ENERGIZING APPALACHIA:

GLOBAL CHALLENGES AND THE PROSPECT OF A RENEWABLE FUTURE

Prepared for the Appalachian Regional Commission

By

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Executive Summary

The global demand for energy is increasing at a staggering rate, particularly as growing countries such as India and China develop at an unprecedented pace. The capacity of conventional resources to meet this growing demand for energy is in serious question. The composition of future energy supplies now dominates the international energy discussion, as it is formative of economic security and development. The influence of energy supply on global relations cannot be overemphasized, and the addition of billions of new energy consumers to already strained conventional energy supplies will further exacerbate energy related tensions. Increasing demand for energy is operating in tandem with increasing global concerns over the impact of conventional energy on our environment, particularly referring to greenhouse gas emissions. As this new energy paradigm continues to reveal itself, actions are underway to establish and grow new energy sources. New sources will not only provide additional opportunities to satisfy growing demand, but non-fossil fuel sources can provide climate friendly alternatives to conventional fossil based resources. Renewable energy sources such as wind, solar and biomass power are growing in importance as resources to address growing energy demand and the requirement to control externalities from fossil fuel consumption.

Over the last three decades, the roles of renewable resources have evolved from experimental afterthoughts to viable means of energy supply. Having evolved over the last thirty years, much of the technology of wind, solar and even biofuels have reached a level of maturity where production has achieved economies of scale and large producers have taken over several of the market niches. An almost singular reliance on fossil fuels has stunted the growth of renewable energy industries in the US. The US now lags behind its global competitors in these strategic industries. Only 20 years ago, the US was an innovator and recognized leader in this emergent sector. Today, while known in the industry group simply based on the size of the national economy, the US is a distant fourth or fifth player in an industrial group that collectively and consistently is growing by at least 25 percent per year for the last five years and is expected to continue or exceed this rate of growth in the foreseeable future. Wind energy is primarily dominated by European companies, with only one of the top ten manufacturers based in the US. India is already a significant global player in the wind industry and China is positioned to enter into this industry in force over the next few years. The Solar energy market is less concentrated than wind and biofuels, with both retail and wholesale markets, than the wind industry, but it also is demonstrating similar trends to wind in that the US is now a net importer of solar photovoltaic (PV) modules.

What the evolving nature of manufacturing within these industries reveals is that the US is allowing itself to be shut out of one of the fasted growing industries in the world. As a nation with increasing annual energy demands itself, left unchecked, the US may well be reestablishing its future energy dependence on the manufacturing of energy equipment from beyond its own borders. Energy security issues aside, this means the US may not be positioning itself to capitalize on an energy sector it was foundational in creating. In particular, areas of the country that may have significant capacity to manufacture

equipment for these industries may lose out on a tremendous opportunity for economic growth from the development of renewable energy technologies. It is from this perspective that this report reviews the renewable energy manufacturing potential of the Appalachian region. Experienced in equipment and components manufacturing, and with substantial infrastructure on the ground, Appalachia may be in a position to engage this growing energy sector and provide local growth in jobs and investment.

This report investigates the status and behavior of the wind, solar and biomass industries in order to better understand how domestically-based manufacturers might best engage this sector. It was revealed that significant consolidation has occurred in the wind industry and is beginning to occur in the solar industry. It is becoming increasingly difficult for small companies to gain a foothold and secure adequate market share in both of these industries. However, the growing demand for these resources has opened up opportunities for the manufacturers of equipment in the supply chain of the finished products to emerge.

To understand what opportunities exist for Appalachia to engage the renewable energy sector, this report analyzed the region's potential capacity to manufacture components for the wind, solar and biomass industries. This was accomplished by a comprehensive review of North American Industry Classification System codes and 2002 County Business Pattern Data collected by Bureau of the Census. Industry codes were selected based upon their degree of similarity to parts utilized by the wind, solar and biomass industries. Analysis reveals not only the degree of potential capacity, but also how it is distributed across the region. As a whole, Appalachian counties' possess almost 200,000 jobs in manufacturing parts and components that could, with modification, be suited for production of renewable energy components. This also includes almost 3,000 existing manufacturers within the region that possess similar potential to engage the renewable energy industry. More specifically, analysis reveals where highly concentrated manufacturing potential exists, either as a result of significant jobs, high numbers of manufacturing establishments or where several industry-specific components are manufactured. The concentrated nature of sub-components manufacturing potential within a given area offers a distinct opportunity for industries siting local manufacturing facilities. Each of the 13 Appalachian member states have counties with concentrated manufacturing potential of over 100 jobs or over five components in each of the three industries considered.

Furthermore, several areas of concentrated employment potential exist for each of the three sectors in excess of 1,000 jobs in a single county, including:

- Greenville County, South Carolina, with over 3,700 jobs and 19 establishments producing components similar to those needed by the wind industry;
- Wood County, West Virginia, with 2,710 jobs and three establishments producing components similar to those needed by the solar PV industry;
- Erie County, Pennsylvania, with over 6,835 jobs and 40 establishments producing components similar to those needed by the biomass electric generation industry;
- Regionally, over 28,000 potential manufacturing jobs exist within economically distressed or at-risk Appalachian counties.

Manufacturing potential is not immediately available for component production for each of these industries. Yet, tools exist that could enable or encourage manufacturing for renewable energy components ranging from educational programs and industry incubator programs to financial incentives and renewable energy policies. In particular, some states have developed and passed legislation providing tax credits for manufacturers producing equipment for renewable energy as well as for consumers who purchase equipment manufactured within their states. Even more, policies have been passed that provide incentives for manufacturers that site renewable facilities within economically depressed regions. Opportunities to pursue similar initiatives exist for Appalachian member states.

Recommendations to facilitate growth in renewable energy manufacturing and production in the region include the following:

Renewable Energy Manufacturers Tax Credits
Renewable Energy Portfolio (RPS) and Tax Credit Multipliers for In-State Manufacturing
Tax Credits or Multipliers for Manufacturing in Distressed Regions
Incubator Programs for Renewable Energy Industries
Renewable Energy Manufacturing Business Outreach Program
Bridging Local Manufacturing with Industry Suppliers and Vendors
Regional Renewable Energy Industry Consortiums
Production Tax Credits, Grants and Loans for Cellulosic Ethanol

In addition to the opportunity for manufacturing components for these industries, Appalachia may have the capacity to produce energy from renewable sources. In particular, beyond current uses of biomass in electrical energy cogeneration, the future of biomass energy extends beyond electricity generation and is growing most rapidly in the area of biofuel production. Ethanol production in the US is significant, and the development of new technologies to utilize cellulosic ethanol is rapidly progressing. It is widely held within the biofuel arena that cellulosic ethanol production will become a mainstream fuel source in the coming decade. Where wind and solar energy production capacity is highly variable across the Appalachian region, it is likely that substantial cellulosic ethanol resources exist throughout the region that can be harvested for this industry. This provides a distinct opportunity for Appalachia above and beyond equipment manufacturing. This report briefly explores the economic potential for this resource to be pursued in Appalachia.

In summary, the results of this report indicate that there is substantial potential to produce components for the rapidly growing renewable industries of wind, solar and biomass energy. The nature of the industry suggests that sub-component manufacturing may be an achievable near-term goal for the economic growth in the region. Medium-term potential for growing locally-based renewable firms exists as well, although the consolidating nature of the industry suggests this requires substantially more support from agencies such as State government and the Appalachian Regional Commission. Finally, long-term potential to become a significant biofuel energy producer may exist. Each of these opportunities will deliver much-needed growth to the region, from a set of industries that show the potential to continue rapid growth into the future.

Introduction

Over the last decade the global wind, solar and biomass industries have grown substantially. In the US alone, generation of wind energy has grown from 10 megawatts (MW) of installed capacity in 1981 to over 10,000 MW today. The solar industry has also experienced record growth: in 2005 a record level of PV was installed globally and the US ranked third in installed solar energy capacity with approximately 450 MW of installed PV capacity. Biomass energy generation has also grown steadily over the last decade and currently provides over 10,000 MW of heat and electrical energy for the US.[1] Growing most quickly in the biomass sector, however, is the production of ethanol and bio-diesel fuels, posing an opportunity of distinct importance for the Appalachian region. More specifically, there is a significant and growing emphasis on the development of cellulose-based ethanol production, derived from the woody and fibrous components of plants rather than the starchy seeds, fruits and roots. The development of such technology will enable the biofuel industry to capture a greater amount of existing biomass resources - resources believed to exist in substantial volumes in the Appalachian region.

