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7.6 CLEAN ENERGY

2016

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7.7 CLEAN ENERGY: Solar, wind, geothermal, and biomass

7.7.1 *What is clean energy?*

In this chapter, clean energy refers to renewable energy sources that have low emissions and lower environmental impacts than coal, petroleum and other fossil fuels.[1] Clean energy includes solar, wind, geothermal, biomass, and hydropower. Although biomass is sometimes considered a form of clean energy, it can be a significant contributor to greenhouse gases and other harmful air pollutants (see Section 7.7.2.4). Although some definitions of clean energy include nuclear power since this source of energy can have lower greenhouse gas emissions than traditional fossil fuel-based generation sources, we do not consider nuclear power extensively in this chapter. We do not include natural gas as a clean energy source since this fossil fuel does not share the same benefits as renewable energy (e.g., low greenhouse gas emissions), although this is one of the "cleaner" fuels and is widely touted as "clean." This chapter focuses on clean energy sources for electricity generation. (See Section 7.8 for more information on clean fuels.)

Clean energy lowers emissions of air pollutants, including both toxic pollutants and greenhouse gas emissions. This is accomplished by displacing "dirty" sources of energy, including coal, oil, diesel, gasoline, and other fossil fuels. Emissions can be reduced by improving energy efficiency, which reduces the energy required. Energy efficiency often is the most cost-effective and short-term strategy to reduce emissions and adverse impacts from "dirty" energy sources.

Today, nearly half (46.4%) of Michigan's electricity is generated by burning coal.[2] There are no active coal mines in Michigan, and coal is imported from Wyoming and Montana, by rail.[3] Because most of Michigan's coal-fired power plants are old and do not have modern emission controls, Michigan's electricity is a particularly "dirty" source of energy. The emissions, health and environmental impacts of coal-fired power plants, discussed in Section 5.5 of this Resource Manual, could be offset by clean energy. Nuclear power accounts for 26% of Michigan's electricity; [4] renewables could replace nuclear energy as older plants are phased out and decommissioned.

Currently, only about 8% of Michigan's electricity comes from renewable sources. Across the United States, the use of renewable energy is expected to rise over the next few decades. While energy forecasts are uncertain, one estimate is that renewable energy will account for about 18% of electricity in the U.S. in 2040, up from 13% in 2013, as shown in Figure 7.7-1. The largest gains in renewable energy are expected for solar

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1 EPA (Environmental Protection Agency). Energy and Environment. Available:https://www.epa.gov/energy/learn-about-energy-and-environment [accessed 3-2-16] and EPA (Environmental Protection Agency). State and Local Climate and Energy Program. Available: http://www3.epa.gov/statelocalclimate/local/topics/renewable.html [accessed 3-2-16].

2 US Energy Information Administration. 2016. State Profile and Energy Estimates: Michigan [WWW Document]. URL http://www.eia.gov/state/?sid=MI [accessed 5-22-16].

3 US Energy Information Administration. 2016. Michigan: State Profile and Energy Analysis. Available: https://www.eia.gov/state/analysis.cfm?sid=MI. [accessed 8-25-16].

4 US Energy Information Administration, 2016. State Profile and Energy Estimates: Michigan [WWW Document]. URL http://www.eia.gov/state/?sid=MI [accessed 5-22-16].

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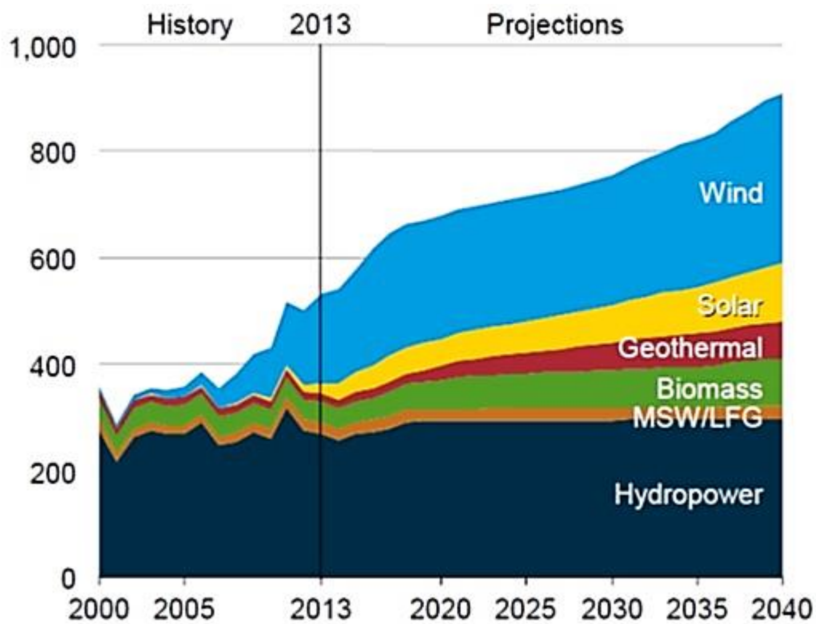
and wind.[5] Much larger increases in the renewable share are possible, and energy forecasts typically present bounding cases (best and worst-cases) to account for the uncertainty.

Figure 7.7-1. Historical and forecasted trends of renewable electricity generation by fuel type in the United States, 2000-2040. Data prior to 2013 are based on historical data. Data after 2013 are based on projections that assume the gross domestic product increases at an annual rate of 2.4% and that current laws and regulations do not change through 2040.[6]



7.7.2 *What types of clean energy can be used?*

7.7.2.1 *Solar*

Solar energy comes directly from the sun; technologies for harnessing this energy include photovoltaic cells, concentrated solar power (CSP, also called solar thermal technology), and passive solar heating. Solar energy is considered one of the cleanest and most abundant forms of clean energy.[7]

5 US Energy Information Administration. 2015. Annual Energy Outlook 2015 with Projections to 2040. Available: http://www.eia.gov/aeo/ accessed 5-23-16].

6 US Energy Information Administration. 2015. Annual Energy Outlook 2015 with Projections to 2040. Available: http://www.eia.gov/aeo/ [accessed 5-23-16].

7 EPA (Environmental Protection Agency). Solar Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/solar.html [accessed 3-2-16].

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Photovoltaic (PV) cells absorb light and convert it to electricity; cells are placed together to form solar panels. Figure 7.7-2 provides a sketch of a PV cell, which generates electricity when photons from the sun "knock loose" electrons within the PV cell semiconductor material that then form an electrical current. Solar panels can be installed on existing structures, e.g., roofs and shade covers over parking lots, or directly on the groud. Solar panels can have a "fixed" orientation or can turn to "track" the sun's path across the sky, which maximizes generating potential. Distributed PV systems place panels near "load centers" (locations where electricity is used), e.g., on a building's roof; such systems may or may not be connected to the grid. In a centralized PV system, large numbers of solar panels are grouped together in a single location (sometimes called "solar farms" or "solar parks"), connected to the electrical grid, and electricity is distributed to consumers.[8]

The price of PV has fallen dramatically in recent years and these systems are often very competitive to other energy systems. PV costs may be lower than wind systems of comparable size.[9] Once installed, solar panels have low maintenance and low operating costs. After recovering the installation costs, electricity from solar panels is essentially "free." In addition, surplus power may be sold back to the grid, which is sometimes called net metering. However, regulatory policies are presently in flux regarding the ability to do this, the price may not be very favorable, and there may be limits on the capacity that can be purchased. A bill in Michigan, S.B. 438, currently under consideration would create disincentives for such sales. This is clearly unfavorable for clean energy.

8 Woods Institute for the Environment, 2010. Distributed vs. Centralized Power Generation. Available: https://woods.stanford.edu/sites/default/files/files/Solar-UD-Distributed-vs-Centralized-Power-Generation-20100408.pdf [accessed 5-21-16].

9 National Renewable Energy Lab, US Department of Energy, 2016. Energy Technology Cost and Performance Data: Distributed Generation Renewable Energy Estimate of Costs [WWW Document]. URL http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html (accessed 5-22-16).

