
Renewable Energy Supply Chains

A Guide for
Economic Developers

International Economic
Development Council



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Renewable Energy Supply Chains

A Guide for Economic Developers

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RENEWABLE ENERGY SUPPLY CHAINS

According to the IEDC State Level Renewable Energy Survey, all regions of the U.S. except for the Midwest region indicated supply chain analysis as one of their top information needs for stimulating renewable energy development. Reliable, cost-effective supply chains play a crucial role for original equipment manufacturers. Many economic development organizations have begun to take inventory of supply chain assets and to develop programs that help suppliers retool for renewable industries. This document examines supply chains for wind, solar, geothermal and biofuels manufacturing and identifies strategies that economic developers are using to strengthen them.

Domestic supply chains are affected by trends in global manufacturing. The United States has seen some losses in this area. For example, technology developed in the U.S. is often sent overseas for commercial production due to lower labor costs in countries like China and India. Yet domestic manufacturing still has a number of distinct advantages, especially in renewable energy:

Supply chain management, as defined by the Association for Operations Management, is the “design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally.”

Manufacturing, renewable energy included, is heavily reliant upon strong supply chain linkages. Recognizing this, economic development organizations are taking an increasingly proactive role in facilitating supply chain networks in their regions.

- 1) **Innovation leadership:** The U.S. has the top gross domestic expenditure on R&D in the world (across all high-tech industries).¹ The U.S. also boasts the world's best university system and has one of the highest populations of scientists and engineers.² In a survey by R&D Magazine, the U.S. was perceived as the leader in innovation related to smart grid, wind, photovoltaic, ocean, battery and fuel cell technologies.³
- 2) **Just-in-time manufacturing:** This is a production strategy that involves inputs arriving "just in time" so as to minimize inventory costs. In this case, domestic suppliers are ideal because they often can supply components more quickly than their foreign counterparts.
- 3) **Natural resources:** Biofuels plants are typically located near the source of feedstock. The U.S. is rich in all areas of renewable energy natural resources.
- 4) **Transportation:** Wind turbines, for example, are expensive and logistically complex to transport. Outsourcing of large turbine blades and towers is impractical. Instead, foreign firms like Nordex, Vestas and Suzlon have invested in facilities in the U.S. to serve the domestic market.
- 5) **Policy:** Some firms, such as solar manufacturer Suntech, have opened U.S. facilities in order to take advantage of funds that were made available through the American Recovery and Reinvestment Act of 2009, which required components to be manufactured domestically. Despite the lack of comprehensive federal energy legislation, renewable energy continues to see steady support on the federal level (such as the Production Tax Credit and the Investment Tax Credit) and state level (renewable portfolio standards implemented by states.)
- 6) **Quality control:** The U.S.'s strong quality control processes are especially advantageous in renewable energy, where components often require high quality standards. Outsourcing manufacturing in these cases can raise quality control concerns. The process can be monitored more easily if U.S. manufacturers and distributors are able to find local suppliers.

¹ "2011 Global R&D Funding Forecast." (2010 December). R&D Magazine. Retrieved from http://www.rdmag.com/uploadedFiles/RD/Featured_Articles/2010/12/GFF2010_FINAL_REV_small.pdf on May 6, 2011.

² Ibid.

³ Ibid.

- 7) **Available industrial space:** Closed plants can be retooled for renewable manufacturing. Wind manufacturing requires large facilities with high ceilings and large doors, and retooling an existing plant can mitigate high investment costs.
- 8) **Available workforce:** The U.S. manufacturing industry is undergoing a metamorphosis, with some sectors declining and others rising. While many skilled workers are migrating to other advanced manufacturing sectors, there continues to be a shortage of skilled workers in some sectors.
- 9) **Currency fluctuations:** International transactions are sensitive to currency fluctuations, which can make importing complicated.

DEFINITIONS

1. *Bottleneck*: Bottlenecks in the supply chain refer to crucial components that, if in scarce supply, can cause delays in the final production of a good.
2. *Just-in-time manufacturing*: This is a production strategy that involves manufacturing inputs arriving “just in time” to reduce costs of storing inventory.
3. *Logistics*: In manufacturing, logistics refers to the management of the flow of inventory, which includes materials, services, information and capital.
4. *Original equipment manufacturer (OEM)*: An OEM purchases components from other manufacturers and sells the final product under its own brand. OEMs may also manufacture or assemble products in-house.
5. *Vertically integrated*: Vertically integrated manufacturers incorporate a wide range of supply chain activities into their in-house capacity. This reduces the risk of bottlenecks holding up delivery of the final product.
6. *Smart grid*: The smart grid uses digital technology to monitor and control the delivery of electricity from the power plant to the end user. The smart grid encompasses a variety of technologies aimed at saving energy, reducing costs, and increasing reliability and safety.

WIND

Background

The modern wind turbine has over 8,000 components, ranging from steel towers to gearboxes to electrical wiring and more.⁴ However, only about 50 percent of the components in U.S. wind turbines currently are manufactured domestically.⁵ Turbine manufacturers typically engineer their proprietary design, contract with a variety of suppliers to manufacture components and assemble the final product. However, trends vary: some manufacturers are producing more components in-house in response to supply chain bottlenecks, while manufacturers such as GE are outsourcing more components in order to focus on core competencies.⁶ Blades and control systems are typically manufactured in-house, while gearboxes, generators and convertors are mainly outsourced.⁷ The following chart gives an overview of top manufacturers and their production preferences. Several top manufacturers are becoming more vertically integrated.

	Buy all components		In-house production of just key technology components		In-house production
Vestas			X		
GE	X				
Enercon					X
Gamesa			X	→	X
Suzlon			X	→	X
Siemens			X		
Clipper	X	→	X		
Nordex	X	→	X		

Source: BTM Consult

⁴ Kenney, B. "Wind Turbine Supply Chain Spinning Up." (2008, December 15). Industry Week. Retrieved from http://www.industryweek.com/articles/wind_turbine_supply_chain_spinning_up_18042.aspx?SectionID=2 on May 6, 2011.

⁵ American Wind Energy Association. Retrieved from http://www.awea.org/rn_release_01-06-11.cfm on May 6, 2011.

⁶ "Supply Chain: The race to meet demand." (January/February 2007). *Wind Directions*, p. 27-34.

⁷ Efiog, A. & Crispin, A. (2007). *Wind turbine manufacturers; here comes pricing power*. Merrill Lynch. Retrieved from <http://www.ml.com/media/81290.pdf> on May 6, 2011.

The increasing size of wind turbines is causing supply chain challenges. The 2.5 megawatt (MW) turbine is now the industry standard, while less than 1 MW turbines were common just a few years ago.⁸ A few manufacturers are already selling 3 and 4 MW turbines, and some are developing 10 and 15 MW turbines for testing by 2015.⁹ As turbines become larger, fewer suppliers are equipped to produce the unique components unless they retool. On the other hand, larger components are more expensive and difficult to transport, thus making the domestic supply chain more crucial than ever.

The following graphic gives an overview of the large-scale wind manufacturing supply chain. Large-scale turbine manufacturers typically distribute their own turbines directly to developers. In the small-wind market, however, it is more common for manufacturers to work through a separate distributor to serve residential or business customers. The complete wind supply chain also includes utilities, which contract with large-scale wind farm developers to buy wind energy over a fixed time period. Energy storage firms also play a crucial role. Battery technologies allow wind energy harvested at night to be used during the day when energy demand is highest.¹⁰ A number of technologies have been developed to store renewable energy for use during off-peak periods; the most promising is compressed air energy storage (CAES). A CAES facility can store large amounts of energy over a long period of time, and currently it is one of the only energy storage technologies capable of serving the utility market.¹¹ Alabama has been operating a CAES plant since 1991, and Iowa has plans under way to open the nation's second CAES facility in 2011.¹²

⁸ Ibid.

⁹ Ibid.

¹⁰ Leber, J. (2009, February 12). "Pushing wind power from night to day via compressed air." *Earth News*. Retrieved from <http://www.earthportal.org/news/?p=2169> on May 16, 2011.

¹¹ Wesoff, E. (2010, January 14). "EPRI on Renewable Energy: Compressed Air Energy Storage" *Greentech Media*. Retrieved from <http://www.greentechmedia.com/articles/read/epri-on-renewable-energy-compressed-air-energy-storage/> on May 6, 2011.

¹² Gardner, J. & Haynes, T. (2007, December). "Overview of Compressed Air Energy Storage." Office of Energy Research, Policy and Campus Sustainability, Boise State University. Retrieved from <http://coen.boisestate.edu/WindEnergy/resources/ER-07-001.pdf> on May 6, 2011.

Wind Manufacturing Supply Chain



Source: Information from The Pantagraph

Policy Issues

Renewable energy development in the U.S. is highly sensitive to the policy landscape. A major roadblock to greater production and use of renewable energy is an outdated national transmission grid. National grid modernization will require the cooperation of over 3,000 utilities across the nation, plus regulatory commissions; federal, state and local governments; vendors, consumers and others.¹³ Because of these barriers, some states are taking steps to modernize their grids ahead of national action. Illinois policymakers, for instance, are working with state utilities and other stakeholders to formulate a legislative plan that would invest in new energy infrastructure, install a smart grid, and negotiate an optimal rate plan.¹⁴ The American Recovery and Reinvestment Act of 2009 is supporting regional efforts through a \$4.5 billion allocation for smart grid projects across the country. The program funded 140 projects related to smart grid investment, technology demonstration and system integration.¹⁵

The wind energy industry is heavily dependent on federal support. The American Recovery and Reinvestment Act of 2009 (ARRA) extended production tax credits and investment tax credits for renewable energy to 2012, and implemented a number of other financial programs specific to renewable energy.¹⁶ ARRA also set up a Department of Treasury grant program in lieu of tax credits for renewable developers that didn't garner significant profits due to the recession.¹⁷ ARRA briefly countered the effects of the global recession on the wind industry, which experienced a banner year in 2009 with 10,000 MW installed.¹⁸ However, the U.S. Senate's rejection of the American Clean

¹³ "Barriers to Achieving the Modern Grid." (2007, July). National Energy Technology Laboratory. Retrieved from http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/Barriers%20to%20Achieving%20the%20Modern%20Grid_Final_v1_0.pdf on May 6, 2011.

¹⁴ "Modernizing Illinois' Electric Grid." ComEd.

¹⁵ "SmartGrid.gov: Overview." U.S. Department of Energy. Retrieved from http://www.smartgrid.gov/recovery_act/overview_on_May_16, 2011.

¹⁶ Union of Concerned Scientists. (2010). *Production Tax Credit for Renewable Energy*. Retrieved from http://www.ucsusa.org/clean_energy/solutions/big_picture_solutions/production-tax-credit-for.html on May 6, 2011.

¹⁷ Ibid.

¹⁸ "AWEA: Wind energy surges 39% despite recession." (2010, April 26). 2020 Climate Change Leadership Campaign. Retrieved from <http://2020climatecampaign.org/content/awea-wind-energy-surges-39-despite-recession> on May 6, 2011.

Energy and Security Act of 2009 created policy uncertainty, and in 2010, installed capacity totaled only 5,000 MW.¹⁹

Meanwhile, individual states are moving ahead with their own renewable energy policies. Thirty states and the District of Columbia have passed renewable portfolio standards, which require utilities to derive a certain percentage of energy from renewable sources.²⁰ Many states also have set up financial incentives specifically targeting renewable energy manufacturing companies. The boxes below offer overviews of production tax credits, investment tax credits and renewable portfolio standards.

Production Tax Credit (PTC) and Investment Tax Credit (ITC)²¹

These two tax credits have been vital to the development of the U.S. wind industry. The PTC issues a tax credit of 2.1 cents per kilowatt hour of renewable electricity produced. Qualified sources include wind, geothermal, biomass, hydropower, landfill gas, waste-to-energy and marine facilities. Established in 1992, the PTC has been extended periodically with a few lapses. Whereas the PTC is available to businesses that pay federal corporate taxes, the Renewable Energy Production Incentive (REPI) complements the PTC by offering an incentive payment of 1.5 cents per kilowatt hour for not-for-profit entities such as electrical cooperatives, public utilities, and state governments.

The ITC can be used in place of the PTC and offers a 30 percent tax credit for investments made in renewable facilities. The ITC also qualifies to be converted into a cash grant from the U.S. Department of Treasury. These two tax credits are widely utilized; the U.S.

