Appendix F

Alternative Generation Work Group Report

Michigan Capacity Need Forum

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Copies of this report are available from the Michigan Public Service Commission's Web site, at: http://www.dleg.state.mi.us/mpsc/electric/capacity/cnf.

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1 Introduction

In Case No. U-14231 the Michigan Public Service Commission (MPSC) established the Capacity Needs Forum (CNF). The goal of this forum is to develop forecasts of optimum power supply and demand for Michigan. As part of the forum, the Alternate Generation Work Group was formed to evaluate nontraditional power supply options that would be feasible within Michigan. Specific tasks include: (1) Define the most promising alternates to traditional generation; (2) Quantify the cost structure of these alternatives; and (3) Determine the capacity that could be on-line by approximately 2009, and detail the location of that capacity by three geographic areas in Michigan (Upper Peninsula, Southeast Michigan, and the balance of the Lower Peninsula).

2 Promising Alternatives

The Work Group decided to evaluate four technologies based on cost, suitability within Michigan, commercial viability, and the availability of data for modeling purposes. The technologies included combined heat and power (CHP), onshore wind energy, landfill gas, and farm based anaerobic digestion. Other technologies that have potential were classified as emerging technologies. They might include, for example, solar electric and solar thermal, small scale biomass and wind, and small scale CHP. However, production from emerging technologies was not incorporated into the data submitted for modeling purposes to the CNF Integration Work Group. At least to some extent, such technologies will be more easily modeled as reductions to demand, rather than as additions to supply. Thus, it can be assumed that at least some contribution from emerging technologies will be captured in historical demand trends. In the future, it may be possible to more accurately predict market penetration from some of these emerging technologies, in which case they might be explicitly incorporated into one or more demand scenarios. In the meantime, such technologies for renewable energy are being explored through the Michigan Renewable Energy Program's various committees and future MREP reports will provide market penetration estimates.

Unlike central station power, there is relatively little cost and operating history available in the public domain for alternative generation, including those technologies that the Work Group identified as promising. While the Work Group compiled sufficient data to develop estimated fixed and operating costs and quantities of alternative generation, it should be noted that the results are current estimates and that technological improvements are continuing. As more information becomes available, the Work Group may update the findings that have been included in this report.

2.1 Combined Heat and Power (CHP)

CHP technology takes process steam generated by industrial or large commercial boilers and passes the steam through a turbine before it is used for its primary 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. This technology provides improved fuel efficiency, compared to generation-only combustion, by effectively utilizing the same fuel source energy twice, once for generation and then for process heat. Such fuel efficiency savings can be up to 60 percent, compared to a traditional, central-station power generation unit.[1] The scale of these installations can range from a fraction of a megawatt per unit to over 1,000 megawatts (MW) per unit.

There is an estimated 4,580 MW of CHP currently installed in Michigan. Of this, 2,419 MW (52%) of CHP is at the Midland Cogeneration Venture (MCV) and the Dearborn Industrial Generation sites, serving Dow Chemical and Dow Corning and the Ford/Rouge industrial complex, respectively. An additional 990 MW (22%) of installed CHP capacity is at eight different utility-owned sites. The installed base of remaining 26 percent of Michigan's CHP capacity is divided among six main sectors, as shown in Table 1.

Table 1: Michigan CHP Capacity

Sector	CHP Capacity (MW)
Pulp and Paper	209
Educational	132
Other Automotive	63
Other Industrial	67
Municipalities	17
Hospitals	5
Total	**493**

Data from the Michigan Boiler Permit database, U.S. EPA E-Grid database, and Midwest CHP Applications Center database, suggests there is up to 1,471 MW of additional base load capacity for CHP that could be developed in Michigan. The Work Group believes that 37 companies that have existing large boilers (100,000+ lbs/steam/hr) have the best potential, to provide an estimated 1,084 MW of CHP capacity. This potential capacity by sector is depicted in Table 2.