For a variety of reasons, demand for all three of these energy sources is predicted to increase in the coming decades. The passage of various energy policies to address energy needs and diversification has proven to be a significant driver behind industry growth. For example, state-level renewable energy requirements detail specified amounts of generation from clean energy sources that must be provided. Renewable fuel requirements have also been instituted in some states, as well as by the nation-at-large with the passage of the *Energy Policy Act (EPACT) of 2005.* Tax incentives are also critical drivers for growth, and federal incentives augment new and existing incentives for renewable energy in an ever-increasing number of states.

The desire for low-emissions energy, relative to conventional energy

Note on Units

We talk about energy in terms of the amount of power over a period of time, for example 1 watt=joule/second. A 60-watt light bulb requires 60 joules of electricity every second, or 60 watts of electricity.

Kilowatts (kW) and megawatts (MW) are units of measurements used in association with large energy producers or users.

1 kW=1,000 watts, 1 MW=1,000 kW=1 million watts

MWs are the standard measure of the generation capability, or capacity, of a power plant. Power plants do not always produce as much power as they are fully capable (peak capacity) all the time, the average amount of power they produce compared to their full potential is referred to as their capacity factor.

For instance, wind power capacity is approximately 35%, and is reported as the average MW (MWa).

1MWa is enough to power approximately 1000 homes.

Source: NM Public Interest Research Group Education Fund Clean Energy Solutions

[1] National Renewable Energy Laboratory: Renewable Energy Poised to Realize Long Term Potential, June 2006: http://www.nrel.gov/director/pdfs/40768.pdf

sources, is also driving demand for these clean energy resources. Finally, steadily increasing and sometimes volatile prices for conventional fuels such as oil and natural gas are driving demand for relatively untapped alternatives that will likely have greater degrees of stability into the future.

There is a growing disconnect, however, between the increasing demand for energy from these sources and a diverse base within the US capable of producing the equipment to meet that demand. Of the record amount of wind installed in the US in 2005, only one US-based turbine manufacturer supplies a significant number of turbines – GE Wind, the only US company in the top ten global wind equipment suppliers.[2] Though GE has dominated the US market for the past three years, all of the remaining suppliers of turn-key products are internationally-based companies including Vestas (Denmark), Mitsubishi (Japan), Suzlon (India) and Gamesa (Spain).

The disparity between local demand and local supply forces a choice between either long-term industry dominance from a small handful of large international companies, largely based in Europe and Asia, or increasing domestic capacity to produce this equipment. The US is in a position to define its role in this growing market, particularly while the opportunity costs of developing manufacturing infrastructure are lower than they will be in the future. The US can pursue opportunities to carve out niches in these arenas, or it can relegate itself to the position of a mere consumer with regard to some of the fastest-growing industries across the globe.

How this opportunity relates to the Appalachian region is the subsequent focus of this report. It focuses primarily on two opportunities to engage Appalachia in the growing renewable energy sectors. The first focuses on the manufacturing of renewable energy equipment domestically. This can come in the form of growing and supporting additional domestic 'turn-key' product manufacturers within these industries to compete within the domestic and international arenas. The second involves establishing partnerships between Appalachian manufacturers of components in the supply chain for renewable technologies and equipment and existing manufacturers and renewable developers. Substantial increases in demand for renewable generation equipment have created significant shortfalls in components and materials for the wind and solar industry alike. This opportunity will be particularly important as internationally-based companies build US-based facilities to meet domestic demand. This opportunity is exemplified by the manufacturing facility in Pennsylvania being established by Gamesa, the world's fourth largest company in terms of market share (as of 2005).[3]

Initial analysis suggests that the region served by ARC may be well-positioned to capitalize on these growing markets, as presented by the results from analyses of the capacity of the Appalachian region to supply major components for renewable energy industries. Information has been compiled on existing manufacturing establishments,

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[2] BTM Consult ApS: International Wind Energy Development World Market Update 2005 Forecast 2006-2010, Press Release: http://www.btm.dk/Pages/wmu.htm
[3] BTM Consult ApS: International Wind Energy Development World Market Update 2005 Forecast 2006-2010, Press Release: http://www.btm.dk/Pages/wmu.htm

employment totals, locations and sector concentrations within the region. Six-digit North American Industry Classification System (NAICS) codes were analyzed for all counties within the Appalachian region and reflect industry-specific manufactured components that are similar to, or substitutable for, the major manufactured components in the biomass, solar, and wind energy industries.

This analysis reflects not only the potential capacity to manufacture renewable components from existing establishments within the region, but also represents the potential distribution of increased manufacturing that might accompany continued growth in the renewable energy sector. The analysis reveals distribution of existing establishments within states as well as potential clusters of manufacturers with the potential to produce parts for individual energy sectors.

The ability of Appalachian-based manufacturers to compete within this global industry is the fundamental question. This report also addresses salient characteristics of three primary renewable industries, both domestically and internationally. Understanding such characteristics will be critical in plans to promote and develop manufacturing capacity within the Appalachian region.

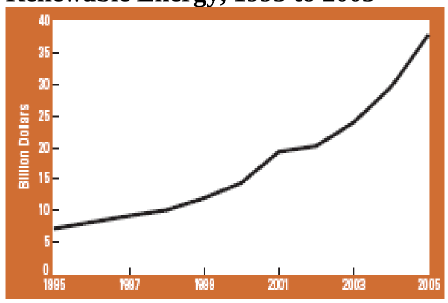
Of particular interest in this report is the capacity of ARC’s member states and counties to produce components for the biomass, solar and wind industry sectors. This report will convey that the region may be well-suited to produce components for these rapidly growing renewable energy sectors, beyond the opportunities that exist to produce energy from them. Finally, in addition to equipment or components manufacturing, this report explores opportunities for the Appalachian region to be at the forefront of the next wave of biomass energy production: cellulosic ethanol.

Renewable Energy Industry Analyses

The ability of Appalachian-based manufacturers to compete within the global wind, solar and biomass industries is an important question. This section of this report addresses characteristics of these three industries, both domestically and internationally. Understanding such characteristics will provide a basis for strategizing and planning the promotion and development of manufacturing capacity within the Appalachian region.

In 2005, the renewable energy sector experienced a record level of investment, with $38 billion dollars put to expanding renewable energy capacity across the globe.[4] This level of investment is likely to continue, and provides the justification for increasing efforts to expand this industry domestically, as well as in areas with the technical capacity to benefit from further growth in this sector.

Figure 1. Annual Investment in Renewable Energy, 1995 to 2005



Source: REN21: Renewable Global Status Report 2006

Wind

Using the kinetic energy of wind to generate electricity has become very common today. Historically, mankind has used wind for purposes far beyond this – from running mills to propelling seaborne ships. Generally, wind energy generation uses the uneven heating of the earth's surface (convection and advection currents) to transfer the kinetic energy of wind into electricity via turbines or generators. Wind turbines utilize this air as it flows past the rotor of a wind turbine and the rotor spins and drives the shaft of an electric generator.[5]

The benefits of wind energy range from its lack of fuel cost to its low-emissions capacity to produce electricity in addition to relatively low maintenance and operations needs. Also, wind energy is clean and abundant. However, due to the nature of the resource, the primary limit of wind power is that it does not produce 100 percent of its generating capacity all of the time. On average, a wind turbine produces at its nameplate capacity roughly 20 percent to 40 percent of the time, termed the 'capacity factor' of the resource. This is in comparison to other conventional resources and biomass energy generation

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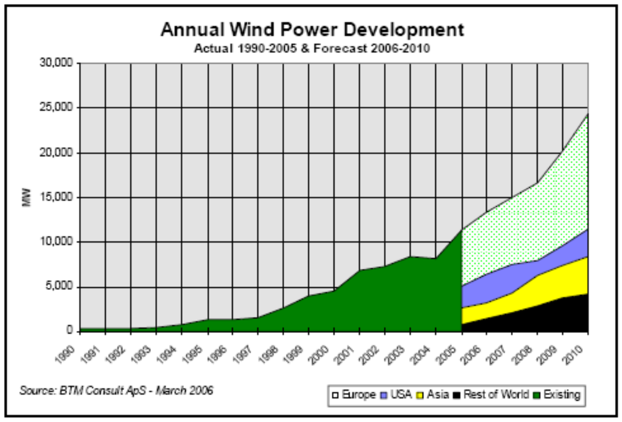
[4] Renewable Energy Policy Network for the 21st Century: Renewable Energy Global Status Report, 2006 Update. http://www.renewableenergyaccess.com/rea/news/story?id=41508
[5] American Wind Energy Association: http://www.awea.org/pubs/factsheets/Wind_Energy_How_does_it_Work.pdf

that have capacity factors typically between 70-80 percent of the time (gas typically around 60 percent and nuclear as high as 90 percent)[6].

