



# Component Manufacturing: Michigan's Future in the Renewable Energy Industry

**R E P P**

RENEWABLE ENERGY POLICY PROJECT

GEORGE STERZINGER  
Jerry Stevens

TECHNICAL REPORT | November 2006

## **REPP STATE REPORTS**

A national program to develop renewable energy will provide significant benefits to states and regions well beyond where projects are developed. A national program will greatly stimulate demand for manufactured components. It is clear from earlier Reports undertaken by the Renewable Energy Policy Project that many of the states and regions that have suffered the greatest loss of manufacturing jobs have a significant concentration of manufacturing potential to supply those components. This potential is little understood even by those closest to it and who stand to benefit the most from it. The REPP State Reports intend to provide an explanation of how this manufacturing potential is calculated and offer detailed analysis showing for a state, region, and county the potential for each of the 43 industrial codes that comprise the major component parts for the major renewable energy technologies. It is intended that the Reports will promote interest at the local level to actually identify the specific firms that could benefit from a national program and begin the discussion as to how best to tie reinvigorated domestic manufacturing activity into a national program to develop renewable energy.

# **Component Manufacturing: Michigan's Future in the Renewable Energy Industry**

## **ENERGY AS THE FUTURE**

At present, the energy sector and the national policy that determines how it evolves leaves the US exposed to three major, interconnected threats. Our national security is compromised by how we get and use energy. The inability to adequately recognize climate change as a problem only makes the inevitable task of dealing with the problem more difficult. Finally, the harmful effect of our present energy policy on the domestic economy needs an expanded and more aggressive response to reverse the damage.

Current US energy policy is often described as “drain America first” referring to our insistence on drilling more and more pristine areas of the US for oil and natural gas, but “drain America first” could also refer to the effects of our current policy on the domestic economy. The threats to the long-term economic well being of our country raised by the present policy's effects on our balance of trade deficit and outsourcing critical manufacturing capabilities cannot be ignored. Perhaps more critically, solving energy problems with policies that provide security, address climate stabilization and direct substantial economic revitalization to our domestic economy offers hope for a greatly expanded political coalition.

A major commitment to renewable electric generation will reduce our security exposure, help stabilize our climate and provide a multi-billion dollar investment and reindustrialization program. A national program of that size and scope offers a tremendous opportunity for Michigan. Seeing an energy policy as a way to create a new thrust of industrial activity requires looking at the renewable technologies in a new way. This Report breaks down renewable generation technologies into their component parts and then examines which existing Michigan industries could, if provided with appropriate support mechanisms, become suppliers of the billions of dollars of new parts that will be necessary.

The recently passed Energy Policy Act of 2005 provided some minor support for renewable energy development but stopped well short of supporting a significant national commitment. The Act completely neglected supports for the development of a robust, domestic industry to provide the component parts that make up modern renewable technology. Michigan recognizes the potential for revitalizing its industrial technology if the potential documented in this Report can be captured. This Report provides that first step, the analysis of the potential, to spur the pursuit of the policies to capture the potential.

It is well understood that a national program to develop renewable energy will benefit the regions and states that have the best renewable resource base – solar, wind, biomass and geothermal. What is less appreciated is that a national program will also create a demand for billions of dollars of components, namely the parts that make up the finished renewable plants. This demand could, if accompanied by appropriate incentives, provide important new markets for domestic manufacturers that are already manufacturing equipment similar to the components that go into new renewable generation.

In 2004, the Renewable Energy Policy Project completed an analysis of modern, large wind turbine technologies. The results of this analysis were very encouraging both for the country as a whole and for Michigan in particular. The Report showed:

Investment in new wind will create a demand for all of the components that make up a wind generator. As a rule of thumb, every 1000 MW requires a \$1 Billion investment in rotors, generators, towers and other related investments...This Report assumes 124,900 MW will be developed nationally and proceeds in three steps to trace the distribution of benefits. First we determine how the total installed cost of the new wind development will flow into demand for each of the 20 separate components of the turbines (grouped into 5 categories). Second, we spread the total demand among the regions of the country by allocating the \$50 billion investment according to the number of employees at firms identified by the NAICS codes. The number of employees is used rather than number of firms to account for the different impact of large vs. small companies, and hence to more accurately distribute the investment. This produces a “map” of manufacturing activity across the United States based on firms that have the technical potential to become active manufacturers of wind turbine components. Third, we translate the regional dollar allocation by assuming that all component manufacturing has the same ratio of jobs/total investment of 3000 FTE jobs/\$1 billion of investment.

The results of this initial research into the distribution of manufacturing activity are encouraging. Twenty-five states have firms currently active in manufacturing components or sub-components for wind turbines; all fifty states have firms with the technical potential to become active. Table 1 below shows the ten states which would receive the greatest portion of the investment, based on the number of employees at potentially active firms identified by the NAICS codes for wind components.

This Report analyses the renewable energy industry assuming that the United States moves to stabilize carbon emissions. As explained more fully below, the Report assumes a “wedge” of renewable energy is developed to stabilize the emissions from the US electric sector. The Report looks at how that major new demand for renewable energy will cascade down to create new demand for the component parts that make up the major renewable energy technologies.

Here in summary form are the results of this Report for Michigan. Stabilizing emissions of carbon requires adding 18,500 MW of new renewable projects each year. The Report looks at the total demand generated by a ten-year stabilization program and tracks that demand down to the individual industries capable of manufacturing the components. The national demand is assigned to individual states and eventually to the county level. Among all of the states, Michigan is ranked fourth in terms of the amount of new investment and seventh in terms of new jobs generated from the expanded manufacturing activity to meet this demand. In all, there are more than 2,000 firms in Michigan that are currently active in the industrial sectors that could supply the component parts to meet the demand necessary to deliver an emissions stabilization wedge. In addition, the demand can support the creation of more than 34,777 new Michigan jobs related to the expanded manufacturing activity.