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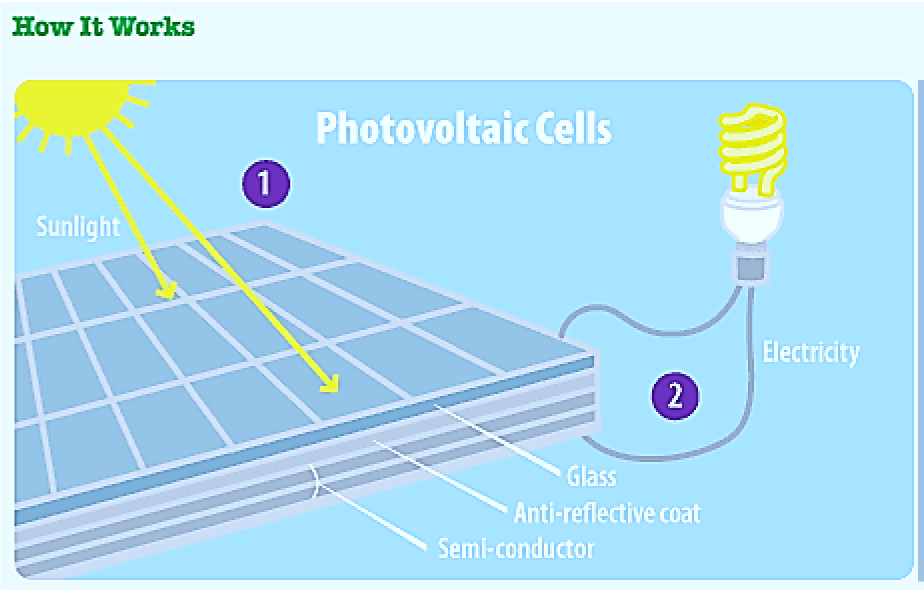
Figure 7.7-2. Schematic of a photovoltaic cell.[10]



1. Sunlight hits the surface of the photovoltaic cell.
2. A material call a semi-conductor converts the light into electricity.

Click here to watch a video

Concentrated solar power (CSP) systems work by directing light from the sun in order to capture the thermal energy. Figure 7.7-3 shows one configuration of a CSP facility. Sunlight is captured by mirrored panels and directed at a pipe containing water or other heat-absorbing materials. This material flows through the pipes, where the heat is exchanged with water to generate steam that turns the turbine generator. CSP facilities for electricity generation are large industrial operations and operate as centralized systems. There are other types of CSP systems that are used to generate hot water (solar water heaters) for businesses and residences. These systems are relatively uncommon, and likely not cost effective in Michigan.

[10] EPA (Environmental Protection Agency). Solar Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/solar.html [accessed 3-2-16].

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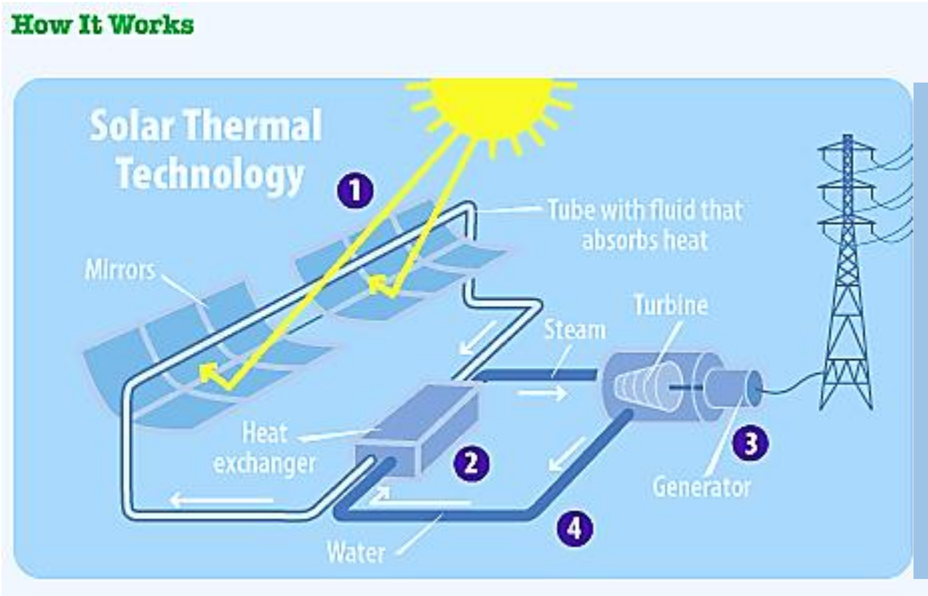
Figure 7.7-3: Schematic of a concentrated solar power system.[11]



1. Mirrors or reflectors concentrate the sun's rays to heat a special kind of liquid.

2. The heat from this liquid boils water to create steam.

3. Steam spins a turbine that is connected to a generator, which creates electricity.

4. The steam cools and condenses back to water, which is recycled, reheated, and converted into steam again.

Click here to watch a video

Passive and solar heating systems are used in buildings, not to generate electricity, but to provide space heating and cooling and to reduce overall energy consumption.[12] In passive solar buildings, solar energy is utilized in the winter to heat the building; in summer, solar energy can be rejected to keep the buildings cool. The design of such buildings include large, south facing windows with overhangs that allow sunlight in during the winter when the sun is closer to the horizon and block sunlight during summer months when the sun is higher in the sky; heat-retaining building and flooring materials; a high degree of thermal insulation; specialized windows, and other features.[13]

Solar energy has several disadvantages. First, it is an intermittent resource, i.e., solar panels can only generate electricity when the sun is shining, and the number of sunny days varies by location. Figure 7.7-4 shows solar resources across the United States. Michigan has relatively modest potential for PV power (approximately 4.0-4.5 kWh/m^2/day).[14] The highest potential is in the desert southwest, e.g., California, Nevada, Utah, Arizona, New Mexico, and Texas. Due to increases in efficiency of solar panels and reductions in production costs, PV is increasingly cost-effective, even in areas with intermittent sunshine. Second, if a large number of solar panels is integrated with the electrical grid, intermittency can lead to instability in the availability of

[11] EPA (Environmental Protection Agency). Solar Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/solar.html [accessed 3-2-16].

[12] Department of Energy, 2016. Passive Solar Home Design [WWW Document]. URL http://energy.gov/energysaver/passive-solar-home-design [accessed -.22-16].

[13] EPA (Environmental Protection Agency). Solar Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/solar.html [accessed 3-2-16].

[14] National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

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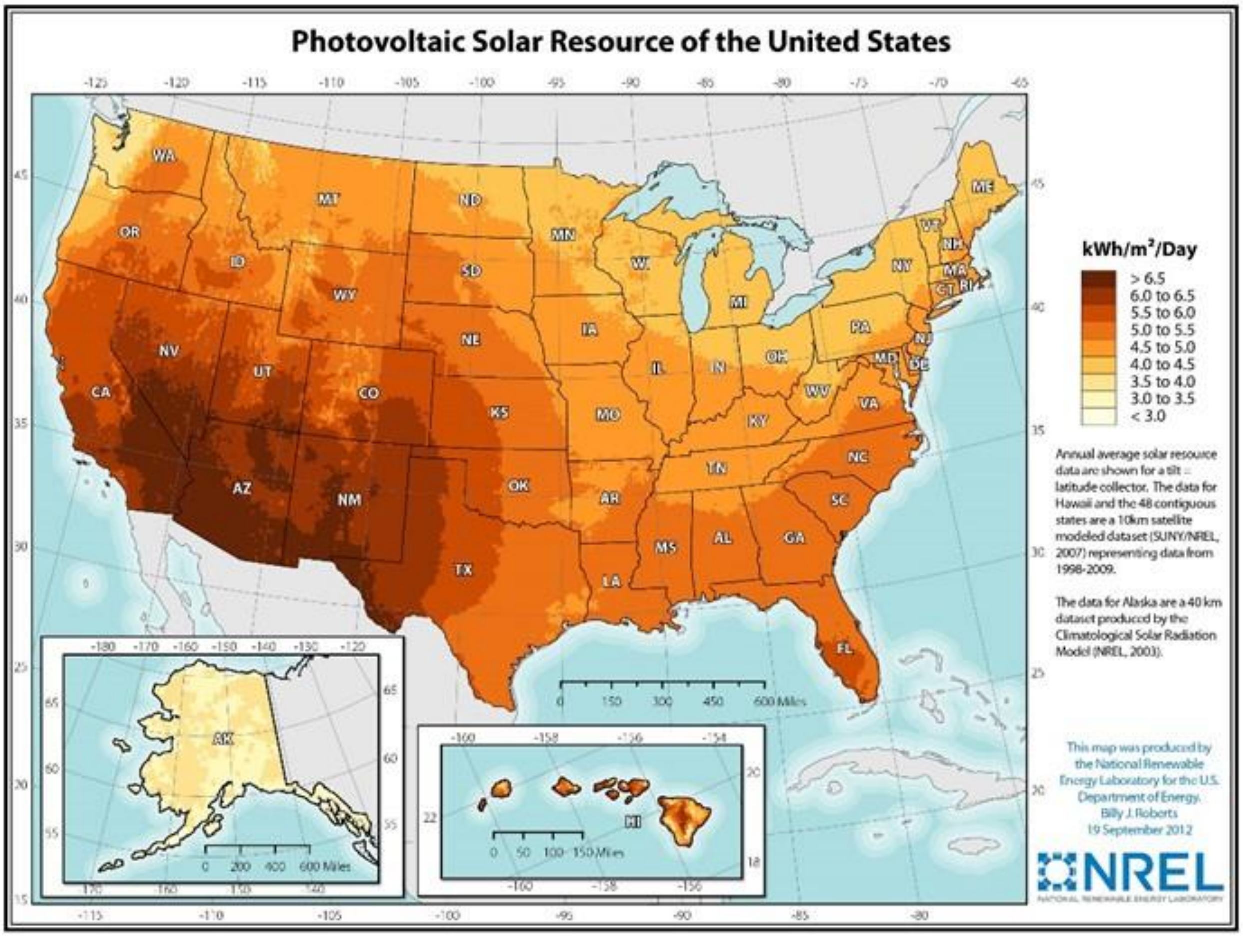
electricity and can reduce the ability to meet demand.[15] Potential solutions to this challenge include the use of new tools and technologies to monitor the electrical grid and better integrate PV systems, and improved storage systems (e.g., batteries) to even out the supply and demand for electricity.[16] Third, solar places different demands on the electric distribution grid, which is not optimized for this purpose, and the current policy, regulatory, and economic structures often do not promote solar and other clean energy options. Fourth, solar requires appropriate siting, building and panel orientation, and unobstructed sun.