Growth, Demand and the Future

As evidenced by increasing deployment across the globe, wind power generation is growing and investments in this industry are increasing at both a national and international level. Over the course of the last 25 years, the wind energy industry has grown significantly with 59,264 MW of installed wind energy generation across the globe at the end of 2005.[7] Wind is currently one of the fastest-growing energy sources globally, with a cumulative annual growth rate of approximately 26 percent in 2005, and sustained growth of over 20 percent over the last five years.[8]

Figure 2. Projected Growth in Wind Power Forecast for 2006-2010



Installations in 2006 are expected to be higher than the record level of installations in 2005 (11,407 MW in 2005 globally).[9] Projected growth rates remain high, with some analysts forecasting annual rates of installation around 16.4 percent through 2010.[10,11] Projections through 2010 suggest the US will add another 18,000 MW installed capacity building upon our current capacity of approximately 10,000 MW. Areas of highest growth will be centered in the US, India and China with sustained growth throughout Europe.[12]

Figure 3. Key Wind Markets 2005 - 2010

Country	Cumulative installation (MW)		CAGR (%)
	2005	2010 E	
France	775	5,575	48
China	1,264	7,764	44
Portugal	1,087	4,687	34
India	4,253	12,253	24
US	9,181	22,381	20

Source : BTM Consult ApS World Market Update 2005

[6] Renewable Energy Research Laboratory, University of Massachusetts, Amherst http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_2a_Capacity_Factor.pdf

[7] http://www.renewableenergyaccess.com/rea/news/story?id=41304

[8] Chua, G. (2006) *Wind Power 2005 in Review, Outlook for 2006 and Beyond.* Article based on **US/Canada Wind Power Markets and Strategies 2005-2010.** Emerging Energy Research. www.emerging-energy.com

[9] /ibid, pg 1.

[10] BTM Consult ApS: International Wind Energy Development World Market Update 2005 Forecast 2006-2010, Press Release: http://www.btm.dk/Pages/wmu.htm

[11] Chua, G. (2006) *Wind Power 2005 in Review, Outlook for 2006 and Beyond.* Article based on **US/Canada Wind Power Markets and Strategies 2005-2010.** Emerging Energy Research. www.emerging-energy.com

[12] BTM Consult ApS: International Wind Energy Development World Market Update 2005 Forecast 2006-2010, Press Release: http://www.btm.dk/Pages/wmu.htm

Driving these rates of growth of demand both nationally and globally are several factors. Wind power is continuing to come down in cost, providing a viable alternative to the increasing costs of oil and natural gas. For example, severe ups and downs in the cost per unit of natural gas have motivated utilities to seek forms of energy with greater price stability, particularly as 70 percent of the costs of a natural gas-powered facility stems from its fuel supply costs.[13] Capital costs for wind power are concentrated up-front during the manufacturing and construction phases of a project, with virtually no fuel costs and comparably low operation and maintenance costs. These factors enable utilities to purchase wind energy at a stable price over long periods of time, reducing uncertainty for consumers and utilities, alike.

The price for wind power has come down over the course of the last few decades not only due to demand growth in the industry, but also as a result of financial incentives offered to developers of wind power projects. The Federal Renewable Energy Production Tax Credit (providing $0.018/kWh of wind energy produced) has been a significant component of the cost reduction of wind power spurring development in wind energy over the last decade.[14] Favorable accelerated depreciation rates also are a major incentive for developing power projects. In addition, many states across the country offer special incentives for wind energy, from research & development grants, to pilot project funding to state-based production tax credits. Section 9006 of the Federal Farm Bill also provides substantial funding for renewable energy projects for rural and agricultural residents and businesses, enabling many small-scale wind projects to receive support.

Standard prices for the purchase of power for wind ('feed-in-tariffs') have been a primary driver for the development in wind energy facilities globally, particularly in Europe (*i.e.* Germany and Denmark). Standard offers, or feed-in-tariffs, guarantee a set price for the purchase of wind energy sold to a utility or end user. The ability of wind power generators to sign long-term contracts at a guaranteed price has greatly reduced the risk to investors, encouraging development of renewable facilities.

Also, many states and nations have passed public policies encouraging or requiring specified amounts of renewable energy to be supplied to electric consumers. These policies, often in the form of renewable

Growth in the Wind Industry

Wind has expanded from 10 MW in 1981 to over 10,000 MW in 2006.

Wind had a cumulative annual growth rate of 26 percent in 2005.

Growth is projected to remain above 15 percent through 2010.

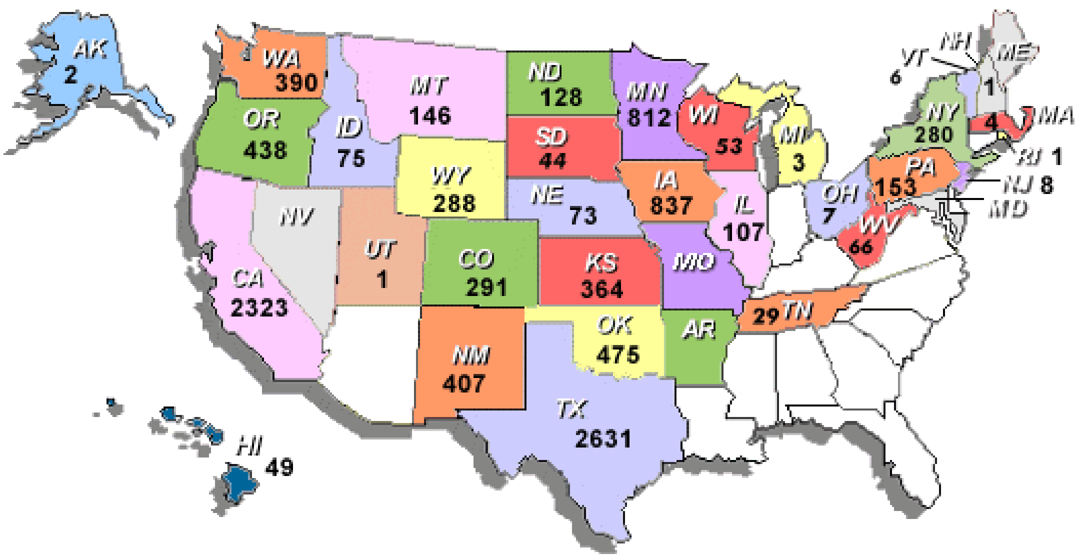
A record level of 11,407 MW of wind was installed across the globe in 2005

28,000 MW of wind are projected by industry analysts to be installed in the US by 2010.

[13] Sterzinger, G. and J. Stevens. (2006) *Renewable Energy Potential A Case Study of Pennsylvania.* Renewable Energy Policy Project p.
[14] American Wind Energy Association, Policy, Transmission and Regulation website: http://www.awea.org/policy/ptc.html

portfolio standards or renewable electricity standards, have been used to set a baseline amount of energy from clean or climate friendly power sources. In theory, these standards are created to enable infant renewable energy technologies to get a foothold in the market place, eventually becoming competitive with conventional fuel sources over the course of a few years. Figure 4 shows the installed capacity in the United States.

Figure 4. Installed MW of Wind Wnergy in the United States, 2005.



(Source: American Wind Energy Association[15])

Of importance to note here are opportunities for states with relatively low wind energy resource production potential to participate in this industry's growth. Namely, there is great demand for manufactured wind components for this industry, demand that may offer a significant opportunity for states in the Appalachian region which may have significant manufacturing capacity rather than high wind resource potential.

Industry Activity: Strategy and Competitiveness

One of the key aspects of the wind industry is the substantial number of large, global companies that currently dominate market share in all of the major areas of high demand for wind energy. As the demand for wind energy has increased over the last several years, an increasing number of large, heavily diversified entities have entered into the market. Examples include GE, Siemens and Mitsubishi. Many of the largest companies either entered into the wind market or grew to prominence through the acquisition of existing wind companies and competitors. GE Wind entered into the arena through the acquisition of Enron Wind[16], Siemens grew its market share through the acquisition of Bonus Wind,

[15] American Wind Energy Association: http://www.awea.org/projects/index.html

[16] Of its many assets at the time of collapse in late 2001, Enron possessed Enron Wind -its wind equipment manufacturing subsidiary. They were global in the sense that they had sold turbines into the US, German, and Spanish markets, with manufacturing facilities in all of these countries plus the Netherlands. As part of the unloading of assets to pay off creditors, Enron Wind was sold to GE's Power Systems

and Vestas grew larger through the acquisition of NEG Micon, a previously significant competitor.

