

# CHAPTER 5

## Alternative Technologies Workgroup Resource Assessment

### 1. Introduction, Overview, Methodology and Approach

#### 1.1 Introduction

Governor Granholm’s Executive Directive charged the 21st Century Energy Plan (Plan) participants to address “The appropriate use and application of energy efficiency, [and] alternative energy technology. . . .” It also directed participants to identify “[n]ew technology options to generate, transmit, and distribute energy more cleanly or more efficiently. . . .” To fulfill this directive, the Alternative Technology Workgroup identified new and enhanced electric generation, transmission, and distribution technologies that have recently become available or are likely to be available, in the not-too-distant future, to help meet the State’s electric energy needs.

For purposes of this Plan, only combined heat and power (CHP) potential estimates were directly used in the modeling. Other forms of distributed generation can be assumed to be captured as part of the renewables modeling (reciprocating engines and perhaps Stirling engines), while the remainder (fuel cells and battery storage) are considered more niche applications that are either not sufficiently developed or have not yet made a significant contribution towards meeting Michigan energy needs.

The Workgroup investigated alternative technologies in two broad categories. The first category represents generation options that are not traditional central station plants and are collectively referred to as distributed energy resources (DER) or distributed generation (DG).<sup>66</sup> DG technologies allow production units to be located at or near the point of end-use, frequently on a customer's premises. CHP represents one type of DG application. The assumptions used for estimating the CHP potential for the expansion modeling program, are discussed in more detail in Chapter 5A of Appendix Volume II, which is the Estimate of Combined Heat and Power Potential document. The review of CHP and other DG applications is presented in Section 2 of this Chapter. The matrix that summarizes the technology characteapplications is presented in Chapter 5B, which is the Distributed Generation and Related Technologies Matrix document.

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<sup>66</sup> Generally speaking, DER can include any combination of demand side, distribution grid, and supply-side resources, whereas the term DG applies only to supply-side resources. Demand side resources affect the efficiency and time of use of services that utilize energy, almost always on the customer’s side of the utility meter. Distribution grid resources affect the efficiency of energy delivery from generator to user, or enable monitoring, communications, and controls necessary for the implementation of other demand- or supply-side technologies. Supply-side resources involve the generation of energy. (See, for example, Lovins, A.B., Kyle Datta, Thomas Feiler, Karl R. Rábago, Joel N. Swisher, André Lehmann, and Ken Wicker; 2002; *Small is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*; Snowmass, CO: Rocky Mountain Institute; [www.smallisprofitable.org](http://www.smallisprofitable.org), p. 7; and U.S. EPA Glossary, *What is Green Power*, at <http://www.epa.gov/greenpower/whatis/glossary.htm>.)

The second group of technologies represents options for the modernization of the nation’s electric transmission and distribution grid, including related sensing, monitoring, communications and control functions. These options are intended to make the electric grid more reliable, secure, and efficient. They will also facilitate the incorporation of DER installations, while maintaining system reliability. These are termed “Smart Power Grid” technologies, and they are briefly reviewed in Section 3 of this Chapter and in more detail in Chapter 5C of Appendix Volume II, which is the Smart Power Grid and Related Technologies document.

## 1.2 Overview

The changing nature of the country’s electric industry – initiated by passage of the federal Public Utilities Regulatory Policy Act of 1978 (PURPA),<sup>67</sup> supplemented and expanded through passage of the federal Energy Policy Acts of 1992 and 2005 (EPACT’92<sup>68</sup> and EPACT’05<sup>69</sup>), and other federal and state initiatives including Michigan’s 2000 PA 141<sup>70</sup> – helped to create and support growing interest in distributed energy resources. Some of the expected benefits from the application of DER technologies include:

1. flexibility for customers to choose the best energy system for their individual circumstances;
2. reliable power, especially in areas where outages are common;
3. high-quality, premium power for sensitive applications;
4. improved power quality, including voltage stabilization for circuits that might otherwise be under greater stress during periods of peak or near-peak utilization;
5. efficiency improvements when DER options are used, often incorporating combined heat and power equipment for space, water, or industrial process heating, cooling, and related applications;
6. utility system cost and customer bill savings, often resulting from reduced customer peak demand and demand charges;
7. power provided less expensively to remote applications like cellular communications towers;
8. environmental benefits associated with emissions reductions, frequently through renewable energy technology applications; and
9. additional fuel source diversity, frequently through renewable resources such as biomass, solar, and wind.

