Component Manufacturing: Ohio's Future in the Renewable Energy Industry

R E P P

RENEWABLE ENERGY POLICY PROJECT

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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 hoped that the Reports will spur 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: Ohio's Future in the Renewable Energy Industry

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. 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, 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. It is the intent of this Report to outline the potential for Ohio from a national commitment to accelerate renewable energy development.

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 Ohio 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 50,000 MW will be developed 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.
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> 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. The table below shows the twenty states with 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.

Investment and Job Creation Potential
Top 20 States Ranked by Average Investment

State	Potential Number of Jobs	Average Investment ($ Billions)	2001 Population	Rank in U.S.	Manufacturing Jobs Lost, Jan. 2001 - May 2004*	Rank in U.S.
California	12,717	4.24	34,501,130	1	318,000	1
Ohio	11,688	3.90	11,373,541	7	165,500	3
Texas	8,943	2.98	21,325,018	2	169,600	2
Michigan	8,549	2.85	9,990,817	8	129,300	8
Illinois	8,530	2.84	12,482,301	5	131,500	6
Indiana	8,317	2.77	6,114,745	14	63,500	13
Pennsylvania	7,622	2.54	12,287,150	6	155,200	5
Wisconsin	6,956	2.32	5,401,906	18	68,300	10
New York	6,549	2.18	19,011,378	3	130,500	7
South Carolina	4,964	1.65	4,063,011	26	56,800	17
North Carolina	4,661	1.55	8,186,268	11	156,600	4
Tennessee	4,233	1.41	5,740,021	16	59,700	15
Alabama	3,571	1.19	4,464,356	23	45,300	19
Georgia	3,532	1.18	8,383,915	10	65,700	11
Virginia	3,386	1.13	7,187,734	12	57,500	16
Florida	3,371	1.12	16,396,515	4	56,800	18
Missouri	3,234	1.08	5,629,707	17	36,700	23
Massachusetts	3,210	1.07	6,379,304	13	84,900	9
Minnesota	3,064	1.02	4,972,294	21	38,800	21
New Jersey	2,920	0.97	8,484,431	9	65,400	12
20 State Total	120,017	40	212,375,542		2,055,600	
% U.S. Total	80%	80%	75%		76%	

The results indicate that a significant national investment in wind has clear potential to benefit regions of the U.S. other than only those states that have a significant wind resource. Furthermore, investigating the demographics of the top 20 states benefiting from wind manufacturing indicates that investment in wind 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 wind 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 in wind 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."

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 50,000 MW of wind would be developed, 9,260 MW of photovoltaic, 8,700 MW of biomass, and 6,077 MW of geothermal.

Summary of National Development, Resulting Investment and Jobs

U.S.	Number of MW	Number of Firms	Millions $ Investment	New FTE Jobs
Wind	50,000	16,163	$26,968	174,308
Solar	9,260	10,179	$32,930	140,847
Geothermal	6,077	4,024	$6,020	29,469
Biomass	8,700	12,447	$5,885	37,053
Total:	**74,037**	**42,813**	**$71,802**	**381,677**

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 74,000 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 $72 billion dollars of manufacturing investment, and would result in more than 381,000 new jobs.

Ohio is particularly well positioned to benefit from such a national development. As shown in the tables below, Ohio stands to receive nearly 23,000 new jobs and $3.6 billion dollars of investment in manufacturing components to supply this national development of renewables. Ohio is ranked fourth among states in terms of job gain, and fifth 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.)