¹⁹ Trabish, H. (2010, December 30). "Wind's Top Ten in 2010: Bust and Building, Coming and Going." Seeking Alpha. Retrieved from <http://seekingalpha.com/article/244075-wind-s-top-ten-in-2010-bust-and-building-coming-and-going> on May 6, 2011.

²⁰ For a summary and map of RPS policies by state, refer to the U.S. Department of Energy website: http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm

²¹ "Production Tax Credit (PTC)." American Wind Energy Association. Retrieved from http://www.awea.org/ei_policy_ptc.cfm on May 6, 2011.

Energy Information Administration estimates that wind production capacity is five to six times higher with these tax credits than it would be without them.²² Understandably so: the PTC represents an allotment of tax-free money that the project owner otherwise would have to recoup through electricity sales, which furthermore are taxed.

The Lawrence Berkeley National Laboratory and the National Renewable Energy Laboratory developed a comparative analysis of the PTC, ITC and cash grant programs.²³ The study found that the ITC generally produced a higher return for “open-loop” biomass projects (those that use waste material), while the PTC was more beneficial for geothermal projects. Wind, landfill gas and “closed-loop” biomass (which uses feedstock planted exclusively for power generation) were split between the ITC and PTC, depending on the project’s parameters:²⁴

ITC Advantages:

- Option to elect for an equivalent cash grant
- No performance risk
- Derived from current tax base as opposed to future projected tax base, which is more uncertain Can be used on top of existing subsidized financing (such as low-interest government loans)
- No power sale requirement
- Availability of leasing structures

PTC Advantages:

- Investment liquidity
- Suitable for projects with extremely low installed cost or high capacity factors

²² “Production Tax Credit for Renewable Electricity Generation.” (2005). U.S. Energy Information Administration. Retrieved from http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo_2005analysispapers/prcreg.html on May 6, 2011.

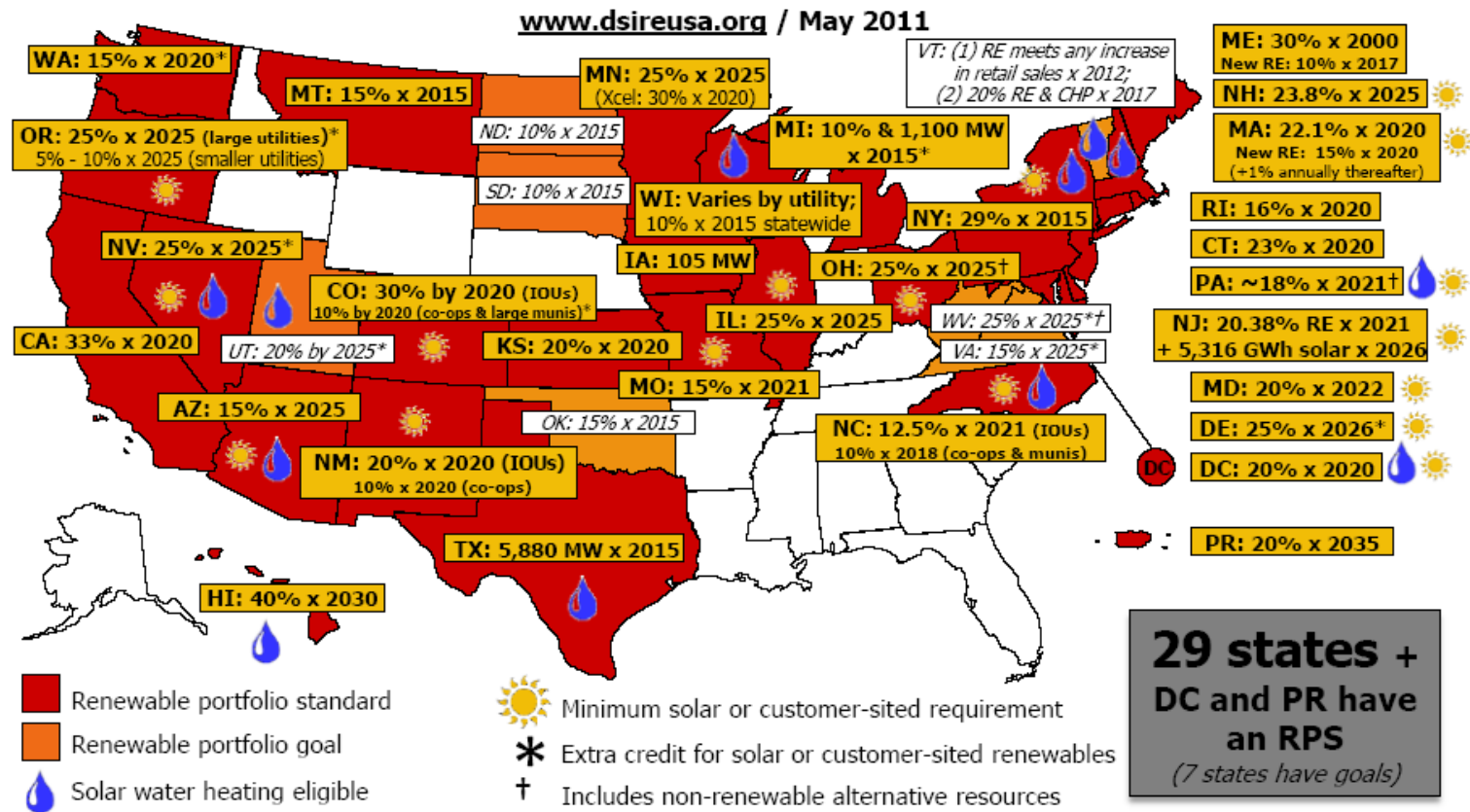
²³ Bollinger, M. et al. “PTC, ITC, or Cash Grant?” (2009 March). National Renewable Energy Laboratory. Retrieved from <http://eetd.lbl.gov/EA/EMP/reports/lbnl-1642e.pdf> on May 6, 2011.

²⁴ Ibid.

Renewable Portfolio Standards

A renewable portfolio standard (RPS) requires utilities to generate a minimum percentage of their electricity from renewable resources. An RPS establishes demand across multiple renewable energy sources: wind, solar, geothermal, biomass and more. Currently, 29 states have a mandatory RPS, which sets penalties for falling short, while seven states have a non-binding RPS goal.

Source: DSIRE



Retooling for the Wind Supply Chain

Turbine manufacturers seek long-term relationships with suppliers, although a lack of access to capital for turbine manufacturers can make these relationships difficult when the economy is in a downturn. Manufacturers aspiring to enter the wind supply chain find that the quality standards are rigorous and that the retooling process can be expensive. Components used for wind turbines are large and precise—similar to those manufactured for the aerospace, defense, energy and mining industries.²⁵ The retooling process varies, so suppliers must gauge whether they have the capacity as well as the incentive to enter the wind supply chain. The following three cases highlight how the retooling experience can vary greatly from firm to firm.

Retooling for Wind: Three Cases

Specialty Metal Fabricators (SMF), a machine shop in Minonk, Ill., first made an emergency steel ring five years ago that saved a foundation at a wind farm in central Illinois.²⁶ SMF had served OEMs in construction, power generation, agriculture, and mining for over 30 years, and the part that it now makes for wind customers is similar to the welded steel parts it makes for Caterpillar. The manufacturing of the wind component is relatively low-tech, and SMF had existing capital and workforce to accommodate the need. Beginning with one wind customer, SMF pursued companies individually and at trade shows, eventually building its wind base to 10 customers across the U.S. and Canada. The company even invested in a facility in Texas to serve its southern customers. While SMF's retooling process was virtually painless, not all companies seeking to enter the wind supply chain are so lucky. Supply chain opportunities in wind are competitive and vary by niche; companies must earn their way in. SMF was able to break into and expand its wind business without state or community help. Today, wind is about five percent of its

²⁵ "Increasing the Participation of Small and Medium-Sized Manufacturers in U.S. Wind Energy Supply Chains." (2010, July 15). BlueGreen Alliance Foundation.

²⁶ Denham, Ryan. (2010, August 10). "Local parts makers see potential in wind industry." *The Pantagraph*. Retrieved from http://www.pantagraph.com/business/local/article_0d7b85ba-9ffc-11df-aa5c-001cc4c03286.html on May 6, 2011.

business and growing.

Source: Interview with Paul Halvorsen, co-owner and chief financial officer at SMF

Transco Products, down the road from SMF, operates solely in the nuclear industry, supplying metal insulation for nuclear power plants. With the market for nuclear energy dwindling in the U.S., Transco exports most of its parts to China's booming nuclear market while primarily producing replacement parts for its domestic customers. Transco was looking to diversify its customer base and attended a wind supply chain workshop sponsored by the Illinois Wind Working Group.²⁷ Manufacturing for nuclear has similarities to manufacturing for wind but actual compatibility to share equipment varies. Transco soon found that it did not possess the casting capability and fiberglass expertise that wind companies were looking for. In order to accommodate the new requirements, Transco would have had to purchase expensive equipment to manufacture more sophisticated, larger parts. Existing capacity did not provide the synergies that SMF had found in its niche. Although state resources originally helped Transco explore the market for wind, the company's lack of suitable in-house capacity kept it from entering the wind industry for the time being.²⁸

Source: Interview with Ken Alessi, vice president, manufacturing at Transco

Merrill Technologies Group is an automotive provider in Saginaw, Mich., that sought to diversify after the downturn in the automotive industry. The company had expertise in the design, manufacturing and assembly of gearboxes, systems that help move cars and other machinery. Its facilities included high-tech machining centers, which are applicable across a number of industries. Merrill was awarded \$3 million from the U.S. Department of Energy's State Energy Program and the American Recovery and Reinvestment Act to retool for the wind industry. With this, it purchased equipment to make advanced-composite wind turbine blades and other components for a partner that owned the intellectual property to the parts. The company also received \$22 million in tax credits to support manufacturing of nacelles, a turbine subsection that houses many engine components. The

²⁷ Case study on Illinois Wind Working Group included later in this report.

²⁸ Denham, Ryan. (2010, August 10). "Local parts makers see potential in wind industry." *The Pantagraph*. Retrieved from http://www.pantagraph.com/business/local/article_0d7b85ba-9ffc-11df-aa5c-001cc4c03286.html on May 6, 2011.

money was used to retool some of Merrill's existing plants as well as to convert an entire plant to serve as a testing and assembly facility for finished turbine systems. Before entering into full production, Merrill will submit a prototype to the National Renewable Energy Laboratory for validation and testing. The new venture allowed the company to rehire employees who were laid off after the automotive bust, as well as to hire 40 new employees, with plans to scale up to 125 new employees in 2011.²⁹