The Report also looks at the likelihood that new demand on the scale necessary to stabilize carbon emissions would lead to bottlenecks in the component supply chain. To analyze the likelihood of this occurring, the Report looks at the incremental, annual demand for components as a percent of the available unused industrial capacity for each of the major industrial sectors. For example, climate stabilization efforts will create an annual demand for approximately \$1 billion for wind turbine gearboxes. Currently, this industrial sector is running at close to full capacity. Department of Commerce data shows an available, unused capacity of roughly \$15 million. In other words, any major push for renewable installations would run into an immediate

shortage of these critical components. Looking more closely at this carbon stabilization program reveals that there is a very great likelihood that severe bottlenecks will develop in many critical sectors. For wind and photovoltaic components, the annual, new demand will greatly exceed available industrial capacity for more than 50% of the industrial sectors. All of the renewable technologies face a bottleneck in one or more critical components.

This Report reveals the enormous potential that a commitment to climate stabilization is likely to produce. Michigan, by acting early, can influence national action to accelerate climate programs. By virtue of its industrial base, Michigan stands to benefit from the increased demand for renewable technology. Michigan should not rest solely on its existing manufacturing base, however. Capturing the maximum economic potential and avoiding supply-chain bottlenecks will require aggressive investment in new manufacturing capacity by the private sector. Public incentives and support mechanisms can and should be used to accelerate that action.

## **STABILIZING CARBON EMISSIONS**

There are many ways to stabilize carbon emissions. For this Report REPP has used the “wedge” analysis developed by Pacala and Socolow. (Pacala, S. and R. Socolow, *Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies*, *Science*, 13 August 2004, Vol. 305) One of the breakthroughs that any complex issue like climate stabilization policy must make to gain public awareness and acceptance is to provide the public with a clear, comprehensible explanation of the problem and a solution that they can understand and believe will work. The recent article in *Science* provided that threshold of clarity for climate stabilization efforts. To stabilize carbon emissions, the authors proposed to split the growth of carbon emissions into seven parts or wedges and look for the set of already existing technologies that can generate the required electricity without a wedge of carbon emissions.

An international program of stabilization based on current levels of global emissions would make the United States responsible for about two wedges or two-sevenths of global carbon emissions. Since transportation and electricity generation each provide about half the emissions, electricity generation in the United States would be responsible for about one wedge.

As the *Science* article makes clear, there are a number of programs using existing technologies that can be used to provide a wedge of carbon reductions. For this Report, however, we look at what would be required to provide a wedge from renewable energy technologies.

The calculation of what is required to stabilize these emissions is straightforward. The base of carbon emissions now is 7 billion metric tons per year of carbon, growing at 1.5% per year. For the first year, global growth would be 105 million tons, and to stabilize or remove the growth each wedge would require removing 15 million tons of carbon. Since the most common emission from the generation of electricity is CO<sub>2</sub>, the 15 million tons of carbon per wedge would translate to 55 million tons of CO<sub>2</sub> per year. Coal generation emits on average 2.1 pounds of CO<sub>2</sub> per kWh produced, which translates to approximately 58 billion kWh generated with zero CO<sub>2</sub> emissions to capture one wedge. (“Carbon Dioxide Emissions from the Generation of Electric Power in the United States” July 2000 Department of Energy Washington, DC 20585 Environmental Protection Agency Washington DC 20460).

The assumption that each CO<sub>2</sub>-free kWh removed a kWh of coal fired generation rather than natural gas fired generation is very likely imprecise. It is used here as a way to begin the discussion of how this type of program might work. It is not meant as a definitive resolution of these complex issues regarding electric generation dispatch. To achieve these reductions would

## Investment and Job Creation Potential Top 10 States Ranked by Average Investment

The results indicate that a significant national investment has clear potential to benefit regions of the U.S. other than only those states that have a significant renewable resource. Furthermore, investigating the demographics of the top 20 states benefiting from manufacturing indicates that investment will particularly target the most populous regions of the country, and will especially benefit regions that are most in need of new manufacturing jobs. Notably, the 20 states benefiting the most from investment in components are almost identically the 20 states that have lost the most manufacturing jobs in the country over the past 3 years. These states account for more than 76% of the manufacturing jobs lost. Investment will particularly benefit these states, sending new jobs where they are needed most. Furthermore, these states are also the most populous, indicating that investment in wind will benefit a large range of people in the country.”

	Number of MW	Number of Firms	Millions \$ Investment	New FTE Jobs
<b>Wind</b>	124,900	16,480	\$62,338	398,470
<b>Solar</b>	23,150	10,272	\$69,624	298,194
<b>Geothermal</b>	15,190	3,926	\$15,330	72,324
<b>Biomass</b>	21,760	12,020	\$13,248	81,615
<b>Total:</b>	185,000	42,698	\$160,541	850,603

## Investment and Job Creation Potential Top 10 States Ranked by Investment

State	Number of Jobs	Average Investment (\$ Billions)	2001 Population	Rank in U.S.	Manufacturing Jobs Lost, Jan. 2001 - May 2004*	Rank in U.S.
California	95,616	\$20.90	34,501,130	1	318,000	1
Texas	60,100	\$13.22	11,373,541	7	165,500	3
Illinois	56,579	\$9.93	21,325,018	2	169,600	2
Ohio	51,269	\$8.84	9,990,817	8	129,300	8
New York	47,930	\$8.40	12,482,301	5	131,500	6
Pennsylvania	42,668	\$7.92	6,114,745	14	63,500	13
Indiana	39,221	\$6.26	12,287,150	6	155,200	5
<b>Michigan</b>	<b>34,777</b>	<b>\$5.53</b>	<b>5,401,906</b>	<b>18</b>	<b>68,300</b>	<b>10</b>
North Carolina	28,544	\$5.33	19,011,378	3	130,500	7
Missouri	22,796	\$5.26	8,186,268	11	156,600	4
<b>10 State Total</b>	524,558	\$91.59	140,674,254		1,488,000	
<b>% U.S. Total</b>	65%	57%	50%		55%	

## I. National Rankings

The methodology we developed for the Wind Report has since been extended to cover photovoltaics, bio-mass steam generators, and geothermal technologies. For the combined renewable technologies, we assumed that 124,900 MW of wind would be developed, 15,190 MW of photovoltaic, 23,150 MW of biomass, and 21,760 MW of geothermal.