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<sup>67</sup>For more information on the Public Utilities Regulatory Policy Act of 1978 (PURPA), see link for article *Electricity Restructuring Background: The Public Utility Regulatory Policies Act of 1978 and the Energy Policy Act of 1992*, <http://www.ncseonline.org/NLE/CRSreports/energy/eng-36.cfm>.

<sup>68</sup>Link to Energy Policy Act of 1992: <http://thomas.loc.gov/cgi-bin/bdquery/z?d102:HR00776:@@D&summ2=m&>.

<sup>69</sup>Link to Energy Policy Act of 2005: [http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109\\_cong\\_public\\_laws&docid=f:publ058.109](http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ058.109).

<sup>70</sup>Link to 2000 PA 141 (MCL 460.10 et seq.): <http://legislature.mi.gov/doc.aspx?mcl-460-10>.

Since energy planning is a dynamic process and energy markets are changing rapidly, it is important for planners to be aware of alternative technologies and the likely roles they might play in meeting the state's energy needs. From a design and engineering standpoint, it is important that steps taken in the near future make it easier, not harder, to implement promising technologies when they become available. It is likewise important to consider these technologies when assessing policy needs to assure that policy recommendations will not inadvertently preclude adoption of new technologies or impose unintended consequences that might undermine the benefits they could otherwise confer.

Due to the large number and widely varying types of alternative technologies related to distributed generation, advanced energy storage systems, and advanced distribution and transmission technologies, the process of analyzing these technologies was divided into four teams: (1) Alternative Technologies; (2) Combined Heat and Power; (3) Smart Power Grid; and (4) Policy (comprised of participants from both the Renewable Energy and Alternative Technologies Workgroups).

The goals of the Alternative Technologies Workgroup were to identify and characterize alternative technologies related to distributed generation, transmission, and advanced storage, focusing on reliability, safety, security, efficiency and compatibility with any given system. The Workgroup also sought to identify barriers to adoption and implementation, and related interconnection issues.

The goals of the Combined Heat and Power Team were to explore the sites identified in the Capacity Need Forum (CNF) report to the extent possible to validate, refine and extend the potential capacity available in Michigan from combined heat and power projects. The Team also identified barriers to, and developed recommendations for, the implementation of such projects in Michigan.

The goals for the Smart Power Grid Team were to identify and summarize current and national programs that are involved in the process of organizing, studying, specifying, designing, testing and implementing the hardware and concepts of a Smart Power Grid, and also, to provide additional information on technology options, barriers to adoption, commercial readiness, and applications related to smart power grid architecture and communications.

### **1.3 Methodology and Approach**

The overall process utilized in developing this report involved a number of stakeholders from various fields and backgrounds. Experts in electric generation, distribution and transmission, advanced storage, and regulatory and policy matters provided input in developing the materials presented as part of the Plan for the state of Michigan. Wherever possible, the participants strived to reach consensus on the methodology and approach used in gathering and cataloging the data and subsequent findings contained in this document. If the stakeholders involved were unable to reach consensus on particular issues, Michigan Public Service Commission (MPSC or Commission) Staff employed its best judgment and a consultative process open to all participants, to ensure, to the extent possible, the quality and accuracy of the data in this report.

Due to the inherent uncertainties associated with the evaluation of alternative technologies for generation, distribution and advanced energy storage, the various technologies evaluated as part of this report were those considered by participants to be the most likely to be commercially available and practical for application in the near to mid-term planning horizon. Workgroup participants acknowledge that as advancements to the various technologies occur over time, the commercial viability and economic affordability of these options will likely change as well.

To the extent that some of these technologies have already been deployed in Michigan, their influence on historical demand and energy use is expected to be captured, at least in part, by the methods used to establish the forecast of future electric power and energy needs. For example, solar electric generating technologies are already commercially available, even though they are still relatively more expensive compared to current and expected near-term electric power rates. To the extent that a small number of customers are already incorporating solar electricity into their homes or commercial buildings, however, the historical trend would be expected to be reflected in Michigan electric utility forecasts.