New Manufacturing Jobs, Investment for 74,000 MW Renewable Energy Development

Location	# of Firms	New Jobs Wind	New Jobs Solar	New Jobs Geothermal	New Jobs Biomass	New Jobs Total
California	4,658	14,147	24,288	3,320	2,848	44,602
Texas	2,795	10,000	12,299	1,841	3,261	27,401
Illinois	1,961	11,303	8,472	1,455	1,715	22,946
Ohio	**2,156**	**13,215**	**5,957**	**1,896**	**1,854**	**22,922**
Pennsylvania	1,839	9,029	8,119	1,538	1,832	20,517
New York	1,605	7,876	6,318	3,136	2,683	20,013
Indiana	1,154	11,186	3,834	1,410	1,524	17,954
Wisconsin	1,123	11,335	2193	845	1844	16218
Michigan	1,817	10,369	2,457	587	1,021	14,435
North Carolina	940	4,897	4,722	1,350	2,006	12,976

Location	# of Firms	Millions $ Wind	Millions $ Solar	Millions $ Geothermal	Millions $ Biomass	Millions $ Total
California	4,658	2,350	6,058	842	511	9,762
Texas	2,795	1,593	4,008	363	497	6,460
New York	1,605	1,357	1,456	746	465	4,025
Pennsylvania	1,839	1,412	1,872	342	326	3,952
Ohio	**2,156**	**1,925**	**1,097**	**337**	**288**	**3,647**
Illinois	1,961	1,660	1,452	256	272	3,640
Indiana	1,154	1,681	694	267	240	2,882
Wisconsin	1,123	1,677	431	153	273	2,534
North Carolina	940	819	1,001	329	319	2,468
Michigan	1,817	1,468	480	105	155	2,207

II. Ohio and Ohio Counties Information

As shown in the wind report on manufacturing activity, Ohio 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 Ohio manufacturing industries is even greater. As in the case of wind technology, Ohio has a manufacturing base in most of the industries relevant to the production of renewable energy components.

Potential Manufacturing Benefit to Ohio from National Development

Ohio	Number of Firms	Millions $ Investment	New FTE Jobs
Wind	1,045	$1,924.70	13,215
Solar	500	$1,097.10	5,957
Geothermal	202	$337.40	1,896
Biomass	750	$287.50	1,854
Total:	2,497	$3,646.70	22,922

This report and the previous wind manufacturing report identify that Ohio stands to benefit greatly from national renewable energy development through the chain of manufacturing. The next step is to identify ways to take specific action to move towards making this potential benefit a reality. In order to do so, it would be useful to have more specific information about the location and nature of the manufacturing potential in Ohio. One important feature of the census information for manufacturing is that it goes 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. Jobs are distributed in the same manner.

Top 20 Counties in Ohio

	Biomass		Geothermal		Solar		Wind		Totals	
County	Millions $	Jobs	Millions $	Jobs	Millions $	Jobs	Millions $	Jobs	Millions $	Jobs
Cuyahoga	19.3	130	20.7	141	117.5	641	257.1	1,743	414.6	2,655
Lorain	4.7	30	3.2	15	138.7	878	95.8	648	242.4	1,571
Hamilton	26.3	175	24.7	145	72.1	437	99.1	663	222.2	1,420
Summit	11.2	80	8.8	56	27.0	129	117.8	833	164.8	1,098
Miami	9.0	47	31.0	179	49.3	310	56.8	382	146.1	918
Lucas	4.5	29	3.0	14	88.6	463	34.2	222	130.3	728
Franklin	14.1	95	11.6	51	25.5	133	74.2	498	125.4	777
Montgomery	14.5	97	23.9	157	3.6	22	82.3	557	124.3	833
Wood	5.6	35	4.3	18	81.1	330	28.7	222	119.7	605
Warren	5.7	27	27.4	151	48.9	124	29.7	172	111.7	474
Stark	13.2	84	7.9	40	7.4	45	76.0	529	104.5	698
Sandusky	0.7	4	1.1	7	80.7	424	16.3	130	98.8	565
Lake	19.4	132	3.1	22	43.4	275	31.7	219	97.6	648
Mahoning	2.9	15	0.9	3	46.6	301	42.6	273	93.0	592
Richland	8.5	40	26.5	129	3.7	22	34.1	229	72.8	420
Butler	4.3	27	17.9	122	30.0	167	17.9	129	70.1	445
Tuscarawas	3.0	20	15.2	109	25.0	152	26.1	178	69.3	459
Williams	6.1	34	24.8	133	9.1	60	25.9	190	65.9	417
Fairfield	47.8	345	9.7	69	0.1	-	7.9	57	65.5	471
Wayne	8.5	56	2.7	17	6.9	48	42.7	305	60.8	426