### Summary of National Development, Resulting Investment and Jobs

U.S.	Total New MW	Number of Firms	Millions \$ Investment	New FTE Jobs
<b>Wind</b>	124,900MW	16,480	\$62,338	398,470
<b>Solar</b>	23,150MW	10,272	\$69,624	298,194
<b>Geothermal</b>	15,190MW	3,926	\$15,330	72,324
<b>Biomass</b>	21,760MW	12,020	\$13,248	81,615
<b>Total:</b>	185,000MW	42,698	\$160,540	850,603

Nearly 43,000 firms throughout the United States operate in industries related to the manufacturing of components that go into renewable energy systems. If the 185,000 MW of renewable energy assumed in this model were to be developed, these companies have the potential to fill the demand for new components that would be generated. This national development would represent nearly \$160 billion dollars of manufacturing investment, and would result in more than 850,000 new jobs. Michigan is particularly well positioned to benefit from such a national development. As shown in the tables below, Michigan stands to receive nearly 34,777 new jobs and \$5.53 billion dollars of investment in manufacturing components to supply this national development of renewables. Michigan is ranked ninth among states in terms of job gain, and seventh for potential investment. (Note: The wind figures shown here are different from those in REPP's initial wind manufacturing report because we are using a more refined model that defines cost information at the component level.)

Location	# of Firms	Jobs Wind	Jobs Solar	Jobs Geothermal	Jobs Biomass	Jobs Total
<b>California</b>	5,409	32,046	48,896	8,465	6,209	95,616
<b>Texas</b>	3,358	25,044	23,221	4,660	7,175	60,100
<b>Illinois</b>	2,289	30,010	19,298	3,396	3,875	56,579
<b>Ohio</b>	2,465	29,820	11,833	5,079	4,537	51,269
<b>New York</b>	1,925	18,523	14,617	8,150	6,640	47,930
<b>Pennsylvania</b>	2,188	19,588	15,767	3,402	3,911	42,668
<b>Indiana</b>	1,321	25,180	7,485	3,191	3,365	39,221
<b>Michigan</b>	2,050	24,350	6,644	1,502	2,281	34,777
<b>North Carolina</b>	1,096	10,964	11,062	2,810	3,708	28,544
<b>Missouri</b>	785	10,260	7,532	2,907	2,097	22,796

## II. Michigan and Michigan Counties Information

As shown in the wind report on manufacturing activity, Michigan is particularly well positioned to benefit from wind energy development. When the picture is expanded to include other

renewable energy technologies, the potential benefit to Michigan manufacturing industries is even greater. As in the case of wind technology, Michigan has a manufacturing base in most of the industries relevant to the production of other renewable energy components.

**Table 4: Potential Benefit to Michigan from National Development**

<b>Michigan</b>	<b>Number of Firms</b>	<b>Investment (Millions)</b>	<b>New FTE Jobs</b>
<b>Wind</b>	967	\$ 3,452.5	24,350
<b>Solar</b>	360	\$ 1,255.6	6,644
<b>Geothermal</b>	129	\$ 271.5	1,502
<b>Biomass</b>	594	\$ 348.8	2,281
<b>Total:</b>	2,050	\$ 5,328.4	34,777

This report and the previous wind manufacturing report identify that Michigan stands to benefit greatly from national renewable energy development throughout the manufacturing supply chain. The next step is to identify specific actions to take in order to move towards making this potential benefit a reality. In order to do so, it is useful to have more specific information about the location and nature of the manufacturing potential in Michigan.

Importantly, the census information for manufacturing industries contains data refined down to the county level. This county level information makes it possible to take a closer look at the locations within a state that have the potential to manufacture components related to renewable energy. The methodology for arriving at investment and jobs numbers at the county level is the same as for the state level. Each county receives a portion of the total investment from the national program, according to the percentage of firms in each of the relevant NAICS industries operating in that county, and jobs are distributed in the same manner.

**Table 5: Top 20 Michigan Counties Ranked by Impact**

County	Wind		Solar		Geothermal		Biomass		Totals	
	Investment (millions)	Jobs	Investment (millions)	Jobs	Investment (millions)	Jobs	Investment (millions)	Jobs	Investment (millions)	Jobs
Wayne	\$300.80	1,976	\$193.50	1,055	\$28.90	174	\$33.80	226	\$557.00	3,431
Kent	\$336.70	2,478	\$104.50	648	\$22.00	117	\$50.80	332	\$514.00	3,575
Oakland	\$278.90	1,927	\$128.10	738	\$38.00	168	\$35.10	230	\$480.10	3,063
Macomb	\$357.70	2,603	\$75.30	437	\$9.40	43	\$22.70	144	\$465.10	3,227
Grand	\$283.20	1,917	\$148.60	1,032	\$1.10	5	\$6.20	45	\$439.10	2,999
Monroe	\$17.00	104	\$365.10	1,518	\$6.40	22	\$7.90	49	\$396.40	1,693
Saginaw	\$164.20	1,135	\$12.50	43	\$1.40	7	\$2.00	12	\$180.10	1,197
Muskegon	\$132.70	915	\$35.30	231	\$5.00	28	\$3.50	21	\$176.50	1,195
Berrien	\$52.70	382	\$6.20	45	\$66.40	411	\$13.50	85	\$138.80	923
Ottawa	\$93.80	701	\$6.50	52	\$4.90	35	\$25.50	178	\$130.70	966
Washtenaw	\$75.20	541	\$17.50	53	\$4.00	21	\$25.40	178	\$122.10	793
St. Joseph	\$103.10	769	\$0.80	5	\$0.00	0	\$2.60	16	\$106.50	790
Kalamazoo	\$39.40	303	\$12.40	37	\$40.60	216	\$13.80	77	\$106.20	633
Calhoun	\$80.80	588	\$3.00	19	\$9.50	50	\$2.70	15	\$96.00	672
Charlevoix	\$88.40	626	\$0.00	0	\$0.00	0	\$2.70	20	\$91.10	646
Clinton	\$82.00	536	\$0.00	0	\$1.10	5	\$0.50	3	\$83.60	544
Shiawassee	\$58.10	396	\$0.20	1	\$2.70	9	\$19.80	143	\$80.80	549
St. Clair	\$62.20	466	\$7.90	25	\$4.90	19	\$2.90	13	\$77.90	523
Allegan	\$42.50	267	\$28.30	144	\$1.70	12	\$2.00	12	\$74.50	435
Livingston	\$62.70	425	\$3.30	15	\$1.30	7	\$3.80	24	\$71.10	471
Ingham	\$41.90	260	\$4.30	12	\$15.80	114	\$2.10	15	\$64.10	401