Unlike central station power, there is relatively little cost and operating history available in the public domain regarding many alternative generation technologies, including some of those technologies that the Workgroup identified as promising. The Workgroup participants' best estimates of the cost, performance and availability of these technologies are summarized in the three documents: Chapter 5A: Combined Heat and Power; Chapter 5B: Distributed Generation and Related Technologies Matrix; and Chapter 5C: Smart Power Grid and Related Technologies.

## **2. Distributed Generation Resource Assessment**

Distributed Generation resources can include both stand-alone resources and those intended to operate in parallel with the utility distribution system.<sup>71</sup> DG can be beneficial to both the electricity consumers served by the DG and to the utility system as a whole, if the systems are properly engineered and the power output is carefully integrated into the grid. Workgroup participants generally acknowledge and accept that centralized electric power plants will remain the major source of base-load power supply for the foreseeable future. However, DG can complement central station power plants by providing incremental capacity to the utility grid or to an end user, providing back-up power in emergencies, and providing more personalized energy options to meet customer needs. Installing DG at or near the end user can also, in some cases, benefit the electric utility by allowing the reduction, postponement, or avoidance of otherwise required transmission and distribution system upgrades. For the consumer, the potential lower cost, higher service reliability, high power quality, increased energy efficiency, and energy independence are all reasons for continued interest in DG.

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<sup>71</sup> Any electrical connection/interconnection between a given utility distribution system and a DG generation source, usually governed by an inverter, which controls, protects and filters direct current (DC) input to alternating current (AC) output power such that parallel operation can occur.

The following DG technologies were evaluated by the Alternative Technologies Workgroup:

1. combined heat and power; fuel cells;
2. reciprocating engines;
3. Stirling engines; and
4. micro-turbines and small-scale combustion turbines.

In addition to these DG technologies, advanced energy storage and battery systems were also investigated by Workgroup participants.

## **2.1 Combined Heat and Power**

Combined heat and power technology often takes process steam generated by industrial or large commercial boilers and passes the steam through a turbine generator before it is used for its ultimate purpose. In some applications natural gas fires a combustion turbine or reciprocating engine and the waste heat in the exhaust or cooling water is used to make steam, hot water, or direct heat for process use at the site.<sup>72</sup> CHP technology offers increased fuel efficiency compared to traditional, central station power generation units.<sup>73</sup> The scale of these installations can range from a fraction of a megawatt per unit to installations comprising multiple units of over 1,000 megawatts (MW).<sup>74</sup>

CHP is practically synonymous with the term, cogeneration. These are installations in which waste heat (almost always in the form of steam or hot water) is captured and used to heat buildings and/or drive turbines in order to produce electricity on-site. (Other uses include absorption chillers and to provide hot water for cleaning.) There is significant CHP technical potential in Michigan, due to the large existing base of manufacturing and industrial facilities. This potential was explored in depth by the CHP Team as part of the Plan development process.

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<sup>72</sup> For more information about CHP, see the U.S. Combined Heat and Power Association website, <http://uschpa.admgt.com/index.html>.

<sup>73</sup> The conversion of fuel energy to useful work in a typical central-station electric generator is typically on the order of 30-40 percent efficient, and then from 5-15 percent of that electricity can be lost in transmission and distribution, so that the total efficiency of conversion from fuel to customer's electric outlet is frequently between 25-33 percent. That is, for each one unit of energy delivered to the customer in the form of electricity, about three to four units of fuel energy are used. CHP systems increase efficiency very substantially by converting fuel energy to two or more forms of useful energy, typically making electricity and using as much of the residual thermal energy as practical for some on-site purposes. By locating CHP units as close as practical to both electric and thermal loads, less energy is lost in transmission and distribution, too. Total system efficiencies for CHP applications can often be roughly twice that of central station power plants. See websites of the U.S. Combined Heat & Power Association, <http://www.uschpa.org> and Midwest CHP Applications Center <http://www.chpcentermw.org/home.html>.

