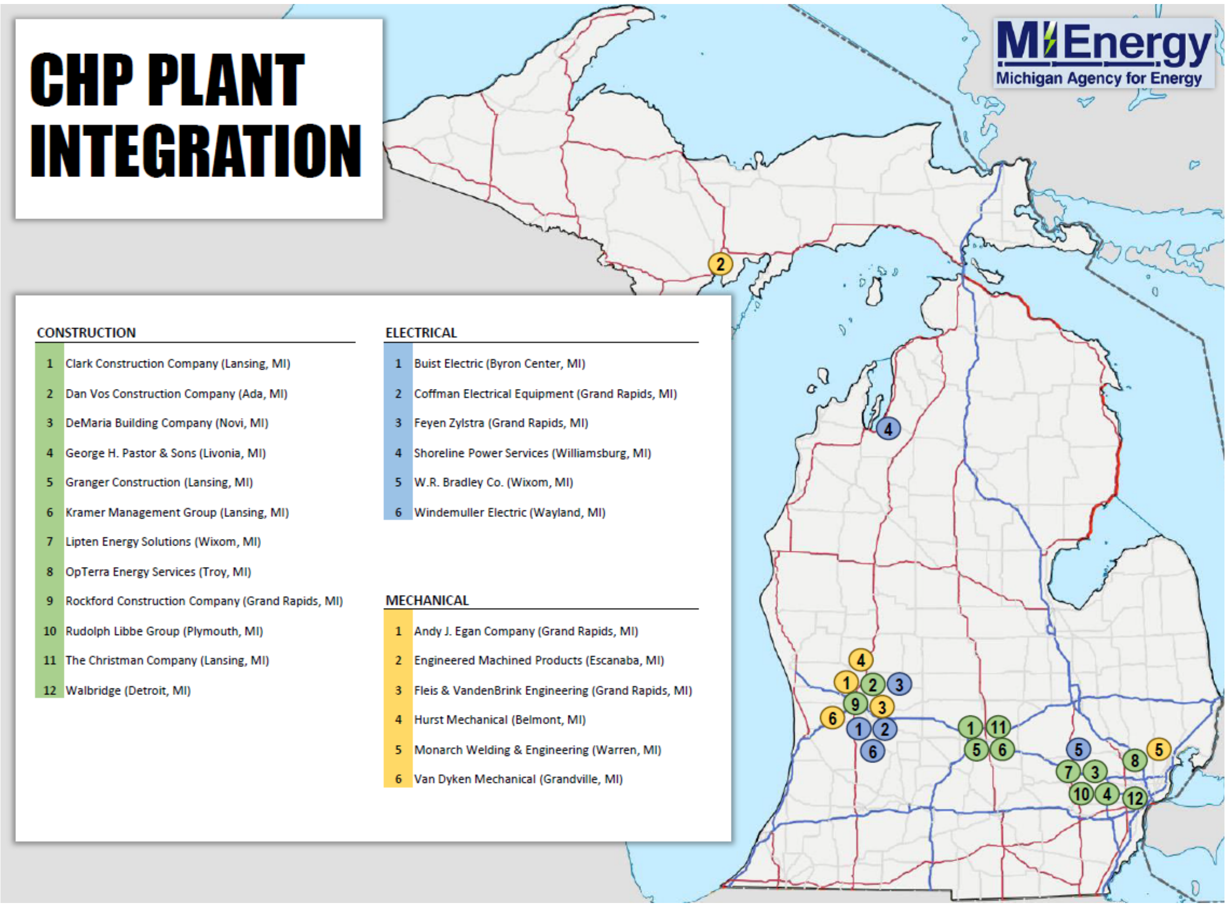

Figure 14: CHP Major Equipment

5.3 Michigan Economic Impact

Deployment of some portion of DOE's estimated 5 GW of Michigan CHP technical potential would generate significant economic activity throughout each project's lifecycle. However, the net economic impact on Michigan due to CHP deployment is quite difficult to discern. We can begin with the assumption that a business will spend less money on energy generation by implementing CHP than by maintaining the status quo, which must be true for a given project to be economically-viable. A business could use this saved money in many different ways. For example, if the business shifted this saved money, which it previously contributed to the Michigan economy, into dividends for company owners, there would be a negative impact on Michigan economic activity following CHP deployment. Alternatively, what is more likely is that widespread CHP deployment would actually be expected to significantly increase Michigan economic activity for a number of reasons:

- Businesses that save money on energy costs with CHP are likely to reinvest a significant portion or all of that savings into company growth;
- Electric utilities cannot simply scale back their generation and infrastructure investments proportionally to the loss of revenue due to CHP deployment. Incrementally, there will need to be more aggregate investments made in electric infrastructure in Michigan with CHP deployed than without, if there is the expectation to maintain an equivalent level of performance;
- Electric utilities will have additional capacity available, providing an opportunity to export to other power providers, or permitting a reduction in purchased power;
- Experience gained by Michigan-based participants in the CHP value chain could be deployed to other states, providing opportunities for many of these firms to bring new revenue streams into the Michigan economy.

Finally, there are factors that do not increase or reduce the economic impact on Michigan, but rather shift the economic impact from one market participant to another. For example, the public electric utilities will experience reduced revenues and likely spend less money on distribution system maintenance with widespread CHP deployment; but in turn, private sector developers, engineering firms, and project implementers will see increased revenues.

In Section 4.8, we determined through STEER modeling that optimal deployment of CHP in Michigan would require direct capital investment of about $865.7 million, annual non-fuel expenditures of about $67.6 million, and produce about $109.5 million per year in incremental profit. Optimal CHP deployment would also save Michigan's economy about $94.7 million per year in fuel costs.

Ultimately, the amount of direct and indirect economic activity in Michigan and the consequent employment (jobs) impact depends on the degree to which Michigan-based businesses are able to participate in the supply and value chains for CHP systems. A directory of Michigan CHP supply and value chain participants has been created and will be shared with potential end-users to foster the use of Michigan-based companies and resources when considering or implementing CHP projects. The database is ultimately envisioned as a tool that will continue to grow as the market for CHP in Michigan also expands. State policymakers could further encourage potential end-users to "Buy Michigan" and "Hire Michigan" through appropriate incentives.

6 Barriers to CHP in Michigan

CHP has the potential to be a significant, reliable, cost-effective, and environmentally protective contributor to Michigan's energy mix. Further, the Michigan CHP supply and value chain is well-positioned to deploy sustainable and cost-effective CHP projects for Michigan's largest energy users. However, those interested in installing CHP projects face a number of obstacles. In order to fulfill the promise of EWR in Michigan through optimal deployment of CHP, these barriers should be examined and understood in general, and in light of the unique circumstances facing Michigan energy users.

While CHP can save a system owner money in the long run, there are a few economic barriers that could prevent a CHP project from moving forward in the first place. The relatively high upfront cost of installing a CHP system can be a barrier in and of itself. Additionally, a lack of sufficient access to financing options can prevent otherwise cost-effective installations. According to the DOE's Advanced Manufacturing Office, "CHP developers must navigate a complex landscape of project financing alternatives and provide detailed project information in order to attract investors. Inadequate information can cause project delays, leading investors to offer less favorable financial terms, or even decline a CHP investment opportunity all together."[77]

Regulatory barriers can dramatically affect a CHP project's bottom line and projected payback period. An overarching barrier that affects the valuation of CHP throughout regulatory and policy discussions stems from the failure to account for the full value of CHP, including qualities such as resilience. Ignoring grid-wide and societal benefits affects how CHP is portrayed in standby rates, avoided cost rates, energy waste reduction standards and integrated resource planning.

Standby rates, or charges a utility customer pays for the utility to provide backup service in case of a scheduled or unscheduled CHP system outage, can be so high as to completely undermine the economic viability of a proposed CHP system. Beyond standby rates, avoided cost or buyback rates under the Public Utility Regulatory Policies Act of 1978 (PURPA) may be insufficient to make a CHP project worthwhile. Interconnection processes can be lengthy, cumbersome and costly. Whereas Michigan has embraced EWR goals through PA 341 and 342 of 2016, a failure to incorporate CHP, or to properly calculate energy savings from participating CHP systems, will lead to less than ideal deployment numbers. Finally, even as regulators and utilities embrace a longer-term resource planning approach, IRP models often fail to recognize the value of CHP as both a supply side and demand side resource, resulting in CHP being overlooked in utility long-range resource plans.

Each of these barriers – which are often dependent on geography, project size and technology, utility constraints, and the prevailing regulatory climate – adds to the risk and cost associated with a potential CHP project. Given the substantial capital investment involved in developing a CHP project, and in light of the benefits offered by more robust deployment of CHP, it is vitally important that these risks and costs be mitigated through thoughtful policies and incentives to avoid killing CHP projects that would otherwise make good sense for Michigan businesses, and good sense for the state's future energy mix.

[77] ICF. Prepared for the U.S. DOE, Advanced Manufacturing Office. 2017. Combined Heat and Power (CHP) Financing Primer. p. ii. https://energy.gov/sites/prod/files/2017/06/f35/CHP%20Financing%20Primer%206-16-17%20Final.pdf.

6.1 Overview of Economic Barriers

One of the most commonly-cited barriers to CHP development is the upfront capital cost associated with the acquisition and installation of equipment. A potential CHP system owner encounters this barrier early in the planning process, as cash or financing is required to purchase components such as turbine or engine parts needed to generate the needed heat and electricity. With an installed cost of between $700 and $3,000 per kW,[78] a potential CHP installation competes for scarce investment capital within a firm. Decision-making structures within a company can pose an additional hurdle, with many business leaders lacking familiarity with the business's typical patterns of energy use, or different energy options, including CHP.

If a business lacks the cash on-hand to invest in CHP equipment, financing can be an option, but a lack of access to low-cost financing can present a major barrier long before a CHP project ever breaks ground. According to the DOE's Advanced Manufacturing Office, "Lenders and investors typically decide to invest in a CHP project based on its perceived level of risk and expected financial performance. These groups focus solely on the expected monetary benefits, and typically do not consider environmental or other non-energy benefits from the project that may be important to the end-user."[79] The size of a typical CHP system can pose a challenge to obtaining financing, with a typical CHP project being too small to interest banks or private equity firms without giving away massive equity stakes.[80] Financing with debt, although generally cheaper than equity financing, can be intimidating due to the high cost of CHP equipment, even if a company has good credit and rates are favorable.[81]

For owners of larger CHP projects intending to sell the power generated, a power purchase agreement (PPA) can be critical to securing CHP project financing (equity and debt). The PPA or off-take agreement typically provides the CHP project's owner with stable and sufficient revenue to pay its project debt obligation, covers the project's operating expenses, and provides a reasonable risk-adjusted return to investor(s). Lenders will look to whether or not there is a guaranteed revenue stream from a creditworthy purchaser that is sufficient to support the project's economics. The terms of the PPA determine whether equity investors and debt lenders view the project as financeable, and lenders are concerned with the length of the PPA term, with a strong preference for longer-term contracts of at least 10-15 years.[82]

Uncertainty about energy costs can pose an additional barrier to CHP development. Fluctuations in natural gas prices introduce a substantial level of risk and uncertainty into the economics of a potential CHP project. Even with natural gas prices perceived as relatively low, natural gas prices can vary widely if "(i) there are significant variations in weather-related factors, (ii) crude oil prices change significantly,

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[78] Chittum, A., and Kaufman, N. American Council for an Energy-Efficient Economy. 2011. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment*. p. 6. http://aceee.org/sites/default/files/publications/researchreports/ie111.pdf.
[79] ICF. Prepared for the U.S. DOE, Advanced Manufacturing Office. 2017. Combined Heat and Power (CHP) Financing Primer. p. iii. https://energy.gov/sites/prod/files/2017/06/f35/CHP%20Financing%20Primer%206-16-17%20Final.pdf.
[80] Ibid., p. 10.
[81] Ibid., p. 10.
[82] ICF. Prepared for the U.S. DOE, Advanced Manufacturing Office. 2017. Combined Heat and Power (CHP) Financing Primer. https://energy.gov/sites/prod/files/2017/06/f35/CHP%20Financing%20Primer%206-16-17%20Final.pdf.