The table above lists the 20 counties in Michigan that would receive the greatest investment in manufacturing from the national development of wind, solar PV, geothermal, and dedicated biomass. To further clarify, the “Investment” dollar figure is arrived at by starting with an assumed number of MW of new capacity for the entire U.S. – we use 124,900 MW new wind for this report. This 124,900 MW results in a certain manufacturing cost for each component that goes into a wind turbine, which we calculate based on specific cost information (\$/MW) that we have researched for each part. Each component also has an NAICS industry associated with it – for example, the wind turbine gearbox falls under the code 333612 “Speed Changer, Industrial”. The total dollars that go into making gearboxes for the 124,900 MW of wind are then apportioned to each county based on the relative number of firms operating in 333612 in that county (to be more precise, the number of employees working at those firms is used to account for different size companies). This process is repeated for each component and then summed to arrive at the total for each technology.

The number of new “Jobs” is also based on census information. By combining the number of employees working in a given industry, the total value of components produced by that industry, as well as the cost per megawatt for those components, we are able to calculate a ratio of Jobs/MW for each NAICS industry for each of the four technologies. This number of jobs is then divided geographically in the same as the investment. To take a closer look at a particular county of interest, we can break out the investment and job allocation by specific NAICS codes, in order to examine the particular kinds of manufacturing that are relevant to a given county. As an example of this, below we look in further detail at the Michigan county with the most renewable

energy manufacturing potential: Wayne. While a variety of data is available, three items are of particular relevance. The number firms operating in the county in each NAICS industry gives an idea of the manufacturing base located in the county for a particular industry, while the investment and new job creation, using the method described above, provide an idea of the potential for the county to benefit in particular industries from the national development of renewable energy. The following tables break down the results for Wayne County.

## Wayne County, MI

### Wind

NAICS	NAICS Description	# of Firms in NAICS	Millions \$ Investment	New FTE Jobs
332312	Fabricated Structural Metal	27	\$123.7	710
326199	All Other Plastics Product Manufacturing	43	\$67.1	534
333612	Speed Changer, Industrial	2	\$35.0	237
335999	Electronic Equipment and Components, NEC	3	\$25.6	166
333613	Power Transmission Equip.	6	\$25.5	167
331511	Iron Foundries	4	\$11.0	77
334519	Measuring and Controlling Devices	6	\$9.8	65
335312	Motors and Generators	3	\$1.4	9
333412	Industrial and Commercial fans and blowers	1	\$1.3	9
334418	Printed circuits and electronics assemblies	1	\$0.4	2
<b>Total:</b>		<b>96</b>	<b>\$300.8</b>	<b>1,976</b>

### Solar

NAICS	NAICS Description	# of Firms in NAICS	Millions \$ Investment	New FTE Jobs
335999	Electronic Equipment and Components, NEC	3	\$64.2	416
335931	Current-Carrying Wiring Device Manufacturing	1	\$50.7	387
325211	Plastics Material and Resin Manufacturing	3	\$37.3	51
326113	Unlaminated Plastics Film and Sheet (Except Packaging)	4	\$24.0	95
334515	Instrument Manufacturing for Measuring and Testing	4	\$7.8	36
332322	Sheet Metal Work Manufacturing	30	\$6.9	56
335313	Switchgear and Switchboard Apparatus Manufacturing	3	\$2.6	14
<b>Total:</b>		<b>48</b>	<b>\$193.5</b>	<b>1,055</b>

### Geothermal

NAICS	NAICS Description	# of Firms in NAICS	Millions \$ Investment	New FTE Jobs
333412	Industrial and Commercial fans and blowers	1	\$15.8	114
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased	4	\$8.6	31
332410	Power Boiler and Heat Exchanger Manufacturing	2	\$2.6	19
333923	Overhead Traveling Crane, Hoist, and Monorail System	3	\$0.6	3
333415	Air-Conditioning and Warm Air Heating Equipment and	3	\$0.6	3
333911	Pump and Pumping Equipment Manufacturing	1	\$0.4	2
333912	Air and Gas Compressor Manufacturing	1	\$0.2	1
332420	Metal Tank (Heavy Gauge) Manufacturing	1	\$0.1	1
<b>Total:</b>		<b>16</b>	<b>\$28.9</b>	<b>174</b>

### Biomass

NAICS	NAICS Description	# of Firms in NAICS	Millions \$ Investment	New FTE Jobs
333411	Air Purification Equipment Manufacturing	2	\$13.1	97
332410	Power Boiler and Heat Exchanger Manufacturing	2	\$9.0	64
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased	4	\$4.2	15
333922	Conveyor and Conveying Equipment Manufacturing	11	\$2.7	17
333412	Industrial and Commercial fans and blowers	1	\$2.0	15
335999	Electronic Equipment and Components, NEC	3	\$1.0	6
333999	All Other Miscellaneous General Purpose Machinery	17	\$0.9	6