[1] The conversion of fuel energy to useful work in a typical central-station electric generator is typically on the order of 30-40% efficient, and then from 5-15% 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 1/4 to 1/3. That is, for each 1 unit of energy delivered to the customer in the form of electricity, about 3 to 4 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, much 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 Web sites of the U.S. Combined Heat & Power Association, http://www.uschpa.org and Midwest CHP Applications Center http://www.chpcentermw.org/home.html.

Table 2: Michigan Estimated CHP Potential

Sector	%	Potential (MW)
Automotive/Transportation	43%	466
Mining/Metal Forming	18%	193
Pulp/Paper	15%	159
Chemical/Pharmaceutical	10%	108
Food Processing	9%	99
Other	5%	59
Total	**100%**	**1,084**

The potential industrial CHP shown in Table 2 is divided by region as shown in Table 3.

Table 3: Michigan Potential CHP by Region

Source of Potential CHP	ITC	METC	ATC	Total
Industrial/Institutional w/Large Boilers[1]	543	504	37	1,084
Industrial/Institutional w/Mid-sized Boilers	70	209	41	320
Total	**613**	**713**	**78**	**1,404**

[1] The Alternative Generation Work Group recommended for inclusion in CNF modeling only 547 MW, 1/2 of the potential from large boilers.

An itemization of installed and potential CHP by fuel type and by Service Territory is shown in Table 4.

Thus, more than 300 MW of potential CHP could be fired by current coal-fired boiler systems, and more than twice that could be available if current gas-fired boiler systems were to be converted.

Finally, there is concern that much of the current CHP potential is related to the automotive industry, which is currently running at 75 percent of capacity and trending downward. Given these dynamics, the Work Group determined it would be prudent to reduce the amount of potential capacity from industrial/institutional facilities with large boilers to 1,000 MW, down from 1,084 MW. Further, the difficulty of providing adequate incentives to a large number of major industrial firms, to cause them to make major investments in their capital stock for energy purposes 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. A reasonable level of ultimate development would likely be closer to 50 percent of the original potential (547 MW), phased in over several years.

Table 4: Installed and Potential Michigan CHP by Fuel Type

Fuel Type	Coal			Gas			Oil			Total
Transmission Area	ITC	METC	ATC	ITC	METC	ATC	ITC	METC	ATC	
Installed CHP (excluding MCV & DIG)	2	67	5	1,113	39	50	0	0	67	1,343
Potential CHP w/Large Boilers	140	166	0	315	316	17	0	0	0	954
Potential CHP w/Mid-sized Boilers	0	18	14	60	175	17	10	12	6	312
Total Potential	140	184	14	375	491	34	10	12	6	1,266
Total Potential by Fuel	Coal = 338			Gas = 900			Oil = 28			

The Work Group's assumptions regarding the estimated cost structure for large-scale CHP systems is presented in Table 5.

Table 5: Large Scale CHP Estimated Cost Structure

	Coal Fired	Gas Turbine	Gas Engine
Assumptions			
Capital Installed Costs ($/kW)	$1,800	$900	$1,200
Capital Recovery Rate (%)[1]	14%	14%	14%
Annual Operating Hours	8760	8760	8760
Capacity Factor (%)	85%	90%	95%
Gross Heat Rate (Btu/kWh)	10,000	9,200	10,400
Recoverable Heat (Btu/kWh)	6,000	3,200	3,300
Efficiency for 150 PSI Steam (Btu/kWh)	4,000	6,000	7,100
Fuel Costs ($ per million Btu)	$3.20	$7.00	$7.00
Resulting Costs per kWh			
Capital Recovery	$0.03	$0.02	$0.02
Fuel	$0.01	$0.04	$0.04
O&M (incremental over process heat)	$0.01	$0.00	$0.01
Average Cost of CHP Power:	$0.05	$0.06	$0.07
[1] For illustrative purposes.			