(iii) other substantial disruptions to the energy market occur, or (iv) certain cost-related assumptions are significantly different."[83]

In addition to natural gas prices, a potential CHP system owner must have a thorough understanding of projected local electricity prices. Any firm must compare the cost of installing and operating a CHP system to the cost of conducting business as usual, and the cost of purchasing power must be higher than the levelized costs of self-generation. Because the price of purchased power is utility-specific, the economic feasibility of CHP varies geographically; higher costs of purchased power make CHP more attractive than in places where electricity is comparatively cheap.[84] According to EIA, Michigan has the 12th highest electricity prices in the U.S.,[85] making it a relatively good candidate for locating CHP based on the cost of power alone.

6.2 Michigan Economic Barriers

Capital Cost, Financing, and Payback Period

Analysis of survey and interview responses showed that the most commonly-cited barrier was "Cost/payback period/value" of CHP. Of the 83 survey respondents that cited potential barriers to CHP in Michigan, 55 (66%) of these respondents identified "Cost/payback period/value" as a major barrier, and 23 (42%) of these respondents cited it as the largest barrier to CHP implementation. 32 respondents (58%) cited it as the first or second largest barrier overall, and 40 out of 55 (73%) put it in the top three.

In one interview response, an attorney with experience representing clients interested in CHP explained: "Companies are reluctant to make a 20-year bet that they will be in business. The horizon where these projects make economic sense, because of the uncertainty in the world economically, can be the 'Achilles heel' of CHP. Just staying in business long enough to really see the economic benefits." Ensuring a reasonable payback period is crucial to the success of CHP development.[86]

According to National Regulatory Research Institute (NRRI), "The simple payback of a CHP system is the number of years that it will take for the annual operating cost savings from CHP to pay back the upfront costs of installing the CHP system… Economic feasibility has no single definition. Some analysts refer to it in terms of the payback period, with one definition specifying the payback period of five years or less."[87] End-user expectations for investment payback are generally less than 10 years in the public and

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[83] Fujihara, R. U.S. EIA. Office of Technical and Regulatory Analysis. 2017. *Wholesale Natural Gas Market Assessment: Wholesale Natural Gas Futures Prices as of October 5, 2017*. https://www.dcpsc.org/PSCDC/media/PDFFiles/NaturalGas/NGAssessmenandinfo_current.pdf.

[84] Chittum, A., and Kaufman, N. American Council for an Energy-Efficient Economy. 2011. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment*. p. 8. http://aceee.org/sites/default/files/publications/researchreports/ie111.pdf.

[85] U.S. EIA. 2017. *Michigan State Profile and Energy Estimates.* https://www.eia.gov/state/?sid=MI.

[86] ICF International. Prepared for the American Gas Association (AGA). 2013. *The Opportunity for CHP in the United States*. p. ES-3. https://www.aga.org/research/reports/the-opportunity-for-chp-in-the-us---may-2013/.

[87] Costello, K. National Regulatory Research Institute (NRRI). 2014. *Gas-Fired Combined Heat and Power Going Forward: What Can State Utility Commissions Do?*. pp. vii, 18. http://energy.ky.gov/Programs/Documents/NRRI%20Report-What%20Can%20Commissions%20Do.pdf

institutional sectors, and less than 5 years in the private sector. Some end-users expect even shorter payback periods – 1 to 2 years – but this will never be realistic for CHP systems, which like utility power generation should be considered as a long-term investment. Ultimately when a CHP system's payback period or return on investment does not meet the end-users' internal requirements, the decision will often be to not implement the CHP project.[88]

Related to the payback period is a lack of low-cost financing to pay for the upfront cost of CHP equipment. As previously stated, the installed cost of CHP is between $700 and $3,000 per kW.[89] This means a relatively small CHP system of 2 MW in capacity could cost up to $6 million to install. Financing is critical for a project to move forward. Of those survey respondents citing potential barriers to CHP, a "lack [of] access to low cost capital" was listed by roughly a third of respondents as a major barrier to the development of CHP, with 20% of these individuals ranking it as the number one barrier to CHP in Michigan. In order to meet minimum equity investor expectations and investment requirements, projects must typically be financed such that the equity investor can achieve a leveraged, after-tax, payback on investment in less than 5 years, or the project will not move forward. To achieve this leveraged return on equity, a debt financing term of at least 7 to 10 years (best case), and often up to 15 or 20 years, typically must be negotiated with a long-term lender.[90]

Uncertain Energy Costs

"Spark spread" – the difference between the price of electricity and the cost of fuel to produce electricity – is widely understood to be one of the most critical factors in the economic viability of CHP projects. The price of natural gas can have a significant effect on spark spread. 31 survey respondents identified "natural gas price risk" as a top five barrier to the development of CHP in Michigan, with 17 respondents (55%) considering it to be either the fourth or fifth largest barrier, and 26 (84%) putting it in the bottom three of the five largest barriers.

Michigan residents and businesses enjoy natural gas choice, meaning they can transparently view competing offers from natural gas suppliers and "shop around." The Department of Licensing and Regulatory Affairs (LARA) provides a helpful website for consumers to easily "shop for gas for your home or business from a diverse market of natural gas suppliers."[91] This system provides flexibility for consumers to "choose an alternative gas supplier (AGS or supplier) that will invest in renewable products on their behalf while others are looking for other pricing options or value added services."[92] Despite the transparency and flexibility of being able to choose a natural gas supplier, Michigan businesses interested in exploring CHP will still be subject to risk from variations in natural gas prices overall. According to EIA, Michigan is currently ranked 40th in the U.S. for its natural gas prices, putting it on the relatively low side in the short term.[93]

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[88] ICF International. Prepared for the American Gas Association (AGA). 2013. *The Opportunity for CHP in the United States*. p. ES-3. https://www.aga.org/research/reports/the-opportunity-for-chp-in-the-us---may-2013/.

[89] Chittum, A., and Kaufman, N. American Council for an Energy-Efficient Economy. 2011. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment*. p. 6. http://aceee.org/sites/default/files/publications/researchreports/ie111.pdf.

[90] Feldman, D. National Renewable Energy Laboratory. 2016. *Put a Fence around It: Project Finance Explained*. https://financere.nrel.gov/finance/content/put-fence-around-it-project-finance-explained.

[91] State of Michigan. 2018. *Compare MI Gas*. https://w2.lara.state.mi.us/gaschoice/.

[92] Ibid.

[93] U.S. EIA. 2017. *Rankings: Natural Gas Residential Prices.* https://www.eia.gov/state/rankings/#/series/28.

According to the DOE's Midwest CHP TAP, "The risk of CHP projects can be reduced by utilizing available commodity price risk management tools."[94] Concerning uncertain natural gas prices, types of hedging include physical hedging and financial hedging. Physical hedging includes storing and withdrawing excess natural gas. Financial hedging includes:[95]

- Index Purchasing, in which natural gas is purchased month-by-month at a 'first of the month' index price;
- Fixed Price Purchase, in which all or a portion of natural gas needs are purchased at one time, with the vendor providing an average fixed price for the term of the contract;
- Cap, in which a fixed price for gas is set, but 'put' contracts are purchased to guarantee that when future market prices for gas settle below the fixed cost, the monthly price is adjusted downward;
- Collar, in which a series of 'put' and 'call' contracts are purchased to guarantee that monthly prices for natural gas will be contained within a defined price range regardless of market conditions;
- Hybrid Approach, in which a percentage of each month's natural gas needs are purchased at a fixed price, and the remainder purchased at an index price; and
- Winter Strip, in which November through March gas is purchased at a fixed price and all other months are purchased at an Index price.

Overall, long-term energy contracts allocate price risk between parties: the buyer faces price uncertainty in the upward direction, and the seller faces price risk resulting from the risk of decline.[96] As a result, longer-term energy contracts "can serve as a 'hedge' on price movements for consumers. Like other forms of hedges and price management tools, there are implications for parties entering into such contracts in terms of future obligations and liabilities."[97]

[94] University of Illinois at Chicago. Energy Resources Center. 2004. *CHP – Managing Commodity Price Risk: An Introduction to Combined Heat and Power*. http://www.midwestchptap.org/Archive/presentations/050518-IL/050518_Pruitt.pdf.
[95] Ibid.
[96] Ibid.
[97] Ibid.

6.3 Overview of Regulatory Barriers

Regulatory barriers to CHP deal with the legal framework around utilities and self-generation which can sometimes put up unintended roadblocks to CHP development. Often, the impact of the regulatory barriers to CHP manifest as negative impacts on project economics, similarly to the economic barriers discussed above. Because a variety of economic and regulatory barriers often intermingle in affecting the prospects of a potential CHP project, there is a critical need to use a holistic approach to achieving optimized CHP adoption. The following section builds upon the fundamental understanding of CHP project economics discussed above with a discussion of regulatory barriers to the optimal deployment of CHP.

Standby Rates

Standby rates are a type of electric tariff paid to utilities by customers with on-site distributed energy resources, such as CHP systems. Standby charges are intended to help the utility recover costs related to reserving such service and providing backup electricity during scheduled and unscheduled outages of the customer's CHP system. Although well-designed standby rates are clear and transparent to the customer, and based on cost of service principles, poorly designed standby rates are often based on erroneous assumptions about CHP reliability, and are frequently unclear and difficult to navigate. (As examples of existing standby tariffs, copies of Consumers Energy Rate GSG-2 and DTE Energy's Rider 3 are attached as **Attachment L.**)

As a result, standby rates can be a significant barrier to the development of otherwise economically viable CHP projects. When rates are too high, inflexible, unpredictable, or simply too difficult for customers to navigate, the economics of a CHP system will fail to provide the needed return on investment, and a potential project will not pencil out.

PURPA Buyback Rates

Owners of CHP projects intending to sell excess generation back to the grid rely on the Public Utility Regulatory Policies Act of 1978 (PURPA). This law, originally designed to encourage energy waste reduction and promote the use of distributed energy resources, such as CHP, requires utilities to purchase or "buy back" power at a rate equal to the utility's "avoided cost." The Federal Energy Regulatory Commission (FERC) has oversight over PURPA, and state utility commissions are in charge of regulating the particular avoided-cost calculation methodology applied by rate-regulated utilities in their state. If avoided cost or buyback rates are set too low, this can have a negative impact on the economics of a proposed CHP installation.

Failure to Recognize Value of Distributed Energy Resources

Until recently, whether in formulating standby rates, PURPA avoided cost/buyback rates, or utility distribution system plans, electric utilities have rarely accounted for the benefits of distributed generation. Many states, including Michigan, have similarly failed to embrace the full value of CHP as a DER in their energy policy development. This means that grid benefits, such as increased reliability and avoided built central-station generating capacity, are not compensated, even with regard to CHP, which can help to stabilize grids while decreasing transmission losses in times of increased electricity demand.[98] Resilience, in particular, is a major potential value of CHP that is often overlooked. When properly configured to operate independently from the grid, CHP systems can provide critical power reliability for businesses and critical infrastructure facilities while providing electric and thermal energy to the sites on a continuous basis, resulting in daily operating cost savings. There are a number of ways in which CHP systems can be configured to meet the specific reliability needs and risk profiles of various customers, and to offset the capital cost investment for traditional backup power measures such as diesel generators. By supporting critical infrastructure in Michigan, CHP can save lives. From reliability to avoided built central-station generating capacity, overlooking CHP's full value represents a missed opportunity, and can be a significant barrier to CHP development.