333415	Air-Conditioning and Warm Air Heating Equipment and	3	\$0.2	1
335313	Switchgear and Switchboard Apparatus Manufacturing	3	\$0.2	1
332420	Metal Tank (Heavy Gauge) Manufacturing	1	\$0.1	1
334513	Instruments and Related Products Manufacturing for	5	\$0.1	1
333911	Pump and Pumping Equipment Manufacturing	1	\$0.1	0
333923	Overhead Traveling Crane, Hoist, and Monorail System	3	\$0.1	1
333997	Scale and Balance (except Laboratory) Manufacturing	1	\$0.1	1
333120	Construction Machinery Manufacturing	3	\$0.0	0
333995	Fluid Power Cylinder and Actuator Manufacturing	6	\$0.0	0
333912	Air and Gas Compressor Manufacturing	1	\$0.0	0
335311	Power, Distribution, and Specialty Transformer Manufacturing	1	\$0.0	0
<b>Total:</b>		<b>68</b>	<b>\$33.8</b>	<b>226</b>
<b>Grand Total for Wayne County, MI:</b>		<b>228</b>	<b>\$557.0</b>	<b>3,431</b>

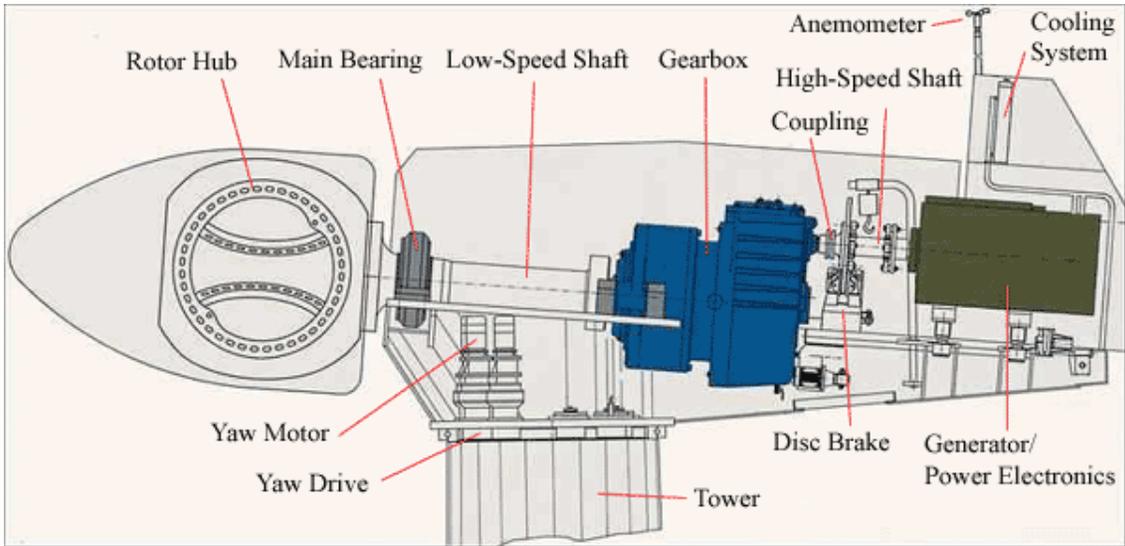
### III. Component Breakdown and NAICS Methodology

Assessing the dispersion of manufacturing of the components of renewable energy systems proceeds in 3 steps. First we identify the component parts that make up each system, then we identify a relevant NAICS code for each component, and finally we use the census data to identify potential manufacturing activity.

#### A. Component Breakdown

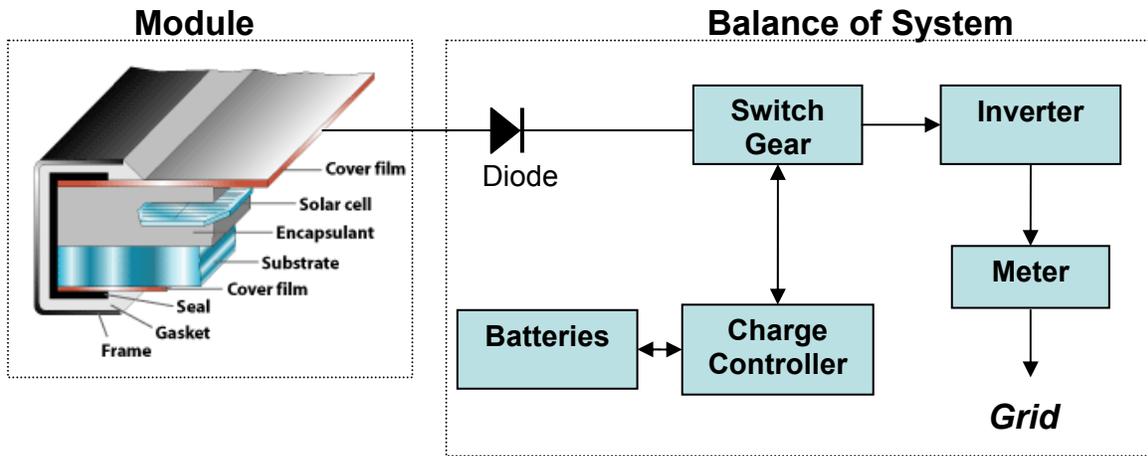
In so identifying the component parts that make up each system, we must decide what constitutes a major component – for this study we consider a part that would likely be sold by a manufacturer as a single unit, and not the parts that went into that unit further up the supply chain. For example, we consider the gearbox in a wind turbine as a component, but not the bolts that went into making the gearbox. For each of four technologies – wind, solar PV, geothermal, and biomass generation – we identified the most prevalent modern technology, and then identified the major components that go into each.

For wind technology, this Report looks at utility scale modern wind turbines, which are three bladed, upwind, horizontal axis machines, typically larger than 1 MW capacity. In this type of wind turbine, wind flows over three large composite blades mounted on a rotor, causing them to rotate. The rotational energy is transferred through a gearbox to a generator, where it is converted into electricity. Almost all wind turbines currently being installed for power generation for electric utilities are of this kind. We identified 19 separate components for the utility scale wind turbine, many of which are shown below in Figure 1. For a complete list of the components and a description and photograph of each, please refer to Appendix A.