Figure 7.7-4: Solar resource (as kWh/m^2/day) across the entire United States. From the National Renewable Energy Laboratory.[17]



[15] US Department of Energy, 2016. Grid Performance and Reliability [WWW Document]. URL http://energy.gov/eere/sunshot/grid-performance-and-reliability [accessed 5-22-16].

[16] US Department of Energy, 2016. Systems Integration [WWW Document]. URL http://energy.gov/eere/sunshot/systems-integration [accessed 5-22-16].

[17] National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

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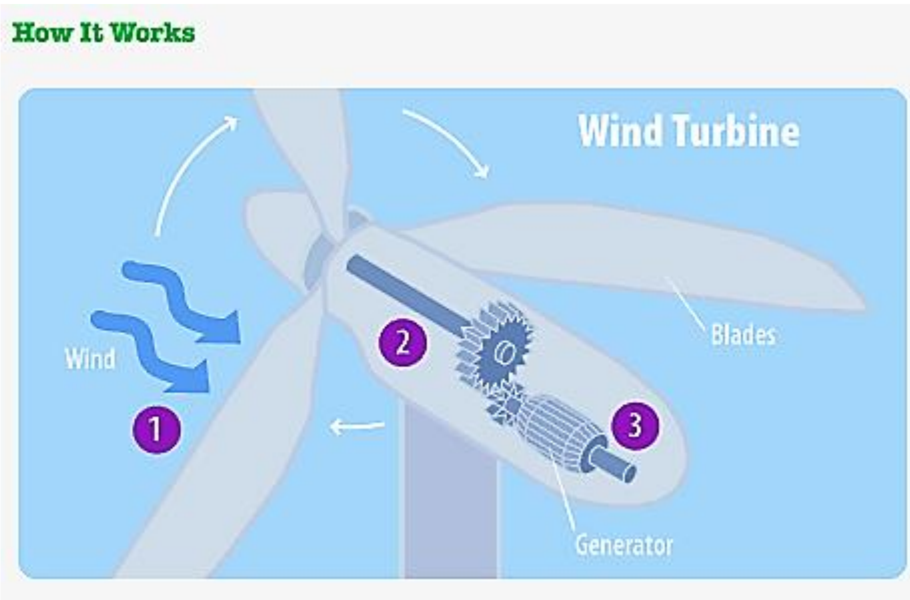
7.7.2.2 *Wind*

Wind energy is produced using wind turbines, large structures that use rotating blades to power a generator and produce electricity (Figure 7.7-5).[18] Michigan ranks 12th in the nation for generating electricity from wind turbines, with over 20 commercial wind farms that collectively can generate 1500 MW of electricity.[19] Locations are shown in Figure 7.7.6. Wind farms can be combined with other land uses, specifically agriculture as well as others, because the turbine towers have small footprints.

Figure 7.7-5: Schematic of a wind turbine.[20]



1. As the wind blows over the blades of a wind turbine, it causes the blades to lift and rotate.

2. The rotating blades turn a shaft that is connected to a generator.

3. The generator creates electricity as it turns.

As with solar power, wind power has advantages and disadvantages.[21] Advantages are that wind is a free, infinite and cost-effective source of power generation that does not emit greenhouse gases or air pollutants. The current cost of electricity from wind is low, between 4 and 6 cents per kWh,[22] and comparable to many other (more polluting) sources of electricity. Its primary disadvantage, like solar power, is its intermittency since the wind does not blow consistently. Thus, wind power faces the same challenges of integrating with existing power grids and being dispatched when needed. Additional disadvantages include: the possibility of

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18 EPA (Environmental Protection Agency). Wind Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/wind.html [accessed 3-2-16].

19 US Energy Information Administration, 2016. State Profile and Energy Estimates: Michigan [WWW Document]. URL http://www.eia.gov/state/?sid=MI [accessed 5-22-16].

20 EPA (Environmental Protection Agency). Wind Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/wind.html [accessed 3-2-16].

21 US Department of Energy, 2016. Advantages and Challenges of Wind Energy [WWW Document]. URL http://energy.gov/eere/wind/advantages-and-challenges-wind-energy [accessed 5-22-16].

22 US Department of Energy, 2016. Advantages and Challenges of Wind Energy [WWW Document]. URL http://energy.gov/eere/wind/advantages-and-challenges-wind-energy [accessed 5-22-16].

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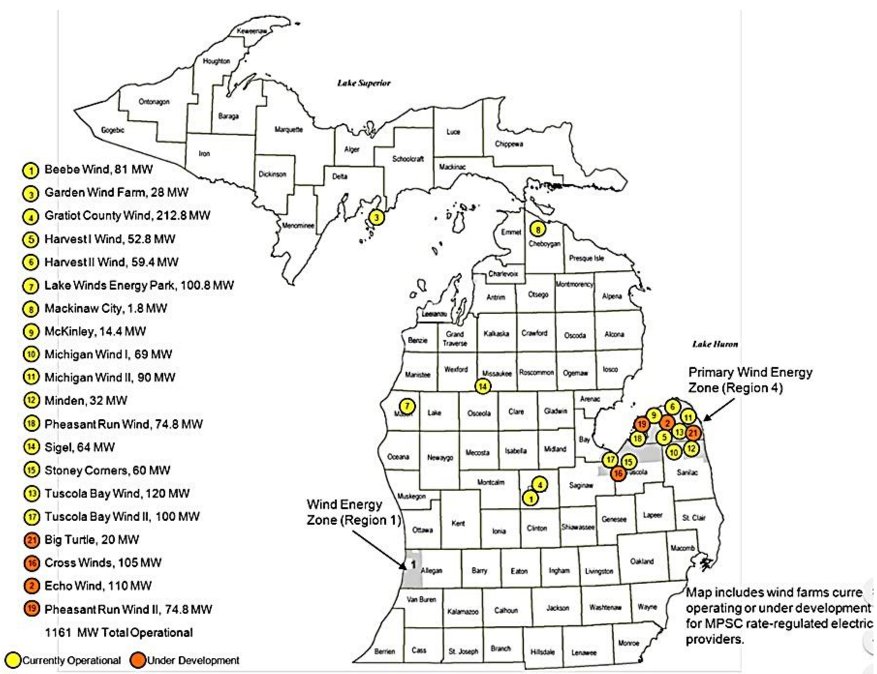
competing land uses, e.g., it may be more profitable to use the land for a different use; concerns over noise and aesthetics that lead to lack of community support for wind projects; concerns that turbines may be harmful to wildlife, especially birds; and the need for appropriate sites.

Figure 7.7-6: Stony Corners Wind Farm, one of the first utility scale wind farms in Michigan.[23]

Figure 7.7-7: Location of known wind projects in Michigan as of 2013.[24]



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[23] Heritage Sustainability Energy. Available: http://heritagewindenergy.com/projects/stoney-corners-wind-farm/ [accessed 6-2-16].

[24] LARA, Michigan, Report on the implementation of P.A. 295 wind energy resource zones http://www.michigan.gov/documents/mpsc/2014WERZReport_449308_7.pdf [accessed 6-1-16].