RE/EWR Standards and Integrated Resource Planning (IRP)

A lack of emphasis on CHP in state portfolio standards relating to renewable energy and EWR can be a major barrier to the deployment of CHP. While some states explicitly include CHP in the language of their RPS, other states' standards bundle CHP in with other energy efficiency measures, making other energy efficiency investments more cost effective in the short term.[99] Other states (including Michigan, discussed below) have tended to overlook CHP almost entirely when it comes to these standards, thus missing out on CHP's full potential for energy waste reduction.

Many states, including Michigan, require utilities to provide regular IRPs. The Regulatory Assistance Project (RAP) defines an IRP as "a utility plan for meeting forecasted annual peak and energy demand, plus some established reserve margin, through a combination of supply-side and demand-side resources over a specified future period."[100] A lack of emphasis on the consideration of CHP as a resource in a utility IRP could have a chilling effect on how CHP is viewed long-term. Alternatively, if a utility is required to consider CHP as a potential resource, CHP has a chance to compete on the merits. According to the National Association of State Energy Officials (NASEO), "By altering or broadening the scope of utility resource planning, state policymakers and regulators place CHP on a more equal playing field with traditional energy resources."[101]

Beyond the need to include CHP within an RPS or EWR standard, or within a utility IRP's scope, it is also important to view CHP as both a supply-side and demand-side resource. Current utility analyses of CHP often examine the costs and benefits of CHP from too narrow a perspective, treating CHP as either a supply-side option or a demand-side option. This ignores a major benefit of CHP – that it can supply cost-effective electricity and save energy. By analyzing CHP merely as an efficiency measure, it is not possible to account for its full benefits, which could include reductions in grid congestion, reduced transmission and distribution costs, and other supply benefits. In contrast, supply-side modeling of CHP

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[98] Ibid.

[99] Chittum, A., and Kaufman, N. American Council for an Energy-Efficient Economy. 2011. *Challenges Facing Combined Heat and Power Today: A State-by-State Assessment*. p. 15. http://aceee.org/sites/default/files/publications/researchreports/ie111.pdf.

[100] Wilson, R. and Biewald, B. Regulatory Assistance Project (RAP). 2013. *Best Practices in Electric Utility Integrated Resource Planning: Examples of State Regulations and Recent Utility Plans*. p. 2. www.raponline.org/document/download/id/6608/.

[101] Friedman, J. and Otto, G. National Association of State Energy Officials (NASEO). 2013. *Combined Heat and Power: A Resource Guide for State Energy Officials*. p. 10. https://www.naseo.org/data/sites/1/documents/publications/CHP-for-State-Energy-Officials.pdf.

often only considers the capital cost of the CHP generation and does not take into account the benefits of the thermal energy. If a utility simultaneously considers CHP as a supply option and a demand/energy waste reduction option, it is much more likely to encourage development of the best CHP projects – projects that capture the full benefits for the utility, the site/host, and all utility ratepayers.

Interconnection Standards

Potential CHP system owners encounter the need to interconnect to the electric grid when they: 1) sign up for standby service from the utility to provide power in case of a CHP system outage; 2) desire to sell excess generation back to the utility; and/or 3) serve a utility customer behind the meter. The process of interconnecting a CHP system to the grid can be onerous and complex, posing a potential barrier to CHP deployment. According to ACEEE, "The lack of a consistent interconnection standard establishing parameters and procedures for connecting to the grid drives up both monetary and transaction costs for technology manufacturers and owners, discouraging CHP deployment."[102] Without standardized and streamlined interconnection processes and fees, potential CHP system owners face a confusing, costly task, which could stand in the way of a potentially beneficial CHP project.

6.4 Michigan Regulatory Barriers

Standby Rates

Among survey respondents, the third most commonly-cited barrier was "high cost standby rates," with 39 respondents naming this as a barrier to CHP development in Michigan. 20 of the 39 respondents (51%) named it as either the first or second largest barrier. The vast majority of the respondents (82%) identified standby rates in the top three. As described previously, in the context of growing stakeholder interest in distributed generation, and concern over standby rates as a potential barrier, the MPSC staff held workgroup discussions aimed at examining standby rates in Michigan.[103] As part of the working group process, Michigan utility standby rates for CHP sites were analyzed and compared to the standby rates of other utilities in the Midwest. The analysis found that standby charges experienced in Michigan are relatively high, potentially posing a barrier to CHP deployment. Further, the analysis found that standby tariffs in Michigan can be confusing and difficult for customers to navigate. While no formal requirements came out of the working group process, the MPSC staff issued several recommendations related to standby rate best practices.[104]

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[102] American Council for an Energy-Efficient Economy (ACEEE). *Interconnection Standards*. https://aceee.org/topics/interconnection-standards.

[103] Michigan Public Service Commission Staff. 2017. *Standby Rate Working Group Supplemental Report June 2017*. http://www.michigan.gov/mpsc/0,4639,7-159-16377_47107-376753--,00.html.

[104] 5 Lakes Energy. Prepared for the Michigan Public Service Commission. 2017. *"Apples to Apples" Standby Rate Analyses*.
http://www.michigan.gov/documents/mpsc/Copy_of_UPPCO_UMERC_jws_rev_03172017_rev2_568778_7.xlsx;
http://www.michigan.gov/documents/mpsc/UPPCO_UMERC_5Lakes_Analyses_03202017_568776_7.docx;
http://www.michigan.gov/documents/mpsc/mca_5_lakes_scenarios_545589_7.xlsx;
http://www.michigan.gov/documents/mpsc/5LE_Standby_Rate_Scenarios_10202016_538737_7.pdf

Coming out of the MPSC staff standby rate working group, engagement in the overall discussion of standby rates continued, and some interested parties went on to pursue formal intervention in utility general rate cases as a means of continuing to raise concerns about the effect of standby rates on CHP installations. Outside of formal intervention, businesses and associations have expressed their support for standby rate reform through comments and sign-on letters submitted to the MPSC.[105, 106]

PURPA Avoided Cost/Buyback Rates

Among survey respondents, the fourth most commonly-cited barrier was "lack of an adequate mechanism to sell excess generation to the grid." As discussed above, implementation of PURPA in Michigan is the legal mechanism by which utilities are required to buy back power generated by qualifying facilities. 38 respondents identified this as a top five barrier, with 19 of the 38 (50%) respondents naming this barrier as the first or second most significant barrier to CHP development in Michigan.

Similarly to standby rates, PURPA avoided cost/buyback rates have recently been a topic of interest at the MPSC. In October 2015, the Commission directed staff to form a technical advisory committee for the purpose of reviewing and considering its implementation of PURPA. "PURPA Technical Advisory Committee (PURPA TAC) participants provided a wide range of backgrounds and perspectives. Participation was welcomed from all who volunteered and included utilities, environmental groups, current and potential future qualifying facilities (QF), industry PURPA experts and MPSC Staff."[107] The PURPA TAC held a series of meetings and a report was issued by MPSC staff on April 8, 2016.[108] Afterwards, the Commission directed utilities to make avoided cost calculation filings in June 2016. While the results of some of these cases are still pending, the concern over an inadequate buyback rate remains, and continues to be a potential barrier to the development of CHP in Michigan. The MPSC has issued one order with new PURPA rates for Consumers Energy.[109]

In addition to its jurisdiction over the avoided cost methodology used in setting buyback rates, the Commission potentially also affects CHP deployment through approving other terms of power purchase agreements under PURPA, including the duration of and project size limitations included in utilities' proposed standard offer contracts. As discussed above, longer-term PPAs are more helpful to CHP

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[105] Michigan Public Service Commission Staff. 2017. Public comments. http://www.michigan.gov/mpsc/0,4639,7-159-16377_47107-376753--,00.html.
[106] Alliance for Industrial Efficiency. 2017. *Signed Coalition Letters.* https://alliance4industrialefficiency.org/resources/type/signed-coalition-letters/.
[107] Michigan Public Service Commission staff. PURPA Technical Advisory Committee. 2016. *Report on the Continued Appropriateness of the Commission's Implementation of PURPA.* p. 2. https://www.eenews.net/assets/2017/06/12/document_ew_05.pdf.
[108] Ibid.
[109] Michigan Public Service Commission. November 21, 2017. *Order in Case No. U-18090.* https://mi-psc.force.com/s/filing/a00t0000005ppUqAAI/u180900273.

projects seeking financing. Allowing larger-sized projects to benefit from the ease of the standard offer contract can also reduce transaction costs related to proposed CHP projects.[110, 111]

Lack of Government and Utility Support for CHP

Survey respondents perceived a lack of support for CHP in Michigan in the form of government or utility incentives. The second most commonly-cited barrier was a "lack of government grants or incentives" for CHP. 22 respondents (51%) ranked this barrier in their top two, and 27 respondents (63%) placed it among the top three. Similarly, the fifth most commonly-cited barrier was "lack of utility incentives." 37 respondents named this in their top five, with 10 of 37 (27%) naming it in the top two most significant barriers to the deployment of CHP. The following discussion of EWR programs, integrated resource planning, and interconnection standards are all captured under the broad umbrella of government and utility incentives for CHP.

Energy Waste Reduction

Among the most important and impactful energy incentive programs in Michigan are the EWR programs run through the utilities.[112] PA 342 of 2016 requires utilities to achieve a specified amount of EWR savings. Electric and gas savings targets are based on prior years sales and are set at 1% per year for electric and 0.75% per year for gas utilities.[113] In order to achieve these savings, utilities conduct outreach and provide incentives to their customers to install energy waste reduction measures. The MPSC may authorize rate-regulated utilities to receive a financial incentive when they successfully meet the required savings reductions.

The law requires a "cost and benefit analysis and other justification for specific programs and measures included in a proposed energy waste reduction plan."[114] Michigan utilities rely on the utility system resource cost test, otherwise known as the Program Administrator Cost Test (PACT) approach, when assessing the cost/benefit ratio of each EWR measure. This approach compares the cost of program administration including incentive costs to supply-side resources. Unfortunately, the supply-side resources in question only refer to the avoided transmission, distribution and fuel costs, and not to the long-term avoided capacity costs as would be modelled under an IRP process. Further, the PACT method does not incorporate additional resource savings, such as natural gas savings, or any societal non-monetized benefits such as cleaner water or air.

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[110] Feldman, D. National Renewable Energy Laboratory. 2016. *Put a Fence around It: Project Finance Explained*. https://financere.nrel.gov/finance/content/put-fence-around-it-project-finance-explained.

[111] Parsons, J. E. Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research, 2008. *The Value of Long Term Contracts for Investments in New Generation*, www.mit.edu/~jparsons/Presentations/Contract%20Value%20w%20Berger.pdf.

[112] Michigan's energy waste reduction standards in PA 342 maintain the energy efficiency goals established with the energy optimization standards developed in PA 295.

[113] Michigan Public Service Commission. 2018. *Energy Waste Reduction.* http://www.michigan.gov/mpsc/0,4639,7-159-52495---,00.html.

[114] Michigan Legislature. 2016. PA 342, Sec.201. http://www.legislature.mi.gov/(S(orha3tn1ppom5z5a11udqezd))/mileg.aspx?page=getObject&objectName=2015-SB-0438.