**Figure 1 – Wind Turbine Component Diagram**

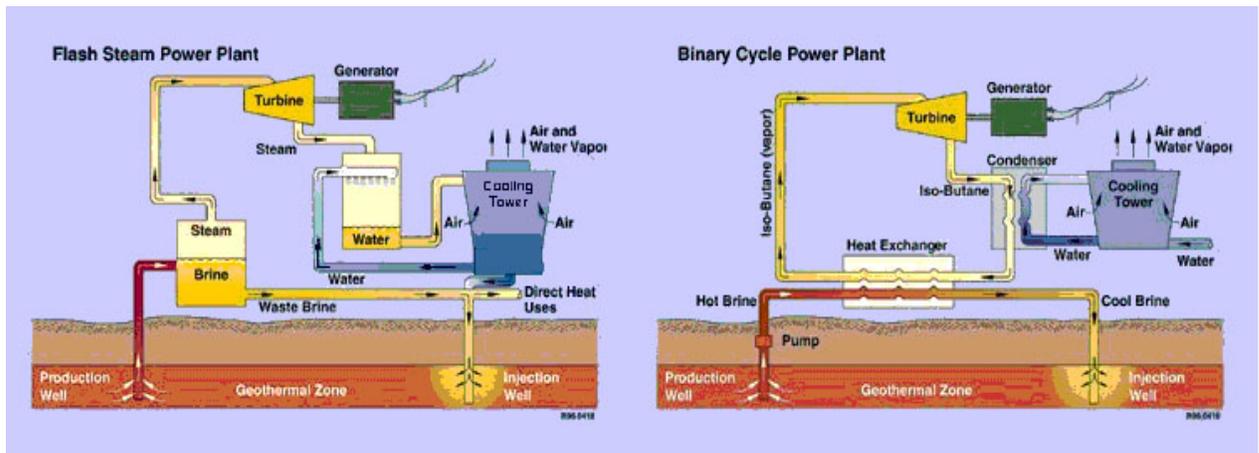
For solar photovoltaics, we considered crystalline silicon modules, as these are by far the most common type of PV module currently deployed. Although not specifically considered in this report, amorphous silicon and other “thin-film” modules are also produced in small amounts in a handful of countries. However, with the exception of the glass top plate and the framing structure, the components for both systems are practically the same and so much of what is written in this report will also apply to thin-film modules. All PV systems convert the energy from photons striking the cells into electrical current. This direct current electricity is then either stored in a battery for later use, or converted into AC power by an inverter, which can then be connected to household appliances and to the electric grid. We identified 13 separate components for solar PV systems.



**Figure 2 – Solar PV Component Diagram**

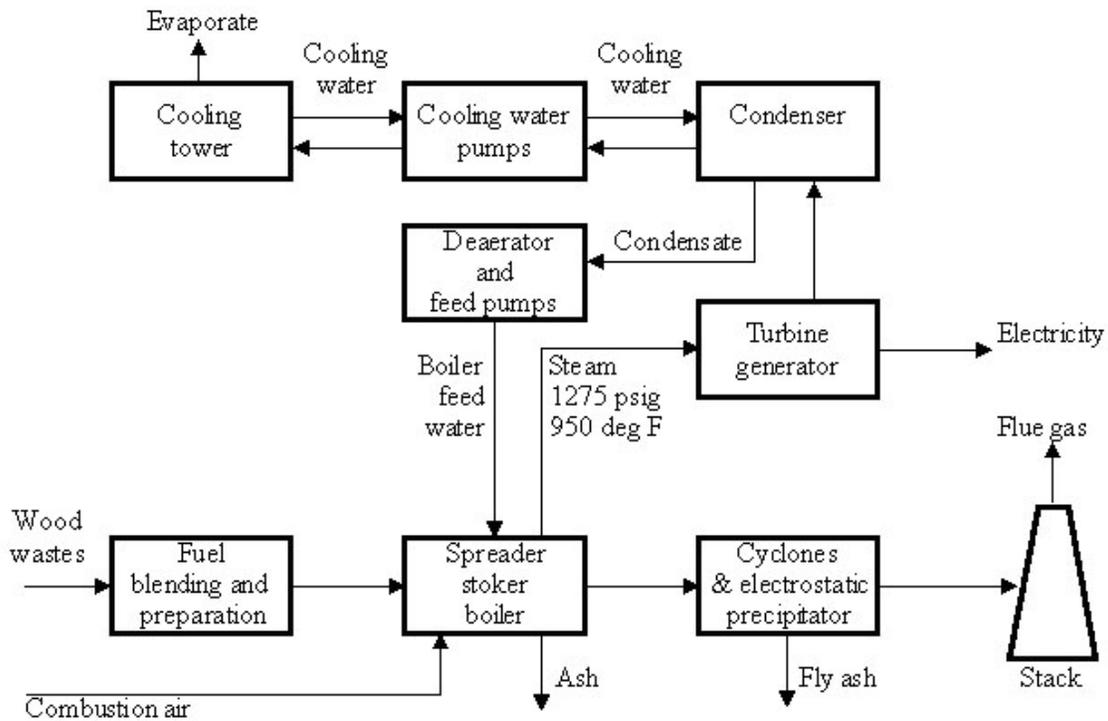
For geothermal power generation, we considered two technologies that represent almost all of the current operating and planned plants – flash steam and binary cycle. Flash steam plants operate by expanding the hot geothermal fluid to make steam, which is then passed through a steam turbine-generator set to make electricity. The steam is then condensed, and in most cases the

excess fluid is reinjected underground to preserve the resource. In a binary plant, a fluid with a low boiling point is circulated in a closed loop, receiving heat from the geothermal fluid through a heat exchanger, vaporizing, being expanded through a turbine-generator, and then recondensed. Most of the components that make up these plants are similar, such as various pumps, heat exchangers and piping, but a handful of parts are distinct for each technology. Listed below are the components that both technologies have in common, and then those that are specialized for each type of plant. The figures below illustrate the major components of a flash steam plant and a binary cycle plant.