Wind Turbine Components

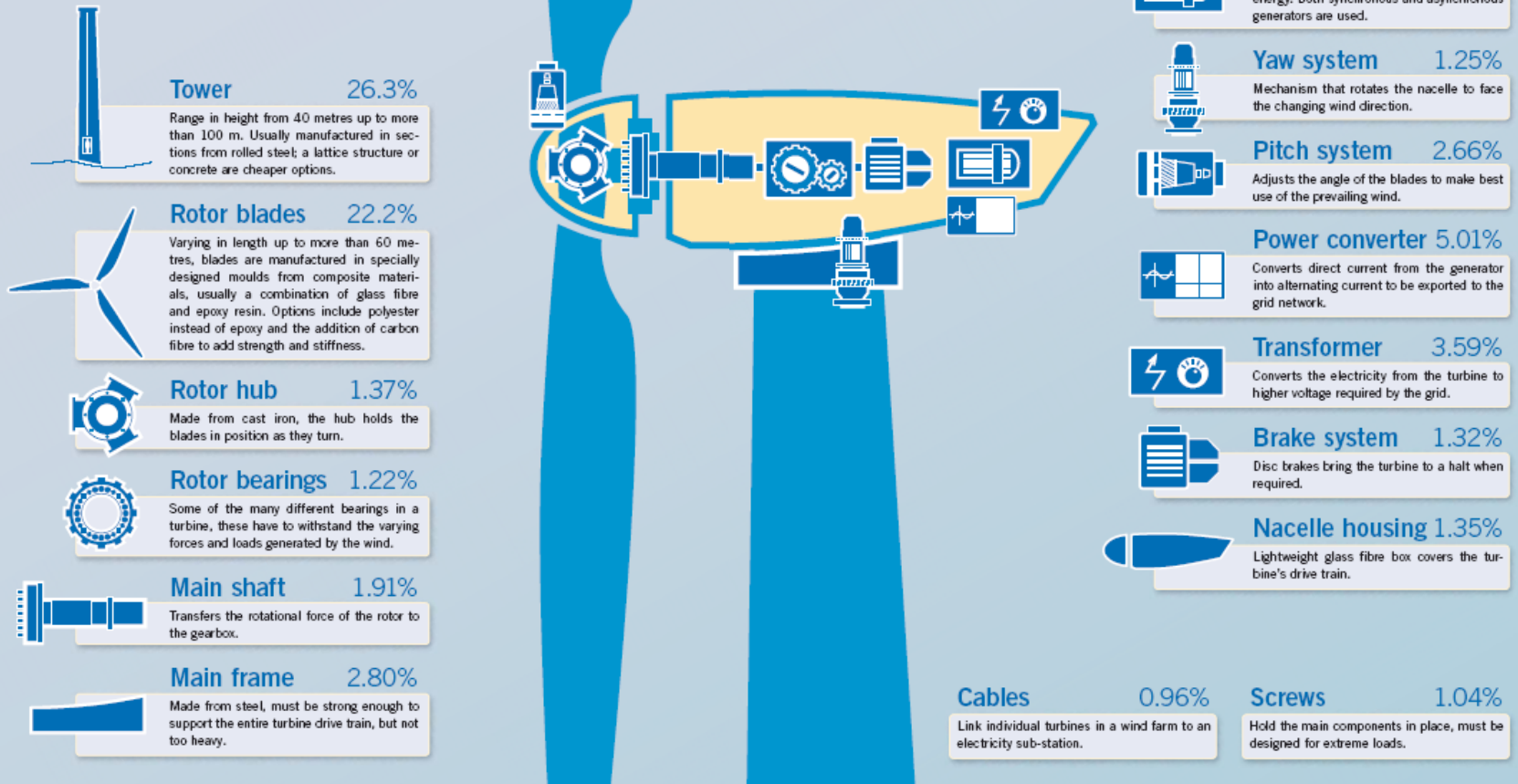
Although there are over 8,000 parts in a single wind turbine, these can be distilled to a few major components. The following diagram summarizes these main components and the overall cost structure of a turbine. The components vary in manufacturing requirements, which dictate the nature of the supply chain. However, supply chains are changing as manufacturers respond to ever-evolving demand and technology. Following the diagram is a chart that offers an overview of the supply chain for each turbine component. The components are organized in order of increasing barrier to entry.

²⁹DeLung, J. (2010, July 21). "VP 100: Retooling Michigan: 'Wheels' to wind." U.S. Department of Energy blog. Retrieved from <http://blog.energy.gov/blog/2010/07/21/vp-100-retooling-michigan-wheels-wind> on May 6, 2011.

Wind Turbine Components and Corresponding Percentage of Total Cost

How a wind turbine comes together

A typical wind turbine will contain up to 8,000 different components. This guide shows the main parts and their contribution in percentage terms to the overall cost. Figures are based on a REpower MM92 turbine with 45.3 metre length blades and a 100 metre tower.



Source: Wind Directions

Major Components in a Wind Turbine

Component	Description	Supplier Market	Market Leaders	Manufacturer Approach	Future Trends
Towers	Typically made of rolled steel, although concrete is becoming increasingly popular as a cheaper alternative. The expertise required is generally widely available. Metal works firms are involved.	Fragmented, locally outsourced, low entry barriers.	Trinity, TowerTech, DMI.	Utilizes multiple suppliers based on region.	Growth of new, localized suppliers to meet new market demand. Becoming more consolidated.
Generators	The nacelle contains the generator, gearbox, and many other components. No shortage of generator supply.	Fragmented, regional suppliers, outsourced. Medium entry barriers.	ABB, Winergy, GE.	3-4 qualified suppliers, relying on 1-2 for larger turbines.	Suppliers becoming more fragmented. Anticipate innovation and simplification.
Gearboxes	Component with the greatest shortage of supply. Several years to ramp up production for new turbine size and capital intensive.	Highly concentrated, outsourced, regional suppliers, high entry barriers.	Winergy, Hansen, Moventas.	Heavy reliance on 1-2 suppliers for larger models, but regional suppliers competing.	Room for new, reliable suppliers. Becoming more fragmented.
Bearings	Delivery time for large bearings can be up to 16-18 months if no long term contract is in place. Wind represents a small fraction of business for bearing manufacturers.	Highly concentrated, outsourced, globally supplied, high entry barriers.	SKF, NTN, Kaydon.	Focus on quality. Secure reliable suppliers to avoid shortages.	Expanding global production networks.
Blades	Require sophisticated manufacturing expertise and are made of high-tech composites (glassfiber-reinforced plastic [GRP]).	Concentrated, both in-house and outsourced, local/regional suppliers, high entry barriers.	LM Glasfiber, NOI, Abeking & Rasmussen.	Produce strategic models in-house while outsourcing older models. One large independent supplier competes with several small-scale regional suppliers.	Trend is toward high strength, fatigue-resistant materials as size of turbines increases.

Sources: Information in this chart is aggregated from the following sources:

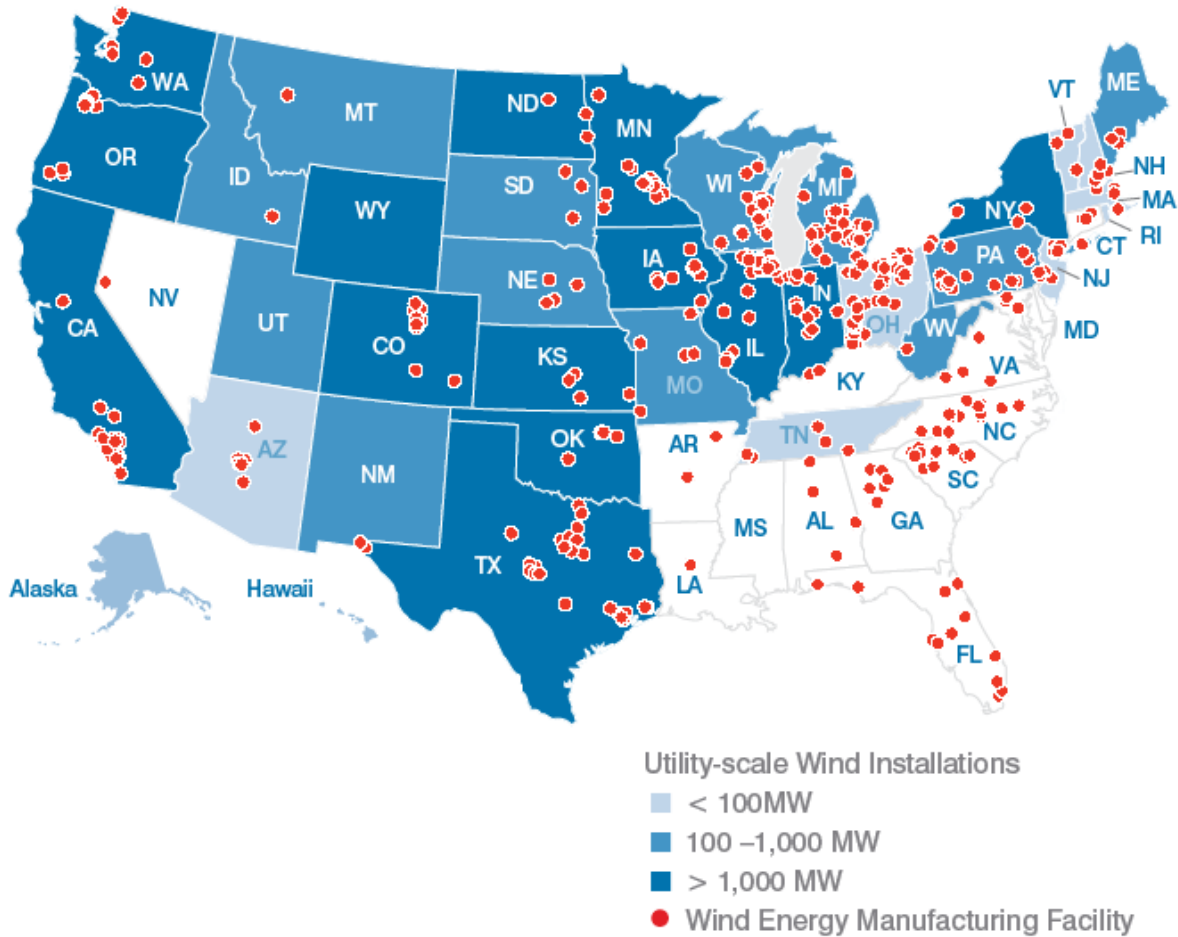
"Supply Chain Key to Delivery." Wind Energy: The Facts. Retrieved from <http://www.wind-energy-the-facts.org/en/part-4-industry--markets/chapter-3-industry-actors-and-investment-trends/wind-turbine-manufacturing-trends/supply-chain-key-to-delivery.html> on May 6, 2011.

"Wind Turbine Supply Chain Strategies, 2009-2020." (2009, July). Leader & Harmony. Retrieved from <http://www.landh.co.kr/en/report/content.asp?idx=2427&cpage=1&spage=1&code01=E01&code02=01&ip=Market+Intelligence+&rtype=&stype=&text=&m=&mm=&svtype=&align=createdate> on May 6, 2011.

Ancona, D. & McVeigh, J. "Wind Turbine - Materials and Manufacturing Fact Sheet." Princeton Energy Resources International. Retrieved from http://www.generalplastics.com/uploads/technology/WindTurbine-MaterialsandManufacturing_FactSheet.pdf on May 6, 2011.

For a more detailed description of component parts, see <http://www.repp.org/articles/static/1/binaries/WindLocator.pdf>

Wind Energy Manufacturing Facilities, as of November 2010



Source: American Wind Power

Opportunities in Wind Energy

For highly specialized and critical turbine components, wind manufacturers typically rely on in-house capacity or dedicated existing suppliers. Blades, control systems, gearboxes, generators and power convertors are bottlenecks in the production process and can delay the entire

manufacturing process if there is short supply.³⁰ These points in the supply chain have high entry barriers due to large investment costs and ramp-up time.³¹

Other components require local sourcing and present a better opportunity for new entrants into the supply chain. The expertise required for tower manufacturing, for instance, is relatively widespread and the high costs of transporting a tower necessitate local sourcing.³² In addition, imported castings and metal forgings can raise quality concerns as well as transportation and logistical issues. A shortage of forgings can in turn be a constraint on the supply of gearboxes and bearings.³³ The following chart details sourcing preferences for major wind components:³⁴

Prefer Existing Suppliers	Prefer Local Suppliers
<ul style="list-style-type: none"> ● Blades ● Control systems ● Gearboxes ● Generators ● Power Convertors 	<ul style="list-style-type: none"> ● Towers ● Castings ● Forging services ● Nacelle cover and spinner

The U.S. Department of Energy (DOE) funded a 2010 study on wind supply chain bottlenecks that identified the effects of the 2008 financial crisis.³⁵ The crisis dampened global investment into wind energy, and its effects rippled through the supply chain as well. Stimulus funds have provided a boost in investment, although supply chains are still catching up with this renewed investment. The DOE-funded study summarized in the chart below, identified bottlenecks for wind sectors that include manufacturing, transportation/shipping, equipment and transmission. While

³⁰ "Growth Opportunities for Chicago Area Manufacturers in the Renewable Energy Industry." Jane Addams Resources Corporation and the Chicago Manufacturing Center. Retrieved from <http://www.slideshare.net/dylantuttle/growth-opportunities-for-chicago-area-manufacturers-in-the-renewable-energy-industry> on May 6, 2011.

³¹ *Wind Energy – The Facts*. (2009). European Wind Energy Association.

³² Ibid.

³³ "Growth Opportunities for Chicago Area Manufacturers in the Renewable Energy Industry." Jane Addams Resources Corporation and the Chicago Manufacturing Center. Retrieved from <http://www.slideshare.net/dylantuttle/growth-opportunities-for-chicago-area-manufacturers-in-the-renewable-energy-industry> on May 6, 2011.