While CHP provides both electric and thermal energy at efficiency levels far above conventional methods, it is not currently included in the EWR plans of Michigan utilities, in part because it does not survive the PACT cost-benefit analysis. Part of what drives this barrier is the complex nature of CHP as a technology application. Unlike more traditional efficiency measures such as lighting improvements, CHP projects often result in greater energy usage on-site. In order to include CHP as an eligible resource in EWR plans, the proper methodology with which to calculate CHP energy savings must be assigned. Because CHP projects provide both thermal and electric supply at increased efficiencies, it is necessary to compare the fuel required under separate generation in order to assess total energy savings. Michigan utilities' reliance on the PACT method as required by law, and resulting failure to properly value the energy savings from CHP, pose an additional barrier to CHP development.

In addition to the reliance on the PACT method, concerns about fuel-switching and competition for customers among utilities pose an additional obstacle to fully encouraging CHP in EWR programs. These concerns will need to be addressed in order to obtain the full benefits of CHP as an energy waste reduction resource.

Integrated Resource Planning

Because CHP functions as both a supply and demand side technology, it is often overlooked in traditional load forecasts. Through an IRP, a utility is required to analyze the least-cost resource mix from both supply and demand-side options. Since EWR measures and CHP applications are often lower-cost resources compared to constructing new generation facilities, proper utilization of IRP can result in the incorporation of these measures as utility system resources, which may reduce the need for additional supply resources. For example, under the STEER model, which was designed to function similarly to IRP models, ideal levels of CHP in Michigan, as a least-cost resource option, range between 722 MW to 1,014 MW of new CHP built.

PA 341 of 2016 requires Michigan's electric utilities to file periodic IRPs with the Commission. While PA 341 requires a utility IRP to include the projected energy and capacity purchased or produced by the utility from a cogeneration resource, there is no requirement that the utility consider customer-sited CHP on the supply-side, or EWR from CHP on the demand-side. In order to realize the full benefit of CHP, IRP analyses should be updated to incorporate CHP as both a supply-side and demand-side measure. Formally requiring utilities to assess CHP on both the supply and demand-side in an IRP would help ensure that these complicated projects are allotted equivalent analysis as other resources. Further, including customer-sited CHP projects with other supply-side resources would signal an acceptance that these projects exist in the grey area between demand reduction and power generation.

Distributed Generation Program

Historically, CHP has not been included in Michigan's net metering program law. Additionally, the full value of CHP as a distributed energy resource has not been fully captured in utility rates or other energy policies and programs. This overarching barrier continues in the revised 2016 PA 342 net metering/distributed generation program currently in the implementation process. Pursuant to 2016 PA 342, the MPSC is in the process of establishing a new distributed generation program to reflect "equitable cost of service for utility revenue requirements for customers who participate in a net metering program or distributed generation program under the clean and renewable energy and energy waste reduction act."[115] Under the law, the distributed generation program is limited to customers who install certain on-site grid-connected, renewable generation. The size limitations of the program likely prevent participation from even renewably-fueled CHP systems (qualifying generation projects must be no larger than 150 kW).[116]

Interconnection Standards

In 2005, the Federal Energy Regulatory Commission (FERC) issued Order No. 2006 requiring all public utilities to adopt standard rules for interconnecting new sources of electricity less than or equal to 20 MW in size. The goal of this order was to decrease interconnection time, increase energy supply, lower wholesale electricity prices, and facilitate development of renewable resources. FERC Order No. 2006 established a "fast track" process based on technical screening criteria for generators under 2 MW.

In response FERC Order No. 2006, the MPSC began a process to revise the rules governing interconnection standards for small electrical generators (under 150 kW). The revised rules were approved by the Commission in March 2009. According to the MPSC, "Technical requirements (data, equipment, relaying, telemetry, metering) are defined according to type of generation, location of the interconnection, and mode of operation (Flow-back or Non-Flow-back). The process is designed to provide an expeditious interconnection to the Utility electric system that is both safe and reliable."[117] The MPSC interconnection standards are general interconnection procedures approved by the MPSC and are intended to be used for reference only. Each utility will has its own set of documents updated with the utility-specific interconnection requirements and all system owners, including CHP system owners excluded by the MPSC general standards due to system size, must work with each utility individually to navigate the complex interconnection process.

In 2013 and 2014, FERC issued Order Nos. 792 and 792-A, which expanded and revised the technical screening process adopted in Order No. 2006, and changed the fast track process to include differentiation by voltage and interconnection location and increased the maximum project size for the fast track process to 4 MW, which can now include many small to medium CHP projects. This technical screening process creates an efficient, expedited, and yet technically sound method to process applications without subjecting projects that do not significantly impact the grid to unnecessary review. Especially with increased demand for interconnection, it is critical to institute policies that avoid costly, time consuming reviews for projects that do not require such reviews. These Orders also established a process to allow developers/customers to request pre-application reports, enabling potential interconnection customers to identify issues that may delay or halt the interconnection process prior to investing significant time and capitol. Finally, Order Nos. 792 and 792-A created the opportunity for a "supplemental study" prior to conducting a full study if a project fails the initial fast track technical screens.

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[115] Michigan Public Service Commission. 2018. *Distributed Generation Program.* http://www.michigan.gov/mpsc/0,4639,7-159-80741_80743-406256--,00.html.
[116] Methane digester generation projects as large as 550 kW may also participate.
[117] Michigan Public Service Commission. 2018. *What is Interconnection?* http://www.michigan.gov/mpsc/0,4639,7-159-16393_48212_58223---,00.html.

The MPSC has not revisited these interconnection standards since FERC issued Order Nos. 792 and 792-A. Michigan's new energy law gives the MPSC authority to revisit and update the interconnection technical standards. As the MPSC considers revisions to the rules governing interconnection standards for electrical generators, it will be important to acknowledge the need for streamlining and expediting CHP system interconnection, where possible.

6.5 Lack of Expertise and Information

CHP is a well-established technology application and itis not new – it has been around for over a century. According to DOE, "CHP has been used in the United States for more than 100 years since Thomas Edison used it to power the world's first commercial power plant. Decentralized CHP systems located at industrial and municipal sites became the foundation of the U.S.'s early electric power industry."[118] Despite this long history, many businesses lack familiarity with CHP. This lack of awareness and need for further CHP education can be a barrier to optimal levels of CHP installations.

One reason for this lack of familiarity is that, according to a 2012 report from DOE and EPA, "CHP is not regarded as part of most end-users' core business focus and, as such, is sometimes subject to higher investment hurdle rates than competing internal options. In addition, many potential industrial project hosts are not fully aware of the full array of benefits provided by CHP, or are overly sensitive to perceived CHP investment risks."[119] As business leaders default to more familiar options, they miss out on the potential benefits of CHP.

For business leaders who are familiar with CHP, some may have longstanding negative expectations regarding the ease of CHP operations. This was confirmed directly via interviews with potential end-users, as many candidates for CHP either have direct negative past experience with CHP, or more commonly, have heard stories about the negative experiences of others with CHP systems. In many cases, these negative stories or rumors lead to CHP never being considered as a legitimate option.

Michigan businesses interested in CHP have access to the DOE Midwest CHP TAP, managed by the Energy Resources Center and based in Chicago, Illinois. The Midwest CHP TAP is one of seven regional CHP TAPs formed in 2003 "to promote greater adoption of clean and efficient energy generation and use through recycled energy. Recycled energy includes CHP, district energy, and WHP."[120] The Midwest CHP TAP educates prospective adopters of CHP and fosters CHP technologies as viable technical and economic options, providing businesses with free or reduced-cost CHP feasibility studies, among other resources. A number of private firms provide similar no-cost or low-cost services.

Despite Michigan's strong relationship with the Midwest CHP TAP, there is a lack of awareness and familiarity with CHP among end-users that is preventing businesses from reaching out for information. This lack of awareness of the potential benefits of CHP is preventing optimal levels of CHP development. In interviews with stakeholders, the need for increased education of end-users was mentioned as a barrier to CHP development in the state. According to a representative from an engineering firm

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[118] Department of Energy. 2013. *Top 10 Things You Didn't Know About Combined Heat and Power.* https://www.energy.gov/articles/top-10-things-you-didn-t-know-about-combined-heat-and-power.

[119] U.S. DOE and U.S. EPA. 2012. *Combined Heat and Power: A Clean Energy Solution.* p. 18. https://energy.gov/eere/amo/downloads/chp-clean-energy-solution-august-2012.

[120] U.S. DOE Midwest CHP Technical Assistance Partnerships. http://www.midwestchptap.org/about/.

specializing in CHP systems, "Michigan's CHP market is at the point of asking: how does CHP benefit my facility? How is it done? Michigan's potential CHP users need education on the technology and financial resources." A Michigan-based component distributor agrees. "The biggest challenge is getting people to understand CHP. Companies don't realize these opportunities are out there." Successful CHP projects in Michigan typically have a strong champion within the end-user organization providing leadership to build consensus for the project across engineering, sustainability, energy, and finance disciplines.

7 Roadmap for CHP Deployment

There is strong interest and capability on the part of participants in the Michigan CHP supply and value chain for Michigan to move closer to optimal levels of CHP deployment. Currently, Michigan is home to over 3,300 MW of installed CHP capacity.[121] STEER model results indicate that ideal levels of CHP in Michigan, as a least-cost resource option, range between 722 MW to 1,014 MW built, in addition to the 3,300 MW in CHP capacity already installed. In order to pursue a greater role for CHP in Michigan's future energy mix, the following roadmap is offered in an effort to outline concrete policy actions for consideration. The following recommendations reflect lessons learned from stakeholder surveys, interviews, Midwest CHP TAP experience and expertise, and best practices from other states. A case study on the impact of incentives on CHP economics is provided in Section 9.1.

7.1 Reduce the Payback Period

In light of the importance of the payback period to the development of a CHP project, efforts to reduce the payback period of CHP by either defraying some of the initial upfront cost through a grant or offering a production incentive would be beneficial in addressing this barrier. For example, AEP Ohio's Combined Heat and Power and Waste Energy Recovery Program (CHP/WER) "supports the installation of high efficiency, sustainable and cost effective projects in AEP Ohio's service territory as allowed by SB 315."[122] CHP projects are eligible for the incentive if they meet minimum efficiency requirements of 60% overall efficiency and 20% useful thermal energy. CHP incentive payments are based on production of kWh recovered by the project, and incentive rates for projects approved in 2017 are $0.035 per kWh recovered for systems >1000 kW. There is a yearly cap of $500,000.[123] This incentive is a critical aspect of AEP Ohio's EWR program. The company estimates that it will generate 600,000 MWh in incremental annual energy savings through its CHP/WER Program between 2015 and 2019.[124]

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[121] U.S. DOE. 2016. *Combined Heat and Power Installation Database*. https://doe.icfwebservices.com/chpdb/.
[122] AEP Ohio. *Combined Heat and Power and Waste Energy Recovery Program.* https://www.aepohio.com/save/business/programs/CombinedHeatandPower.aspx.
[123] Ibid.
[124] AEP Ohio. 2014. *Energy Efficiency/ Peak Demand Reduction Action Plan*. p. 118. https://aceee.org/files/pdf/aep-ohio-2015-2017-ee-pdr-plan.pdf.