The table above lists the 20 counties in Ohio that would receive the greatest investment in manufacturing from the national development of wind, solar PV, geothermal, and dedicated biomass. To further clarify, the Millions $ figure is arrived at by starting with an assumed number of MW of new capacity for the entire U.S., for example we use 50,000 MW new wind for this report. This 50,000 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". Then the total dollars that go into making gearboxes for the 50,000 MW of wind are divided into each county based on the relative number of firms operating in 333612 in that county (actually, the number of employees working at those firms is used to account for different size companies). This process is repeated for each part, and then summed to get 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 were 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 way that the investment was.

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, we look at the Ohio county which had the most renewable energy manufacturing potential: Cuyahoga. While a variety of data is available, three items seemed particularly relevant. 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 out the results for Cuyahoga county.

Cuyahoga, OH

Wind

NAICS	NAICS Description	# of Firms in NAICS	Millions $ Investment	New FTE Jobs
333612	Speed Changer, Industrial	5	$119.8	811
331511	Iron Foundries	5	$44.9	315
326199	All Other Plastics Product Manufacturing	42	$22.0	175
333613	Power Transmission Equip.	6	$21.9	143
332312	Fabricated Structural Metal	16	$15.0	86
335312	Motors and Generators	10	$13.9	85
335999	Electronic Equipment and Components, NEC	4	$10.5	68
334519	Measuring and Controlling Devices	11	$7.0	46
333412	Industrial and Commercial fans and blowers	1	$1.2	9
332991	Ball and Roller Bearings	3	$0.5	3
334418	Printed circuits and electronics assemblies	2	$0.4	2
Total:		105	$257.1	1,743

Solar

NAICS	NAICS Description	# of Firms in NAICS	Millions $ Investment	New FTE Jobs
335911	Storage Batteries	2	$40.5	213
335999	Electronic Equipment and Components, NEC	4	$26.2	170
335931	Current-Carrying Wiring Device Manufacturing	7	$16.5	126
334515	Instrument Manufacturing for Measuring and Testing Electricity a	13	$11.5	52
334413	Semiconductors and Related Devices	1	$11.4	29
335313	Switchgear and Switchboard Apparatus Manufacturing	9	$4.3	23
325211	Plastics Material and Resin Manufacturing	5	$2.7	4
326113	Unlaminated Plastics Film and Sheet (Except Packaging) Manufa	6	$2.6	10
332322	Sheet Metal Work Manufacturing	27	$1.8	14
Total:		74	$117.5	641

Geothermal

NAICS	NAICS Description	# of Firms in NAICS	Millions $ Investment	New FTE Jobs
333412	Industrial and Commercial fans and blowers	1	$14.8	107
333923	Overhead Traveling Crane, Hoist, and Monorail System Manufact	4	$2.1	12
332410	Power Boiler and Heat Exchanger Manufacturing	3	$1.5	11
333911	Pump and Pumping Equipment Manufacturing	2	$0.8	4
333415	Air-Conditioning and Warm Air Heating Equipment and Commerc	5	$0.7	4
333912	Air and Gas Compressor Manufacturing	2	$0.5	2
332420	Metal Tank (Heavy Gauge) Manufacturing	3	$0.2	1
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Ste	1	$0.1	0
Total:		21	$20.7	141