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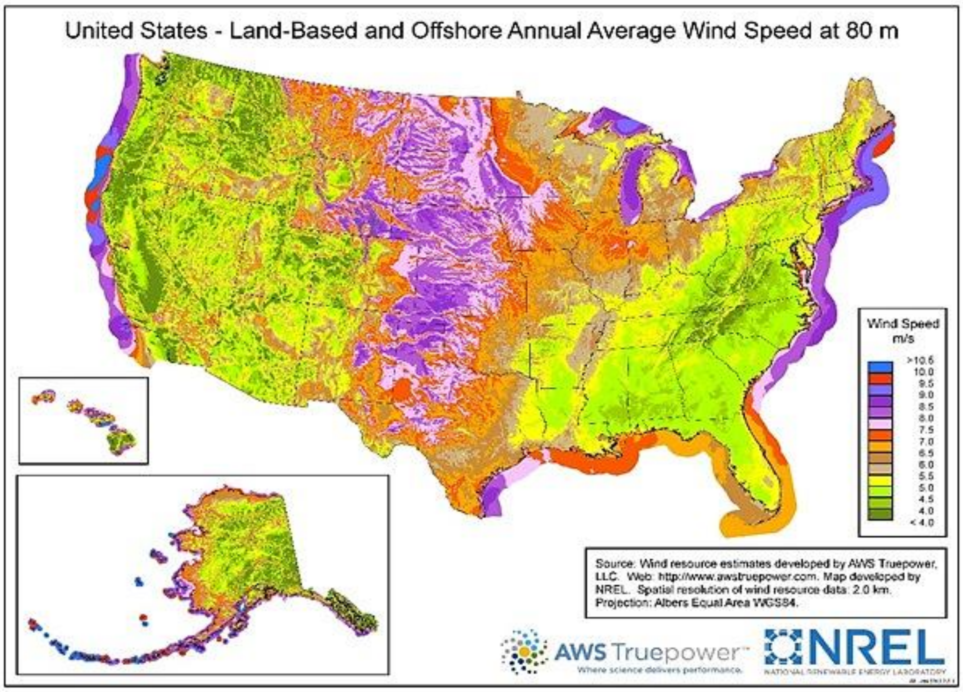
Figure 7.7-8 shows wind resources across the United States.[25] Southeast Michigan has modest land-based annual wind speeds (5 - 6.5 m/s), but there is considerable potential for off-shore wind power in the Great Lakes, and in the "thumb" of Michigan, as shown in the previous figure. Across the US, the greatest land-based wind resources are in the Great Plains region, which is sparsely populated, thus capitalizing on this wind resource would require new transmission lines to bring electricity to more densely populated areas.[26]

Figure 7.7-8: Map showing the annual average land-based and offshore wind speeds (at 80 m) for the US.[27] Bottom: location of known wind projects in Michigan as of 2013.[28]



25 US Department of Energy, 2016. Advantages and Challenges of Wind Energy [WWW Document]. URL http://energy.gov/eere/wind/advantages-and-challenges-wind-energy [accessed 5-22-16].

26 US Department of Energy, 2016. Advantages and Challenges of Wind Energy [WWW Document]. URL http://energy.gov/eere/wind/advantages-and-challenges-wind-energy [accessed 5-22-16].

27 National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

28 LARA, Michigan, Report on the implementation of P.A. 295 wind energy resource zones http://www.michigan.gov/documents/mpsc/2014WERZReport_449308_7.pdf [accessed 5-22-16].

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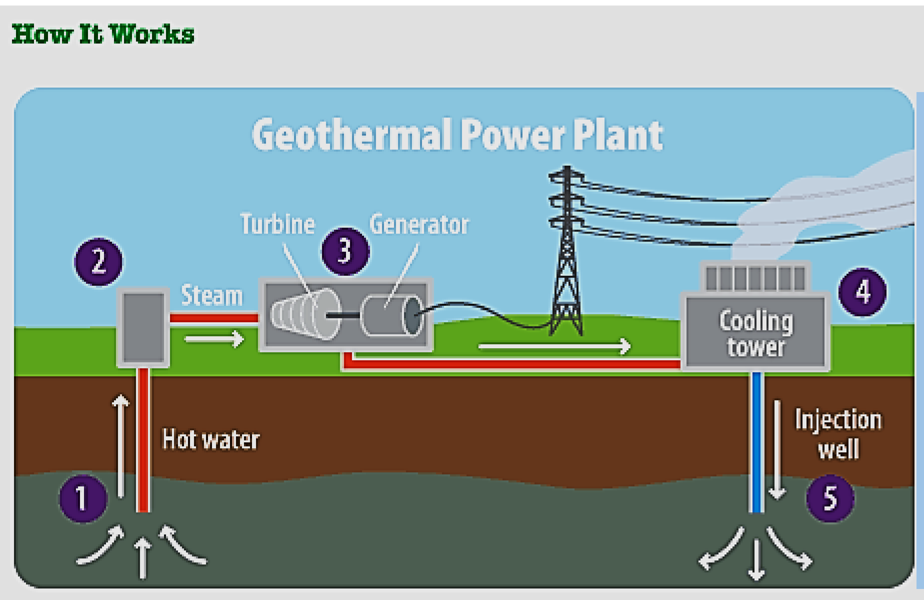
7.7.2.3 *Geothermal*

Geothermal energy is thermal energy generated and stored in the earth, arising from the hot dense core of the earth and from radioactive decay in the earth's crust. Examples of geothermal energy include geysers and hot springs, where groundwater is heated when it interacts with hot rocks below the surface of the earth.[29] Geothermal energy can be captured and used to generate electricity and provide thermal energy. Geothermal power plants use wells drilled 1-2 miles deep to pump steam or hot water to the surface.[30,31] Figure 7.7-7 shows a schematic of a typical geothermal plant. Hot water is pumped from the geothermal reservoir and used to generate steam that turns the turbine generator. The steam is condensed in a cooling tower and returned to the reservoir to be reheated.

Figure 7.7-9: Schematic of a geothermal power plant.[32]



1. Hot water is pumped from deep underground through a well under high pressure.
2. When the water reaches the surface, the pressure is dropped, which causes the water to turn into steam.
3. The steam spins a turbine, which is connected to a generator that produces electricity.
4. The steam cools off in a cooling tower and condenses back to water.
5. The cooled water is pumped back into the Earth to begin the process again.

Geothermal heat pumps are another type of geothermal technology that takes advantage of the relatively constant temperature of the earth. Geothermal heat pumps do not generate electricity; instead, they help to reduce energy demand. As depicted in Figure 7.7-10, in winter, surface temperatures are typically lower than

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[29] US Department of Energy, 2016. Geothermal Basics [WWW Document]. URL http://energy.gov/eere/geothermal/geothermal-basics [accessed 5-22-16].

[30] EPA (Environmental Protection Agency). Geothermal Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/geothermal.html [accessed 3-2-16].

[31] US Department of Energy, 2016. Geothermal Electricity Generation [WWW Document]. URL http://energy.gov/eere/geothermal/electricity-generation [accessed 5-22-16].

[32] EPA (Environmental Protection Agency). Geothermal Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/geothermal.html [accessed 3-2-16].

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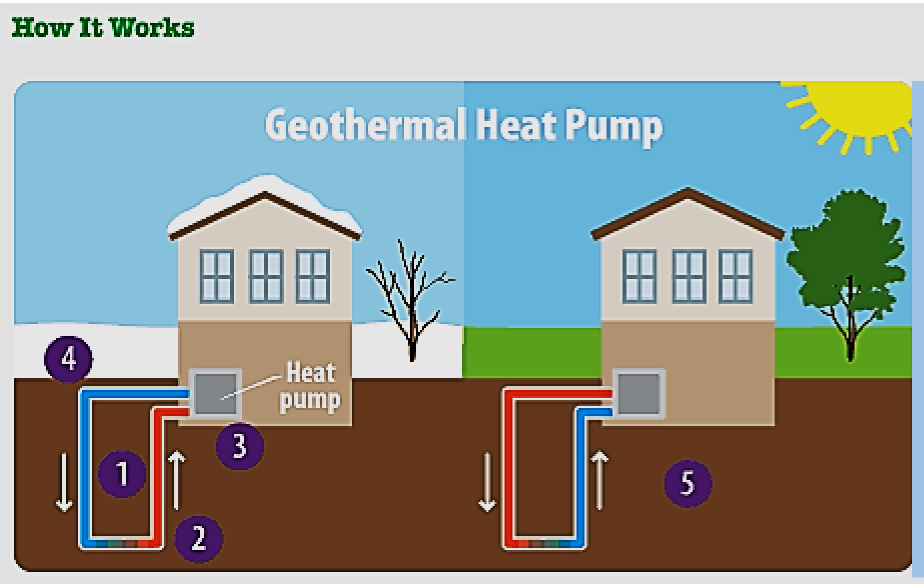
sub-surface temperatures (which are typically between 50-60° F), so heat from the ground can be transferred to water or refrigerants in a pipe system to provide heating. In the summer, surface temperatures are higher than ground temperatures, so excess heat in the building is transferred to the ground.[33]

Figure 7.7-10: Schematic of geothermal heat pump.[34]



1. Water or a refrigerant moves through a loop of pipes.

2. When the weather is cold, the water or refrigerant heats up as it travels through the buried loop.

3. Once it gets back above ground, the warmed water or refrigerant transfers heat to the building.

4. The water or refrigerant cools down, then is pumped back underground where it heats up once more, starting the process again.