<sup>74</sup> In practice, most CHP systems are relatively small in scale (less than 100 MW). There is no technical reason why CHP systems cannot be much larger, as is evidenced by the MCV cogeneration plant in Midland (over 1,200 MW). However, there are few opportunities to use the very large quantities of heat energy associated with central station power plants, so in the past it has been unusual for CHP systems to be built at scales larger than about 100 MW.

The Alternative Technologies CHP Team obtained the most recent boiler data available from the Michigan Department of Environmental Quality, Michigan Air Emission Reporting System (MAERS) in order to improve the accuracy of estimates of the statewide CHP potential. The MAERS data (2005 reporting year) used as part of this process provided a more detailed measurement of CHP potential based on actual fuel consumed annually at Michigan boiler facilities, as reported in the MAERS data. The resulting analysis indicated approximately 720 MW of power could be produced by the various existing systems that have favorable characteristics for CHP installations. This potential CHP capacity, by sector, is depicted in Table 1.<sup>75</sup>

**Table 1: Michigan Estimated CHP Potential**

<b>Sector</b>	<b>Percent of Total</b>	<b>Total CHP Potential (MW)<sup>1</sup></b>
Automotive/Transportation	43%	310
Mining/Metal Forming	18%	130
Pulp/Paper	15%	108
Chemical/Pharmaceutical	10%	72
Food Processing	9%	64
Other	5%	36
<b>Total</b>	<b>100%</b>	<b>720</b>

Source: MDE Quality, Michigan Air Emission Reporting System (MAERS) boiler data available from the 2005 reporting year.

<sup>1</sup> The potentials indicated here, in MW, represent 100 percent of the total potential identified by the CHP team. Due to existing economic factors related to fuel and technology costs for CHP, as well as an unfavorable regulatory structure for CHP, it was determined that a 25 percent penetration factor would be used, providing a realistic estimate of the total amount of estimated CHP potential for Michigan.

There is a concern, however, that much of the identified CHP potential is at facilities related to the automotive industry, which is currently running at about 75 percent of capacity and is trending downward. Further, the difficulty of providing adequate incentives to a large number of major industrial firms, to cause them to make significant energy related investments when so many other factors affect the viability of their core business, must be recognized. Not all those facilities will choose to go forward with the development of CHP facilities, regardless of the economics. Experience has shown that it is often difficult for manufacturing facilities to adopt CHP technologies, regardless of the industry type.

<sup>75</sup> For information on existing CHP capacity in Michigan, refer to the CNF report, Appendix F, Pages F1-F5. (Available online at [http://www.dleg.state.mi.us/mpsc/electric/capacity/cnf/othergen/finalreportjan\\_2006.pdf](http://www.dleg.state.mi.us/mpsc/electric/capacity/cnf/othergen/finalreportjan_2006.pdf).)

In addition, the CHP Team with the help of MPSC Staff mailed out a survey questionnaire to select, potential CHP candidates, in order to assess the barriers and issues to implementation of such CHP projects, and hence the market potential for future CHP. The results of the CHP survey and subsequent CHP assessment analysis can be found in Chapter 5A of Appendix Volume II which is the Combined Heat and Power (CHP) document. Survey respondents indicated that major impediments to adoption of CHP units include high fuel costs (typically, for natural gas) and utility standby rates.<sup>76</sup>

Given the dynamics presently affecting the automotive industry in particular and Michigan manufacturing in general, the CHP Team determined that for modeling purposes it would be prudent to reduce the amount of potential capacity from industrial and institutional facilities with large boilers to 180 MW. This is based on the assumption is that approximately 25 percent of all the candidate facilities would apply CHP technology, down from the 50 percent assumption made in the CNF study. Also, it should be noted that the facilities identified as potential candidates for CHP applications are overwhelmingly industrial operations. That is a result of the CHP Team focus on boilers that produce rather high temperature and pressure steam. In addition to those candidate facilities however, many institutional and commercial facilities may also be good candidates for CHP applications. Thus, the adoption rates modeled for the Plan are not as aggressive as they would first appear. Nevertheless, the CHP team believes the quantities presented for the Plan's expansion modeling are both technically and economically possible, but it should be understood that reaching this level of adoption would be a significant challenge and some important public policy changes, as discussed in the Policy document of Appendix Volume I, might be required in order to attract sufficient interest in the pursuit of these CHP opportunities.