The Work Group believes it is also important to note that there is a huge untapped potential market for CHP at smaller industrial facilities. Changes in the economics – through any combination of changes in fuel costs, technology improvements, or utility rate structures – could lead to rapid deployment. For the time being, however, the Work Group considered small scale CHP to be an emerging technology.

2.2 Wind Energy

Wind generation technology today is most commonly comprised of a generator placed atop a 70-90 meter tower and driven by three 30-meter-long wind turbine blades. Output of each generator is between one and three megawatts. Groups of turbine generators are located in favorable locations (wind farms) that provide consistent winds with substantial velocity to drive the wind turbines.

Based on data from the National Renewable Energy Laboratory (NREL), approximately 830 MW of Class 4 (high quality) or higher wind capacity exists on-shore in Michigan.[2] Taking into account siting issues, transmission constraints, the need for large tracts of land to achieve economies of scale, and lack of specific wind data at the potential sites, the Work Group decided to take a conservative approach and estimate approximately 50 percent or 415 MW of capacity could feasibly be installed within the timeframe of the study. Of this amount, an estimated 95 MW exists in the Upper Peninsula, 50 MW in Southeast Michigan and the balance of 270 MW is available in the remainder of the Lower Peninsula. The estimated cost structure for Class 4 and higher wind systems is shown in Table 6.

Capital cost was based on five 1.5 MW wind turbines at an elevation of 80 meters. These costs are based on an estimated 25 percent annual capacity factor and monthly on and off peak average wind speeds to calculate capacity factors that would equate to the 25 percent annual number. Capacity factor calculations are difficult for wind generation because wind speed varies significantly both by location and due to variable weather and climate conditions. The capacity factors used by the Work Group, as shown in Table 7, are based on average wind speeds recorded at the Muskegon Airport.

[2] See the report, *Potential for MI Offshore Wind Energy*, at http://www.dleg.state.mi.us/mpsc/electric/capacity/cnf/othergen/other.htm.

Table 6: Michigan Estimated Cost Structure for Class 4 and Higher Wind Systems

Assumptions	
Capital Installed Costs ($/kW)	$ 1,200
Capital Recovery Rate (%)[1]	14%
Annual Operating Hours	8,760
Capacity Factor (%)	25%
Efficiency (Btu/kWh)	-
Fuel Costs ($ per million Btu)	$ 0.00
Resulting Costs per kWh	
Capital Recovery	$ 0.077
Fuel	$ 0.000
O&M	$ 0.010
PTC (10 Years Only)[2]	($ 0.018)
Average Cost of Wind Power:	$ 0.069

[1] For illustrative Purposes.
[2] The Federal Production Tax Credit (PTC) for wind power was originally enacted as part of the Energy Policy Act of 1992 and was first scheduled to sunset on June 30, 1999. The PTC has been extended by Congress four times. The most recent extension, in the Energy Policy Act of 2005, is through December 31, 2007. The PTC provides a 1.9-cent per kWh incentive for the first ten years of a facility's operation.

Table 7: Capacity Factors Based on Average Wind Speeds at the Muskegon Airport

Month	Weighted Average Wind Speed	On-Peak Wind Speed	Off-Peak Wind Speed	On-Peak Capacity Factor	Off-Peak Capacity Factor	Weighted Capacity Factor
January	8.52	8.68	8.19	45.66	37.44	41.55
February	8.21	8.47	7.70	42.42	31.11	36.77
March	7.61	8.06	6.72	36.56	20.68	28.62
April	7.60	8.00	6.81	35.75	21.52	28.63
May	7.34	7.99	6.05	35.61	15.09	25.35
June	6.42	7.18	4.92	25.84	8.12	13.98
July	5.94	6.73	4.37	21.28	5.69	13.48
August	5.59	6.35	4.05	17.88	4.53	11.20
September	6.63	7.17	5.55	25.73	11.65	18.69
October	6.57	6.84	6.03	22.34	14.94	18.64
November	7.67	8.01	6.98	35.88	23.18	29.53
December	7.69	7.86	7.36	33.90	27.17	30.54
Total	**7.15**	**7.61**	**6.23**	**31.57**	**18.43**	**25.00**