These examples reflect a growing development in the wind industry of larger companies actively acquiring or merging with other competitors, smaller manufacturers and component makers. A company that has grown to prominence serving the Indian market, Suzlon, has actively focused on acquiring and/or merging with components manufacturers such as Hansen Transmissions, the largest European gearbox manufacturer. Mergers with foreign-based entities and opening satellite manufacturing facilities in areas of increasing market demand are growing in prominence, as well. A sign of the relative maturity of the industry, companies like GE are forming partnerships with foreign companies such as Chinese-based Nanjing High Speed & Accurate Gear Company (NGC) to jointly develop gearboxes for GE's 1.5 MW wind turbines. NGC is now one of GE's leading component suppliers in the wind energy business.[17] Growth through acquisition is enabling the 'big' players to get even bigger while becoming more vertically integrated and thus able to raise entry barriers to keep out new entrants while limiting the growth of small companies. Even as recently as the late 1990s, it was possible for a company to grow through the ability to serve domestic demand, as demonstrated by India-based Suzlon. That window of opportunity, however, seems to be closing as large global players further extend their global reach.

Suzlon Energy Limited: Profile of an Industry Leader from the Ground Up

Growth in the wind industry in India had been tremendous and in 2005, India overtook Denmark in total installed capacity. In the middle of this rapid growth has risen Suzlon Energy, Asia's leading wind manufacturer and fifth largest supplier of turbines worldwide. Suzlon has been India's leading turbine producer for the past eight years, installing 53 percent of the country's capacity in 2005.

Suzlon: Founded in 1995
Headquartered in Pune, India
Revenues of $854,000 in 2006
8,600 employees, 1,900 overseas

Source: Suzlon Energy Ltd. Press Resease 2006, Suzlon Energy Ltd. continues record performance in Q1, FY07

Suzlon's founder, Tulsi Tanti, was a textile manufacturer in the early 1990s. Faced with escalating energy costs, Tanti installed wind turbines at his facility. From this experience, Tanti decided to buy bankrupt Sunwind, founding Suzlon wind in 1995. *Source: Venture Intelligence Blog: http://ventureintelligence.blogspot.com/2006/03/what-makes-suzlons-tanti-tick.html*

Components	Locations
Rotor blades	**India** : Daman, Maharashtra Gujarat, Pondicherry **US** : Minnesota **China** : Tianjin
Gearboxes	**Belgium** (Hansen Transmissions)
Generators	**India** : Maharashtra (JV with Elin, Austria)
Control systems	**India** : Daman, Pondicherry
Towers	**India** : Gujarat, Maharashtra

Suzlon is an example of a fully-integrated company, producing equipment exclusively for the wind industry. Facilities in Germany, India and the Netherlands are engaged in cutting-edge R&D. Manufacturing facilities are located in India, Belgium, China and the US. Suzlon now supplies turbines for projects from as far as the US, to Brazil to Australia, Europe and across Asia. *Source: Suzlon Annual Report 2005*

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subsidiary in 2002 in its bankruptcy auction for $358 million. They also took over maintenance of Enron's wind farms. It was a profitable arena for Enron, making real money for the company. According to the *New York Times*, it grew from $50 m in 1997 to approximately $800 m by 2001 http://www.enron.com/corp/pressroom/releases/2002/ene/022002ReleaseWindLtr.html; http://query.nytimes.com/gst/fullpage.html?res=9F07E0D6173CF931A25757C0A9649C8B63.

[17] GE Wind, Press Release Aug. 30, 2006: GE, China's NGC to Jointly Develop Wind Turbine Gearbox. http://www.gepower.com/about/press/en/2006_press/083006.htm

Thus far, the window is not yet completely closed. Clipper Wind is an example of a US-based company that is working to accomplish a successful shift from small to middle to large industry player. In the near term, and perhaps of most widespread significance for American manufacturers, is the opportunity to supply components to an industry that is struggling to meet market demand.

According to energy industry analyst *Emerging Energy Research*, wind energy market share in 2005 was a factor of manufacturing capacity rather than competitive strategy:

> ". . .scale continues to drive competitive advantage. Attributes such as a good track record, capability to deliver large-scale projects, and market reach that is able to span multiple markets, are now par for the course. Building an edge in the competition for power purchase agreements entails taking these attributes to an even higher level and, at least for the near-term supply and demand scenario, simply having the wind turbines with which to build wind plants." [18]

Characteristics of the Wind Industry

- Dominated by highly consolidated and vertically integrated manufacturing firms
- The top 10 wind manufacturers supply over 95 percent of the global wind capacity
- The top 5 wind manufacturers supply over 80 percent of the global wind capacity
- One of the top ten is a US-based firm – GE wind
- The capacity to manufacture turbines determined market share in 2005
- Turbine suppliers are increasing their reliance on outsourced components

Market share in 2005 was ultimately determined by how many turbines a company could manufacture and supply. This situation has favored large, consolidated companies such as GE and Vestas, which possess the greatest market shares in the US and Canada, respectively. *Emerging Energy Research* has identified primary points along the supply chain acting as constraints, including gearboxes, castings and blades. Market share is protected or achieved by in-house manufacturing and ownership or close relationships with manufacturers of wind energy components. Growing wind companies such as Gamesa, Suzlon and Clipper have opened additional manufacturing facilities in the US for this reason.[19]

Suppliers of wind energy components have been reluctant to increase capacity due to the unstable market created by the Federal Production Tax Credit's (PTC) biannual expiration. Yet sustained demand over the last two years and into next year have encouraged increases, largely based upon this planning. However, analysts have pointed out that entities willing to take risks by jumping into the market have thus far been rewarded. Many vendors are sold out through the next expiration date of the PTC in

[18] Sterzinger, G. and J. Stevens. (2006) *Renewable Energy Potential A Case Study of Pennsylvania.* Renewable Energy Policy Project p.
[19] *Ibid.*

2007. The following year, 2008, will be important for the sustained momentum of the wind industry if the PTC expires again.[20]

In attempts to alleviate near-term supply constraints, wind industry vendors are increasing their reliance on outsourced component manufacturing – pushing original equipment manufacturers previously 100 percent vertically integrated to outsource much, if not all, of their supply. Restructuring the supply chain will enable the industry to become less subject to and reliant upon government support and interaction. Wind energy system and component manufacturers are addressing constraints by "moving production of non-essential components to low cost centers and increasing the number of venders supplying components", spreading risk outward from original equipment manufacturers.[21]

Also important to the ability of new players to enter and grow in this arena is the influence of project financing, and the requirements and preference of the lending institutions for project backing. The relationship between wind equipment suppliers, project developers, project financiers and project owners reinforces top manufacturers in the industry. Project developers not only contract with suppliers but seek funding for the project as a whole. This is important in two ways. First, developers often establish long-term relationships with suppliers in order to reduce project costs. Second, financiers are often only able to assess assets of the specific project they are financing, reinforcing their preference for large, established players in the industry. These 'proven' industries typically have no less than 100 installed turbines. Project developers, in response to project financing, are therefore unlikely to contract with companies that are not one of the top international players.[22]

The nature of project financing may determine the kind of arrangements developers have with wind technology suppliers. Private finance companies tend to fund projects on a non-recourse basis, a form of financing that preserves a proponent's other assets and makes available to creditors only the assets of the project itself, should any difficulties arise. As a result, investment companies tend to procure turbines from firms with strong financial and technological records. This usually means proven suppliers that have at least 100 turbines installed and operating in wind farms around the world. Companies that operate under these arrangements are therefore unlikely to engage a supplier outside the top six international companies.