7.2 Promote PACE and Other Financing Tools

For those citing a lack of low-cost financing as a barrier to CHP development in Michigan, PACE financing could be a solution. PACE financing is a long term financing tool for commercial property owners to pay for energy efficiency, water efficiency, and renewable energy upgrades, including CHP systems. According to Kyle Peczynski of Petros PACE Finance, "PACE financing eliminates the high upfront cost and spreads the repayment over a long enough term that the annual savings generated from the CHP project exceed the PACE payments starting in the very first year. In other words, PACE is a no-money-down, cash-flow-positive way to fund large CHP projects." Michigan's "Property Assessed Clean Energy" Act, or PA 270 of 2010, authorizes local governments to adopt PACE financing programs. This means PACE must first be adopted at the local level in order for PACE to be active in a particular county or city. PACE financing is currently available in 23 Michigan counties and 11 of the larger cities in non-participating counties. The adoption of local PACE authorization ordinances should be encouraged, and Michigan residents and businesses should be educated about this innovative financing tool.

On-Bill Financing (OBF) could also be helpful in facilitating CHP development. In OBF, the customer's costs of energy waste reduction retrofits or equipment are amortized and added to savings from the measures on the customer's utility bill. In Michigan's new energy legislation, PA 342, Part 7, Sec. 201-209 describes a framework for creating a residential OBF program. The new law invites utilities to file a residential OBF plan proposal for Commission approval. On April 24, 2017, the MPSC and MAE initiated a stakeholder meeting for the purposes of receiving feedback for OBF program goals. Currently, the OBF program is limited to residential energy installations, which would exclude industrial and commercial CHP installations. However, in the future, OBF programs could be revised to allow for commercial and industrial applications such as CHP projects.

7.3 Reform Standby Rates

Standby rates have a significant impact on whether a CHP project is developed. Both in terms of how difficult they are to interpret and navigate, and in terms of the negative impact on a project's bottom line, the need for a revised approach to standby rates in Michigan stands as a prime example of a barrier to CHP that can be readily reduced or eliminated. The MPSC Staff Standby Rate Working Group began a constructive conversation with stakeholders, with several important recommendations issued in the June 2017 Supplemental Report.[125] These include recommendations dealing with transparency and clarity of the published standby tariffs, the desire to encourage efficient use of the grid by incenting scheduled maintenance of CHP systems, and the overarching principle that standby rates should be based on cost of service principles.[126] A case study on the impact of standby rate mitigation is presented in Section 9.2.

The MPSC should continue to look to best practices in standby rate design as Michigan utilities further develop their approach to working with customers with CHP systems.

The RAP outlines best practices for standby rates,[127] including:

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[125] Michigan Public Service Commission Staff. 2017. *Standby Rate Working Group Supplemental Report June 2017*. http://www.michigan.gov/mpsc/0,4639,7-159-16377_47107-376753--,00.html.
[126] Ibid.
[127] Selecky, J., Iverson, K., and Al-Jabir, A. Regulatory Assistance Project (RAP). 2014. *Standby Rates for Combined Heat and Power Systems*. p. 5. http://www.raponline.org/knowledge-center/standby-rates-for-combined-heat-and-power-systems/?sf_data=results&_sf_s=standby+rates+for+combined+heat+and+power+systems.

- Reservation fees should be based on the utility's cost and the forced outage rate of the CHP system;
- Standby rate design should not assume that all forced outages of CHP systems occur simultaneously, or at the time of the utility system peak;
- Demand charges should be designed to recognize the scheduling of maintenance service during periods when the utility generation requirements are low.

With regard to clarity and transparency of standby rates, utilities should provide educational materials to help customers navigate complex standby rate structures. For example, AEP Ohio helpfully provides bill calculation spreadsheets on its website.[128]

Ameren Missouri, another example, provides a standby rate billing model to any inquiring customer. The purpose of the model is to simulate the annual bill for a customer on the new standby rate given standby contract capacity and generation output and to calculate the standby avoided rate. The model includes a customer's annual 15-minute interval consumption data. The customer, or a third party entity, would only need to enter anticipated generation, supplemental capacity, and standby capacity. Once entered, the model calculates the annual bill and the avoided rate percentage create by the standby tariff. This model provides important information on the financial impact that Ameren's standby rate has on CHP customers. Further, this model allows customers to assess the financial effect of different operating schedules, standby contract capacities, and outages durations.[129]

The transparency provided by AEP Ohio and Ameren Missouri should be emulated by Michigan's utilities, including Consumers Energy and DTE Energy.

7.4 Improve Distributed Generation Program

PA 341 of 2016 requires the MPSC to determine "an appropriate tariff reflecting equitable cost of service for utility revenue requirements for customers who participate in a net metering program or distributed generation program." While Michigan's current distributed generation program is targeted at small installations and does not include CHP, future consideration of the cost and benefits of distributed energy resources should include CHP and attempt to capture its full value, including the value of resilience. This analysis would build on the findings regarding the distributed generation program.

According to the National Association of Regulatory Utility Commissioners (NARUC), "...a growing number of parties involved in the [distributed energy resource] debate acknowledge DER can provide material benefits beyond just those enjoyed by the customer behind whose meter the DER is sited... Some jurisdictions, utilities, researchers, and advocates have also concluded or posited that responsible encouragement of other types of DER adoption leads to positive cost benefit results. In this respect, when using the traditional model for rate design, which does not compensate (or charge) particular customers for producing particular benefits (or costs) for the grid... a regulator would be missing that

[128] AEP Ohio. https://www.aepohio.com/account/bills/rates/AEPOhioRatesTariffsOH.aspx.

[129] Standby Service Rider - Ameren, March 8, 2017, *available at* https://www.ameren.com/-/media/rates/files/missouri/uecesheetno92riderssrstandbyservicerider.ashx.

portion of the cost benefit analysis for DER... At the very least, neglecting DER benefits could represent a lost opportunity to meet customer needs on a more cost-effective basis."[130]

For example, in New York, under the Reforming the Energy Vision (REV) process, New York Public Service Commission issued its Value of Distributed Energy Generation Phase One Decision[131] in March of 2017, and the Phase One Implementation Order was released September 14, 2017. The New York methodology moves beyond Net Energy Metering (NEM) "to a more accurate valuation and compensation of Distributed Energy Resources. [The new method's] factors include the price of the energy, the avoided carbon emissions, the cost savings to customers and utilities, and other savings from avoiding expensive capital investments."[132] New York is wrestling with the issue of how to consider non-metered technologies, such as CHP projects, in its valuation of distributed energy resources. "A number of existing tariffs and programs govern the treatment and compensation of projects that are not eligible for NEM. Inclusion of those projects in VDER tariffs will require a thorough analysis of how a transition from those tariffs and programs can best be achieved."[133]

Michigan will be required to undergo a similar transition and accompanying analysis of larger distributed energy resources, such as CHP, as it pursues its grid modernization objectives. As the full benefits of CHP are increasingly taken into account, this barrier to CHP development should be diminished.

7.5 Update Interconnection Standards

As previously discussed, the MPSC has not yet revisited the interconnection standards since FERC issued Orders 792 and 792-A. Michigan's new energy law (passed in December 2016, PA 341 and PA 342) gives the MPSC authority to revisit and update the interconnection technical standards. Other states in the Midwest have recently revised their interconnection standards for small electrical generations to follow best practices and reflect the proposed standards in FERC 792 and 792-A. Michigan should follow their lead and adopt the following revisions to the state's interconnection standards:

1. Require utilities to facilitate pre-application reports to enable early assessment of proposed interconnections, decrease utility interconnection queues, and streamline applications.
2. Develop and implement a technical screening process for projects based on size, voltage, and location to allow those projects with limited expected impact on the grid to avoid undergoing full distribution and engineering studies.
3. Develop and implement a supplemental review process for projects that do not meet the criteria for expedited approval based on the original technical screening process, but that are not likely to significantly impact the grid or require grid upgrades.

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[130] National Association of Regulatory Utility Commissioners (NARUC) Staff Subcommittee on Rate Design. 2016. *NARUC Manual on Distributed Energy Resources Rate Design and Compensation*. http://pubs.naruc.org/pub/19FDF48B-AA57-5160-DBA1-BE2E9C2F7EA0.

[131] New York Public Service Commission. 2017. *Order in Cases 15-E-0751 and 15-E-0082.* http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b5B69628E-2928-44A9-B83E-65CEA7326428%7d.

[132] New York State Energy Research and Development Authority (NYSERDA). 2017. *Value of Distributed Energy Resources (VDER).* https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Project-Developers/Value-of-Distributed-Energy-Resources.

[133] New York Department of Public Service. 2016. *Staff Report and Recommendations in the Value of Distributed Energy Resources Proceeding*. p. 47. https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Project-Developers/Value-of-Distributed-Energy-Resources.

4. Address energy storage as an "electrical generator."
5. Require utilities to create and utilize dynamic electronic submittal and tracking portals.
6. Require utilities to create maps of the grid system to facilitate siting of proposed interconnections (including hosting capacity analysis, interconnection points).

With updated and streamlined interconnection processes in place, distributed energy resources such as CHP will have an easier path to connecting to, and providing benefits to, Michigan's electric grid.

7.6 Incorporate CHP as a Resource in Michigan Utility EWR Plans

The STEER model results indicate that ideal levels of CHP in Michigan, as a least-cost resource option, range between 722 MW to 1,014 MW built – in addition to the 3,300 MW in CHP capacity already installed. A key way to achieve this increase in CHP deployment is for Michigan utilities to embrace CHP as an EWR resource.

Michigan utilities have so far been extremely successful in setting and meeting their EWR goals, even without relying on CHP. "For the seven year period of 2009 through 2015, Energy Optimization program savings achieved for electric utility providers were 129 percent of the target… EO program savings achieved for natural gas utility providers were 127 percent of the required target."[134] There have been job creation benefits, as well. "The EO programs have led to the creation of new jobs in Michigan, by process contractors and by installation contractors. EO programs have also prompted the increasing availability of higher efficiency equipment such as LED lighting for homes and businesses."[135]

However, as more traditional energy efficiency measures become increasingly common in the market, utilities in other states are beginning to struggle to meet efficiency savings targets. When allowed as an eligible measure, CHP can improve a utility's ability to meet energy reduction goals and further increase CHP deployment. For example, in 2016, CHP was only responsible for 10% of AEP Ohio's efficiency portfolio savings; however, AEP Ohio's business plan aims to increase CHP contribution to efficiency savings targets to over 30% by 2020.[136] This proposed increase stems in part to the large energy savings that CHP applications can create, as well as the increased familiarity of their CHP incentives.

By failing to embrace the potential contribution of CHP as an EWR resource, Michigan is missing out on an opportunity to reap the full benefits of its EWR strategy. EWR program savings could be even higher with CHP and by deploying participants in the Michigan CHP supply and value chains, Michigan could experience increased job creation from CHP development, as well. According to ACEEE, which ranks states on progress towards energy efficiency metrics, "All of the highest-scoring states define CHP as an eligible resource in an energy efficiency resource standard, have implemented a standard for connecting CHP systems to the grid, and have a state-approved CHP production goal."

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[134] Michigan Public Service Commission. 2016. *2016 Report on the Implementation of P.A. 295 Utility Energy Optimization Programs*. p. 2.
http://www.michigan.gov/documents/mpsc/2016_Energy_Optimization_Report_to_the_Legislature_with_Appendix_Nov_30_543919_7.pdf.

[135] Ibid., p. 10.