³⁴ Ibid.

³⁵ "The future supply chain." (2010). European Wind Energy Conference. Retrieved from <http://ewec2010proceedings.info/proceedings/index2test.php?page=info2&id=28&id2=364&ordre=48&tr=&searchin=&what=&searchtext=&day=3&top=&fil1=&fil2=&fil2&ord1=&sess=> on May 6, 2011.

some bottlenecks are relatively short-term, transmission capacity will require long-term coordinated planning and investment.

2010 Supply Chain Bottlenecks	
Manufacturing	Highly engineered bearings Blades Generators Gearboxes Towers
Transportation/Shipping	Train Boat Truck
Equipment	Cranes Installation vessels and underwater cable-laying vessels for offshore wind
Transmission	Transmission capacity

Source: PowerAdvocate

Strategies for Economic Developers

Economic development organizations can facilitate the growth of the wind industry in their communities in a number of ways. Targeting these areas will benefit supply chain development as well.

- **Public Policy:** A crucial role is to inform the public policy debate on local, state and national levels, especially involving renewable portfolio standards, production and consumption incentives, and smart grid development.
- **Infrastructure/Property:** Wind manufacturers require large industrial sites and buildings with high ceilings to accommodate the large dimensions of towers, blades, etc. Having qualified sites is integral to attracting manufacturers.
- **Workforce Development:** States are consistently finding that there is a shortage of skilled wind technicians, and demand for skilled workers will only rise as wind energy is expected

to become more prevalent.³⁶ To meet this need, community colleges, technical schools, universities and other institutions have begun to offer training programs partially funded by state grants and industry donations.³⁷

- **Transportation:** Transporting a wind turbine can comprise up to a quarter of the total cost of installation. Having a port is a great asset, as transporting via water is not only cheaper and more efficient than truck or rail, but more environmentally friendly.³⁸ Intermodal connections to truck, barge and rail further boost a community's viability for wind manufacturing.
- **Marketing:** Understand your community's assets and gaps, and adopt a marketing plan that focuses on your strengths and what can realistically be delivered. See the case study below on the Greater Oklahoma City Partnership.

³⁶ "Guide for Wind Turbine Service Technicians in California." (2010, November 10). Employment Development Department of California. Retrieved from <http://www.calmis.ca.gov/file/occguide/wind-turbine-service-technicians-green.pdf> on May 6, 2011.

³⁷ AWEA maintains a complete list of wind education programs at <http://www.awea2.org/html/group.php?group=EDUCATION&id=1&code=cc0000>

³⁸ Patel, A. (2010, July). "The Role of the Great Lakes-St. Lawrence Seaway Ports in the Advancement of the Wind Energy Industry." Great Lakes Wind Collaborative.

Case Study: Marketing Messaging

Many economic development organizations have begun to develop marketing plans specific to renewable energy. For example, the Greater Oklahoma City Partnership, an alliance of economic development organizations covering 10 counties, markets the renewable energy assets of the entire region by emphasizing the following key messages.

Essential Natural Resources

Oklahoma is in the middle of the nation's wind corridor and receives 300 days of sunlight annually. The partnership touts these natural resources, and its website links to the Oklahoma Wind Power Initiative (OWPI), the state's research consortium for wind energy.³⁹ OWPI provides a variety of information including interactive wind maps, education resources and news updates on renewable energy development in the state.⁴⁰

Existing Capacity and Synergies

The partnership highlights the continued evolution of the city's energy sector, which is historically heavy in oil but has expanded to natural gas and, more recently, alternative energy. The city's strong aerospace industry also creates synergies for manufacturing and supply chain linkages. Oklahoma Gas & Electric, the state's largest utility, offers customers wind energy from two of the nation's largest utility-owned wind farms.

Commitment to Renewable Energy

The partnership emphasizes the commitment of civic, corporate and community partners to the development of renewable energy in the region. This is manifested in the state's relatively low business tax rates as well as its recent passage of an RPS.

³⁹ For the Partnership website, refer to <http://www.greateroklahomacity.com>

⁴⁰ Oklahoma Wind Power Initiative. Retrieved from <http://www.ocgi.okstate.edu/owpi/#none> on May 6, 2011.

Case Study: Partnerships in Illinois

In Illinois, wind economic development activities have centered on the work of the Illinois Wind Working Group (IWWG),⁴¹ Illinois State University's Center for Renewable Energy (CRE), the Illinois Department of Commerce and Economic Opportunity (DCEO), and the Illinois Manufacturing Extension Center (IMEC). IWWG is affiliated with the U.S. Department of Energy's Wind Powering America initiative and operates out of Illinois State University's CRE. Together, these organizations have partnered to address the needs of the state's wind industry and to develop the supply chain using some key tactics.

MEPs Play Important Role

Over the past two years, Illinois' Manufacturing Extension Center (IMEC) has worked to educate regional companies about opportunities in the wind industry. It has partnered with organizations such as the Center for Renewable Energy at Illinois State University to conduct open workshops to discuss manufacturing requirements and market penetration strategies for the wind industry. IMEC has brought to the table the Great Lakes Wind Network (GLWN), Jane Addams Resources Corporation (a nonprofit community development organization), wind manufacturers and suppliers in efforts to connect the needs of the wind industry with the capabilities of potential suppliers.

Conducting Supplier Conferences

In the past few years, a number of states have begun to conduct wind supply chain conferences to offer potential suppliers a more in-depth look at the opportunities available in wind. The Illinois DCEO, the CRE at Illinois State University, and IMEC hosted the second annual "Building the Wind Supply Chain" workshop in July 2010. The workshop was held the day before the annual "Advancing Wind Power in Illinois" conference to capture the synergies of both conferences. Presenters included industry leaders such as Acciona and Suzlon Wind Energy Corp., as well as partnering organizations. Attendees learned about opportunities in the wind supply chain, industry quality expectations, developing a market penetration plan and connecting with potential customers.

⁴¹ Illinois Wind Working Group. Retrieved from <http://renewableenergy.illinoisstate.edu/wind/> on May 6, 2011.

Marketing Resources to Potential Suppliers

One business assistance group may not be able to meet all the needs of an interested supplier. IMEC outlines a resource model that covers four key services and where to seek help for each:

- **Assessing readiness to enter supply chain:** Companies first need to assess whether they have both the potential and desire to enter the wind supply chain. IMEC offers a pre-assessment questionnaire that explores a manufacturer's vision, leadership, capabilities and obstacles in diversifying into wind (see link to questionnaire in footnote). GLWN provides a more rigorous analysis with its on-site Wind Capabilities Profile and Analysis; companies pay \$5,000 plus travel and hotel costs for an assessment of their capabilities, qualifications and competitiveness in supplying for wind.
- **Addressing operational performance gaps:** IMEC supports manufacturers in refining their quality standards, cost competitiveness, and other areas of operational performance. IMEC contributes over \$100 million annually in improved manufacturing performance.
- **Addressing capital equipment capacity gaps:** IMEC can support technology scouting, evaluation of return on investment, and assist in incorporating new technology into the manufacturing process. The Illinois DCEO manages state funding available for plant expansions and job creation. Local incentive programs may also exist, varying from city to city.
- **Addressing workforce development gaps:** A number of resources exist for both assessing workforce gaps and addressing them. IMEC provides a workforce development needs analysis and offers workforce training related to improving operational performance. Community colleges are also a great resource for workforce training programs. In addition, equipment vendors often provide training for their customers.

Case Study: Great Lakes Wind Network

Great Lakes Wind Network (GLWN), a nonprofit corporation based in Cleveland, Ohio, is a consortium of wind manufacturers seeking to strengthen the domestic supply chain in the wind sector.⁴² GLWN operates an online wind industry supply chain map with over 1,500 manufacturers and suppliers.⁴³ The map is searchable by industry sector, specialty, state, company name and more.⁴⁴ Naturally, the map is heavier in Great Lakes region suppliers, but any North American supplier can be posted by subscribing to a GLWN membership.



Three-Part Supply Chain Service Model

In order to educate potential and existing wind industry suppliers, GLWN has developed a three-part wind industry supply chain service model:

- **Training and development** of regional wind specialists who can in turn work with companies in their area to become effective suppliers. These specialists can be manufacturers, service providers, economic developers or others. Specialists are trained in wind industry trends, turbine designs, turbine component elements, supply chain buying schemes, and supplier performance and qualification requirements.
- **Workshops** developed separately for existing wind industry suppliers and potential suppliers. The basic workshop gives potential suppliers the opportunity to evaluate their qualifications and interest; advanced workshops address targeted modules in detail.
- **“Wind capabilities profiles”** using GLWN’s proprietary profile and analysis tool. This tool examines a potential supplier’s capability, qualifications, and competitiveness to meet domestic and international wind component standards. Regional wind specialists trained by GLWN have access to the tool and can refer suitable potential suppliers to

⁴² Great Lakes Wind Network. Retrieved from <http://www.glwn.org/info.aspx> on May 6, 2011.

⁴³ “Increasing the Participation of Small and Medium-Sized Manufacturers in U.S. Wind Energy Supply Chains.” (2010, July 15). BlueGreen Alliance Foundation.

⁴⁴ “Wind Industry Supply Chain Map.” Great Lakes Wind Network. Retrieved from <http://maps.glwn.org/wind/> on May 6, 2011.

original equipment manufacturers and first-tier companies through GLWN.⁴⁵

Plans to Establish Centers of Excellence Across the Country

To meet growing demand for its services, GLWN established a Center of Excellence at Kansas State University's Advanced Manufacturing Institute (AMI) in 2010.⁴⁶ AMI operates within KSU's College of Engineering and provides engineering and business services to manufacturers and entrepreneurs. Under this partnership, AMI will combine its expertise with that of GLWN staff to consult with potential wind suppliers regarding site assessment, component parts, and production systems.⁴⁷ In addition to its existing services, AMI's newly expanded services in wind technology include:⁴⁸

- Business planning and research
- Technical reviews
- Design verification
- Manufacturing process development
- Quality systems development
- Additional services in sustainable products, biomass and environmental technology

Companies that work with AMI and meet certain criteria will also become part of GLWN's Wind Alert System, which notifies companies when OEMs and upper-tier suppliers are seeking suppliers.⁴⁹ GLWN plans to establish several more Centers of Excellence to serve regions of the U.S. where wind manufacturers are taking root or where existing suppliers are intent on entering the wind industry.

Great Lakes Wind Network: <http://www.glwn.org>

Kansas State University Advanced Manufacturing Institute: <http://www.amisuccess.com>

⁴⁵ "Increasing the Participation of Small and Medium-Sized Manufacturers in U.S. Wind Energy Supply Chains." (2010, July 15). BlueGreen Alliance Foundation.

⁴⁶ Advanced Manufacturing Institute at Kansas State University. Retrieved from <http://www.amisuccess.com/> on May 6, 2011.

⁴⁷ "Great Lakes WIND Network Announces Center of Excellence." (2010, January 13). Industry Week. Retrieved from http://www.industryweek.com/articles/great_lakes_wind_network_announces_center_of_excellence_20834.aspx on May 6, 2011.

⁴⁸ "Wind Technology Development." Advanced Manufacturing Institute at Kansas State University. Retrieved from http://www.amisuccess.com/services/Wind_Technology_Development.asp on May 6, 2011.

⁴⁹ "Nation's First Great Lakes WIND Network Center of Excellence Announced." Great Lakes Wind Network. Retrieved from http://www.glwn.org/centers_of_excellence.aspx on May 6, 2011.

SOLAR

Background

Solar energy manufacturing is a highly innovative, diverse industry. It includes established technologies like photovoltaic cells, concentrating solar power, and solar thermal energy. Within the photovoltaic cell market, traditional crystalline silicon cells hold 93 percent of the share, while up-and-coming thin film cells are at 7 percent.⁵⁰ The primary differences between the two technologies are detailed in the chart below. Concentrating solar power is produced by utility-scale solar installations involving reflective mirrors or concentrating lenses. Finally, solar thermal energy preempts electricity generation by directly using sunlight for water, pool and space heating. Solar thermal energy can also be used for cooling; recent technology chemically converts solar-heated water into air conditioning.⁵¹ In addition to these technologies, current research focuses on developing advanced technologies to produce cells with greater conversion efficiency (the proportion of sunlight converted to electrical energy).⁵²

Current research in solar energy focuses on a few key issues:

- Flexible thin film cells with higher efficiencies
- General increases in efficiency to reduce installation size and cost
- Light-tracking control
- Dealing with intermittency, storage, and maximizing efficiency of transfer to the grid⁵³

⁵⁰ Cullen, S. (2009). "Alternative Energy Powers Up." Thomson Reuters.