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[20] *Ibid.*

[21] Newswire Today (7/20/2006). 'Outsourcing to Help Wind Industry Avoid Supply Constraints.' Frost & Sullivan www.newswire.com

[22] International Market Research Reports, Industry Sector Analysis – Wind Energy: http://strategis.ic.gc.ca/epic/internet/inimr-ri.nsf/en/gr109984e.html

Top Wind Energy Manufacturers

Over the course of the last five years, cumulative annual growth in the industry has been 26.3 percent. The US, Germany, Spain and India lead the world in installed MW, with the top ten manufacturers supplying over 95 percent of global capacity.[23] Furthermore, the top five manufacturers represent over 80 percent of the total installed global capacity for wind energy.[24]

Figure 5. Top Wind Turbine Suppliers

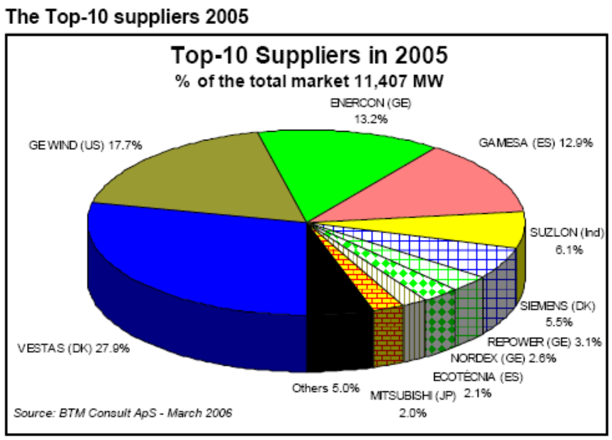


Table 1. Top Five Global Wind Energy Manufacturers (Headquarters, Installed Wind Energy Capacity in MW, Number of Employees, Manufacturing Facilities)

Company	HQ	Installed MW	Employees	Manufacturing Facilities
Vestas[25]	Denmark	20,818	10,618	Denmark, Germany, India, Italy, Scotland, England, Spain, Sweden, Norway, and Australia
GE[26]	USA	5,600	1,700	USA, Germany, Spain
Enercon[27]	Germany	10,200	8,000	Germany, Sweden, Brazil, India, Turkey
Gamesa[28]	Spain	7,547	8,186	Spain, USA (pending facilities in China, Portugal)
Suzlon[29]	India	4,253	5,300	India, Belgium (China and US FY06/07)

[23] BTM Consult ApS: International Wind Energy Development World Market Update 2005 Forecast 2006-2010, Press Release: http://www.btm.dk/Pages/wmu.htm
[24] Ibid.
[25] Vestas Website: Key Figures for Vestas: http://www.vestas.com/uk/profile/profile/main_figures/main_figures_uk.htm
[26] GE Wind Energy Website: http://www.gepower.com/businesses/ge_wind_energy/en/comp_snapshot.htm
[27] Enercom Website: At a Glance: http://www.enercon.de/en/_home.htm Capacity Installed: http://www.enercon.de/en/_home.htm
[28] Gamesa Annual Report 2005: http://www.gamesa.es/gamesa/modules/idealportal/uploadlink/memoria2005ing.pdf
[29] Suzlon Energy, LTD Suzlon Energy Ltd. continues record performance in Q1, FY07, Press Release: http://www.suzlon.com/images/you/SEL%20FY07%20Q1%20Release.pdf

Domestic Wind Market

As of December, 2005, the US had an installed wind capacity of 9,149 MW.[30] This number has grown to over 10,000 MW as of August, 2006. According to the American Wind Energy Association (AWEA), by the end of 2006 the US installed 3,000 new MWs of wind energy — more than the total capacity of the US in the year 2000. New manufacturing facilities have opened in Iowa, Pennsylvania and Minnesota, building on existing wind manufacturing facilities in Georgia, Florida, California and Oregon (not including components subcontracts).[31] Significant component manufacturing for the wind industry is occurring in California, Texas, Florida, Wisconsin, and Michigan. For a more detailed list of these manufacturers, including those located in Appalachian states, please see Appendix A.

Table 2. Wind Energy Manufacturers' Share of Installed Wind Energy Capacity in the US. (Note: GE acquired Enron Wind, Vestas acquired NEG Micon Wind.)

Manufacturers' shares of installed capacity for the past five years:

2005	GE Energy 1,433 MW	Vestas 700 MW	Mitsubishi 190 MW	Suzlon 55 MW	Gamesa 50 MW
2004	GE Energy 171 MW	Mitsubishi 120 MW	Vestas 97 MW		
2003	GE Energy 903 MW	Vestas 359 MW	Mitsubishi 201 MW	NEG Micon 129 MW	Gamesa 56 MW
2002	Vestas 175	NEG Micon 98 MW	GE Energy 62 MW	Mitsubishi 61 MW	Bonus 48 MW
2001	Vestas 653 MW	Enron 418 MW	Bonus 278 MW	Mitsubishi 221 MW	NEG Micon 119 MW

(Source: US Wind Energy Industry Rankings, AWEA)

As discussed previously, the American wind industry is faced with the challenge of establishing itself as a base of domestically-prominent wind equipment manufacturing. Given the strong demand for wind power generation in the US as well as Canada, the potential benefits of successfully entering the market are obvious. The question remains, however, as to how to best enter and sustain a company in this highly competitive market. The establishment of a viable 'Industry Consortium' to actively promote growth of the US wind industry, to help bridge the gap between small, middle and ultimately large players in the industry, is one suggestion. In order to promote successful research and development practices, it is important for US industry to penetrate existing R&D activity in Europe to further local industry growth in this arena. Finally, providing direct support for this mid-size 'infant' industry by providing a renewable energy

[30] American Wind Energy Association, US Wind Energy Industry Rankings: http://www.awea.org/pubs/factsheets/pdf/USwindindustryrankings2006.pdf
[31] American Wind Energy Association, U.S. Wind Energy Installations Reach New Milestone, Press Release: http://www.awea.org/newsroom/releases/US_Wind_Energy_Installations_Milestone_081006.html

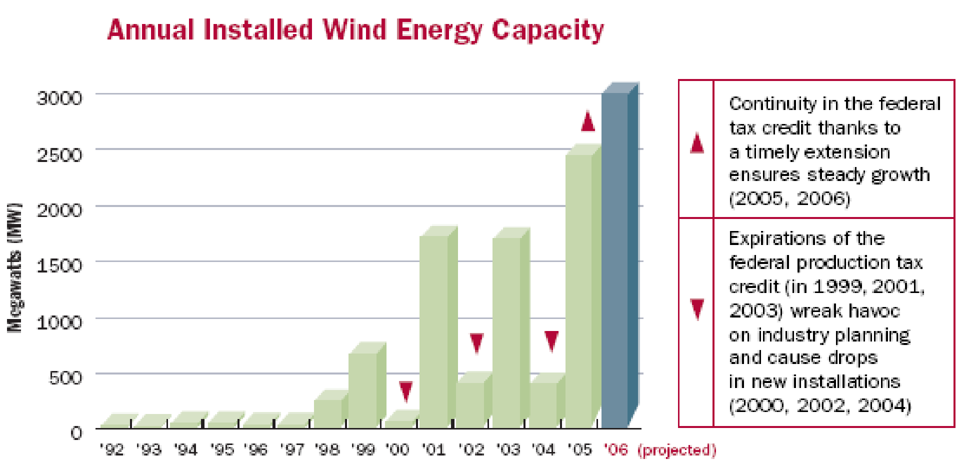
manufacturers' production tax credit for companies below a certain threshold would ease the market entry for both new and existing manufacturers.

Challenges to Industry Growth

As mentioned earlier, supply chain constraints exacerbated by the on-again, off-again PTC severely limited the number of turbines available for installation in both 2005 and 2006, and will likely be severely limiting in 2007. Also mentioned earlier is the nature of financing for large projects, which can limit new entrants into the market. In addition to these challenges, the following issues will ultimately require attention before wind energy can be fully realized:

> **Inconsistent national policy:** Unstable support for the wind industry at the national level has produced an environment of uncertainty for manufacturers, investors and project developers. This is evidenced most directly with the bi-annual expiration of the Federal Renewable Energy Production Tax Credit (PTC).[32] In the US, the single largest influence on consistent growth, as cited by the industry, is the impermanence of the Federal PTC, which provides \$0.018/kWh for ten years for each facility. The credit has been available for two-year segments since its inception, expiring three times in the last seven years, leading to a 'boom and bust' cycle for the industry.[33] The PTC is currently set to expire again at the end of 2007.

Figure 6. Annual Installed Wind Energy Capacity and Patterns of Production Tax Credit Availability



(Source: AWEA Wind Power Outlook 2006)[34]

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[32] Energy Information Administration: Electric Power Annual: http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html

[33] Ibid.