[136] AEP Ohio, Energy Efficiency, *available at* https://www.aep.com/about/IssuesAndPositions/Distribution/EnergyEfficiency/GeneralPolicy.aspx

There are two main approaches to creating utility CHP incentive programs: passive and active. The passive approach, employed in states like Illinois and Ohio, is to define EWR broadly enough as too include savings from CHP. Utilities in those states are thereby incented to create CHP incentive programs themselves once the technology is deemed eligible. In 2013, Illinois passed Public Act 98-0090, which redefined “Energy Efficiency Project” as a measure that reduces the total Btus of electricity and natural gas needed to meet the end use or uses.[137] This new definition removed any concerns over fuel switching for CHP projects and allowed for future CHP incentive programs such as the Illinois public sector CHP pilot program, the Commonwealth Edison CHP incentive program and the Nicor Gas CHP incentive program. The downside of such an approach is that there is no requirement to include CHP as eligible. Indeed utilities such as Ameren Illinois, North Shore Gas, Duke Energy and First Energy do not yet have CHP incentives, though they are allowed under state law.[138] However, this approach may be more feasible to accomplish in the short term, as it does not require a CHP-specific carve-out, but instead only a broad redefinition of efficiency as total energy savings.

The active approach, on the other hand, involves creating a mechanism with which to require utilities to achieve specific savings targets from CHP installations. This is the approach used in Massachusetts through the Green Communities Act (S.B. 2768) passed in 2008, which created the state’s Alternative Energy Portfolio and Energy Efficiency First Fuel Requirement.[139] The efficiency requirement requires utilities to prioritize cost-effective energy efficiency and demand reduction over supply resource and specifically mentions CHP as an eligible technology. The Alternative Energy Portfolio Standard (AEPS) is similar to Michigan’s EWR program, but instead of requiring a certain level of load from efficiency, the AEPS requires utilities to achieve a specific amount of load from “alternative energy generating sources,” including CHP projects, flywheel energy storage, energy efficient steam technology and renewable technologies that generate useful thermal energy. From 2009 to 2014, roughly 99% of compliance was met using CHP technologies.[140]

Under either approach, the proper methodology with which to calculate CHP energy savings must be carefully chosen. As discussed above, Michigan utilities’ reliance on PACT fails to accurately capture the full energy savings of a CHP system. As an alternative, the Illinois Technical Reference Manual (TRM) provides a potential methodology for calculating energy savings from CHP.[141] Strengths of the Illinois TRM include the fact that it accurately reflects the energy required from the grid and on-site boilers/furnaces to produce an equivalent amount of electricity and thermal energy. On the electricity side, the Illinois TRM divides CHP into two categories, those operating above 6,500 hours a year and those operating below 6,500 hours a year. For systems operating fewer than 6,500 hours per year, the

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[137] Illinois General Assembly. Illinois Compiled Statutes 3501/825-65 (a)(iii)(b). http://www.ilga.gov/legislation/ilcs/fulltext.asp?DocName=002035010K825-65.

[138] U.S. DOE. 2015. *Energy Incentive Programs, Illinois*. https://energy.gov/eere/femp/energy-incentive-programs-illinois.

[139] Massachusetts Legislature. 2008. Chapter 169. https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169.

[140] Ballam, J. Massachusetts Department of Energy Resources. 2013. *Massachusetts Alternative Portfolio Standard for Combined Heat & Power (CHP): An Effective Program for Clean, Efficient Energy*. https://www.maeep.org/sites/default/files/CHP2013/MAEEP%20CHP%20061913%20(Ballam).pdf.

[141] *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 6.0*. 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf.

avoided grid energy calculations use the non-baseload heat rate provided by EPA eGRID for utility specific regions (RFC West region for ComEd territory and SERC Midwest region for Ameren territory) and includes any line losses.[142] For systems operating more than 6,500 hour per year, the avoided grid energy calculations use the All Fossil Average heat rate provided by EPA eGRID for utility specific regions.[143] The utilities then monetize the energy savings from CHP using utility-specific avoided cost data to calculate the cost and value of incentives as outlined in a resource cost test (and requiring some sort of evaluation measurement and verification protocol). These cost tests determine what costs and benefits may be incorporated when assessing energy savings and their respective implementation costs.

An efficiency threshold for CHP projects should be a required feature of incorporating CHP in the EWR program. A reasonable eligibility threshold for CHP systems is one that is set high enough that so that it is clear that the CHP is achieving energy savings compared to separate heat and power, but not so high as to prevent CHP systems considered to be "high efficiency" from eligibility.[144]

The New York State Energy Research and Development Authority (NYSERDA) CHP incentive program is commonly thought of as the gold standard for state supported CHP policies.[145, 146] Incentives levels are divided between geographies, system sizes, and technology types and are capped at $2.5 million per project. The NYSERDA CHP Program provides incentives through a catalog approach and a custom approach. According to NYSERDA, under the catalog approach, approved CHP vendors act as a single point of responsibility for the entire project and provide a minimum 5-year maintenance/warranty agreement on the CHP system.[147] Under the custom approach, NYSERDA accepts applications from the site owner, the CHP System owner, or any member of the project team takes responsibility for the proper design, integration, installation, commissioning and maintenance of the CHP System.[148] NYSERDA will contract only with the applicant. The Custom Approach is available for projects 1 MW and larger in size.[149]

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[142] Ibid.
[143] Ibid.
[144] U.S. EPA. 2017. *Methods for Calculating CHP Efficiency*. https://www.epa.gov/chp/methods-calculating-chp-efficiency.
[145] CleanEnergy States Alliance. 2015. *Clean Energy Champions: The Importance of State Programs and Policies*. p. 112. https://www.cesa.org/assets/2015-Files/Clean-Energy-Champions-LR.pdf.
[146] New York State Energy Research and Development Authority (NYSERDA). 2017. *Combined Heat and Power Program.* https://www.nyserda.ny.gov/All-Programs/Programs/Combined-Heat-and-Power-Program.
[147] Ibid.
[148] Ibid.
[149] The deadline for applications to the program is December 31, 2018 and projects are to be commissioned within 30 months of approval of application. Therefore, comprehensive program evaluation is expected to commence by June 2021. https://portal.nyserda.ny.gov/CORE_Solicitation_Document_Page?documentId=a0lt0000000kzvQAAQ.

7.7 Consider CHP Supply and Demand in IRP

Building upon Michigan's 2016 energy law's requirement that CHP must be considered in a utility's IRP, utilities should also be required to consider:

- the demand-side savings from CHP;
- on-site CHP as both a supply-side and demand-side resource.

IRP analysis should incorporate CHP as both a supply and demand-side measure. On the supply side analysis, CHP would be included as another generation resource similar to combined cycle generation. Unlike combined cycle plants, CHP requires a host facility capable of using the thermal output. Relatedly, the value of this thermal load would need to be accounted for either through a credit or another mechanism to account for the total cost of CHP to the utility. Formally requiring Michigan utilities to assess CHP on both the supply-side and demand-side in an IRP would help ensure that these complicated projects are allotted equivalent analyses as other resources. While the final proposed course of action might not include CHP, its required inclusion as a supply-side and demand-side resource would ensure a level playing field between all potential resources.

As one example of utility that has successfully included CHP in its IRP, Alabama Power includes more than 500 MW of company-owned and 1,500 MW of customer-owned CHP generation in its IRP. The plan states that the company aims to identify "CHP projects that are expected to bring benefits to all customers" and attributes its success in developing CHP resources to "a good working arrangement between all parties" and "an adaptive regulatory process."[150]

7.8 Promote Outreach and Technical Assistance

The DOE Midwest CHP TAP is an enormously helpful resource for those interested in developing CHP projects. Businesses in Michigan that are interested in CHP should work closely with the Midwest CHP TAP to utilize all available services and resources needed to better understand if CHP is right for them. Government leaders, along with trade associations and advocacy groups like the Midwest Cogeneration Association and the Michigan EIBC, should work in close collaboration with the Midwest CHP TAP to ensure their constituents and members are aware of the potential benefits of CHP and the resources provided by the Midwest CHP TAP. This can include assistance with navigating the complex array of financing options available for the development of CHP projects. Proactive engagement with technical assistance resources can also help to overcome structural organizational challenges necessitating education for energy and financial decision-makers within a company.

Targeted outreach to emergency management professionals are an additional key group that must be engaged in the effort, because they provide a gateway to their stakeholders who play an important role, at the local level, in developing emergency response plans and taking action when needed. Those involved with emergency planning and critical infrastructure are likely to be most interested in the resilience benefits of CHP. As discussed above, when properly configured to operate independently from the grid, CHP systems can provide critical power reliability for businesses and critical infrastructure facilities while providing electric and thermal energy to the sites on a continuous basis, resulting in daily

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[150] Alabama Power. 2016. *2016 Integrated Resource Plan*. p. 34. https://www.alabamapower.com/our-company/how-we-operate/regulation/integrated-resource-plan.html.

operating cost savings. There are a number of ways in which CHP systems can be configured to meet the specific reliability needs and risk profiles of various customers, and to offset the capital cost investment for traditional backup power measures. In order to optimally deploy CHP for Michigan's critical facilities, outreach and education will need to be a high priority. "Successful application of CHP in critical infrastructure sectors will depend on overcoming institutional barriers, and engaging the support of decision-makers who build, manage, and operate these facilities. An element of 'out-of-the-box' thinking is also required as the needs of our infrastructure evolve to contend with growing and changing risks."[151]

8 Moving Michigan Forward

Michigan is poised to move forward toward optimal levels of CHP development. According to the DOE, Michigan has nearly 5 GW of CHP technical potential across more than 10,000 sites across 17 industrial and 24 commercial sectors. This potential, on a capacity basis, is roughly evenly split between 17 industrial sectors and 24 commercial sectors.[152] As discussed above, STEER model results indicate that ideal levels of CHP in Michigan, as a least-cost resource option, range between 722 MW and 1,014 MW built, in addition to the 3,300 MW in CHP capacity already installed.

This increase in CHP deployment will enhance Michigan's efforts to lead on EWR among other states. Currently, Michigan ranks 7th in the nation for potential annual CO_2 reductions from industrial energy efficiency and CHP/WHP.[153] In the 2017 ACEEE Energy Efficiency Scorecard, Michigan scored 14th (tied with Arizona, Delaware, Iowa, New Jersey, New Mexico, Ohio, Texas, and Wisconsin) in the CHP category, slightly lower than its overall energy efficiency rank of 11th.[154]

Demonstrating leadership in CHP development will serve to both reinforce and grow Michigan's demonstrated commitment to serious levels of energy waste reduction. According to the MPSC, regarding EWR overall, "For 2015, Michigan utility providers successfully complied with the energy savings targets laid out in PA 295. Providers met a combined average of 121 percent of their electric energy savings targets and 117 percent of their natural gas energy savings targets – one percent of retail sales for electric providers, and 0.75 percent of retail sales for gas providers. EO programs across the state accounted for electric savings totaling over 1.1 million MWh (megawatt hours) and natural gas savings totaling over 4.58 million Mcf (thousand cubic feet) for program year 2015."[155] CHP could be key

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151 State and Local Energy Efficiency Action Network. U.S. DOE. 2013. *Guide to the Successful Implementation of State Combined Heat and Power Policies*. p. 4. https://www4.eere.energy.gov/seeaction/system/files/documents/see_action_chp_policies_guide.pdf.

152 U.S. DOE. 2016. *Combined Heat and Power (CHP) Technical Potential in the United States*. https://www.energy.gov/eere/amo/downloads/new-release-us-doe-analysis-combined-heat-and-power-chp-technical-potential.

153 Alliance for Industrial Efficiency. 2016. *State Ranking of Potential Carbon Dioxide Emission Reductions through Industrial Energy Efficiency*. https://alliance4industrialefficiency.org/wp-content/uploads/2016/09/FINAL-AIE-State-Industrial-Efficiency-Ranking-Report_9_15_16.pdf.