⁵¹ "Solar Heating and Cooling." Solar Energy Industries Association. Retrieved from http://www.seia.org/cs/solar_heating_cooling on May 6, 2011.

⁵² Top third generation solar technologies include dye-sensitization, nanotechnology and organic material.

⁵³ "Solar Heating and Cooling." Solar Energy Industries Association. Retrieved from http://www.seia.org/cs/solar_heating_cooling on May 6, 2011.

Types of Photovoltaic Cells

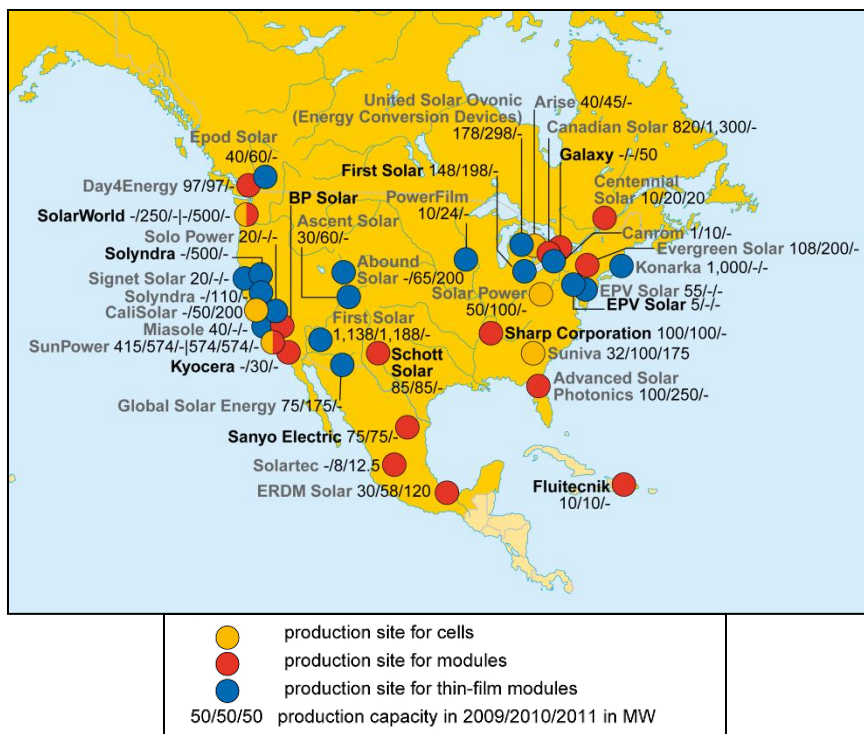
	Crystalline Silicon	Thin-film
Description	Higher efficiency than thin-film. Silicon is used to manufacture crystalline wafers. Silicon supply is subject to boom-and-bust cycles; historically high, the prices of silicon have dropped recently due to lower demand and overcapacity.	Lower efficiency, but lighter, sturdier panels allow for more versatile applications. Cost was initially high but continues to fall. Requires only 1 percent of the material needed for crystalline cells.
Barriers to Entry	High barriers to entry. Startup capital investment for building a plant ranges from \$500 million to \$1 billion. Manufacturing is energy-intensive; many plants are operated on hydropower.	Small-scale production and development has relatively few barriers to entry. Capital becomes more important as suppliers scale up.
Suppliers	Many semiconductor firms in the silicon solar industry. Suppliers mainly operate on long-term contracts (another barrier to entry.)	Suppliers are chemical companies that produce thin-film photovoltaic material, such as cadmium telluride and amorphous silicon. The supply for these components is less volatile than that for polycrystalline silicon.
Competition	Seven companies hold 90 percent of the market share. Wafer and cell manufacturers are expanding into silicon manufacturing as well.	There are many startups doing thin-film, especially in amorphous silicon, and they are primarily competing on conversion efficiency and cost.
Outlook	As thin film technologies continue to mature, silicon will become less cost-competitive.	Thin-film technologies are the best bet for a high-efficiency, low-cost solar cell. The industry is evolving at a fast pace, with players ranging from large conglomerates like Sharp to startups to university labs.
Top Firms Worldwide	Hemlock Semiconductor, Wacker Chemie, Renewable Energy Corporation, MEMC, Tokuyama, Mitsubishi and Osaka Titanium	First Solar, Sharp, Solar Frontier, Miasole, Solyndra, Q-Cells, Abound Solar, GE ⁵⁴

Sources: Thomson Reuters

⁵⁴ "The Top 15 Thin Film Solar Companies." (2011, February 20). SolarFeeds. Retrieved from <http://www.solarfeeds.com/green-world-investor/16019-the-top-15-thin-film-solar-companies> on May 6, 2011.

Prices of solar cells around the world have plummeted due to global economic recession, expansion of low-cost manufacturing and fluctuating government subsidies. Solar panel factories require millions in startup costs, leading some companies to keep domestic R&D facilities intact while outsourcing commercial production abroad. In early 2011, Evergreen Solar announced that it would relocate its 800-employee Massachusetts plant to China, aided by a \$33 million loan from the Chinese government.⁵⁵ On the other hand, in the same year, General Electric announced it would open the largest solar plant in the United States. Other U.S. solar plants have been highly successful; Arizona-based First Solar is the largest manufacturer of thin-film solar panels in the world. This suggests that while cost plays a key role, the locations of solar plants are also highly demand-driven. The following map shows the locations of solar photovoltaic firms in the United States.

U.S. Map of PV Industry, as of September 2010



Source: Advanced Solar Photonics

⁵⁵ "Evergreen Solar to Close Devens Manufacturing Facility" [News Release]. (2011, March 9). Evergreen Solar. Retrieved from <http://evergreensolar.com/en/2011/01/evergreen-solar-to-close-devens-manufacturing-facility/> on May 6, 2011.

The Solar Supply Chain

Supply chains are taking on a more crucial role than before as top manufacturers have geared up to gigawatt scales. In 2000, 170 megawatts of photovoltaic capacity were installed in a single year; in 2010, 10 gigawatts (10,000 megawatts) were installed.⁵⁶ Today, Suntech has a single building that has a one-gigawatt capacity. These new scales have put pressure on the solar supply chain to deliver components on shorter lead times. For this reason, solar OEMs typically prefer local sourcing.

Certain components must meet stringent quality standards, while other components are primarily cost-driven. Solar manufacturing involves heavy labor and power costs, which suppliers seek to minimize.⁵⁷ Local sourcing allows OEMs to have close and frequent contact with their suppliers, simplifying logistics. Sourcing preferences for a few main components are given in the chart below.

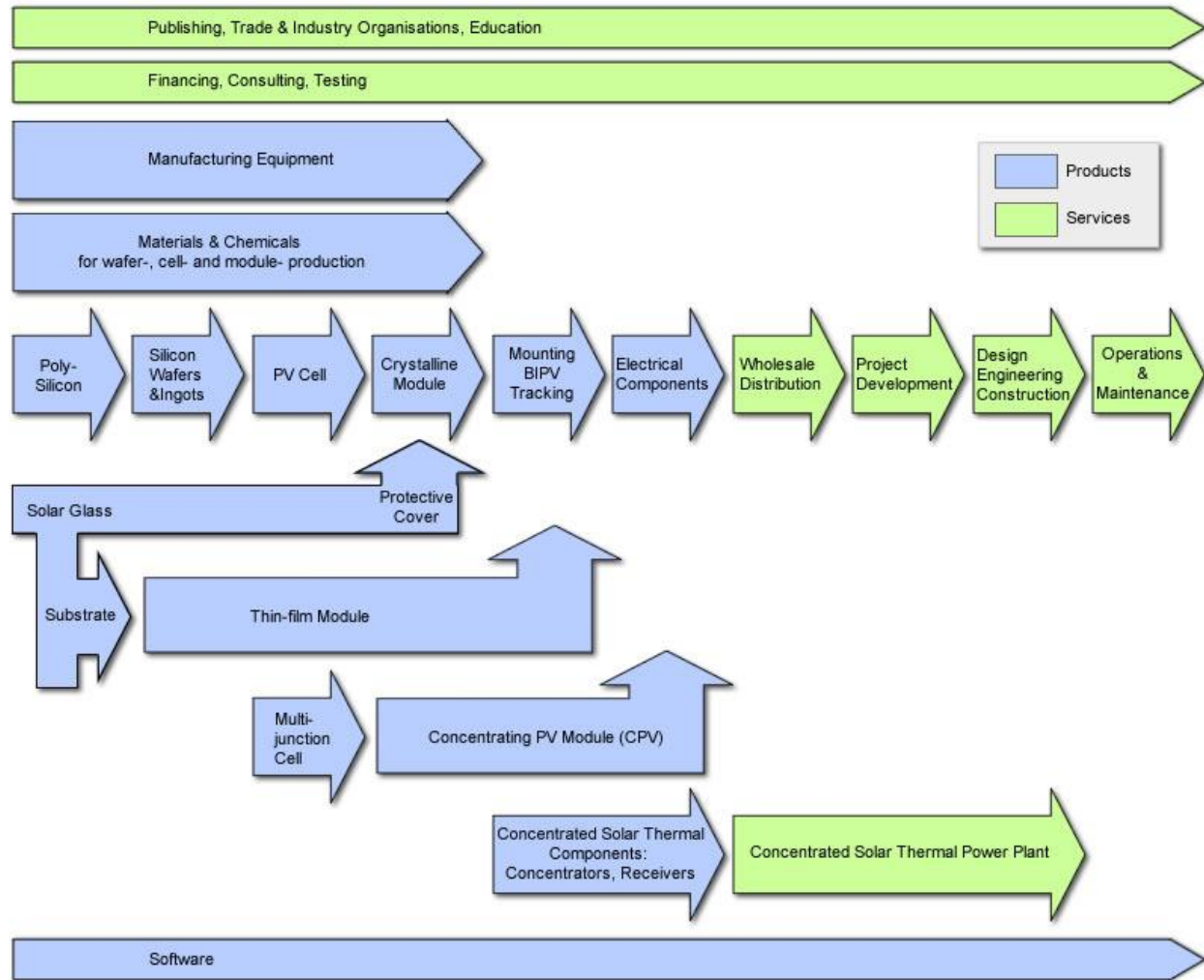
Solar component	Sourcing preference
Glass	Special composition; domestic production
Aluminum frame	Cost-driven
Bus wiring and junction boxes	Require qualification
Silicon solar cells	Cost-driven; imported

The solar supply chain involves a variety of players in both the production and services sectors. As indicated by the graphic below, the supply chain varies depending on the specific technology, although all technologies involve software and service firms.

⁵⁶ Wesoff, E. (2010, October 7). "Milestone: 10 Gigawatts of Solar Panels in 2010, Part 2." GreenTech Solar. Retrieved from <http://www.greentechmedia.com/articles/read/milestone-10-gigawatts-of-pv-in-2010-part-2/> on May 6, 2011.

⁵⁷Fine, G. (2010, January 27). "The Solar Supply Chain." SCHOTT Solar. Retrieved from http://www.luthcommunications.com/uploads/Gerry_Fine_-_Schott_Solar_-_Supply_Chain.pdf on May 6, 2011.

Solar Supply Chain



Source: Green Rhino Energy

Opportunities in Solar Energy

The solar industry is diverse. Players include conglomerates, for which solar is one sector of their business, as well as firms that specialize exclusively in solar. Many are at least partially vertically integrated, yet no firm spans the entire supply chain. Because solar is a relatively nascent industry, potential opportunities reach well beyond manufacturing—the development of solar will require gains in efficiency, infrastructure and energy storage. In their article “Entrepreneurship

Opportunities in the Solar Industry,”⁵⁸ Causey, Causey, McClain and White identify both short- and long-run opportunities, which can be summarized according to five main sectors:

1. **Manufacturing:** This involves production but can also include procurement of raw materials; training; servicing equipment and distributing or marketing PV cells.
2. **Distribution:** There are many independent solar distributors, as well as firms that prefer to both produce and distribute. Independent distributors sometimes specialize in solar, but more common are electrical distributors who break into the solar business. Seventy percent of renewable energy systems are comprised of materials that electrical distributors already have in stock—pipe, wire, panelboard, breakers, switches and more.⁵⁹
3. **Installation:** Some firms have arranged contracts with utilities to focus on installation and maintenance of solar panels. In 2008, Duke Energy launched a plan to dedicate \$50 million to solar development, seeking bids for solar panels, electrical equipment and installation services.⁶⁰
4. **Infrastructure conversion:** The electrical industry will need new infrastructure to accommodate solar-powered systems. Opportunities exist in installing, replacing or modifying equipment.
5. **Energy captivation and storage:** Improving energy captivation and storage is a crucial step in deploying an efficient national grid. Future technology will be based on platforms like fixed storage units and mobile devices. Down the road, there could be further opportunities in energy exchange and trading.