[34] AWEA Wind Power Outlook 2006: www.awea.org

Transmission Capacity for Renewable Energy: Particularly relevant to long-term industry growth is the current lack of investment in transmission capacity across the US, which is flagging relative to demand growth and necessary capacity additions. Significant 'bottlenecks' exist in the current transmission grid, particularly between areas that possess large amounts of renewable energy generation capacity (*i.e.* Great Plains and Intermontane West) and the areas of highest growth in electricity demand, not to mention areas with the highest demand for renewable energy (*i.e.* California). Not only are there limits on existing capacity, but intermittent energy sources, such as wind, are significantly disadvantaged in Federal Energy Regulatory Commission (FERC) transmission interconnection procedures. Where the grid can operate as 'back-up' capacity for intermittent resources such as wind, utilities currently keep spinning reserves of energy waiting in the background, adding a layer of difficulty integrating wind into the existing energy mix.

Competition from Conventional Energy Sources: Wind energy has come down in cost over 80 percent in the last 20 years. However, even with growth in capacity over the last decade second only to natural gas, installation of wind energy is still largely driven by public policy.[35] Conventional power sources such as coal, natural gas and even nuclear energy are still largely favored by utilities across the country and receive substantial subsidies from state and federal governments.

Solar

One of the most significant global resources, solar energy can be utilized passively and actively. Passive solar energy is used in building design to maximize the natural lighting and heating benefits of the sun; active solar energy is captured to produce electricity via thermal or photovoltaic (PV) technologies. Solar thermal technology uses reflectors to focus light onto a central receiver that uses the gathered heat to power a turbine. This technology converts solar energy into mechanical energy, which is then converted into electricity.

Photo courtesy of the New Mexico Solar Energy Association

Solar electricity can also be produced using a PV cell. PV cells are composed of semiconductor materials that gather sunlight and directly convert it to electricity with no moving parts. Panels of these cells connect to form modules and arrays that have the capacity to produce enough power for several or more homes.[36] For example, a PV array the size of a football field would create 1.2 million kWh of electricity per year, enough for approximately 122 homes.[37]

[35] American Wind Energy Association, Resources Cost: http://www.awea.org/faq/cost.html
[36] New Mexico Public Interest Research Group Education Fund, *Clean Energy Solutions*. March 2002.
[37] Department of Energy, Energy Efficiency and Renewable Energy website: www.eere.energy.gov

The nature of the solar energy market creates several interesting dynamics in the industry. Demand for solar PV cells spans the spectrum from small residential PV systems to large commercial systems which generate electricity for entire corporate campuses or provide electricity generation for utility companies. Systems that provide energy to a grid system represent a portion of electricity generation in Italy, Spain, and the US under heavily subsidized markets.

Growth in the Solar Industry

Global solar PV installed capacity expanded from less than 500 MW in 1990 to over 5,000 MW by 2006.

Grid-tied solar PV experienced a 55% increase in installed capacity in 2005.

The average annual growth rate over the last 10 years has been 25%.

A record level of 1,460 MW of solar was installed across the globe in 2005

Growth, Demand and the Future

In general, the industry is currently characterized by demand exceeding supply. In 2005, total global capacity reached 5,400 MW of installed solar PV, 3,100 MW of which were connected to the grid.[38] Installations in 2005 were a record 1,460 MW of new capacity, led by Germany and Japan. However, this figure is estimated to only meet approximately 80 to 90 percent of solar PV demand.[39]

The availability and distribution of silicon is a major determinate of MW output. Approximately 95 percent of all solar systems produced today are made using mono- or polycrystalline silicon wafers.[40] This report will explore the influence that major international firms have on the market, the influence of raw material supply, and external factors such as regulation and subsidization. The main focus will be on US PV manufacturing firms and US subsidiaries of key international players.

Industry Structure

There are three general types of firms in the solar industry: independent solar power specialists, consolidated electronics and semiconductor manufacturers, and diversified energy companies.

Independent solar power specialists concentrate on select components involved in the production of PV cells. Large international companies still dominate market share based on total megawatt production output per year.

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38 Renewable Energy Policy Network for the 21st Century: Renewable Energy Global Status Report, 2006 Update. http://www.renewableenergyaccess.com/rea/news/story?id=41508

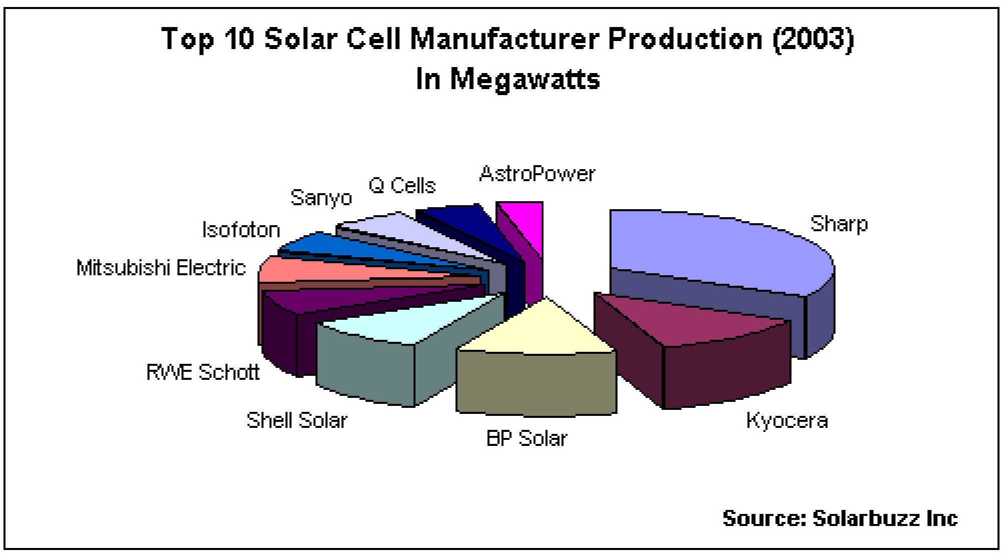
39 Renewable Energy Access News Story. website: http://www.renewableenergyaccess.com/rea/news/story?id=41508

40 Department of Energy, Energy Efficiency and Renewable Energy: Quick Solar Facts: http://www1.eere.energy.gov/solar/pv_quick_facts.html

Consolidated electronics and semiconductor manufacturers such as Sharp, Kyocera, and Mitsubishi produce finished systems as well as many other electronic products. Many of the high-selling products manufactured by these electronic companies also use silicon as a raw material, and involve a comparable manufacturing process. Cell phone screens, flat panel televisions, and computer monitors, for example, all involve silicon and flat glass manufacturing processes. Companies that already produce electronics compatible with solar energy technologies have easily transitioned into solar PV manufacturing. Existing companies have the advantage of economies of scope and scale. These large multinational companies, while not specializing in solar energy, have advantages due to their preexisting infrastructures and greater availability of resources.

A similar story applies to diversified energy companies such as BP and Shell Solar. Because of their size and market reach, moving into new areas through acquisition rather than development is an efficient and relatively low-risk endeavor. However, Shell Solar was acquired by the smaller, solar-specific SolarWorld, illustrating that even the largest of firms is not unassailable. Yet the upstream portion of the solar industry remains dominated by a few large players involved in the manufacturing of PV cells, modules and systems.

Figure 7. Top Solar Cell Manufacturers in 2003.



Note: Shell Solar sold 100% of all crystalline silicon production to SolarWorld

The chart in Figure 7 displays the market distribution as of 2003. Within the past three years the characteristics of the market have shifted in several ways. The current market condition can be analyzed by using 2006 actual MW production output in conjunction with 2008 projected output[41].

[41] We offer this comparison purely as a rough benchmark. In ideal circumstances we would prefer to compare same year data, but even these figures give a good snapshot.

Total solar manufacturing capacity in 2005 was 1.1 gigawatts (GW) worldwide, with Japan accounting for 500 MW, Europe accounting for 300 MW, the US accounting for 140 MW, and the rest of the world 140 MW. By the end of 2006, total worldwide manufacturing capacity was expected to double to well over 2.4 GW, and although many companies report upgrades/factory openings in quarterly results, many others only provide long-term production capacity plans.

Table 3. Top Solar PV Manufacturers

Company	**Production Capacity**
Sharp	600MW; 2006
SunPower	300 MW projected 2008
Sanyo	260 MW projected 2008
Conergy	250 MW projected 2008
Q Cells	180 MW; 2006
SolarWorld	175MW; 2006 350 projected 2008
Suntech	150 MW; fiscal end 2005
Mitsubishi	135 MW; April 2005
Solar Company	Production Capacity
RWE Schott	130 MW; fiscal end 2005
Kyocera	120 MW; 2004
*BP Solar	75 MW; 2006 150MW projected 2008

It is important to note that the difference in projected and current output will likely affect the ranking of firms in the industry. However, some conclusions can still be made with this data set.