154 Berg, W., et al. American Council for an Energy-Efficient Economy. 2017. *The 2017 State Energy Efficiency Scorecard*. http://aceee.org/research-report/u1710.

155 Michigan Public Service Commission. 2016. *2016 Report on the Implementation of P.A. 295 Utility Energy Optimization Programs*. p. 1.

to continuing to meet strong energy savings targets in the future. According to the ACEEE, "In states with energy efficiency goals, CHP can offer a more cost-effective way to reach efficiency targets and earn performance incentives. A single CHP system can offer the efficiency savings of many smaller efficiency projects. In times when some utilities are reporting less low hanging efficiency fruit in the commercial and industrial sector, CHP can offer deep savings at a very low cost, enhancing the overall cost-effectiveness of energy efficiency portfolios."[156]

Execution of the Michigan CHP Roadmap will likely have significant impacts on the levels of CHP deployed in Michigan. For example, by addressing the CHP barrier of standby rates, STEER Model results using the EIA 2016 Annual Energy Outlook Reference Case indicate that Michigan could see an increase of 345 MW of CHP capacity built. In Missouri, this pattern has already been demonstrated. In 2016, the Missouri Energy Office and Ameren Missouri reached a settlement agreement on standby rate reform. The new standby rate was a significant improvement to the previous rate, which was modelled to have detrimental financial effects on CHP development. As a result, there has been a noticeable uptick in CHP qualification screenings requested and provided by the Midwest CHP TAP. In 2016, before the standby model was created, the Midwest TAP provided technical assistance to only 10 sites in Missouri. In 2017, this number jumped to 46 sites, including Mercy Hospital in St. Louis. The renewed interest in CHP by Mercy Hospital was due in large part to the new standby rate in conjunction with the Missouri Energy Office's outreach.

Additionally, CHP incentive programs in other states have seen dramatic results in additional CHP capacity coming online. The NYSERDA CHP incentive program has had an enormous market impact in New York. Between 2013 and 2016, the NYSERDA program has provided incentives to over 150 sites with a cumulative total capacity of over 70 MW. In New York City alone, the program is directly responsible for over 100 MW of new CHP capacity since 2003. Similarly, in Illinois, the impact of the public sector CHP incentive was immediately felt. When released in 2013, the public sector incentive program received 17 applications providing 31 MW of capacity. Of these applicants, seven were selected as finalists to receive incentives. Through implementing the Michigan CHP Roadmap, well-crafted CHP incentive programs could have similar positive effects on CHP development in Michigan.

Building on its strong commitment to EWR, Michigan is well-positioned to take advantage of the opportunities offered by increased CHP development in the state. By implementing the Michigan CHP Roadmap, the state can expand its energy waste reduction vision to include the many benefits of CHP, helping businesses to achieve their cost-savings and energy reliability goals. With key revisions to programs and policy, CHP has the potential to be a significant, reliable, cost-effective, and environmentally protective contributor to Michigan's energy mix.

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http://www.michigan.gov/documents/mpsc/2016_Energy_Optimization_Report_to_the_Legislature_with_Appendix_Nov_30_543919_7.pdf.

[156] Chittum, A. American Council for an Energy Efficient Economy (ACEEE). 2013. *How Electric Utilities Can Find Value in CHP*. p. 5. http://aceee.org/files/pdf/white-paper/chp-and-electric-utilities.pdf.

9 Case Studies

9.1 Impact of Incentives

Incentive programs help to improve the economics of proposed projects and can be an important consideration in the decision to move forward. Several models from other states exist for how such a CHP incentive program may be structured:

- Commonwealth Edison's (ComEd) Smart Ideas program provides CHP incentives for business customers in northern Illinois;
- Nicor Gas's (Nicor's) Energy Smart program provides natural gas incentives for CHP projects pursued by business customers in its in northern Illinois territories;
- The Illinois Energy Office, under its Illinois Energy Now program, provides incentives to public entities for CHP projects;
- Dayton Power and Light (DP&L) provides CHP incentives to public and private customers in its Ohio service territory;
- Baltimore Gas and Electric (BG&E) provides CHP incentives to public and private customers in its Maryland service territory.

Each of the five incentive programs has unique features, although they have some commonalities. All of the programs set a minimum efficiency level for eligibility – 60% for the Illinois-based programs and DP&L and 65% for BG&E.[157] The ComEd, Nicor, and DP&L programs provide incentives for feasibility assessments and the ComEd program further provides cost sharing for interconnection expenses. The Illinois Energy Now and BG&E programs offer a design incentive and these two programs along with DP&L provide incentive payments at the time of project commissioning. The design and commissioning incentives effectively act as up front capital cost buy downs.

All of the programs provide production incentives after a period of operation based on the electric generation and, in the case of Nicor, on the gas displaced from the existing on-site boilers. The production incentives are frequently structured to encourage higher efficiencies in the CHP systems. For example, DP&L's incentive ranges from 80% to 100% of $0.08/kWh depending on the system efficiency. For basic systems with a CHP efficiency of 60%, Illinois-based programs allow only 65% of generation to be eligible for incentives, but this percentage increases as the efficiency of the system increases. Some of the gas savings are also counted when CHP efficiencies exceed 65%. The BG&E program is not structured to incentivize higher efficiencies, but it sets the highest efficiency threshold for eligibility.

Table 10 summarizes the incentive structure for each of the five programs. Note that each of the programs has additional requirements that can be examined through the sources cited.[158] In northern

[157] The Illinois and BG&E programs calculate the CHP efficiency based on higher heating value (HHV), whereas the DP&L program uses Lower Heating Value (LHV). HHV and LHV are a measure of the range of expected energy content for a volume of fuel, typically natural gas for CHP applications. Therefore, the DP&L eligibility is a lower threshold.
[158] CHP Incentive Program Details:

Illinois, when a customer is shared by both ComEd and Nicor, the incentive programs operate in concert under rules for counting savings in the Illinois Technical Reference Manual.[159]

Table 10: Comparison of Five CHP Incentive Programs

Category	ComEd[1]/Nicor[2]	ComEd Only[1]	Illinois Energy Now[3]	DP&L[4]	BG&E[5]
Minimum CHP Efficiency	60% HHV	60% HHV	60% HHV	60% LHV	65% HHV
Feasibility Assessment	up to $25,000 or 50% of study cost	up to $25,000 or 50% of study cost		up to $10,000 for study cost	
	up to $12,500 or 25% of study cost				
Design incentive			up to $75/kW, max. 50% of design cost or $195,000		$75/kW
Installation/Commissioning Incentive			$175/kW, max. $650,000 including design incentive	$100/kW	$275/kW for <250 kW, $175 kW for ≥250 kW
Interconnection Incentive	up to $25,000 or 50% of interconnection cost				
Production incentive rate	$0.07/kWh @ 12 months	$0.07/kWh @ 12 months	$0.08/kWh @ 12 mos. if CHP eff ≥70% HHV	$0.08/kWh @ 12 months	$0.07/kWh @ 6, 12, & 18 months
	$1/therm @ 12 months		$0.06/kWh @ 12 mos. if CHP eff ≤60%<70% HHV		
Savings eligible for incentives	65% of kWh + 1% x each % CHP eff ≤60%<65% HHV	65% of kWh + 1% x each % CHP eff ≥60%	65% of kWh + 1% x each % CHP eff ≤60%<65% HHV	100% of kWh CHP eff ≥80% LHV	100% of kWh
	70% of kWh CHP eff ≥65% HHV		70% of kWh CHP eff ≥65% HHV	90% of kWh CHP eff ≤70%<80% LHV	
	2.5% of therms x each % CHP eff>65% HHV		2.5% of therms x each % CHP eff>65% HHV	80% of kWh CHP eff ≤60%<70% LHV	
Incentive Caps	$2,500,000 or 50% of project $2,000,000 elec, $500,000 gas	$2,000,000 or 50% of total project costs	$2,000,000 or 50% of total project costs	$500,000 or 50% of total project costs	$1.25 million design & installation $1.25 million production

To assess the impact of these incentives on a potential CHP project, we begin with the operating and financial data for a sample university as defined in Table 11.

Table 11: University Base Energy Load and Costs

Annual Operating Hours	8,760
Average Electric Demand (kW)	7585
Annual Electric Demand (kWh)	66,444,600
Average Thermal Demand (MMBtu/hr)	25
Annual Thermal Demand (MMBtu)	219,000
Annual Natural Gas Demand (therms)	2,737,500

(1) ComEd. 2017. https://www.comed.com/SiteCollectionDocuments/WaysToSave/Business/PY9_CHP_flyer_v03.pdf.
(2) Nicor Gas. 2018. https://www.nicorgasrebates.com/your-business/custom-incentive/Combined-Heat-and-Power.
(3) Illinois Department of Commerce & Economic Opportunity. 2017. https://www.illinois.gov/dceo/whyillinois/TargetIndustries/Energy/Pages/CHPprogram.aspx.
(4) Dayton Power & Light. 2018. https://www.dpandl.com/save-money/business-government/custom-rebates/chp-rebates.
(5) Baltimore Gas and Electric. 2015. http://www.bgesmartenergy.com/business/chp.

159 *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 6.0*. 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf.

Average electricity price ($/kWh)	$0.072
Average natural gas price ($/MMBtu)	$3.56

A feasibility evaluation had specified a gas turbine system with a net capacity of 4,324 kW and 25.2 MMBtu/hour of useful thermal output, as the optimal technical solution for this end-user. The specifications for this CHP project are sourced from a DOE factsheet[160] and summarized in Table 12.

Table 12: CHP Specifications

Nominal Electric Power (kW)	4,600
Net Electric Power (kW)	4,324
Fuel Input (MMBtu/hr)	59.1
Useful Thermal (MMBtu/hr)	25.2
Electric Efficiency	25%
CHP System Efficiency (HHV)	67.6%
CHP System Efficiency (LHV)	74.7%
Total Installed Cost ($/kW)	2,817
CHP O&M costs ($/kWh)	$0.013

[160] U.S. DOE. *Combined Heat and Power Basics.* http://energy.gov/eere/amo/combined-heat-and-power-basics#factsheet.

Using the specified gas turbine, and in the absence of incentives, the sample university would expect an implemented CHP project to achieve the metrics outlined in Table 13.

Table 13: Energy Savings and Payback

Energy Savings	
Net electric generation (kWh)	$35,984,328
Natural Gas Boiler Savings (therms)	$2,621,430
Energy in Btus	
Fuel total CHP (mmBtu) HHV	$491,830
Net CHP generation (mmBtu)	$122,779
Useful thermal (mmBtu)	$209,714
Costs and Payback	
Annual Operating Savings	$1,046,302
Total Installed Costs	$12,180,708
Incentives	$0
Simple Payback, Years, w/o incentives	11.6
Assumptions	
CHP up-time	95%
Thermal utilization	100%
Parasitic load	6%
Existing boiler efficiency	80%
% of electricity costs saved by CHP	90%

Table 14 summarizes what kind of incentives the hypothetical University project would be eligible for under these five utility programs. Note that 70-100% of the generation would be eligible for production incentives across the various programs, based on CHP system efficiency. In addition, 6.5% of the boiler natural gas displaced by the system would be eligible for incentives under the Nicor program.