2.3 Landfill Gas

Landfill gas technology involves extracting methane gas produced from waste buried in landfills and using the gas to fuel micro-turbines or other internal or external combustion engines to produce electricity. In the past the methane would typically be flared. If the gas were not flared, then the methane, a potent greenhouse gas, would be emitted. Since the methane gas production is anaerobic (absent the presence of oxygen), the rate at which methane is extracted is somewhat limited. If it is extracted too rapidly, oxygen will be pulled into the buried landfill and the anaerobic process will be disrupted. However, technology and operating experience have developed sufficiently so that landfill generators can now vary the production of electricity to follow load.

Currently there are 79 MW of landfill gas generators in Michigan. Expansion potential at these sites is estimated to be 54 MW to provide a total of 123 MW of capacity. New sites are also expected to be developed, which are estimated to be capable of providing another 104 MW of capacity over the next ten years. The geographic locations of these sites and existing and potential capacity are shown in Table 8.

Table 8: Geographic Location of Existing Michigan Landfill Sites and Potential Capacity at sites.

	Existing	Expansion	New	Total
Upper Peninsula	0	0	2	2
SE Michigan	53	29	62	144
Balance of Lower Peninsula	26	15	40	81
Total	**79**	**44**	**104**	**227**
Source: Data on landfills from Michigan Department of Environmental Quality.				

Since new landfill gas sites will be smaller in size, require transmission, and will not likely be able to utilize the existing interconnect, the capital costs are estimated to be approximately 30 percent higher than for expansions at existing sites. The typical unit size is 800 kW and all expansion would be in 800 kW increments. Capacity factors were based on sufficient landfill gas being available for all on-peak periods to provide full generator output. The estimated cost structure for landfill gas generation is shown in Table 9.

Based on operating experience of existing facilities, both new units and expansions will be capable of achieving 95 percent annual availability rates. Incremental emissions are considered to be zero because of the need to otherwise flare the methane generated by the landfill**.**

Table 9: Estimated Cost Structure for Landfill Gas Generation

Assumptions	**New**	**Expansion**
Capital Installed Costs ($/kW)	$ 1,200	$ 1,000
Capital Recovery Rate (%)[1]	14%	14%
Annual Operating Hours	8,760	8,760
Capacity Factor (%)	90%	90%
Efficiency (Btu/kWh)	10,000	10,000
Fuel Costs ($ per million Btu)	$ 1.80	$ 1.80
Resulting Costs per kWh		
Capital Recovery	$ 0.021	$ 0.018
Fuel	$ 0.018	$ 0.018
O&M	$ 0.030	$ 0.030
Average Cost of Power	$ 0.069	$ 0.066
[1] For illustrative purposes.		

2.4 Anaerobic Digesters

Like landfill gas, anaerobic digesters produce methane from farm waste (typically cattle waste, but sometimes blended with other agricultural or food processing waste materials) and use it to fuel engines for power generation as well as for farm heat. Farm digesters require that a digester dome be constructed to capture the methane as it is produced. This process becomes economically feasible for herds of over 500 head of cattle. Due to the manure management practices of different types of farms, this usually means that large dairy farms are the most likely candidates for anaerobic digesters. The Work Group estimates that there are farms in Michigan that could use anaerobic digesters to produce approximately 51 MW. The geographic locations of these farms are shown in Table 10.

Table 10: Estimated MW Production by Anaerobic Digesters in Three Michigan Regions

Upper Peninsula	2
SE Michigan	5
Balance of Lower Peninsula	44
Total	**51**

It should be noted that very limited cost and operational data is available about anaerobic digestion. The Work Group's best estimates are presented in Table 11.