Biomass

NAICS	NAICS Description	# of Firms in NAICS	Millions $ Investment	New FTE Jobs
332410	Power Boiler and Heat Exchanger Manufacturing	3	$5.2	37
333922	Conveyor and Conveying Equipment Manufacturing	9	$3.8	23
333411	Air Purification Equipment Manufacturing	3	$3.0	22
333412	Industrial and Commercial fans and blowers	1	$1.9	14
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	6	$1.2	8
333999	All Other Miscellaneous General Purpose Machinery Manufacturi	20	$1.2	8
332911	Industrial Valve Manufacturing	7	$0.9	5
333923	Overhead Traveling Crane, Hoist, and Monorail System Manufact	4	$0.5	3
335999	Electronic Equipment and Components, NEC	4	$0.4	3
335313	Switchgear and Switchboard Apparatus Manufacturing	9	$0.3	2
333415	Air-Conditioning and Warm Air Heating Equipment and Commerc	5	$0.3	1
333911	Pump and Pumping Equipment Manufacturing	2	$0.2	1
333120	Construction Machinery Manufacturing	3	$0.2	1
334513	Instruments and Related Products Manufacturing for Measuring,	7	$0.1	1
332420	Metal Tank (Heavy Gauge) Manufacturing	3	$0.1	1
335311	Power, Distribution, and Specialty Transformer Manufacturing	1	$0.0	0
333995	Fluid Power Cylinder and Actuator Manufacturing	2	$0.0	0
333912	Air and Gas Compressor Manufacturing	2	$0.0	0
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Ste	1	$0.0	0
327993	Mineral Wool Manufacturing	5	$0.0	0
Total:		97	$19.3	130
Grand Total for Cuyahoga, OH:		**297**	**$414.6**	**2,655**

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 doing so, 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.

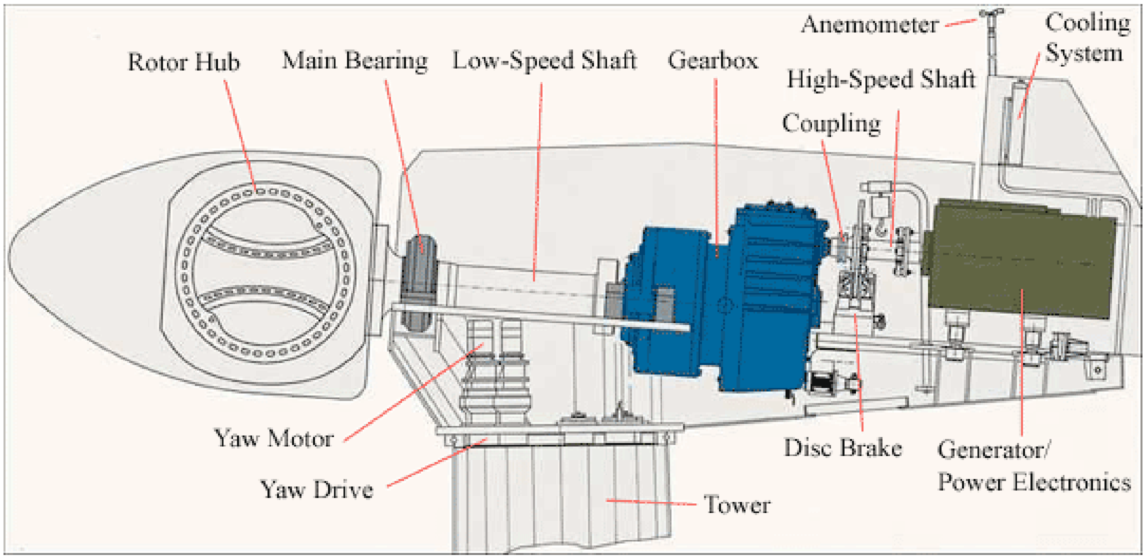


Figure 1 – Wind Turbine Component Diagram

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 modulese. 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.