Sharp maintains a powerful lead in the market, with twice the production capacity of SunPower. While some companies have shifted in rankings, most of the big players remain dominate. This is an important characteristic of the solar industry. The large players listed above have significantly greater output than the next set of companies, making it difficult for small players to compete in the market.

Furthermore, while the current output from BP Solar does not place it within the top ten in 2006, the projected 2008 value does. This is especially significant due to the expansion of its existing manufacturing plant in Frederick, Maryland. BP Solar, pending their projected output, will be the largest PV producer in the United States.

Challenges and Opportunities

Silicon Availability: The biggest present difficulty facing the solar industry is the shortage of silicon. Polysilicon accounts for 25 percent of polycrystalline silicon wafers' input costs, and as previously noted, silicon wafers are considered the industry standard for PV technology. The current price (July 2007) of

> polycrystalline silicon is $60/kg which is double that of 2003.[42] Market forecasts expect the price to continue to increase to $80/kg in the next couple of years. All contracted silicon supply agreements are filled through 2007, meaning increased purchases must be made at the on-the-spot price of $100/kg .[43]

Companies currently holding contracts have the most power to increase output and subsequent revenues in the near future.

Table 4. Total Forecasted Polysilicon Capacity (in Metric Tons).[44]

Year	2004	2005	2006	2007	2008
Total Capacity	28,000	30,200	34,500	38,050	49,550

While capacity is increasing, it is increasing less than global MW production output projections, which explains the increase in price. Coping with the shortage of silicon and increase in prices may be the most influential factor to future success. Silicon supply is predicted by some analysts to become more available in the coming years, however, as large markets such as Germany begin to reduce the level of electricity buy-back rates in conjunction with efforts to increase silicon production.[45]

Those companies that secure silicon supplies will have much more stable forecasts of production in the foreseeable future. Suntech Power Holdings, Co. the top Chinese solar cell producer and a top ten competing player globally, has two major silicon wafer agreements with SolarWorld and MEMC for ten-year supplies of wafers. Along with their recent purchase of MSK Corp. of Japan, Suntech Power Holdings, Co is in a position to grow substantially in the near future.

Yet despite the threat of silicon's non-

Characteristics of the Solar Industry

Vertically integrated companies dominate the solar PV manufacturing industry and consolidation is expected to increase.

The top ten solar manufacturers supply the majority of the global solar PV capacity

All of the top five solar PV manufacturers are based in Japan or Germany

The ability to secure long term contracts for polysilicon through 2005 was critical to a firm's manufacturing capacity

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[42] http://www.researchconnect.com/downloadreport.asp?RepID=20162
[43] Renewable Energy Access: News Story, website: www.renwableenergyaccess.com/rea/news/story?id=41508
[44] PJC estimates, Rare Metals News, Photon International
[45] Renewable Energy Access: Price Decrease and Consolidation: The Solar PV Supply Chain, www.RenewableEnergyAccess.com

availability, the demand for solar energy continues to increase and the price for large-scale solar energy-based supply has begun to decrease since the middle of 2006.[46] Renewable energy incentives and government subsidies provide a large opportunity for solar cell manufacturers. In the US, many of these programs are operated at a state level. For instance, the New Jersey Clean Energy Program initiated a $40 million per year incentive for solar, wind, and biomass projects. The program includes net metering, renewable energy credits and trading, and direct customer rebates. Direct rebates allow customers or businesses to apply for rebates of 50 to 70 percent of the system purchase cost, including installation and purchase price.[47] Incentives such as these can be compared to Germany's 100,000 rooftop program, or Japan's similar program. Germany's incentive program encourages consumers to purchase solar systems by offering 10-year low-interest loans to cover costs.[48] Japan has allotted over $200 million every year to rebate solar panels. This investment pushed Japan to number one globally in both MW installed and MW production output.[49] Increases in US renewable incentives should offset consumer costs and increase demand for PV, resulting in greater output among the domestic players.

New Technology and Innovation

Many companies are beginning to look beyond silicon wafer solar cells, and exploring new product technologies. InnovaLight, founded in 2001 and based in California, is one of several companies involved in PV film production. This technology involves silicon inking which uses much less silicon per cell. The finished product is thin and malleable and can even be placed in clothing. Moreover, the cells are able to capture more than just visible light waves resulting in a higher conversion rate.

Research and development of new technology may be the thriving strategy for competition in the solar industry. ARC programs to encourage solar industry growth should go beyond the scope of component production and look ahead to the promise of emerging technologies

Challenges to Industry Growth

The mature nature of the solar industry is a positive in the sense that the technology has been in existence for many decades. Components used in PV cells are already manufactured in many regions of the US. Yet industry growth cannot be spurred solely from the supply end. US demand is crucial not only for energy independence, but for economic independence as well. While the majority of PV systems produced in the US are currently exported overseas, incentive programs could help to increase domestic demand. Looking to other countries as examples, Germany and Japan have both shown

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[46] Ibid.
[47] Database of State Incentives for Renewables and Efficiency, New Jersey: http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&State=NJ&RE=1&EE=1
[48] Solar Integrated website: Germany: http://www.solarintegrated.com/germany.htm
[49] SEIA, The Solar Photovoltaic Industry in 2006: http://www2.dupont.com/Photovoltaics/en_US/assets/downloads/pdf/SEIA_StateofSolarIndustry2006.pdf

that offsetting costs through rebates can accelerate product penetration. Within the US, New Jersey's Clean Energy Program has successfully rebated the consumer costs of the purchase and installation of solar systems.

Demand can also be increased through increasing solar energy requirements for utility companies. Renewable Portfolio Standards require utility companies to have a percentage of their electricity come from renewable sources. However, only three states (Pennsylvania, New York, and Maryland) within the Appalachian Region currently have renewable portfolio standards. Pennsylvania's Alternative Energy Portfolio Standard is two-tiered. First, renewables such as wind, biomass, and solar are set at 1.5 percent in 2007 and should increase 0.5 percent every year until reaching 8 percent by 2020. Tier Two includes coal abatement and demand management which will contribute 10 percent by 2020. New York's Public Service Commission will require 25 percent by 2013.[50]

Even so, the US cannot make up the global market gap with current technology alone. Innovation is key to global competitiveness. Developing the US market for solar products requires more effective technology to reduce the problem of silicon shortages. Allocating tax dollars from utility revenues to support research and development in new technologies will have a direct impact on the competitiveness of US firms competing in the solar industry.

Not to be ignored, Appalachia has a commanding supply of science doctorates, research programs, and leading universities. Pennsylvania ranks fifth in number of doctoral scientists and has four of the top 15 undergraduate engineering programs. Maryland ranks second in the amount of federal R&D funding. Georgia Tech is home to the US Department of Energy's University Center of Excellence for Photovoltaics Research and Education (UCEP), one of two such centers.[51] The resources are available and will be of considerable advantage to the solar industry.

Biomass

Energy from biomass resources is unique relative to both wind and solar power for the simple reason that energy production requires a feedstock that is itself a commodity. This characteristic sets it apart from renewable sources such as solar and wind power in important ways, both economically and environmentally. Biomass production, harvesting and transport introduces both economic costs as well as opportunities and carries with it environmental considerations that do not exist with other forms of renewable energy. This has created a controversial and uncertain future for biomass energy, to say the least, and will be discussed in greater detail below.

Biomass can be derived from many sources and can be used in equally as many ways. Sources of biomass range from forest thinnings, to agricultural waste such as manure and

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[50] Renewable Energy Policy Project website: www.repp.org/rps_map.html
[51] University Center of Excellence for Photovoltaics Research and Education: www.ece.gatech.edu/research/UCEP

corn stover, to methane gas from landfills. Many of these sources are currently produced as waste products from other agricultural or industrial processes, yet there is an increasing degree of research and activity around biomass production exclusively for use as a fuel in the form of dedicated energy crops. Short rotation woody crops including fast-growing willow and poplar species, as well as agricultural commodities such as corn are currently being grown for use as fuel feedstocks in the energy sector.

Biomass is burned directly to produce heat, to run a turbine, or to be converted into a biofuel or biogas, which is then used to produce electricity or transportation fuel. For the purposes of this report, biomass energy was divided into two categories. The first category deals with biomass electricity generation from dedicated steam facilities. The second category deals with biomass related fuel production, or biofuels.