**Figure 3 – Geothermal Component Diagram**

For biomass power generation, we looked at dedicated biomass plants (as opposed to co-firing with coal) that burn biomass in a boiler to generate steam. The steam is then passed through a steam turbine-generator, just like the kind used in coal or other fossil-fuel plants, to generate electricity. While other methods of power-generation from biomass exist, such as gasification or anaerobic digestion, direct steam plants are the most common, and are the only technology widely ready for commercialization. We identified 33 separate components for a biomass-fired steam plant.

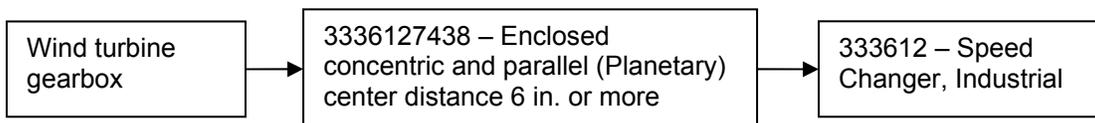


**Figure 4 – Direct-fired Biomass Steam Plant Component Diagram**

### B. Identifying the NAICS Codes

Manufacturing activity has historically been tracked by Standard Industrial Classification (SIC) codes. The four-digit SIC code was developed in the 1930s to classify businesses by the type of activity in which they are primarily engaged and to promote the comparability of business data to describe various aspects of the U.S. economy. In 1997 the SIC was replaced by the North American Industry Classification System (NAICS). In the Economic Census conducted by the U.S. Census Bureau, every firm operating in North America reports one or more NAICS codes, indicating what types of products or services they provide. Companies reporting the same NAICS code are involved in similar activities, for example every company that reports “333911” manufactures some type of pump.

Using this system, REPP was able to tabulate the companies involved in activities similar to the manufacturing of renewable energy components. The NAICS codes have several levels of detail, up to ten digits, with each digit indicating a higher level of detail. For example, a first digit of 3 indicates Manufacturing, 333 is “Machinery Manufacturing,” 333911 is “Pump and Pumping Equipment Manufacturing,” and 333911148M is “All other centrifugal pumps, over 6 in. discharge.” For this report, we matched each component with a 10-digit code, the highest level of detail in the NAICS, in order to ensure that we had accurately identified the correct code. We then went back up the hierarchy to the 6-digit code for interfacing with the census data.



### **Advantages to Using the 6-digit Codes**

The 6-digit NAICS codes replaced the 4-digit SIC codes, which were the highest level of detail available in the SIC. Hence the 6-digit NAICS are the standard level reported by all companies in North America, with the 10-digit codes providing additional detail. The U.S. Census Bureau itself provides data primarily at the 6-digit level, reporting 10 only at the request of a special study. Furthermore, for a given NAICS code and a given geographical area, such as a county, if there are less than 2 companies operating or if one company is dominant, disclosure rules require the Census to not report information for that particular code and for that area, to avoid disclosing private company information. The small number of companies reporting in a given 10-digit code makes it unlikely that information would be available for all codes and states. Therefore, for this study we had to rely on the 6-digit codes. Additionally, the specificity of a 10-digit code could have excluded companies with good potential for entering the geothermal market, which the 6-digit industry code includes.

### **Caveat to Using the 6-digit Codes**

When interpreting the results of a 6-digit code search, it is important to be aware of the potential broadness of companies included. For example, under the 6-digit NAICS, charge controllers and inverters fall under “Electronic Equipment and Components, Not Easily Classified.” Along with rectifying equipment, such as inverters, this also includes laser power supplies and ultrasound equipment. However, this is mostly a problem for one or two particular codes, the majority of NAICS codes used in this study have much less variation of product type. Furthermore, even a company that makes laser power supplies has a significant advantage over a company starting from scratch, as they have basic knowledge and capabilities for making sophisticated electrical equipment.

## **C. Identifying the Economic Impact of Renewables Manufacturing**

To provide an estimate of market development, we must start with a figure for the amount of development to occur in each of the technologies considered in this report. This assumed development figure drives the demand for manufacturing of the components, which in turn creates the potential for economic development in locations that could supply these components. The intention of this report is not to take guesses at the number of MW of renewable energy likely to be installed in the next 20 years; rather we base our calculations on reasonable assumptions in order to provide an estimate of the economic potential. The table below lists the drivers we used for each of the four technologies, and their source.

**Table 6: Sources for Assumed National Development**

	<b>Number of MW</b>	<b>Number of Firms</b>	<b>Investment (Millions)</b>	<b>New FTE Jobs</b>
<b>Wind</b>	124,900	16,480	\$62,338	398,470
<b>Solar</b>	23,150	10,272	\$69,624	298,194
<b>Geothermal</b>	15,190	3,926	\$15,330	72,324
<b>Biomass</b>	21,760	12,020	\$13,248	81,615
<b>Total:</b>	185,000	42,698	\$160,541	850,603

**Investment Allocation**

Having identified components and a NAICS code for each, the next step in determining the potential involvement of this manufacturing base in the development is to determine how demand will flow into each industry based on component cost information. This cost information results in a dollar amount allocated to each industry. Each component is assigned a specific cost (\$/MW) based on research by REPP into the most relevant current cost study for each technology. The table below summarizes the sources for cost information for each of the technologies.