Table 11: Estimated Cost and Operational Data of Anaerobic Digesters

Assumptions	
Capital Installed Costs ($/kW)	$ 2,500
Capital Recovery Rate (%)[1]	14%
Annual Operating Hours	8,760
Capacity Factor (%)	90%
Efficiency (Btu/kWh)	10,000
Fuel Costs ($ per million Btu)[2]	($ 0.00)
Resulting Costs per kWh	
Capital Recovery	$ 0.044
Fuel	$ 0.000
O&M	$ 0.025
Average Cost of Power	$ 0.069

[1] For illustrative purposes.

[2] Fuel costs are shown as zero. It should be noted that the residue that remains after anaerobic digestion usually can be land-applied as a fertilizer and soil amendment. Thus, there may be some additional residual value to more than offset any costs associated with delivering waste materials, as feedstocks, to an anaerobic digester.

3 Summary

The four technologies studied have the potential to provide nearly 1,200 MW of capacity in Michigan by approximately 2009. The capacity and cost by technology is summarized in Table 12.

Table 12: Technology Capacity and Cost

Technology	**MW**	**$/kWh**
CHP – Coal	182	$0.052
CHP – Gas	365	0.061
Landfill Gas – Expansion	44	0.066
Landfill Gas – New	104	0.069
Anaerobic Digesters	51	0.069
Wind	415	0.069
Total/Average	**1,161**	**$0.064**

This analysis did not include any incentives for emissions reductions or subsidies for green/renewable energy programs. It did assume that the current wind energy production tax credit program would be extended. Such programs can be instrumental in improving the cost structure of the four technologies that were evaluated.

Alternative generation resources can play a significant role in capacity growth within Michigan. Due to their generally smaller size and lower environmental impacts, alternative units typically could be brought on line within a shorter timeframe compared to central station power plants. This generation could provide a stopgap solution for meeting projected capacity needs.

Extensive data analyses have been performed to support the conclusions in this report. Information detailing the data compiled and analyses undertaken is described in the following reports:[3]

- CHP Summary Data
- Hourly Wind Capacity Factors
- Michigan Wind Energy Potential
- Landfill Gas Cost Data
- Anaerobic Digester Cost Data

4 Emerging Energy Technologies

As noted in the beginning of this report, there are a number of emerging energy technologies that could play significant roles in satisfying Michigan's future electric infrastructure needs. Unfortunately, at this time, there are too many unknowns associated with these technologies to make any reasonable projections of the contributions they might make to Michigan's energy future. The Alternative Generation Work Group recommends regular review and update of technology information, through the Michigan Renewable Energy Program Collaborative process and as a follow-up to the CNF, to prepare and maintain current analyses of alternative options.

4.1 Solar Photovoltaic Systems

Photovoltaic (PV) technology, including some commercial applications, has been in existence for decades. It was born in the U.S. in 1954 when Bell Labs researchers developed the first silicon photovoltaic cell. However, for purposes of the Electric Capacity Need Forum and utility scale electric generation, PV systems are still fairly expensive. This is due in part to the high cost of semi-conductor materials. For purposes of the CNF, this technology is still considered an emerging technology. It should be noted, however, that PV systems are already cost effective in many niche applications, especially for off-grid and portable power (e.g., calculators, watches and other small

[3] To learn more about these topics, the reader is encouraged to visit the CNF website and consult the Alternate Generation Work Group's products. These reports are available on the CNF Web site at: http://www.cis.state.mi.us/mpsc/electric/capacity/cnf/othergen/other.htm.

consumer products, mobile highway signs, solar attic fans, battery charging on boats and recreational vehicles, etc.).

PV costs continue to drop and PV technology has many attractive attributes including no air pollution and peak production in the summer when electric demand is high. Distributed PV systems, like other distributed energy resources, can help to minimize line losses and improve system reliability. PV systems are popular with the general public and progress with building-integrated systems is helping to minimize aesthetic concerns. PV systems could be considered a demand-side measure that could help reduce peak electric power demands, assuming that customers were provided a sufficient incentive to encourage greater market penetration.