A significant advantage of geothermal energy is its reliability, i.e., it does not have the variability or intermittency of wind or solar energy. This makes geothermal energy particularly useful for "base load" electricity generation (the minimum electricity needed essentially all of the time). In addition, geothermal plants can have small footprints and use less water than conventional power plants.[35] Its primary disadvantages are the limited number of suitable hydrothermal sites and the high costs of installation. Locations suitable for commercial or large scale geothermal energy extraction are called "hydrothermal" sites. Figure 7.7-11 shows identified hydrothermal sites across the US and the potential for "deep enhanced geothermal systems". There are no identified hydrothermal sites in Michigan. However, geothermal heat pumps can be used in Michigan, and these help improve the efficiency of heating and cooling systems. Note

[33] EPA (Environmental Protection Agency). Geothermal Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/geothermal.html) [accessed 3-2-16].

[34] EPA (Environmental Protection Agency). Geothermal Energy. Available: http://www3.epa.gov/climatechange/kids/solutions/technologies/geothermal.html) [accessed 3-2-16].

[35] US Department of Energy, 2016. Geothermal Basics [WWW Document]. URL http://energy.gov/eere/geothermal/geothermal-basics [accessed 5-22-16].

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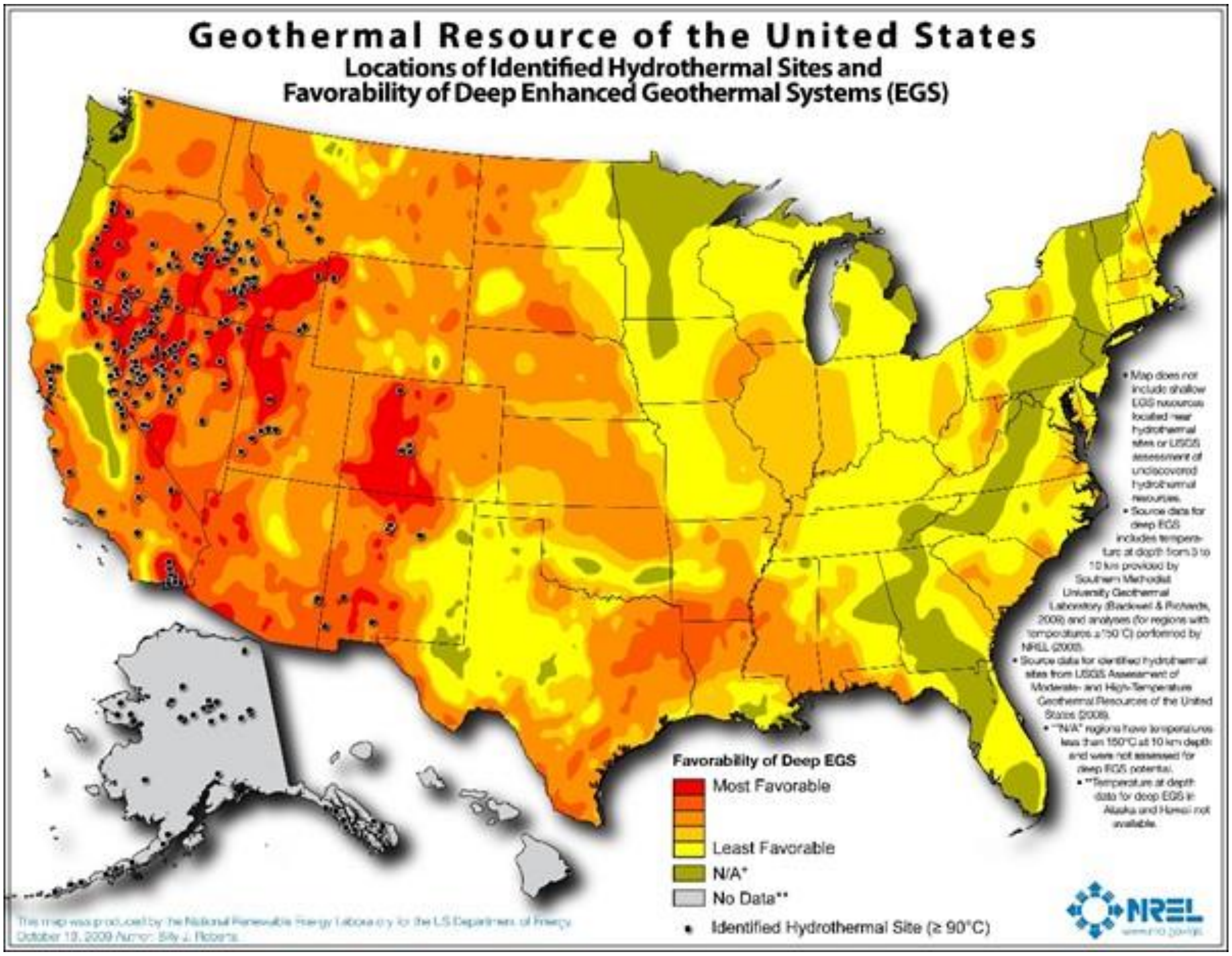
that these geothermal heat pumps still require electricity (although a reduced amount), and much of this electricity in Michigan is generated using dirty fuels.

Figure 7.7-11: Map showing identified hydrothermal sites and the potential for enhanced geothermal systems for the United States. Map from the National Renewable Energy Laboratory.[36]



7.7.2.4 *Biomass*

Biomass energy derives from plants and animals. It includes agricultural waste, forest residues, wood mill waste, urban wood waste and municipal waste.[37] Biomass can be burned directly, e.g., generating steam for

[36] National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

[37] US Department of Energy, 2016. Biomass Technology Basics [WWW Document]. URL http://energy.gov/eere/energybasics/articles/biomass-technology-basics [accessed 5-22-16].

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electricity generation. When combusted, biomass is often blended with other fuels, e.g., coal. Potentially less polluting ways to use biomass include conversion into biofuels (e.g., ethanol),[38] or gases (e.g., methane), or liquids (e.g., biodiesel).[39]

About 35% of Michigan's non-hydropower renewable energy comes from biomass, primarily from landfill gas, municipal solid waste, and forest residue.[40] Figure 7.7-12 shows the potential biomass resources at the county level across the United States. Wayne County has between 250 and 500 thousand tons of biomass made available each year. Other areas of southeast Michigan have more modest biomass resources. Some of the waste entering the Detroit Resource Recovery Facility, a mass-burn incinerator with energy recovery, is biomass.

An advantage of biomass energy is the reliability of the fuel source, thus, biomass can generate "base load" power. Its primary disadvantage is the production of air pollutant emissions. Biomass energy production can emit greenhouse gases, PM, NO_x, CO, VOCs, and potentially other hazardous air pollutants.

[38] EPA (Environmental Protection Agency). Biomass. Available: (http://www3.epa.gov/climatechange/kids/solutions/technologies/biomass.html) [accessed 3-2-16].

[39] US EPA. 2016. Biogas Opportunities Roadmap. Available: https://www3.epa.gov/climatechange/Downloads/Biogas-Roadmap-Factsheet.pdf [accessed 5-22-16].

[40] US Energy Information Administration, 2016. State Profile and Energy Estimates: Michigan [WWW Document]. URL http://www.eia.gov/state/?sid=MI [accessed 5-22-16].