**Table 7: Sources for Component Cost Information**

<b>Energy Source</b>	<b>Component Cost Information Source</b>
<b>Wind</b>	NREL WindPACT Study
<b>Solar PV</b>	Solar PV Industry Roadmap, as well as NREL Solar Energy Technologies Program
<b>Geothermal</b>	EPRI "Next Generation Geothermal Power Plants"
<b>Biomass – Dedicated Steam</b>	Capital costs for the McNeil Generating Station in Burlington, VT

The cost allocated to each component group is then allocated to states and geographic regions according to the number of employees working for companies with the technical potential to manufacture components in that component group. The number of employees is used rather than number of firms to account for variation in size of the firms. A firm employing 1,000 people will bring a larger investment to a region than one employing 10. To illustrate the allocation, consider the wind turbine gearbox, which has a specific cost of \$80,000 per MW of wind capacity. Multiplying by the 124,900 MW of wind assumed as the driving development results in a total investment in gearbox manufacturing of approximately \$10 billion. This \$10 billion is now allocated geographically. Consider Wayne County in Michigan, which has 237 employees working at firms operating in the NAICS code for gearboxes (Speed Changer Industrial – 333612 NAICS), as compared to 63,698 employees in the entire U.S. Therefore, Wayne gets 237/63,698 or 0.37% of the \$10 billion dollars, which means around \$37 million goes to Wayne for the NAICS industry associated with gearboxes (it is possible to verify this by looking at the Wayne Wind breakdown in Section II of this report). To get the total investment for given county or state, we then simply sum up the investment for all of the NAICS codes.

## Jobs Allocation

We are also interested in investigating the impact of the national development of renewable energy on job creation. To do this, we assign a manufacturing job creation ratio to each of the component industry, a number of jobs created manufacturing in a certain industry per MW of new capacity. This ratio is calculated, again using the NAICS census data in combination with the specific cost information discussed above. For each NAICS code, the census reports the number of employees working in that industry, as well as the total value of products shipped from that industry. We make the assumption that this shipped value of a product is the same value represented in the specific cost information used for the investment allocation (the \$/MW for each component). Combining these two pieces of information results in a number of employees per MW. Because the census value of shipments is calculated on an annual basis, this “number of employees” is equivalent to number of annual jobs, or an amount of labor equal to the number of employees times 2000 hours. The table below shows the total jobs/MW number for each technology, summing over all of the component parts:

**Table 8: Jobs per MW Development**

<b>Energy Source</b>	<b>Number of Jobs/MW</b>
<b>Wind</b>	7.5
<b>Solar</b>	62.6
<b>Geothermal</b>	8.25
<b>Biomass – Dedicated Steam</b>	10.5

REPP recently completed a study of the labor that goes into manufacturing renewables, which included a detailed survey of employment related to wind and solar PV. The overall manufacturing jobs/MW numbers found using the NAICS census method and shown in the table above agree with the numbers found in the previous REPP study, giving confidence in the above method. Having obtained a jobs/MW number, the jobs are allocated geographically according to the census manufacturing in the exact same manner that the investment was allocated.

## D. Identifying Potential Supply Bottlenecks

To identify potential bottlenecks in the component supply chain we first established for each NAICS code the current production capacity, then compared that to the maximum available production capacity. For each NAICS code we established an Available Production Capacity. Available Production Capacity is compared to the Incremental Demand for parts from that NAICS code. The Incremental Demand is the annual demand related to the installation of the wedge of 18,500 MW. If the Incremental Demand is greater than the total Available Production Capacity, there is a strong chance of a bottleneck developing. Identifying these bottlenecks should be met with a concerted effort to begin building industrial capacity to avoid the bottleneck.

**Table 9: Bottlenecks in Wind Component Parts**

<b>Wind 10 Digit NAICS Codes</b>	<b>Incremental Demand</b>	<b>Available Production Capacity</b>	<b>Incremental Demand as a % of Available Production Capacity</b>
Nacelle Case	\$132,643	\$55,931	237.15%
Rotor Blade	\$1,133,332	\$477,888	237.15%
Blade Extender	N/A	N/A	N/A
Tower Flange and Bolts	N/A	\$25,554	N/A
Hub	\$471,700	N/A	N/A
Nacelle Frame	\$251,300	\$248,692	101.05%
Towers	\$1,476,550	\$381,607	386.93%
Bearings	\$145,075	\$240,042	60.44%
Cooling System	\$19,200	\$137,235	13.99%
Generator	\$551,900	\$99,554	554.37%
Gear Box	\$942,025	\$14,593	6455.34%
Brakes	\$33,606	\$75,786	44.34%
Coupling	\$16,015	\$58,101	27.56%
Shafts	\$135,254	\$173,851	77.80%
Electronic Controller	\$44,125	N/A	N/A
Sensors/Data Loggers	\$117,525	\$315,294	37.27%
Anemometer	\$0	\$315,294	0.00%
Pitch Drive	\$262,942	\$458,739	57.32%
Yaw Drive	\$58,433	\$101,945	57.32%
Power Electronics	\$447,150	\$191,626	233.34%

**Table 9: Bottlenecks in PV Component Parts**

<b>PV 10 Digit NAICS Code</b>	<b>Incremental Demand</b>	<b>Available Production Capacity</b>	<b>Incremental Demand as a % of Available Production Capacity</b>
Encapsulant	\$248,575	\$1,099,869	22.60%
Rear Layer	\$260,300	\$1,520,380	17.12%
Top surface	\$479,950	\$50,904	942.86%
Wiring	\$241,550	\$57,176	422.47%
Frame	\$118,050	\$116,924	100.96%
Blocking Diode	\$93,327	\$75,510	123.59%
Solar cells	\$2,691,123	\$1,282,194	209.88%
Complete Module	N/A	N/A	N/A
Meter	\$111,900	\$293,423	38.14%
Circuit Breakers and Fuses	\$108,875	\$343,195	31.72%
Switch Gear	\$105,310	\$861,303	12.23%
Electrical Connections	\$400,388	\$103,055	388.52%
Charge Controller	\$477,569	\$50,056	954.07%
Inverter	\$643,392	\$171,306	375.58%

As these two tables show, there are severe supply-chain bottlenecks in more than half of the crucial components for both wind and PV power. A successful program to take advantage of the benefits of renewables manufacturing will require enhanced coordination and investment to ensure that these bottlenecks do not shortchange the amount of economic benefits captured.