## **2.2 Fuel Cell Technologies**

In fuel cells, hydrogen and oxygen are separated by an electrolyte, inducing an electrochemical potential. The kind of electrolyte used determines the kind of chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable.

Fuel cell types include phosphoric acid, molten carbonate, solid oxide and proton exchange membrane. Phosphoric acid fuel cells and to a much smaller extent molten carbonate fuel cells, are available commercially now, and proton exchange membrane fuel cells have been used in a limited way in standby applications. Advances in other fuel cell technologies may enable their increased commercialization in the near future. The various types of fuel cells can be fueled by natural gas, hydrogen, biogas, methanol, or propane. Today however, hydrogen – usually extracted from natural gas – is the most commonly used source for fuel cells. Companies developing products for utilities and electric customers are concentrating on fuel cells that run on

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<sup>76</sup> It should be noted that recent changes in wholesale markets could allow the option of purchasing standby power either through bilateral contracts with non-utility suppliers or through day-ahead or real-time wholesale markets. Thus, the impression that high utility standby rates remains an obstacle to CHP adoption needs to be reexamined and existing Michigan utility rates and tariffs for interconnected CHP systems may need to be revised to reflect current market conditions.

natural gas, but the automotive industry is investigating models that would run on gasoline or methanol. Appropriate applications of fuel cells include rural off-grid power supply, microgrids,<sup>77</sup> portable power generation, back-up for uninterrupted power needs, and other uses. See Chapter 5B of Appendix Volume I which is the Distributed Generation and Related Technologies Matrix document for additional details.

### **2.3 Reciprocating Engines**

Most of us are familiar with reciprocating engines, such as those found in cars, trucks, light planes, or even trains. Annual North American production tops 35 million units for cars, trucks, heavy equipment, and a wide variety of power generation applications, from small backup power systems to utility-size units. For power generation, internal combustion (IC) engines benefit from having the lowest first cost, by being easy to start, and by being reliable when properly maintained. IC engines are well suited for standby, peaking, and intermediate power applications, as well as for combined heat and power in commercial, institutional, and light industrial applications of less than 10 MW. Two main IC engine types are used for power generation – the four-cycle, spark-ignition and the compression-ignition reciprocating engines. To date, reciprocating engines and CHP represent the DG options that have experienced the most significant commercial adoption. See Chapter 5B for additional details.

### **2.4 Stirling Engines**

The Stirling engine was invented in the early 1800s by Robert Stirling, who sought to create a safer, more reliable alternative to traditional steam engines of the time. Stirling engines convert any temperature differential directly to movement: they use a displacer piston to move an enclosed gas back and forth between cold and hot reservoirs. At the hot reservoir, the air expands and pushes a power piston, producing work and displacing the air to the cold reservoir. There, the air contracts and pulls the power piston, effectively closing the cycle.

The Stirling engine itself is a heat recovery device, like the steam turbine. Stirling engines produce mechanical power not by explosive internal combustion, but using the heat produced by an external heat source. Until recently, however, reliability problems have limited their commercial application. Recent test results of "free-piston" Stirling engines have increased confidence in this technology. For example, one free-piston Stirling engine has demonstrated more than 50,000 hours of continuous operation on a single engine/alternator. This high level of availability, however, applies only to the Stirling generator and not the heat source. In addition, it is only in the past decade that a viable "free-piston" Stirling was developed. All Stirling engines can be operated on a wide variety of fuels. When used with fossil and biomass fuel, the continuous-combustion heater head avoids temperature spikes. Thus, in operation, Stirling engines can offer comparatively low emissions that are relatively easy to control. Stirling engines closely couple a burner to a heater-head heat exchanger. The exchanger induces harmonic oscillations in a piston that is placed inside a hermetically sealed container. The piston power is delivered directly by a conventional copper wound induction motor to produce

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<sup>77</sup> The term microgrid refers to viewing individual distributed generators and their associated loads as a subsystem or microgrid. These microgrids require specific attention to operational details required to maintain the transmission grid's integrity.

alternating current power at any desired voltage. More details about Stirling engines can be found in Chapter 5B of Appendix Volume II.