⁵⁸ Causey, D. et al. “Entrepreneurship Opportunities in the Solar Industry.” Association for Small Business and Entrepreneurship. Retrieved from <http://sbaer.uca.edu/research/ASBE/2009/p03.pdf> on May 6, 2011.

⁵⁹ Fischbach, A. (2010, February 1). “Slicing into the Solar Supply Chain.” Electrical Wholesaling Magazine. Retrieved from http://ewweb.com/greenbiz/electric_slicing_solar_supply/ on May 6, 2011.

⁶⁰ “Duke Energy Seeks Solar Suppliers to Launch \$100 Million Solar Plan.” [News Release]. (2008, September 4). Duke Energy. Retrieved from <http://www.duke-energy.com/news/releases/2008090401.asp> on May 6, 2011.

Case Study: San Jose, Calif. and the UL Photovoltaic Technology Center of Excellence

Part of San Jose's recent success in fostering a dynamic green economy has come through its ability to bring in a network of key institutions as partners. One of those key institutions is Underwriters Laboratories' (UL) Photovoltaic Technology Center of Excellence. City government and the local solar industry worked to attract UL to San Jose to accelerate its specialization in the solar industry. Local solar companies benefit from having their products tested and certified in close proximity. Further, the requirement that photovoltaic modules comply with UL standards in both U.S. and Canadian markets has increased demand for product testing and certification services. With 70 of the approximately 200 solar-related firms in the U.S. located within a few hours' drive of San Jose, having UL in San Jose helps to drive the cluster forward.

Case Study: Griffith Electric Supply, Retooling for Solar

Griffith Electric Supply Co. is a Trenton, N.J.-based electrical distributor that broke into the solar market in mid-2009. Although New Jersey has had an RPS since 1999, Griffith saw an opportunity when the state utility board adopted an amendment that made the solar portion of the RPS more robust. The increased demand enticed the company to consider supplying for the solar market.

Griffith began by partnering with solar integrators (installers) and specialists. Instead of solar panels, the company focused on selling more traditional electrical products to local contractors. Solar installations require electrical equipment such as fuse holders, specialized building wire and roof supports, and Griffith had capacity to meet the need. To capitalize on its existing customer relationships, Griffith hosted a free seminar to teach contractors how to install solar panels and utilize government rebates and tax incentives.

Source: "Slicing into the Solar Supply Chain," Electrical Wholesaling Magazine

Case Study: Northwest Supply Chain Initiative

The Oregon Manufacturing Extension Partnership (OMEP) and Impact Washington (formerly Washington Manufacturing Services) recently launched a renewable energy supply chain initiative spanning the Pacific Northwest. OMEP was awarded a \$1.5 million grant from the National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership to develop renewable energy supply chains in both Oregon and Washington. OMEP has identified specific supply chain opportunities, including support of OEMs, installation and maintenance of specialized equipment, and development of the transmission line infrastructure. To these ends, OMEP will consult with its clients to meet supplier profile qualifications, develop initial marketing plans and connect with sales contacts. Clients will include manufacturers (especially rural) who are currently operating in renewable energy supply chains or are interested in doing so. The NIST grant will pay two-thirds of OMEP's consulting charges while clients pay the remaining third (a typical five-month contract would cost the client \$1,667 a month.) OMEP can assist with a number of areas:

- Marketing and sales strategies
- Process retooling
- Developing and introducing new products
- ISO certification and quality systems⁶¹
- Lean and clean manufacturing technologies
- Strategic business planning

OMEP also helps businesses utilize the Northwest Connector. The Northwest Connector is an Oregon-based supply chain database operated by Business Oregon and the Pacific Northwest Defense Coalition. The service is free to use and to join, and provides detailed profiles of participating businesses, including capabilities, products and services. There are currently over 3,600 companies listed in the Connector.

Sources:

"Opportunities in Renewable Energy." Oregon Manufacturing Extension Partnership. Retrieved from http://www.omep.org/sites/default/files/NWSCSI_Fact_Sheet.pdf on May 6, 2011.

"Find Oregon Suppliers." Business Oregon. Retrieved from <http://www.oregon4biz.com/Grow-Your-Business/Business-services/Find-Oregon-Suppliers/> on May 6, 2011.

⁶¹ ISO certification is an independent quality certification through the International Organization for Standardization

BIOFUELS

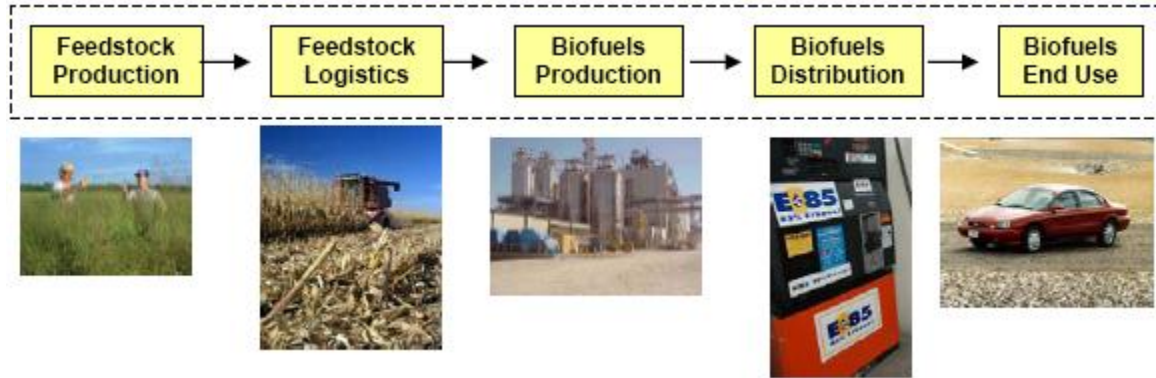
Background

Biofuels are a form of renewable energy derived from biomass feedstocks—plant and animal materials that are used as energy inputs. Biofuels can be solid, liquid and gaseous. Biomass electricity plants burn solid feedstocks, such as wood chips, to generate electricity. Ethanol and biodiesel, liquid derivations of biomass, can be used as auto fuel. Methane sequestered from landfills and farms is a gaseous biofuel. Biofuels rank as the second largest source for renewable energy in the U.S. behind hydropower.⁶²

The feedstocks used in biofuels have evolved over the years. First generation feedstocks are vegetable and animal fats, starches and sugar. These include corn and soybeans and are commonly used in ethanol and biodiesel production. There has been some controversy over whether food crops used for fuel have caused spikes in food prices around the world. This “food versus fuel” debate is especially relevant in developing countries where food prices have a high impact on quality of life. Second generation feedstocks are non-food crops and include by-products from crop harvests, such as wheat straw, and forest residues. These “cellulosic” feedstocks are a large focus of current research and development because they don’t divert food crops for energy use. Even more recent is third generation algae fuel, which is already being used as jet fuel by the U.S. military. Because of the large variety of feedstocks, most parts of the U.S. have at least some biofuels production capability.

⁶² “The most important renewable energy sources in United States.” (2010, November 23). Renewables Info. Retrieved from http://www.renewables-info.com/interesting_energy_articles/the_most_important_renewable_energy_sources_in_united_states.html on May 6, 2011.

The Biofuels Supply Chain and Policy Support



Source: National Advisory Council for Environmental Policy and Technology

The supply chain for biofuels consists of five main steps: feedstock production, feedstock logistics, biofuels and co-product production, distribution and end use. The following chart provides an overview of major technologies and processes involved in the biofuels supply chain.

Biofuels Technologies ⁶³					
Feedstock Production		Feedstock Logistics	Biofuels & Co-Product Production	Biofuels Distribution	Biofuels End Use
<u>Agricultural Crops</u> -Corn -Sorghum -Barley -Oats -Wheat -Soybeans -Canola -Rice -Alfalfa -Other Crops <u>Agricultural Residues</u> -Corn Stover -Wheat Straw -Barley Straw -Rice Straw -Cotton Lint <u>Energy Crops</u> -Switchgrass -Energy Cane -Sweet Sorghum -Hybrid Poplar -Willow -Other Coppicing Trees	<u>Forest Residues</u> -Logging Residues -Forest Thinnings -Fuel Treatments -Hog Fuel -Sawdust -Paper Sludge -Black Liquor <u>Wastes</u> -Manure -Fats & Greases -Municipal solid waste -Urban Wood Waste -Food Processing Waste	<u>Harvesting and Collection</u> -Single-pass -Multi-pass -Baled -Bulk <u>Storage</u> -Dry storage -Wet storage -Baled -Bulk -Landfills (MSW) -Floating storage <u>Preprocessing</u> -Shredding -Pelletizing -Briquetting -Ensiling -Drying -Separation <u>Transportation</u> -Truck -Rail -Barge -River/Stream Floating	<u>Fuel Types</u> -Ethanol -Biobutanol -Mixed Alcohols -Biodiesel -Green Diesel -Renewable Diesel -Synthetic Diesel -Synthetic Gasoline -Dimethyl Ether -Synthesis Gas -Hydrogen <u>Biochemical Conversion Ops.</u> -Acid Hydrolysis -Pretreatment & Enzymatic Hydrolysis -Fermentation <u>Thermochemical Conversion Ops.</u> -Gasification -Pyrolysis -Hydrothermal Depolymerization -Fuel Synthesis -Combustion <u>Anaerobic Digestion</u> -Aqueous -Dry	<u>Transportation</u> -Truck -Rail -Barge -Pipeline <u>Storage</u> -Blending Terminals <u>Dispensing</u> -Dedicated Pumps -Blending Pumps	-Light Duty Vehicles -Light Duty Trucks -Heavy Duty Trucks -Off Road Vehicles -Locomotives -Airplanes -Jets -Boats -Ferries -Ships -Handheld Power Equipment -Generators -HVAC Units, -Etc.

Feedstock production is the most labor-intensive step in the supply chain. A study by Bio-Era, a research and advisory firm, estimates that 46 percent of direct job creation in bioenergy will come from feedstock production and 35 percent will come from construction, engineering and

⁶³ "Strategic Framework for Biofuels Efforts." (2007, July 13). National Advisory Council for Environmental Policy and Technology. Retrieved from <http://www.epa.gov/ocempage/nacept/pdf/nacept-biofuels-framework-final.pdf> on May 6, 2011.

procurement.⁶⁴ There are a variety of policies on the local, state and national levels that can support each of these steps.

Feedstock Production: The major issues in feedstock production include choosing a feedstock and deciding where and how to grow it. Second and third generation feedstocks are relatively foreign and can create a challenge for farmers to grow effectively. The most high-yield land is being used to grow food crops, making land availability an issue also.⁶⁵

Policy Support

- Support for inputs, such as fertilizer and irrigation subsidies
- Energy and water pricing policies
- Land tenure policies
- Domestic agricultural subsidies
- Farm income support
- Trade policies⁶⁶

Feedstock Logistics: There are four steps in the logistics process: harvesting, storing, pre-processing and transportation. Moving feedstocks from cropland to refineries can comprise up to 20 percent of the final cost of cellulosic ethanol. Increasing the energy density of the feedstock can help offset this cost, especially if fuel prices rise. Feedstock is harvested in a specific season each year, and production varies from year to year due to crop rotation, weather and other factors. This makes it difficult to secure a cost-effective, stable supply.

Policy Support:

- Create incentives for improving the efficiency of logistics systems based on feedstock type, geography, storage/pre-processing facilities and transportation modes

⁶⁴ “U.S. Economic Impact of Advanced Biofuels Production: Perspective to 2030.” (2009 February). Bio-era. Retrieved from <http://bio.org/ind/advbio/EconomicImpactAdvancedBiofuels.pdf> on May 6, 2011.