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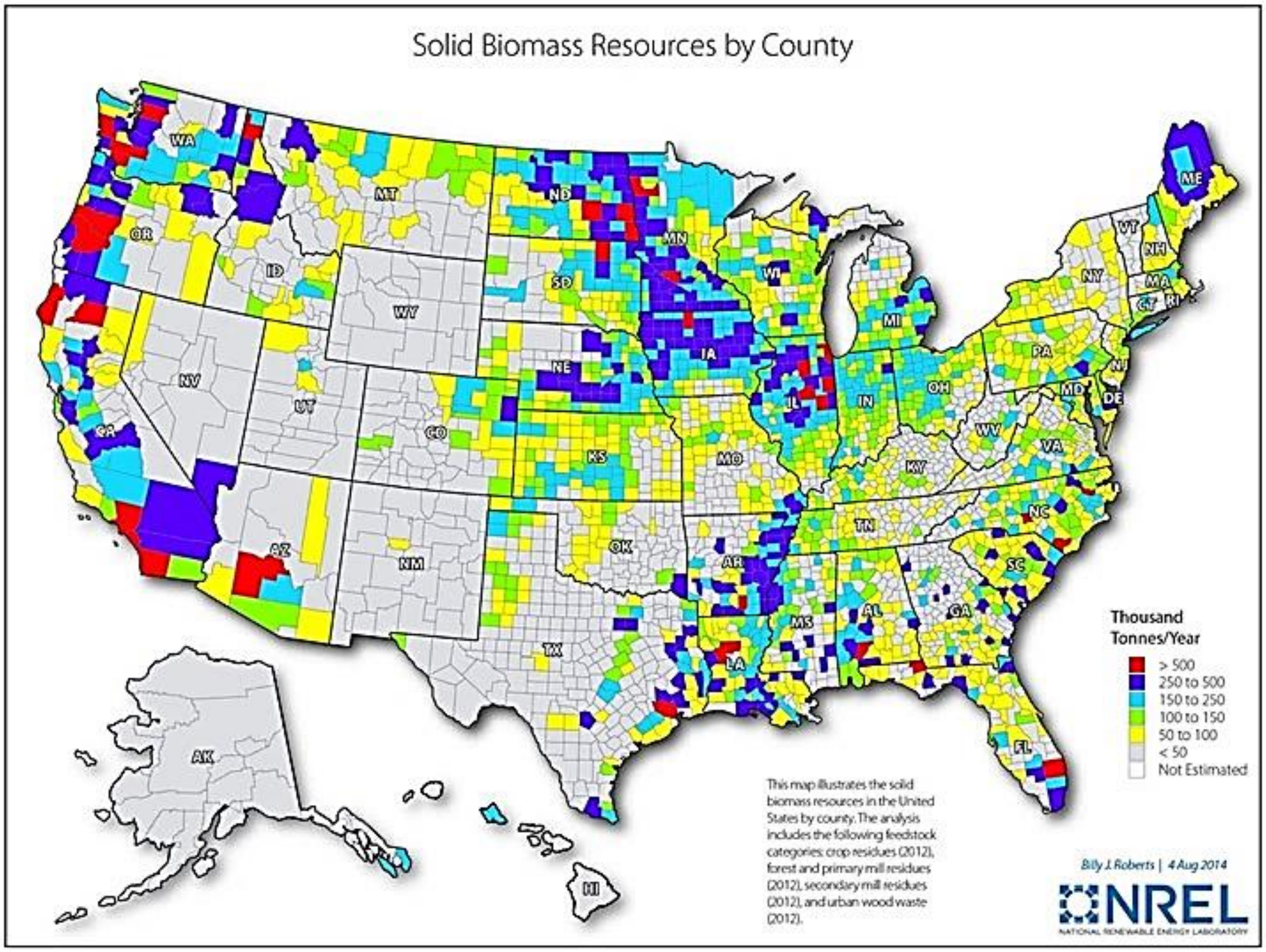
Figure 7.7-12: Tons of biomass resources available at the county level across the United States. Map from the National Renewable Energy Laboratory.[41]



7.7.2.5 *Cost of renewable energy*

Costs of clean energy depend on capital, fixed and variable costs, projected utilization and sales of energy, and fuel costs (if applicable). Costs are affected by economic incentives, including state and federal tax credits.[42] Presently, the key challenges to the economic viability of clean energy are the low cost of natural gas, the end of federal and state tax credits (including the expiration of Michigan's Renewable Portfolio Standard or RPS in 2015), and other policies favoring the use of renewable technologies. The low cost of natural gas is a challenge since many existing fossil fuel facilities can be retrofitted to burn natural gas, which has the effect of

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[41] National Renewable Energy Lab, US Department of Energy, 2016. Dynamic Maps, GIS Data, and Analysis Tools [WWW Document]. URL http://www.nrel.gov/gis/maps.html [accessed 5-22-16].

[42] US Energy Information Administration. 2015. Annual Energy Outlook 2015 with Projections to 2040. Available: http://www.eia.gov/aeo/ [accessed 5-23-16].

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delaying the development of renewable resources. In addition, as energy efficiency improves, electricity production declines and demand decreases for new facilities, thus slowing the development of new facilities using renewable or cleaner technologies.

Table 7.7-1 shows the "levelized cost of electricity" (LCOE) for new generation facilities that would come online in 2020.[43] This LCOE represents the total cost per kilowatt-hour (kWh) of building and operating a new facility to generate electricity and represents an average cost. Location-specific factors are not considered, e.g., the local resource mix. Energy sources are divided into "nondispatchable" resources, which can be used to meet peak loads, and dispatchable resources, which can be used to generate "base load" electricity. Costs in the table are for utility-sized facilities. (They do not reflect costs for smaller units, e.g., solar panels installed on the roof of a residence.)

Costs vary regionally (Table 7.7-1). For dispatchable technologies, geothermal power has the lowest LCOE. For the non-dispatchable technologies, land-based wind power has the lowest LCOE, which is on par with some of the dispatchable technologies (e.g., combined cycle facilities that burn natural gas). LCOEs for solar PV facilities are slightly higher than traditional and advanced coal-fired facilities, but considerably less expensive than new facilities that use carbon capture and sequestration to limit emissions of greenhouse gases. As discussed earlier, an important challenge with directly replacing dispatchable resources with wind and solar is the intermittent availability of these resources. As integration with the grid and storage capacities improve, there may be more opportunities for solar and wind to replace more conventional fuels.

[43] US Energy Information Administration. 2015. Levelized cost and levelized avoided cost of new generation resources in the annual energy outlook 2015. Available: http://www.eia.gov/forecasts/aeo/pdf/electricity_generation.pdf [accessed 5-23-16].

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Table 7.7-1 Estimated levelized cost of electricity for new generation resources, 2020. Table from the US Energy Information Agency.[44]

	Range for Total System LCOE (2013 $/MWh)			Range for Total LCOE with Subsidies[2] (2013 $/MWh)		
Plant Type	Minimum	Average	Maximum	Minimum	Average	Maximum
Dispatchable Technologies						
Conventional Coal	87.1	95.1	119.0			
Advanced Coal	106.1	115.7	136.1			
Advanced Coal with CCS	132.9	144.4	160.4			
Natural Gas-fired						
Conventional Combined Cycle	70.4	75.2	85.5			
Advanced Combined Cycle	68.6	72.6	81.7			
Advanced CC with CCS	93.3	100.2	110.8			
Conventional Combustion Turbine	107.3	141.5	156.4			
Advanced Combustion Turbine	94.6	113.5	126.8			
Advanced Nuclear	91.8	95.2	101.0			
Geothermal	43.8	47.8	52.1	41.0	44.4	48.0
Biomass	90.0	100.5	117.4			
Non-Dispatchable Technologies						
Wind	65.6	73.6	81.6			
Wind – Offshore	169.5	196.9	269.8			
Solar PV[3]	97.8	125.3	193.3	89.3	114.3	175.8
Solar Thermal	174.4	239.7	382.5	160.4	220.6	351.7
Hydroelectric[4]	69.3	83.5	107.2			

[1]Costs for the advanced nuclear technology reflect an online date of 2022.

[2]Levelized cost with subsidies reflects subsidies available in 2020, which include a permanent 10% investment tax credit for geothermal and solar technologies.

[3]Costs are expressed in terms of net AC power available to the grid for the installed capacity.

[4]As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

Note: The levelized costs for non-dispatchable technologies are calculated based on the capacity factor for the marginal site modeled in each region, which can vary significantly by region. The capacity factor ranges for these technologies are as follows: Wind – 31% to 40%, Wind Offshore – 33% to 42%, Solar PV- 22% to 32%, Solar Thermal – 11% to 26%, and Hydroelectric – 35% to 65%. The levelized costs are also affected by regional variations in construction labor rates and capital costs as well as resource availability.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015*, April 2015, DOE/EIA-0383(2015).

7.7.2.6 *Why is this important?*

Coal-fired power plants make up 39% of the net electricity generation in the United States, and account for a large portion of air pollution (Figure 7.7-13). Natural gas power plants, which also contribute to greenhouse gas and air pollutant emissions, account for another 27% of electricity generation. The U.S. vehicle fleet also

[44] US Energy Information Administration. 2015. Levelized cost and levelized avoided cost of new generation resources in the annual energy outlook 2015. Available: http://www.eia.gov/forecasts/aeo/pdf/electricity_generation.pdf [accessed 5-23-16].