## **2.5 Micro-turbines and Combustion Turbines**

Micro-turbines are a relatively new technology, which is now making the transition to commercial markets. Micro-turbines can run on a variety of fuels, including natural gas, propane, and fuel oil. They consist of a compressor, combustor, turbine and generator. These very small turbines contain essentially one moving part and use either air or oil for lubrication. Micro-turbines require little maintenance, but usually need a major overhaul every four years. They can be used in a variety of applications, including baseload generation, peak shaving and cogeneration or CHP.

Combustion turbines, or gas turbines, consume large quantities of air, compress it and then mix with fuel in a combustor to generate hot gases. These hot gases are converted into useful work by a power turbine, which drives an attached generator to produce electricity. Combustion turbines are a proven industrial and utility technology ranging in size from 30 kilowatts (kW) to hundreds of MW. Emissions from these systems can be controlled to very low levels using dry combustion techniques, water or steam injection, or exhaust treatment. They also require less maintenance than reciprocating engines, and are generally smaller per MW and more modular in size/configuration. Drawbacks include low efficiency at low power due to compressor losses, as well as extremely high combustion temperatures and high blade speeds and a higher first cost basis on units less than 25 MW, when compared to reciprocating engines. More details about micro-turbines and combustion turbines are provided in Chapter 5B of Appendix Volume II.

## **2.6 Advanced Storage and Battery Systems**

Energy storage technologies are generally compared to the cost and performance of lead-acid batteries, since lead-acid batteries have been the standard for over 100 years. Today, there are various advanced battery systems available commercially for use in a variety of electricity storage applications, including balancing renewable energy production and cycling and short-duration emergency power back-up applications. These battery and related electricity storage options will likely play an important and increasing role in the future, in complementing distributed generation technologies and providing on-site energy options for customers. Technologies available include; lithium, nickel cadmium (NiCad), nickel metal hydride (NiMH), lead acid (sealed and flooded) and ultracapacitors. Many other alternative battery technologies exist. However, this report is limited to a discussion of the products most prevalent in the marketplace today and which are briefly summarized in Table 2.

**Table 2: Basic Characteristics of Major Battery Types**

Characteristics	Battery System Type			
	Lead	Cadmium	NiMH	Lithium
Negative electrode	Pb	Cd	H (as MH)	Li
Positive electrode	PbO <sub>2</sub>	NIOOH	NIOOH	Lix COO <sub>2</sub>
Electrolyte	H <sub>2</sub> SO <sub>4</sub>	KOH	KOH	PC OR DMC
Nominal voltage	2	1.2	1.2	4
Specific energy (Watt-hours per kilogram)	35	50	70	120
Energy density (Watt-hours per Liter)	70	75	170	200
Cycle life 80% DOD	150-300	1000+	1300	600
Source: EPRI, <i>Battery Storage: Big Opportunities on a Smaller Scale</i> , spring 2006. See link: <a href="http://mydocs.epri.com/docs/CorporateDocuments/EPRI_Journal/2006-Spring/1013289_storage.pdf">http://mydocs.epri.com/docs/CorporateDocuments/EPRI_Journal/2006-Spring/1013289_storage.pdf</a>				

More details about the various battery and other storage systems investigated for the Plan are provided in Chapter 5B.

## 2.7 Current State of Alternative Generation Options

Combustion turbines and reciprocating engines are commercially available today. Fuel cells, though available, are relatively expensive for most distributed applications. Development work on several fuel cell designs is ongoing and improvements in efficiency and lower costs are likely in the near to intermediate-term future. Stirling engines are also available, although not widely adopted. Stirling engine development work continues to take place. Chapter 5B provides more information on the current and projected state of these generation technologies.

## 2.8 Current State of Energy Storage Options

Four battery technologies are commercially available in various sizes. Lithium ion batteries are used in cell phones and laptop computers because of their small size. Because of their light weight and high energy to weight ratio, lithium ion batteries are also being explored as a preferred option for use in hybrid electric vehicles.