⁶⁵ Chung, S. & Farrey, M. (2010). Biofuel supply chain challenges and analysis. *Massachusetts Institute of Technology*. Retrieved from <http://dspace.mit.edu/handle/1721.1/60830> on May 6, 2011.

⁶⁶ “The State of Food and Agriculture.” (2008). Food and Agriculture Organization of the United Nations. Retrieved from <ftp://ftp.fao.org/docrep/fao/011/i0100e/i0100e.pdf> on May 6, 2011.

Biofuels Production: This step involves the conversion of feedstock into fuel. Major issues include increasing the yield of conversion, developing by-products, and refining the conversion process. There are chemical limitations to the energy yield of feedstocks—plant walls resist being broken down into intermediate sugars (the “recalcitrance” effect). Current research focuses on how to overcome these limitations in order to make the production process more cost-efficient. In addition, the size and location of conversion plants also influences production costs. The biofuels industry can glean best practices from traditional energy industries in order to improve this step of the supply chain.

Policy Support:

- Tax credits linked to production levels
- Subsidies for capital investment
- Mandated use requirements for biofuel blends

Biofuels Distribution: High-grade biofuels blends are transported from production plants to retail facilities or blending stations because they are not compatible with existing structures for distributing fossil fuels. As demand increases for biofuels, its distribution infrastructure will have to be expanded. There will also be opportunity to streamline storage and blending stations and various transportation modes (trucks, trains, barges, and possibly pipes in the future) to reduce costs and improve accessibility.

Biofuels End Use: Biofuels are currently more expensive than fossil fuels on the market. However, government subsidies and the rising price of oil are changing that. Ethanol costs around \$3.85 per gallon to produce, which was lower than gas prices in many parts of the U.S. during first quarter of 2011.⁶⁷ The key is to reduce costs along all steps of the supply chain. Reducing price and increasing the proportion of biofuels in blends are ways to boost demand. It is also imperative in the short run to make biofuels blends compatible with existing vehicle engines. A number of firms are focusing on developing “drop-in” biofuels—fuels that can be used in the existing transportation infrastructure.⁶⁸ Codexis and Amyris are two San Francisco-area firms that are using bioengineering to make cellulosic feedstocks more efficient. Although the technology is still in

⁶⁷ Chung, S. & Farrey, M. (2010). Biofuel supply chain challenges and analysis. *Massachusetts Institute of Technology*. Retrieved from <http://dspace.mit.edu/handle/1721.1/60830> on May 6, 2011.

⁶⁸ “The post-alcohol world.” (2010, October 28). *The Economist*. Retrieved from <http://www.economist.com/node/17358802> on May 6, 2011.

the R&D phase, the market for drop-in fuels is promising because it does not require costly infrastructure updates.

Policy Support:

- Demand-side subsidies for biofuels and co-products
- Subsidies for purchasing flex-fuel vehicles.

Case Study: Noble Foundation

The Sam Noble Research Foundation is a nonprofit, independent institute in Ardmore, Okla., that conducts research in agriculture, plant biology and forage improvement, among other missions. Researchers at the Noble Foundation are utilizing decades of plant experience to improve the efficiency of switchgrass as an ethanol feedstock. Switchgrass is a low-maintenance, perennial grass common in Oklahoma and many of the Great Plains states, making it a natural target for ethanol research. The main barrier in cellulosic ethanol, however, is breaking down the tough plant walls that resist the conversion process. The Noble Foundation led the research project on behalf of the Oklahoma Bioenergy Center, which has planted a 1,000-acre pilot switchgrass plot in the Oklahoma panhandle.

In 2011, Noble Foundation researchers announced preliminary findings of a modified switchgrass that produces one-third more ethanol than traditional strains. This presents savings along multiple points of the cellulosic ethanol supply chain. The amount of land required is reduced by a third, leading to savings in herbicides, land management, transportation and feedstock storage. The conversion process is also cheaper, because the feedstock can be processed at a lower temperature and requires fewer enzymes.

The lead scientists on the project were granted \$1.2 million in funding from the Oklahoma Experimental Program to Stimulate Competitive Research (EPSCoR). Oklahoma EPSCoR aims to increase the state's research capacity by supporting research collaborations, educational programs and facility and instrument costs. The program is funded through 2013 by a five-year, \$6 million National Science Foundation Research Infrastructure Improvement Grant. EPSCoR also received \$3 million in matching funds from the Oklahoma State Regents for Higher Education. The project also received early funding from USDA and the DOE Office of Science.

Sources:

Bevill, K. (2011, February 17). "Modified switchgrass reduces enzyme use, boosts ethanol yield." Checkbiotech.org. Retrieved from http://bioenergy.checkbiotech.org/news/modified_switchgrass_reduces_enzyme_use_boosts_ethanol_yield on May 6, 2011.

Ray, R. (2006, September 24). "Switch to Switchgrass." Tulsa World. Retrieved from http://www.noble.org/press_release/Features/2006/SwitchtoSG/index.html on May 6, 2011.

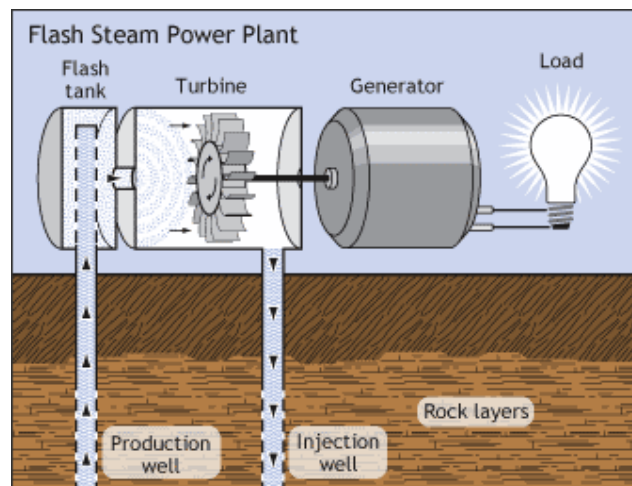
"Noble Foundation receives \$1.2 million for biofuels research" [News Release]. (2008, November 10). The Samuel Roberts Noble Foundation. Retrieved from http://www.noble.org/press_release/2008/08-050.html on May 6, 2011.

GEOHERMAL

Background

Geothermal electricity utilizes hot water or steam that has been heated beneath the earth's surface to propel turbines that generate electricity. "Dry steam" power plants operate directly off of geothermal steam, while "flash steam" power plants create steam by drawing compressed hot water into low-pressure tanks. Flash steam plants are the most common type of geothermal plant. The graphic below illustrates basic flash steam technology. Binary cycle plants, a more recent development, allow cooler water to be used to heat a secondary fluid, which boils at a lower temperature and generates steam to power turbines. Geothermal energy also is used for direct heating without the use of power plants or heat pumps.

Flash Steam Power Plant Mechanics



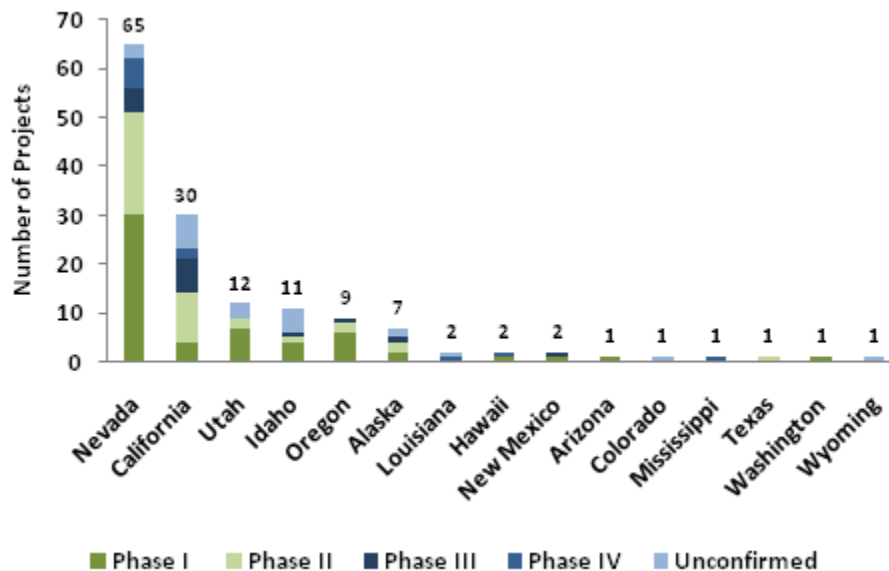
Source: U.S. Department of Energy

The U.S. leads the world with 3,102 MW of total installed geothermal capacity.⁶⁹ As of March 2011, nine states had geothermal electricity online: Alaska, California, Hawaii, Idaho, Nevada,

⁶⁹ "Geothermal Power Plants – USA." Geothermal Energy Association. Retrieved from <http://www.geothermalenergy.org/plants.aspx> on May 6, 2011.

New Mexico, Oregon, Utah, and Wyoming. In addition to these states, there are also development plans in Arizona, Colorado, Louisiana, Mississippi, Texas and Washington (as of March 2011).⁷⁰ New projects are expected to add at least 5,102 MW of installed capacity in the U.S., according to the Geothermal Energy Association. The chart below summarizes ongoing geothermal projects by state and project phase.

Geothermal Projects Under Development (as of March 2011)



Source: Geothermal Energy Association

⁷⁰ For a list of new projects, refer to http://www.geo-energy.org/plants_dev.aspx

The Geothermal Supply Chain

The geothermal supply chain spans the entire timeline of project development, from start-up leasing activities to manufacturing and operations. Each step in the supply chain requires vastly different amounts of capital. Geothermal power plants have low operating and maintenance costs, but capital investment is high and can represent over two-thirds of the total cost.⁷¹ Exploratory drilling and initial construction require around \$3,000 per installed kW.⁷²

1. **Start-up Phase:** The developer works with state and federal regulatory offices to obtain a variety of required permits. This includes obtaining a geothermal lease from the U.S. Bureau of Land Management (BLM), often a lengthy and complex process.
2. **Exploration Phase:** The developer conducts a range of airborne, geological, geochemical and geophysical surveys to improve the chances of successful drilling operations. Exploratory drilling is also part of this phase. This process heavily engages professionals skilled in the geological and engineering sciences.
3. **Drilling Phase:** Once permitting and exploratory activities have been conducted, the developer begins to drill production wells. It will typically hire a company that specializes in drilling geothermal wells. This phase can comprise up to half the total project cost.⁷³
4. **Plant Design and Construction:** In this phase, the developer enters into an engineering, procurement and construction contract. The contractor may in turn use subcontractors for various parts of the construction process. At the final stages of construction, employment can peak at 300 to 400.⁷⁴
5. **Manufacturing:** Although components vary by type of plant, geothermal plants generally include a power unit (which generates electricity), as well as electrical, cooling, and piping

⁷¹ "Geothermal Basics – Power Plant Costs." Geothermal Energy Association. Retrieved from http://www.geo-energy.org/geo_basics_plant_cost.aspx#cost on May 6, 2011.

⁷² "Geothermal – Economics." Renewable Energy Policy Project. Retrieved from http://www.repp.org/geothermal/geothermal_brief_economics.html on May 6, 2011.

⁷³ Trabish, H. "Nevada's Big Bet on Geothermal." (2010, July 30). Greentech Media. Retrieved from <http://www.greentechmedia.com/articles/read/nevadas-big-bet-on-geothermal/> on May 6, 2011.

⁷⁴ "Green Jobs Through Geothermal Energy." (2010, October). Geothermal Energy Association. Retrieved from http://www.geo-energy.org/pdf/reports/GreenJobs_Through_Geothermal_Energy_Final_Oct2010.pdf on May 6, 2011.

systems.⁷⁵ The components for geothermal power plants are similar to that for biomass power plants, concentrating/heating solar systems, and wind turbines, so it is common for wind and solar manufacturers to also supply geothermal parts. There are also a growing number of firms specializing in geothermal parts.⁷⁶ Firms that manufacture geothermal components include large international firms like Toshiba and Mitsubishi. In the U.S., players include Rotoflow, Mafi-Trench and United Technologies.⁷⁷ Although there is no official count of geothermal firms, the Geothermal Energy Association had a membership of 123 U.S. firms in various supply chain roles as of April 2011.