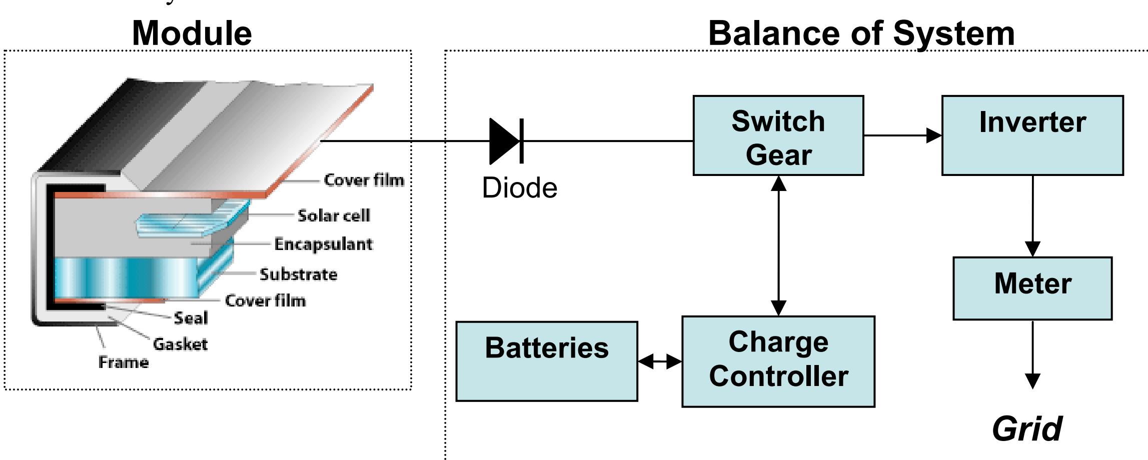


Figure 2 – Solar PV Component Diagram

For geothermal power generation, we considered two technologies which 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.

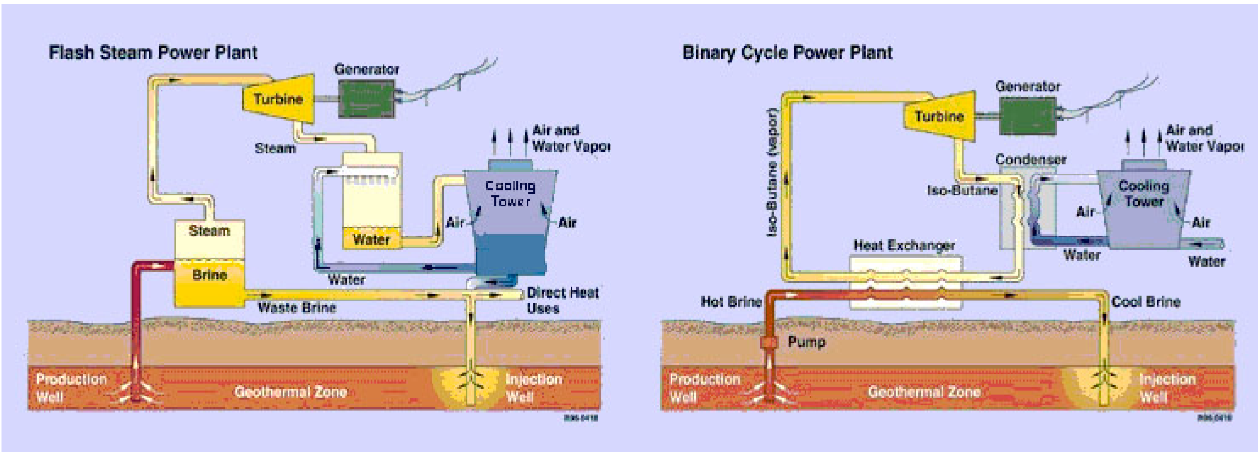


Figure 3 – Geothermal Component Diagram

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 anearobic 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.