NiMH is used in digital cameras because of its ability to recycle, as well as in hybrid vehicles for the same reason. In the stationary power market, NiMH is beginning to attract customers who are concerned more with life-cycle, rather than initial, costs. NiMH has a long calendar life, limited explosion hazard, is recyclable, and environmentally benign, and has a compact weight and volume. The chemistry of NiMH makes it an ideal battery for storage and recycling applications when used with wind, solar, or peak shaving applications. Cycled once daily, a NiMH battery operating in parallel with one of these generation technologies can be expected to last approximately seven years. A comparable lead acid battery will last only one year.

NiCad batteries have been in the market place for many years as an alternative to lead acid. Because of the environmental hazards associated with exposure to lead and cadmium, there are significant concerns regarding the proper recycling of NiCad and lead acid batteries.

In the near term, lead acid batteries will continue to dominate the battery market because they cost significantly less than NiMH. Many power systems have been developed to work with lead acid and lead acid manufacturers have an OEM (original equipment manufacturer) relationship in the industry to use sealed and valve regulated lead acid batteries with uninterrupted power systems (UPS). As other battery technologies become more available and economies of scale improve, the technologies may gain market share.

The opportunities in renewable energy systems for storage and recycling will be an advantage for NiMH. Recent issues with the volatility of lithium will have to be addressed for the public to be more confident of their use in larger applications. Automotive applications of advanced battery systems for hybrid automobiles should also boost markets for these technologies. Additional details regarding the various battery and electricity storage technologies are included in Chapter 5B.

## **2.9 Economic Considerations for DER Technologies**

Cost is an important factor when considering the purchase of any technology, including DER technologies. However, determining the cost of a DER technology is often times complex and difficult. A unit's cost includes equipment (or capital cost) and other expenses related to installing the equipment, and ongoing costs for operations and maintenance. The supplemental documents include estimated prices where available, associated with the DER technologies analyzed by the Workgroup.

As equipment production levels and sales increase, it is expected that economies of scale in manufacturing and deployment will result in decreased equipment costs. Installation costs can vary widely for a given technology especially for less prevalent technologies, and are often approximately 30 percent of the capital cost, but can equal or exceed capital costs for highly customized applications. Therefore, customers need to carefully consider the expected performance of a proposed DG system, along with its capital and operating costs, in order to determine whether the option is appropriate.

## **2.10 Environmental Impacts of DER Technologies**

A description of each distributed energy resource's air emissions profile and other environmental characteristics are included in Chapter 5B of Appendix Volume II. From that document, it is evident that most of these options have fairly low emissions characteristics, compared to existing central station power plants.

Environmentally, lead acid batteries contribute a significant portion of the lead and acid in the environment. Cadmium has similar disposal issues, and some countries have considered a ban on the cadmium in their landfills. NiMH batteries, on the other hand, are environmentally safe.

### **3. Smart Power Grid Technologies**

Change brought on by national energy policy, market forces, technology and regulation are transforming the various components of our country's traditional electric infrastructure and the way the power grid is operated. For example, new regional commercial patterns are presently developing along with wholesale competition, and additional operational issues such as the deployment of distributed generation resources, are resurfacing. These changes have been underway for approximately the last 10 to 15 years and have drawn attention to the need for improved grid reliability, increased market efficiencies, enhanced customer value, and the application of a variety of new technologies.

Electric industry changes are also being driven by new technologies that are gradually beginning to transform the national power grid from one controlled and operated by electro-mechanical controls to micro processed digital devices. The "Smart Power Grid" is a general concept for this process of transforming the nation's electric power grid by applying computers, electronics, and advanced materials to implement advanced communications, automated controls, and other forms of information technology to improve the economics, reliability and safety of the grid. This vision of a smart power grid integrates energy infrastructure, processes, devices, information, and markets into a coordinated and collaborative process which will allow energy to be generated, distributed, and consumed more effectively and efficiently. Eventually, implementation of smart power grid architecture will enable devices at all levels within the grid (from power generator to customer) to communicate, independently sense, anticipate and respond to real-time conditions by accessing, sharing and acting on real-time information.