6. **Operation and Maintenance:** In addition to operations personnel, a geothermal plant requires regular maintenance. The supplier of the power-generating unit typically provides maintenance services. Other units of the geothermal system require maintenance as well.

The geothermal supply chain supports a variety of jobs in the legal, engineering and construction sectors at different points in the supply chain. The graphic below summarizes the key roles played by each of these sectors.

⁷⁵ Ibid.

⁷⁶ Ibid.

⁷⁷ "Geothermal Manufacturer Options." (2009, August 17). Alaska Center for Energy and Power. Retrieved from <http://energy-alaska.wikidot.com/geothermal-manufacturer-options> on May 6, 2011.

Geothermal Supply Chain and Job Types



Source: Geothermal Energy Association

Case Study: Geothermal Energy Association

The membership of the Geothermal Energy Association (GEA) can be taken as an informal reference list of U.S. geothermal firms.⁷⁸ As of April 2011, the list included 123 U.S. firms and eight foreign firms. GEA membership spans geothermal developers such as Gradient Resources, vertically integrated firms such as Ormat Technologies, and power companies such as Nevada Power. Although GEA membership is not an exhaustive listing of U.S. geothermal companies, it is a good starting point for understanding the types of companies operating in this arena.

⁷⁸ For the membership list, refer to http://geo-energy.org/gea_members.aspx

QUANTITATIVE ANALYSIS OF COMMUNITY STRENGTHS

Aggregate Searches

The Renewable Energy Policy Project (REPP) has published an analysis of the U.S. renewable energy supply chain⁷⁹ and is in the process of conducting state-level analyses⁸⁰ (19 states have been covered thus far). The state reports rank counties in terms of investment and employment for the wind, solar, geothermal and biomass sectors. REPP breaks down each industry by North American Industry Classification System (NAICS) code and lists the corresponding number of firms, investment level and employment to shed light on supply chain potential.

NAICS codes provide a rough overview of a region's strengths. Although not all companies within a NAICS code may be suitable for an industry supply chain, the numbers should indicate whether a region has critical mass to be competitive. A useful tool in this area is the Bureau of Labor Statistics' Location Quotient Calculator, which measures a region's competitiveness among various NAICS industries.⁸¹ The tool allows users to compare relative employment levels in the United States among the national level, states, counties, and metropolitan statistical areas. For example, a location quotient (LQ) of 1 signifies that a region employs the same share of workers in a given industry as does a comparison area. An LQ higher than 1 indicates that the region employs a relatively larger share of workers for that industry.

Following is a sample location quotient analysis that compares Ohio's employment in fabricated metal manufacturing (which includes bearings made for wind turbines) to that of the nation. The data reveal an LQ of 2.21, indicating that Ohio has a much higher relative concentration of industry employment for manufacturing bearings. Ohio economic developers recognize this strength and have worked to nurture and grow the state's wind industry. The Ohio Wind Working Group is a collaboration among manufacturers, government, researchers and land owners to further wind energy development in the state. The Ohio Manufacturing Extension Partnership

⁷⁹ Sterzinger, G. & Svrcek, M. (2004, September). "Wind Turbine Development: Location of Manufacturing Activity." Renewable Energy Policy Project. Retrieved from <http://www.repp.org/articles/static/1/binaries/WindLocatorShort.pdf> on May 6, 2011.

⁸⁰ Renewable Energy Policy Project. Retrieved from <http://www.repp.org/> on May 6, 2011.

⁸¹ "Location Quotient Calculator: New BLS Web Tool Allows Local Area Comparisons." (2005, March 30). U.S. Department of Labor, Bureau of Labor Statistics. Retrieved from <http://www.bls.gov/cew/cewlq.htm> on May 6, 2011.

offers specialized services to advanced energy manufacturers. The Great Lakes Wind Network, which is based in Ohio, also connects manufacturers in the wind supply chain. Assessing state and regional comparative strengths is a critical step in creating a realistic economic development strategy around renewable energy development.

Search Summary	
Data Year:	2009
Data Period:	Annual Average
Datatype:	All Employees
Ownership:	Private
Establishment Sizes:	All establishment sizes
Base Industry:	Base Industry: Total, all industries
Base Area:	U.S. TOTAL
Source:	Quarterly Census of Employment and Wages Data

Total Employment and Analysis-Industry Employment		
Industry	U.S. TOTAL	Ohio -- Statewide
Base Industry: Total, all industries	106,947,104	4,198,597
NAICS 3329 Other fabricated metal product manufacturing	250,404	21,724

Analysis-Industry Employment as a Percentage of Total Employment		
Industry	U.S. TOTAL	Ohio -- Statewide
Base Industry: Total, all industries	100%	100%
NAICS 3329 Other fabricated metal product manufacturing	0.23%	0.52%
Percentage of Employment: Ratio of analysis-industry employment to base-industry (total) employment times 100.		

Location Quotients	
Industry	Ohio -- Statewide
Base Industry: Total, all industries	1.00
NAICS 3329 Other fabricated metal product manufacturing	2.21

Location Quotient: Ratio of analysis-industry employment in the analysis area to base-industry employment in the analysis area divided by the ratio of analysis-industry employment in the base area to base-industry employment in the base area.

The following chart breaks down wind components by NAICS code, which makes it useful for conducting a location quotient analysis.⁸² The stars indicate current supply bottlenecks according to the PowerAdvocate report referenced in the wind section of this report.⁸³ The next three tables offer common NAICS codes for the biofuels, geothermal and solar industries.

⁸² Sterzinger, G. & Svrcek, M. (2004, September). "Wind Turbine Development: Location of Manufacturing Activity." Renewable Energy Policy Project. Retrieved from <http://www.repp.org/articles/static/1/binaries/WindLocatorShort.pdf> on May 6, 2011.

⁸³ "The future supply chain." (2010). European Wind Energy Conference. Retrieved from <http://ewec2010proceedings.info/proceedings/index2test.php?page=info2&id=28&id2=364&ordre=48&tr=&searchin=&what=&searchtext=&day=3&top=&fil1=&fil2=&fil2&ord1=&sess> on May 6, 2011.

Wind Components and NAICS Codes

Component	Sub component	NAICS 6-digit	Code description	NAICS 10-digit	Code description
Rotor	Blade ★	326199	All other Plastics Products	A141	Other fabricated fiberglass and reinforced products
	Blade Extender	331511	Iron Foundries	1116	Ductile iron fittings 14 in. or more
	Hub	331511	Iron Foundries	3221	Other ductile iron casting for all other uses
	Pitch Drive	335312	Motors and Generators	30	Integral horsepower motors and generators other than for land transportation equip. (746 watts or more)
Nacelle and Controls	Anemometer	334519	Measuring and Controlling Devices	7025	Other meteorological instruments and parts
	Brakes	333613	Power Transmission Equip.	3111	Friction-type Clutches and Brakes
	Controller	334418	Printed circuits and electronics assemblies	A015	Industrial process control board assemblies
	Cooling Fan	333412	Industrial and Commercial fans and blowers	04	Axial fans
	Nacelle Case	326199	All other Plastics Products	A141	Other fabricated fiberglass and reinforced products
	Nacelle Frame	331511	Iron Foundries	3221	Other ductile iron casting for all other uses
	Sensors	334519	Measuring and Controlling Devices	7	Commercial, Meteorological, Geophysical, and General Purpose Instruments
	Yaw Drive	335312	Motors and Generators	30	Integral horsepower motors and generators other than for land transportation equip. (746 watts or more)
Gearbox and Drive Train	Bearings ★	332991	Ball and Roller Bearings	3032	Tapered roller bearings (including cups and cones), unmounted
				1023	Complete ball bearings, unmounted, annular, including self-aligning, ground or precision, angular contact, precision
	Coupling	333613	Power Transmission Equip.	3329	Non-gear-type flexible couplings
	Gearbox ★	333612	Speed Change, Industrial	7438	Enclosed concentric and parallel (Planetary) center distance 6 in. or more
	High and low speed shafts	333613	Power Transmission Equip.	3792	Mechanical power transmission equipment, NEC, except parts
Generator and Power Electronics	Generator ★	333611	Turbines, and Turbine Generators, and Turbine Generator Sets	0871	Turbine generators
	Power Electronics	335999	Electronic Equipment and Components, NEC	3219	Other rectifying(power conversion) apparatus, except for electronic circuitry
Tower	Tower ★	332312	Fabricated Structural Metal	5106	Fabricated structural iron and steel for transmission towers, radio antenna, and supporting structures
	Tower Flange	331511	Iron Foundries	116	Ductile iron fittings 14 in. or more

Biofuels Industry Supplier NAICS Codes⁸⁴
327993 Mineral Wool
331210 Iron, Steel Pipe & Tube from Purchased Steel
332410 Power Boiler & Heat Exchanger
332420 Metal Tank (Heavy Gauge)
332911 Industrial Valve
333120 Construction Machinery
333210 Sawmill & Woodworking Machinery
333411 Air Purification Equipment
333414 Heating Equipment (except Warm Air Furnaces)
333415 AC and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing
333911 Pump & Pumping Equipment

Geothermal Industry Supplier NAICS Codes⁸⁵
331210 Iron, Steel Pipe & Tube from Purchased Steel
332410 Power Boiler & Heat Exchanger
332420 Metal Tank (Heavy Gauge)
333415 AC and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing
333911 Pump & Pumping Equipment
333912 Air & Gas Compressor
333923 Overhead Traveling Crane, Hoist & Monorail System
331210 Iron, Steel Pipe & Tube from Purchased Steel
332410 Power Boiler & Heat Exchanger
332420 Metal Tank (Heavy Gauge)

⁸⁴ Debbage, K. (2008, August). "Renewable Energy in North Carolina: The Potential Supply Chain." Institute for Emerging Issues. Retrieved from <http://www.ncsu.edu/iei/programs/energy-environment/documents/debbage-report.pdf> on May 6, 2011.

⁸⁵ Ibid.

Solar Industry Supplier NAICS Codes⁸⁶
325211 Plastics Material & Resin
326113 Nonpackaging Plastics Film & Sheet
327211 Flat Glass
332322 Sheet Metal Work
334413 Semiconductors & Related Devices
334515 Electricity & Signal Testing Instruments
335313 Switchgear & Switchboard Apparatus
335911 Storage Battery
335931 Current-Carrying Wiring Device
335999 Misc Electrical Equipment

Searching Out Individual Companies

In addition to an aggregate overview, EDOs may want to know which local companies comprise an industry sector. EDOs in smaller cities and towns may anecdotally know who their manufacturers are, but this becomes more difficult in larger cities. Online resources can provide an exhaustive list of companies based on NAICS code, geography, number of employees, sales revenue, growth and more. This information can be useful when reaching out to individual companies—such as when conducting a supply chain conference or building a supply chain network.

Hoovers is one example of an online tool that can provide a list of companies based on certain search criteria. The example below shows the result of companies that meet the following search specifications:

- NAICS Code 333612 Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing (suitable for gearbox manufacturing)

⁸⁶ Debbage, K. (2008, August). “Renewable Energy in North Carolina: The Potential Supply Chain.” Institute for Emerging Issues. Retrieved from <http://www.ncsu.edu/iei/programs/energy-environment/documents/debbage-report.pdf> on May 6, 2011.

- Within the Chicago-Naperville-Joliet, IL-IN-WI metro area
- Sales over \$1 million (most recent data available)
- Employing over 50

Company Name	Location	Location Type	Sales (\$ Mil)	Employees	SIC	Phone Number
Yaskawa America, Inc. - Drives & Motion Division D-U-N-S# 064486434	Waukegan IL United States	Headquarters	295.42M	200	36210000 Motors and generators	847-887-7000
Dynamax, Inc. D-U-N-S# 147527295	Wheeling IL United States	Headquarters	20.00M	85	36790100 Electronic circuits	847-680-8833
Chicago Gear - D. O. James Corporation D-U-N-S# 005144209	Chicago IL United States	Single Location	18.00M	109	35669903 Reduction gears and gear units for turbines, except auto	773-638-0508
Reliance Gear Corporation D-U-N-S# 002993673	Addison IL United States	Single Location	7.00M	65	35669902 Gears, power transmission, except auto	630-543-6640