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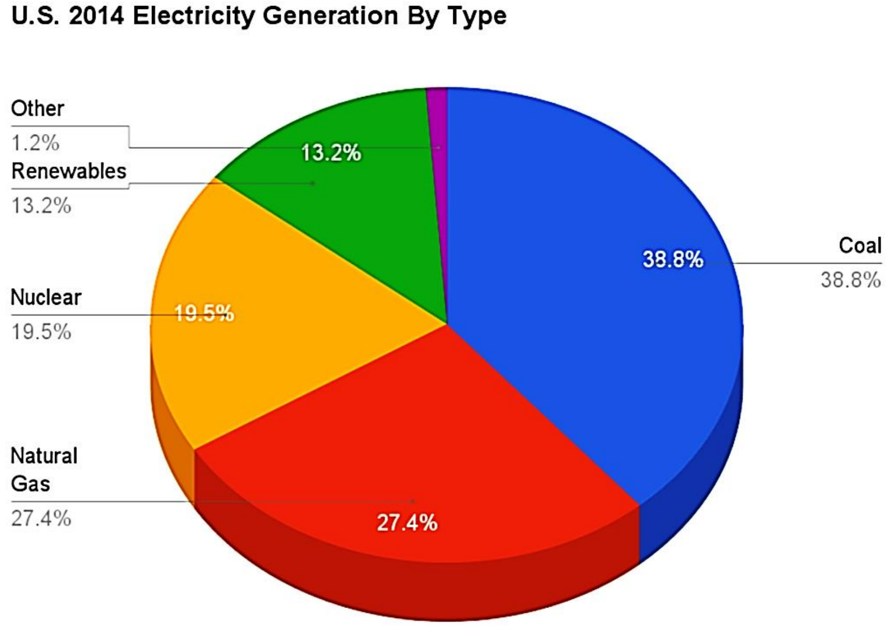
relies on fossil fuels. Replacing fossil fuels and "dirty" energy production with clean energy can play an important role in reducing adverse health effects from air pollution by substantially reducing pollution levels.

Figure 7.7-13: Net electricity generation in the United States by source.[45]



The fraction of electricity in Michigan produced through coal-fired power plants (the "coal-fired fraction") is 46.4%, exceeding the US average.[46] In southeast Michigan, DTE intends to retire one third of its coal-fired power plants by 2025, and switch to both natural gas and wind. They do not intend to retire the coal-fired power plant in Monroe, MI, their largest facility. This facility has been upgraded with SO_2 scrubbers to reduce emissions of this air pollutant.[47] Health impacts attributable to emissions from coal-fired power plants and other facilities in the region are discussed in Section 5.5.

Although there are no coal-fired power plants within the City of Detroit, four large facilities (DTE Monroe, DTE Trenton Channel, River Rouge, and Detroit Industrial Generation) are nearby and influence air quality within the city (see Section 5.5). This is especially important in Southwest Detroit, which is currently out of compliance with the EPA's SO_2 standards, largely due to the coal-fired facilities (power plants, steel mills, lime

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[45] U.S. Energy Information Administration. Michigan State Profile and Energy Estimates. Available:http://www.eia.gov/state/?sid=MIhttp://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_01[accessed 3-2-16].
[46] U.S. Energy Information Administration. Michigan State Profile and Energy Estimates. Available: http://www.eia.gov/state/?sid=MI [accessed 3-2-16].
[47] PLATTS McGraw Hill Financial. DTE to Cut Coal Fleet by a Third, Issue RFP for Gas Plant. Available: http://www.platts.com/latest-news/coal/louisville-kentucky/dte-to-cut-coal-fleet-by-a-third-issues-rfp-for-21786852 [accessed 3-2-16].
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and coke production. (For more information, see CAPHE SO2 Fact Sheet). DTE recently announced that three coal-fired power plants will be retired between 2020 and 2023: River Rouge, St. Clair, and Trenton[48].

Transitioning to the use of clean energy sources could offset the need for coal-fired power plants, which could lead to improvements over time in air quality. There are also many benefits of clean energy. As noted, renewable energy produces little if any greenhouse gas. Renewable energy diversifies the energy supply and reduces dependence of imported fuels. Renewable energy also can create and revitalize economic development, utilize vacant land productively, provide jobs (in manufacturing, installation, etc.), potentially increase the resiliency of infrastructure, and decentralize the energy sector.[49] Solar panels may be installed on buffers between emission sources and populations and provide energy, a co-benefit, as well as the pollution benefits discussed in Section 7.3 on Buffers.

7.7.3 *Implications for health*

7.7.3.1 *What pollutants are affected?*

Clean energy displaces fossil fuel energy and its attendant emissions of pollutants, including PM, NO_x, SO_2, CO, greenhouse gas emissions, and toxics such as mercury and arsenic.[50]

7.7.3.2 *What health effects can be mitigated?*

Adverse health effects mitigated by clean energy depend on the extent to which renewables replace conventional fuels, which determines pollutant reductions. Health effects range from minor outcomes, like missed school or work days due to respiratory symptoms, to severe outcomes, such respiratory disease, cardiovascular disease, cancer, and premature mortality.

7.7.4 *What is happening in Michigan?*

7.7.4.1 *The Michigan Renewable Energy Portfolio*

Michigan passed the Renewable Energy Portfolio (RPS) in 2008, also known as Public Act 295. The RPS states that by the end of 2015, 10% of Michigan's energy mix should be from renewable energy sources. This act incentivizes investment in renewable sources, creates a long-term planning framework and ensures that the state invests in cleaner energy sources. This can mitigate some of the negative health effects that disproportionately affect frontline communities in Michigan. For example, River Rouge, one of the dirtiest coal plants in the nation, sits in the River Rouge community where people of color make up 65% of the population.

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[48] Detroit Free Press. 2015. 25 Michigan coal plants are set to retire by 2020. Available: http://www.freep.com/story/money/business/michigan/2015/10/10/25-michigan-coal-plants-set-retire-2020/73335550/. [accessed 8-25-16].

[49] EPA (Environmental Protection Agency). State and Local climate Energy Program: Renewable Energy. Available: http://www3.epa.gov/statelocalclimate/state/topics/renewable.html [accessed 3-2-16].

[50] EPA (Environmental Protection Agency). Mercury and Air Toxics Standards (MATS): Cleaner Power Plants. http://www3.epa.gov/airquality/powerplanttoxics/powerplants.html [accessed 3-2-16].

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This Act expired at the end of 2015. The legislature is currently looking at various energy packages, led by Senator Nofs and Representative Nesbitt respectively.

7.7.4.2 *The Clean Power Plan*

President Obama and the EPA announced the Clean Power Plan on August 3, 2015. This plan reduces carbon pollution from power plants to affect climate change. Informed by years of outreach and public engagement, the final Clean Power Plan is designed to move the US towards lower-polluting, cleaner energy. The plan sets standards for power plants, and customized goals for states to cut the carbon pollution that is driving climate change.[51]

On February 9, 2016, the Supreme Court stayed implementation of the Clean Power Plan pending judicial review. The Court's decision was not on the merits of the rule. EPA firmly believes the Clean Power Plan will be upheld when the merits are considered because the rule rests on strong scientific and legal foundations.

7.7.5 *What is happening in and around Detroit?*

7.7.5.1 *Organizing and activism*

Some activities to promote the transition to clean energy in Detroit (which provide networking opportunities for CAPHE) include:

- Detroit Climate Action Collaborative. This group has been working since 2011 to reduce greenhouse gas emissions in Detroit. They have advocated for increased efficiency for Detroit buildings and an increased investment in renewable energy in all sectors.[52]
- Sierra Club's Beyond-Coal Campaign. This campaign focuses on replacing coal with clean energy sources by mobilizing grassroots activists in local communities to advocate for the retirement of old and outdated coal plants, and to prevent new plants from being built. Their goal is to retire one-third of the nation's more than 500 coal plants by 2020.[53] Sierra Club actively participated in hearings and organizing in Michigan.
- American Lung Association. ALS has been active in advocating for clean air and against pollution emitted by Detroit's current energy sources.

[51] EPA (Environmental Protection Agency). Clean power plan for existing power plants. Available: https://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants. [accessed 8-29-16].

[52] Detroiters Working for Environmental Justice. Detroit Climate Action Collaborative. Available: http://www.detroitclimateaction.org/) [accessed 3-2-16].

[53] Sierra Club. Coal is an outdated, backward and dirty 19th-century technology. Available: http://content.sierraclub.org/coal/about-the-campaign [accessed 3-2-16].

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- Clean Power Plan Environmental activists from across Michigan have rallied against the state's decision to suspend Clean Power Plan compliance strategies.[54] [55]

7.7.5.2 *Activity in Detroit and Michigan*

Cities across the United States and throughout the world are increasing the use of clean energy and improving energy efficiency, and many are phasing out and/or supplementing current sources with renewable energy sources. Examples elsewhere in the US are noted throughout this *Resource Manual*. For example, cities including Grand Rapids MI (population 192,294) and San Diego, CA (population 1.4 million) have pledged to obtain 100% of their energy from renewable sources by specific dates.