Planning, managing, and operating the electric power system in a coordinated and collaborative way can provide many benefits for both customers and power system providers, alike. Ideally, as new technologies become available, they will be integrated into the system where they can be shown to provide higher value. Not all of the technology advances currently envisioned are immediately available for implementation, though. Advanced smart power grid technologies are in many different stages of development and commercialization. Many will require further development, testing, and demonstration before they are ready to be deployed throughout the highly complex power grid, while others are available today. Incremental deployments of the new technologies will happen as their cost effectiveness is demonstrated and as industry participants agree to various applicable standards. Many stakeholder groups are currently involved in the process of organizing, studying, specifying, designing, testing and implementing the hardware and concepts of a Smart Power Grid through a variety of study groups, alliances, collaborative, and pilot projects.

Additional information on technology options, barriers to adoption, commercial readiness, and applications related to smart power grid architecture and communications is presented in Chapter 5C.

#### **3.1 Technology Adoption Issues – Grid Interconnection**

Grid interconnection policies were identified by participants in the Alternative Technologies Workgroup as a particularly important issue associated with the adoption of DG technologies. The Michigan Customer Choice and Electricity Reliability Act (2000 PA 141, Section 10e;

MCL 460.10e) directed the Michigan Public Service Commission to establish standards, “for the interconnection of merchant plants with the transmission and distribution systems of electric utilities ... consistent with generally accepted industry practices and guidelines ... established to ensure the reliability of electric service and the safety of customers, utility employees, and the general public.”<sup>78</sup> The Commission subsequently developed Electric Interconnection Standards rules (R 460.481–460.489).<sup>79</sup>

Once the rules were fully developed, Michigan utilities filed interconnection procedures in concert with those rules.<sup>80</sup> These rules generally provide for the procedures Michigan’s regulated electric distribution companies must employ when considering interconnection requests. They describe the required application process, basic technical criteria, filing fees, and deadlines for the completion of the various steps in the process. The criteria, procedures, and timelines vary for five different categories of generators, based on the size of the generators and the related complexity of the required interconnection and protective equipment. In reviewing technologies for consideration for Michigan’s 21st Century Energy Plan, a critical assumption has been that all interconnections with the utility grid must meet all technical and safety requirements, and must always be operated in a manner that assures the reliability and safety of all utility grid and interconnected equipment and the health and safety of individuals who may come into contact with the grid and its interconnected equipment.

#### **4. Conclusions**

Among all the technologies analyzed by the Alternative Technologies Workgroup, only CHP is included in the expansion plan modeling, because it historically and continues to provide near-term contributions to Michigan’s future electricity infrastructure.<sup>81</sup> Many of the other DG technologies explored for the Plan project can provide specialized applications for power needs, fill important, but limited capacity roles, or are continuing to undergo commercial development.

Similarly, Michigan utility companies are already engaged in a variety of projects that can reflect Smart Power Grid applications.<sup>82</sup> But, implementation of Smart Power Grid applications will be with incremental changes and adaptation over time.

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<sup>78</sup> [http://www.legislature.mi.gov/\(wgbxkq55zjnwtc2ym2nhu145\)/mileg.aspx?page=getObject&objectName=mcl-460-10e](http://www.legislature.mi.gov/(wgbxkq55zjnwtc2ym2nhu145)/mileg.aspx?page=getObject&objectName=mcl-460-10e).

<sup>79</sup> [http://www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin\\_Num=46000481&Dpt=&RngHigh=48702110](http://www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin_Num=46000481&Dpt=&RngHigh=48702110).

<sup>80</sup> The utility procedures were approved in Cases Nos. U-14085 (for Northern States Power Company – Wisconsin, d/b/a.Xcel Energy), U-14091 (for Indiana Michigan Power Company, d/b/a American Electric Power), and U-14088 for all other utilities regulated by the Michigan PSC.

<sup>81</sup> Other forms of DG (reciprocating engines or Stirling engines) can be assumed to be captured as part of the Renewable Energy Workgroup’s modeling estimates. The remainder of DG options studied are considered to be niche applications that are not readily commercially available at competitive prices.

<sup>82</sup> These projects are described in Chapter 5C of Appendix Volume 2 which is the Smart Power Grid and Related Technologies Supplemental Document attached to this report and also posted on the Plan website.