Table 14: Electricity Generation and Natural Gas Savings Eligible for Incentives

Category	ComEd/Nicor	ComEd Only	llinois Energy Now	DP&L	BG&E
Electric (%)	70.0%	72.6%	70.0%	90.0%	100.0%
Natural gas %)	6.5%	0.0%	0.0%	0.0%	0.0%
Electricity (kWh)	25,189,030	26,125,771	25,189,030	32,385,895	35,984,328
Natural gas (therms)	170,602	-	-	-	-

Before applying any program caps on total incentives, the project would be eligible for incentives of $1.9 to $4.9 million under the various programs, as depicted in Table 15. However, given the size of the potential university CHP system, the program caps would apply under some of the programs. The Illinois Energy Now program would cap the incentives at $2 million, while the BG&E program would cap the production incentive portion of the incentive, resulting in a total incentive of about $2.3 million. The

DP&L program has the lowest cap – $500,000 – but DP&L encourages customers considering larger projects (over 500 kW) to contact the utility to discuss potential incentive levels that could be higher than this cap.

Table 15: Potential Incentives under the Various CHP Programs

Category	**ComEd/Nicor**	**ComEd Only**	**Illinois Energy Now**	**DP&L**	**BG&E**
Feasibility study	$37,500	$25,000		$10,000	
Design incentive			$195,000*		$324,300
Installation/Commissioning incentive			$455,000*	$432,400	$756,700
Interconnection Incentive	$25,000	$25,000	$0	$0	
Electric production incentive	$1,763,232	$1,828,804	$1,350,000*	$67,600*	$1,250,000*
Natural gas incentive	$170,602	$0	$0	$0	$0
Incentive (calculated w/o cap)	$1,996,334	$1,878,804	$2,592,342	$3,033,272	$4,859,354
TOTAL Incentive (with caps)	$1,996,334	$1,878,804	$2,000,000	$510,000	$2,331,000

**Cap applied to this portion of the incentive.*

The impact on total project costs and simple paybacks are summarized in Table 16. The combined incentives from ComEd and Nicor and the Illinois Energy Now incentive would reduce the payback period by nearly two years, whereas if the DP&L caps were applied the incentive would only reduce the payback by about one-half year. The BG&E program would provide the greatest benefit, offsetting nearly 20% of installation costs and reducing the payback period by over two years. Again, other rules and requirements may apply and utilities (as DP&L suggests) may negotiate different incentive levels in individual situations.

Table 16: Cost Reductions from Incentives

Category	**ComEd/Nicor**	**ComEd Only**	**Illinois Energy Now**	**DP&L**	**BG&E**
Installed Cost with incentive	$10,184,374	$10,301,904	$10,180,708	$11,670,708	$9,849,708
% of Project Offset	16.40%	15.40%	16.40%	4.20%	19.10%
Simple Payback (in years) w/o incentive	11.6	11.6	11.6	11.6	11.6
Simple Payback (in years) w/incentive	9.7	9.8	9.7	11.2	9.4
Reduction in Payback (in years)	1.9	1.8	1.9	0.5	2.2

9.2 Impact of Standby Rates

Using data from nine Michigan CHP project evaluations, completed by the Energy Resources Center from 2014 to 2017 to support potential new projects, project partners were able to model the effects of standby rate changes on system payback for each of the projects, as identified in Table 17 by their corresponding utility, market sector, estimated capacity, and estimated system payback. While two of these sites are viewed as economically viable under existing conditions (Consumers Casino and Consumers University), none of these nine sites are currently proceeding with a CHP installation. We consider economic viability to include a payback period of less than 10 years for the public and institutional sectors and less than 4 years for the private sector.

Table 17: Michigan Site Screening Results for CHP

Site	Utility	Capacity	Base Case Payback (years)
Office Building	DTE	613 kW	21.1
Waste Water Plant	Consumers	1,000 kW	14.4
Casino	DTE	600 kW	12.5
Waste Water Plant	DTE	9,800 kW	11.3
Auto Mfg.	DTE	9,400 kW	6.9
Metals Mfg.	DTE	9,000 kW	6.5
Food Mfg.	DTE	7,000 kW	6.2
University	Consumers	3,000 kW	5.3
Casino	Consumers	600 kW	3.5

Current standby rates are unfavorable to the financial viability of CHP applications in Michigan. Project partners used an avoided rate model to analyze the financial effects that standby rates have on CHP system payback. The concept of avoided rate evaluates the financial impacts of standby rates on distributed generation systems by comparing the per kilowatt-hour (kWh) cost of full-requirements customers to that of standby customers. Ideally, a decrease in electricity purchased from the utility would be commensurate with a decrease in monthly electric costs. However, many standby rates are created such that they increase capacity demand charges when a customer decreases energy consumption, thus negating much of the expected savings.

The avoided rate is a percentage that reflects the relationship between the aggregate cost of a kWh before and after CHP implementation. An avoided rate of 70% means that the savings for each kWh generated on-site will only equal 70% of the utility's aggregate kWh price. According to the EPA, avoided rates above 90% are not considered a significant barrier to CHP implementation. [161] With an avoided rate of 100%, standby rates are not considered a barrier at all.

Project partners have calculated that the standby rates of DTE Energy create avoided rates that range from 70% to 77%, while the avoided rates of Consumers Energy range from 81%-86%. These are both

[161] Regulatory Assistance Project. Prepared for the U.S. EPA. Office of Atmospheric Programs, Climate Protection Partnerships Division. 2009. *Standby Rates for Customer-Sited Resources: Issues, Considerations, and the Elements of Model Tariffs*. https://www.epa.gov/sites/production/files/2015-10/documents/standby_rates.pdf.

considered major barriers to CHP implementation and significantly increase project payback periods as illustrated in **Figure 15**.

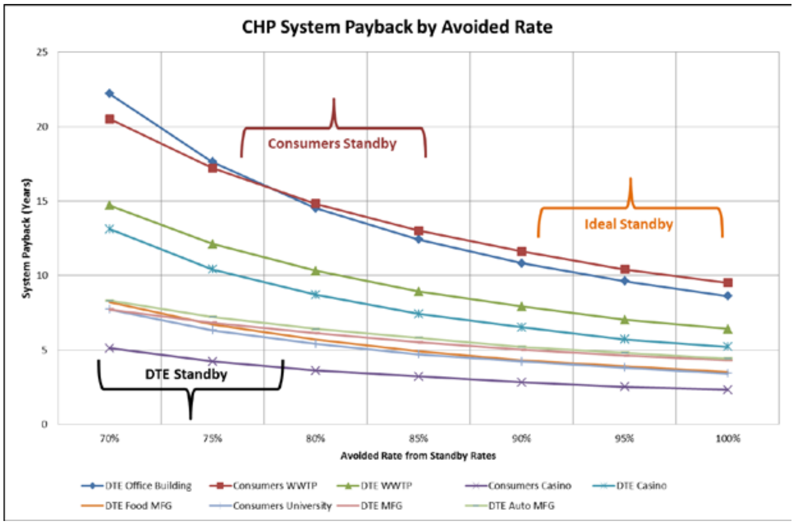

Figure 15: CHP System Payback by Avoided Rate

Project partners modeled the effects of standby rate improvement on system payback for each site, as depicted in **Figure 16**. Under ideal standby rates all sites would experience paybacks under ten years with a majority having paybacks less than five years. Compared to status quo, this change causes an additional two sites to become economically viable (Consumers Waste Water Plant and DTE WWP) while three sites are on the cusp of viability (DTE Food MFG, DTE MFG, DTE Auto MFG).

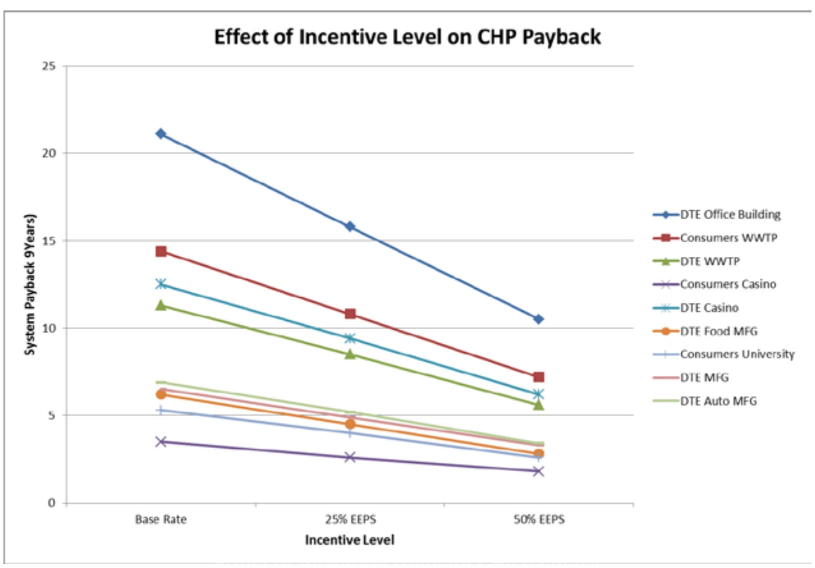

Figure 16: CHP System Payback by Incentive Level

Project partners also modeled the effects of EWR incentives (offered in the form of rebates) on system payback. Two levels were analyzed, 25% of installed costs and 50% of installed costs. Under a 25%

incentive level, one additional site becomes economically viable (DTE WWP), bringing the total to three viable projects. Under a 50% incentive an additional four sites become economically viable (Consumers WWP, DTE Food MFG, DTE MFG, DTE Auto MFG), bringing the total to six.

When both measures are implemented, eight of the nine sites become economically viable. Table 18 shows the revised system paybacks under each scenario. It is important to note that the one site not achieving economic viability was an office building located within DTE Energy's territory. Though the "Commercial Buildings" category contains 718 MW of CHP potential according to DOE estimates, most of this potential is very unlikely to be realized as these facilities do not operate enough hours per year or do not have large enough total energy requirements for CHP to be a reasonable economic fit.

Table 18: CHP Payback by Avoided Rate and Incentive Levels

Site	Utility	Capacity	Base Case Payback (years)	Ideal Standby Payback (Years)	Ideal Standby + 25% Incentive	Ideal Standby + 50% Incentive
Office Building	DTE	613 kW	21.1	8.6	6.5	4.3
Waste Water Plant	Consumers	1,000 kW	14.4	9.5	7.1	4.7
Casino	DTE	600 kW	12.5	5.2	3.9	2.6
Waste Water Plant	DTE	9,800 kW	11.3	6.4	4.8	3.2
Auto Mfg.	DTE	9,400 kW	6.9	4.4	3.3	2.2
Metals Mfg.	DTE	9,000 kW	6.5	4.3	3.2	2.1
Food Mfg.	DTE	7,000 kW	6.2	3.8	2.9	1.9
University	Consumers	3,000 kW	5.3	3.4	2.6	1.7
Casino	Consumers	600 kW	3.5	2.3	1.7	1.1

Attachments

<u>List of Attachments</u>

A. Property Assessed Clean Energy (PACE) Overview
B. Michigan CHP Directory of Supply/Value Chain Participants
C. CHP Survey and Interview Responses
D. STEER Results - EIA 2016 Annual Energy Outlook Reference Case w/ renewables
E. STEER Results - EIA 2016 Annual Energy Outlook Reference Case w/o renewables
F. STEER Results - EIA 2016 Annual Energy Outlook High Resource Case w/ renewables
G. STEER Results - EIA 2016 Annual Energy Outlook High Resource Case w/o renewables
H. STEER Results - EIA 2016 Annual Energy Outlook Low Resource Case w/ renewables
I. STEER Results - EIA 2016 Annual Energy Outlook Low Resource Case w/o renewables
J. STEER Results – Resilience Values and EIA 2016 Annual Energy Outlook Reference Case w/ renewables
K. STEER Results – Standby Rates and EIA 2016 Annual Energy Outlook Reference Case w/ renewables
L. Sample Standby Tariffs – Consumers Energy Rate GSG-2 and DTE Energy Rider 3