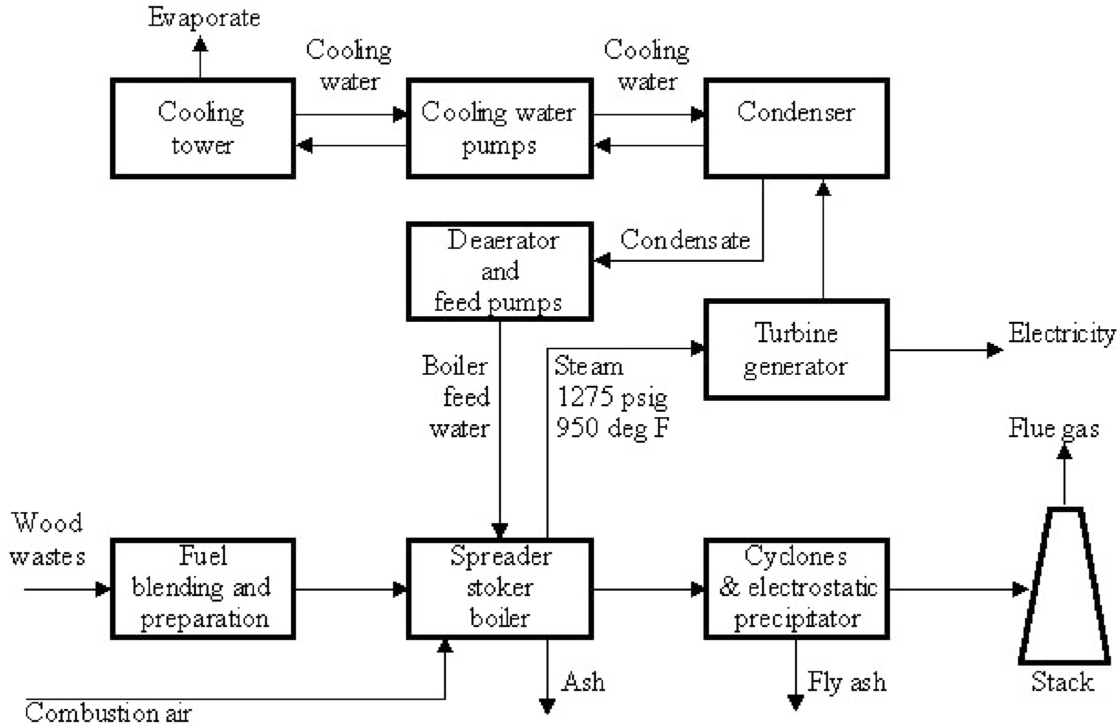
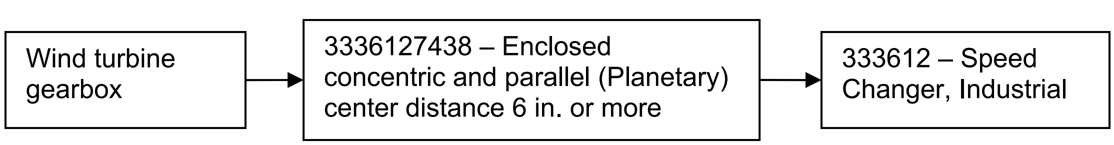


Figure 4 – Direct-fired Biomass Steam Plant Component Diagram

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 1930's 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 simply take some reasonable numbers 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.

Sources for Assumed National Development

Energy Source	Number of New MW	Source
Wind	50,000	½ of AWEA's projection for next 20 years
Solar PV	9,260	Solar PV Industry Roadmap
Geothermal	6,077	EIA Projection for a 20% RPS by 2020
Biomass – Dedicated Steam	8,700	EIA Projection for a 20% RPS by 2020

Investment Allocation
Having identified components and a NAICS code for each, the next step in determing 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.

Sources for Component Cost Information

Energy Source	Component Cost Information Source
Wind	NREL WindPACT Study
Solar PV	Solar PV Industry Roadmap, as well as NREL Solar Energy Technologies Program
Geothermal	EPRI "Next Generation Geothermal Power Plants"
Biomass – Dedicated Steam	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 50,000 MW of wind assumed as the driving development results in a total investment in gearbox manufacturing of $4 billion. This $4 billion is now allocated geographically. Consider Cuyahoga county in Ohio, which has 419 employees working at firms operating in the NAICS code for gearboxes, as compared to 13,991 employees in the entire U.S. Therefore, Cuyahoga gets 419/13,991 or 3% of the $4 billion dollars, which means around $120 million goes to Cuyahoga for the NAICS industry associated with gearboxes (you can check this by looking at the Cuyohoga 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:

Jobs per MW Development

Energy Source	**Number of Jobs/MW**
Wind	3.5
Solar PV	15.2
Geothermal	4.8
Biomass –Dedicated Steam	4.3

REPP had recently completed a study of the labor that goes into renewables for the Pennsylvania RPS, as well as for other purposes, 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 well 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.