4.2 Urban Wind Generators

The wind generators most familiar throughout the U.S have horizontal axis blades. Vertical axis rooftop wind turbines are being developed by McKenzie Bay International. Wind resource evaluations are being performed for a number of buildings including a 22-story condominium complex in downtown Toronto and five Michigan sites.[4] Vertical axis wind generators are also being considered for the Freedom Tower that will be built on the former site of the World Trade Towers in New York City. The Freedom Tower is to rise 70 floors and be topped by wind turbines that designers predict will provide 20 percent of the building's electricity. If plans to commercialize the technology are successful, these systems are likely to be cost competitive in many installations.

Other new types of small wind generators are being developed for use by homeowners. For example, Aerotecture, a small company in Illinois, is developing a 1,500-watt (1.5 kW) wind generator for urban use. The generator could be installed on the roofline of a house and would have very low startup speeds. According to the manufacturer, the low speed operation and rigid structure eliminates maintenance and noise concerns and improves performance throughout the year. Unless combined with battery storage, however, it is not likely that these systems would significantly reduce peak loads.[5] In Michigan, wind speeds tend to be low during the same weather patterns that lead to the highest demands for air conditioning, and therefore the highest summer peak loads.

4.3 Offshore Wind Generators

New wind energy resource maps for Michigan indicate a significant energy resource offshore in the Great Lakes. Wind speeds in the offshore areas are considered excellent for wind energy development. The National Renewable Energy Laboratory has estimated that Michigan has over 44,000 MW of wind energy potential in the area between 5 and 10.8 nautical miles offshore (about 10-20 kilometers). Exclusions include all areas less

[4] McKenzie Bay has already broken ground for its first Michigan project, which is in Ishpeming. See http://web.mckenziebay.com/.
[5] See *Wind Capacity Credits* draft report and presentation, at http://www.dleg.state.mi.us/mpsc/electric/capacity/cnf/othergen/other.htm.

than 5 nautical miles from shore and 2/3 of the area between 5-10.8 nautical miles.[6] Although the costs associated with offshore development are presently higher than on land, it is expected that the superior offshore wind production capability will more than make up for the cost differential. That has been the experience with offshore wind developments in Europe, which have been growing very rapidly. In Europe, installed wind generation capacity in offshore areas grew from zero in the early 1990s to 613 MW by October 2004. An additional 20,000 MW of offshore capacity is now being explored or already under development in Europe. A large number of issues – environmental, economic, regulatory, and technical – would need to be addressed before any development could take place in the Great Lakes. However, it is expected that significant development could occur before the end of the 20-year time horizon being addressed by the CNF.

4.4 Fuel Cells

Fuel cells use hydrogen or hydrogen-derived from other fuels, such as methanol, ethanol, natural gas, gasoline, or diesel fuel, to produce electricity. Waste heat from a fuel cell can be used to provide hot water or space heating. More than 2,500 fuel cell systems have been installed as stationary power sources all over the world – in hospitals, nursing homes, hotels, office buildings, schools, utility power plants, a police station, and an airport terminal – providing primary or emergency power backup.

According to Allied Business Intelligence, Inc., the current $40 million stationary fuel cell market will grow to more than $10 billion by 2010, and the overall fuel cell energy capacity will increase by a factor of 250, with global stationary fuel cell capacity jumping to over 15,000 MW by 2011 from just 75 MW in 2001.[7]

[6] See *Wind – MI Energy Potential, 2006-2020, Draft Report*, pp. 7-8, at http://www.dleg.state.mi.us/mpsc/electric/capacity/cnf/othergen/other.htm.

[7] "Fuel Cell Vehicles to Number 800,000 by 2012, According to ABI," Oyster Ball, New York www.alliedworld.com