Some examples of Michigan activities are listed below. The first several are conducted by DTE, a publically-regulated utility. Note that DTE's actions require approvals by the Michigan's Public Utility Commission (PUC).

- DTE Solar Current Program. DTE has easement rights to locate solar arrays on suitable property in southeastern Michigan.[56]
- DTE Solar Currents Program – Ann Arbor. DTE installed 4000+ photovoltaic solar panels along 9.37 acres of the interchange of M-14 and US 23. This is the largest solar array in Michigan. It will provide enough energy to power 200 average sized homes.[57]
- DTE Wind Energy – Echo Wind Park. Echo Wind Park is located in Elkton, Chandler, and Oliver townships in Huron County, MI. Built on nearly 18,000 acres and 70 turbines, it has the capacity to power 52,000 homes.[58]
- Ikea Solar Energy. In Canton, Mil, this retailer has installed over 4900 solar panels that will reduce 971 tons of carbon dioxide (CO2), equivalent to the emissions of 204 cars or 134 homes.[59]
- 1-800-LAW-FIRM Southfield, MI and Solar Energy and Wind Turbines. This firm in Southfield (near Lodge and Lahser) installed 550 solar panels (Figure 7.7-14) and four wind turbines, which will generate

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[54] Midwest Energy News. Michigan halts Clean Power Plan work, but joins clean energy accord. Available: http://midwestenergynews.com/2016/02/16/michigan-halts-clean-power-plan-work-but-joins-clean-energy-accord/ [accessed 1 June 2016].

[55] Michigan United. Environmental groups call for clean power plan in Michigan. Available: http://www.miunited.org/environmental-groups-call-for-clean-power-plan-in-michigan/ [accessed 1 June 2016].

[56] DTE Energy. Solar Energy. Available: Click here for Webpage [accessed 3-2-16].

[57] MLive. Michigan's largest solar panel installation taking shape outside Ann Arbor. Available: http://www.mlive.com/news/ann-arbor/index.ssf/2015/05/ann_arbor_township_solar.html [accessed 3-2-16]. MLive. Michigan's largest solar panel array now up and running near Ann Arbor. Available: http://www.mlive.com/news/ann-arbor/index.ssf/2015/09/michigans_largest_solar.html [accessed 3-2-16].

[58] DTE Energy DTE. Echo Park Wind. Available: Click here for Webpage [accessed 3-2-16].

[59] IKEA. 2016. IKEA Plugs-in addition to Solar Installation at Detroit-Area Store. Available: http://www.ikea.com/us/en/about_ikea/newsitem/012716_pr-IKEA-Canton-solar [Accessed 5-19-16]. The conversion given in this article was created using the clean energy equivalent calculator at: www.epa.gov/cleanenergy/energy-resources/calculator.html

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$45,000 worth of energy per year, or about half of the building's energy use. This development received incentive financing from Detroit as well as federal tax credits ($300,000).[60]

Figure 7.7-14: Solar panels at 1-800-LAW FIRM.[61]

- Detroit-Wayne County Metro Airport and Wind Turbines. Metro Airport installed wind turbines that power the lights in their south cell phone lot in a very visible installation (at an airport entrance). The turbines produce energy worth $3000 annually.[62]
- The Detroit Zoo and Renewable Energy Credits: The Zoo in Royal Oak purchased Renewable Energy Credits and now gets 100% of its energy needs from wind energy sources. This is part of the Detroit Zoological Society's goals to promote sustainability and health literacy.[63]

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[60] Detroit Free Press. Law office makes $1M renewable energy investment. Available: http://www.freep.com/story/money/business/michigan/2014/12/03/law-office-environment-wind-solar/19863549/ [accessed 3-1-16]

[61] Detroit Free Press. Law office makes $1M renewable energy investment. Available: http://www.freep.com/story/money/business/michigan/2014/12/03/law-office-environment-wind-solar/19863549/ [accessed 3-1-16]

[62] Metromode Metro Detroit. Can Metro Detroit Develop a Wind Power Economy? Available: http://www.secondwavemedia.com/metromode/features/windpowermetrodetroit0346.aspx [accessed 3-2-16].

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- Kent County Michigan and geothermal energy. In 2008, Kent County initiated a plan to reduce energy use in county facilities and buildings. This included the installation of heat pumps in the County Courthouse (built to LEED standards, see Section 7.2 for more information on LEED standards) and the Correctional Facility, which decreased energy usage at these facilities by 45%.[64]

- PV installations. An increasing number of firms and residences are installing these systems, typically on flat roofs or on roofs or walls with southern exposure.

- Heat pumps. A number of homes and buildings in Michigan have long used these systems to improve energy efficiency.

- Michigan's Renewable Portfolio Standard (RPS). In 2008, Michigan required electric utilities to generate at least 10% of their energy from renewable resources, or to negotiate the equivalent using tradable renewable energy certificates. By 2015 all but three of Michigan's 72 utilities were on track to meet the target. These renewables included wind, solar, biomass and biogas.[65]

- Michigan Rebates and Incentives for Clean Energy. Michigan has rebates and incentives available to residents and businesses. For full listing, see: http://www.cleanenergyauthority.com/solar-rebates-and-incentives/michigan/

7.7.6 How many people would be affected in Detroit?

The number of people affected by the use of clean energy depends on the type of clean energy used, what it replaces, and where it is implemented. Switching to cleaner forms of energy could lessen the amount of pollutants generated by coal-fired power plants, a key source of pollution in and around the City of Detroit, replacing it with power generated by clean sources.

7.7.7 Applicable strategies for Detroit

Clean energy sources most appropriate for Detroit include much higher use of PV panels, heat pumps, and bioenergy. A landscape with clean and renewable energy could help transform the energy and physical landscape in Detroit, and help with economic revitalization. While Detroit is not a favorable location for cost-effective wind power, wind power-generated electricity still can be provided to Detroit from distant facilities, as encouraged by the renewable portfolio standards (RPS) discussed below.

Strategies to promote investment in renewable and clean energy are listed below.

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[63] Daily Detroit. Detroit Zoo Switches to Wind Power. Available: http://www.dailydetroit.com/2015/12/15/detroit-zoo-switches-to-wind-power/ [accessed 3-2-16].

[64] Energy.gov. A Michigan County Unearths Savings with Geothermal Energy. Available: http://energy.gov/articles/michigan-county-unearths-savings-geothermal-energy [accessed 3-2-16] and Kent County access Kent. Energy Use Reduction Program. Available: https://www.accesskent.com/Departments/BOC/Energy/ [accessed 3-2-16].

[65] NDRC (Natural Resource Defense Council). Renewable Energy for America: Harvesting the benefits of homegrown, renewable energy, Michigan. Available: http://www.nrdc.org/energy/renewables/michigan.asp [accessed 3-2-16]

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- Extend or create tax-credits for businesses and individuals. Create incentives, or utilize current incentives, to increase the use of renewable energy systems. Unfortunately, the Federal tax credits for solar PV, solar water heaters, geothermal heat pumps, and small wind systems expire after 2016, and Congress seems unlikely to renew this bill. On the other hand, costs of PV and some other renewable technologies have dramatically fallen, thus increasing the cost-effectiveness of renewables.

- Utilize tax credits or other incentives to promote geothermal heat pumps and energy efficiency in buildings.

- For new construction and major renovations of building, require or incentivize energy foot-printing or compliance with building certification systems, such as LEED. This can be applied to governmental, school, residences, and other buildings.

- In zoning and new construction, consider site orientation in building design to allow PV panel installation.

- Use solar panels on buffers designed to reduce pollutant exposure and noise, providing a significant co-benefit.

- Remove regulatory and financial barriers regarding renewable energy. This may include reforming utility approaches and Public Service Commission rules regarding purchase agreements for renewable energy.

- Commit Detroit, and other cities in the region to renewable energy targets.

- Commit DTE and other power generators in the region to transition to clean energy.

- Promote a more aggressive renewable portfolio standard, e.g., 25% renewable by 2025. (Michigan's current standard is 10% by 2016.)

- Ensure that all biomass collected in Detroit is used for clean biofuels. This includes food wastes, utility right-of-way clearing waste.

- Ensure that current waste-to-energy systems utilize state-of-the-art pollution controls, or are phased out to cleaner technology.

- Expand and certify green pricing programs that allow utility customers to volunteer to pay a small price premium in order to receive greater percentages of their power from renewable resources. For example, DTE has a program called "Green Currents, which enrolls about 23,000 customers (2014) with several options, e.g., you can pay an additional $0.02 per kilowatt hour to get 100% of your power from renewable sources. [66]

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[66] http://www.michigan.gov/mpsc/0,1607,7-159-16393_48209_49896-179571--,00.html

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