Biomass Electricity Generation

Biomass experienced a 50-100 percent increase in production capacity in 2004 in several countries across the globe, bringing the total global biomass power capacity to over 44,000 MW by the end of 2005.[52]

There are four primary methods by which biomass can be used to produce electricity: direct-fired, co-fired, gasification and modular systems. Direct and co-fired facilities burn biomass fuel in a boiler to produce high pressure steam which is used to run a turbine. Direct-fired plants burn only biomass fuel, while co-fired facilities burn biomass in tandem with coal. Co-firing plants are the most economical, near-term opportunity for expanding biomass power generation. This process takes advantage of economies of scale associated with large coal burning facilities with only minor modifications to existing equipment with no fuel efficiency losses.[53] Virtually any form of biomass can be burned to produce electricity, though the energy content of different forms of plant material vary based upon physical properties including moisture content, heat value, mass, and chemical properties.


Source: Energy Efficiency and Renewable Energy

Currently, over 10,000 MW of biomass-derived energy is generated in the US: 5,000 MW from pulp and paper, 2,000 MW from dedicated biomass and 3,000 MW from municipal solid waste and landfill gas sources.[54] Biomass steam generation provides base load power from a clean energy source, and has been used to offset air emissions by many conventional energy producers. Yet, despite a large total installed capacity of biomass power generation in the US and across the globe, the average annual growth rate

Renewable Energy Policy Network for the 21st Century: Renewable Energy Global Status Report, 2006 Update. http://www.renewableenergyaccess.com/rea/news/story?id=41508

[53] US Department of Energy, Energy Efficiency and Renewable Energy: Technologies, Electric Power Generation, website: http://www1.eere.energy.gov/biomass/electrical_power.html

[54] National Renewable Energy Laboratory: Renewable Energy Poised to Realize Long Term Potential, June 2006: http://www.nrel.gov/director/pdfs/40768.pdf

between 2000 and 2004 was less than 5 percent.[55] This is significantly lower than the other renewable industries considered in this report. For this reason, this report also considers another arena of biomass energy utilization: biofuel energy production.

Biofuel Energy Production

In contrast to the low levels of growth in the biomass electric industry, the biofuel industry is experiencing tremendous levels of growth. The two dominant biofuels in use today are biodiesel and ethanol. This report will focus exclusively on ethanol as a resource.

Ethanol, in its current form, is primarily a simple sugar- or starch-based fuel refined from food crops such as corn, sorghum and sugar cane. Starch-based ethanol from corn is the primary biofuel produced in the US today, and involves the chemical conversion of sugar-based polysaccharides into an alcohol suitable for combustion in a conventional engine. Fuel blends containing ethanol are now relatively common, with over 30 percent of the gasoline in the US containing some level of starch-based ethanol.[56] However, there are many serious and complicated economic and environmental issues surrounding the use of food crops such as corn for the production of energy. For example, the National Academy of Sciences estimated that converting 100 percent of the corn grown in the US in 2005 to ethanol would have offset approximately 12 percent of the nation's gasoline demand. Furthermore, due to the net energy balance of corn ethanol of roughly 25 percent over fossil gasoline, the net energy gain from devoting 100 percent of the US corn crop to ethanol would have been only 2.4 percent.[57] The economics of devoting food crops to fuel production have been called into question due to the seemingly marginal gain.

It is also necessary to consider the impact of using food-based crops for ethanol production and the market impacts and interactions between crops grown for food or for fuel. The market has already experienced price increases for downstream products from corn as the price paid for corn has increased, ranging from staple products such as bread and tortillas to products containing corn syrup. Meat and diary products have also increased in price as the cost of feed for livestock and poultry has increased. Finally, the cost of other agricultural commodities has increased as farmers convert land into corn production and out of production for soybeans, for example. The myriad policies and subsidies embedded within the agricultural sector at both the national and international level further complicates the economic viability of growing a crop such as corn for ethanol production. In 2005, production costs for ethanol were roughly $0.46 per energy equivalent liter compared to $0.44/ liter for gasoline. Crop subsidies that lower crop prices dramatically impact the cost of ethanol, where corn prices are roughly 50 percent of a production facility's operating costs.[58] Finally, market fluctuations in gasoline prices

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[55] Ibid.
[56] Renewable Fuels Association. (2006*) From Niche to Nation, Ethanol Industry Outlook 2006.* www.rfa.org
[57] Hill, J., Nelson, E., Tilman, D., Polasky, S., and D. Tiffany (2006) Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *PNAS* 103:30, 11206-11210,
[58] *Ibid.*

as well as efficiency gains in ethanol production improve the profitability of corn based ethanol, as do regulations promoting ethanol production. This economic picture changes further when crop growers consider converting less productive land into corn production to produce ethanol. In such situations, the net energy balance of ethanol decreases further as fossil inputs increase to attain productive crop yields. In sum, the economic reality of using corn to produce ethanol is both complicated and controversial. However, this is not the only challenge facing corn-based ethanol.

Significant environmental concerns revolving around large-scale corn production exist in terms of its energy, chemical in water inputs, and emissions. Corn inputs and impacts are higher than many other agricultural crops, including those corn is currently displacing. Corn requires higher levels of chemical fertilizers such as nitrogen and phosphorous, as well as pesticides that leach into the water supply and contaminate drinking water, lakes, rivers and create environmentally devastating realities such as the 'dead zone' in the Gulf of Mexico.[59] Also, where the National Academy of Sciences estimates that corn-based ethanol is roughly 12 percent less greenhouse gas-intensive as gasoline, there are growing concerns over ethanol's relatively high emissions of air pollutants such as carbon monoxide, sulfur and nitrogen oxides, among others.[60]

As is the case with each of the renewable resources considered in this report, the availability or supply of renewable fuel within the Appalachian region is important when considering the possible generation of energy using non-conventional sources. Viability for both wind and solar-powered projects will be highly site-specific. Only some regions within Appalachia will be suited for the development of projects given these two land-dependent energy sources. Yet, due to the nature of biomass as a transportable feedstock for energy production, the capacity of Appalachia to produce energy from this resource will be governed by other factors. Namely, which biomass products and resources does the region currently produce or possess, what sources might it have the capacity to produce or possess, and under what circumstances might the region import fuel from elsewhere? As the answers to these questions are sought, particular opportunities for the Appalachian region may become immediately obvious. This report considers the manufacturing potential for Appalachia regarding many renewable energy sources; this opportunity may exist for ethanol as well. The region possesses considerable resources for research and development, in private, public and academic sectors, many of which are already employed in the biomass energy arena to some degree. Finally, the Appalachian region may bear considerable opportunities to develop biomass energy directly.

Corn-based ethanol, however, is not the only biomass derived fuel available. Considerable efforts are underway to bring lignocellulosic ethanol technology (referred to as 'cellulosic' for the purpose of this paper) to maturity. Chemical hydrolysis, enzymatic hydrolysis and gasification are three current methods by which cellulosic ethanol is produced, yet each of these technologies is still in relatively nascent stages of development.

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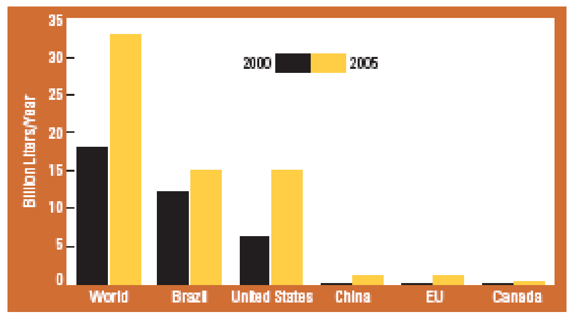
[59] *Ibid.*
[60] *Ibid.*

There is substantial justification for moving from a starch-based ethanol focus to a cellulose-based ethanol focus, potentially alleviating some of the concerns raised above. For example, burning ethanol in conventional combustion engines is less greenhouse gas-intensive than burning petroleum. This is particularly important to consider since transportation fuel is responsible for roughly one-third of US-based greenhouse gas emissions.[61] However, the US Department of Energy calculates that cellulosic ethanol generates as much as 75 percent less greenhouse gas than oil, as compared with corn-based ethanol.[62] This differential is due, in large part, to the resource intensity of feedstock production in conventional starch and grain crops, mentioned above. Cellulosic feedstocks, though still in need of collection and delivery, can be composed of vegetative waste material as compared with the direct cultivation of resource-intense sugar and grain crops.

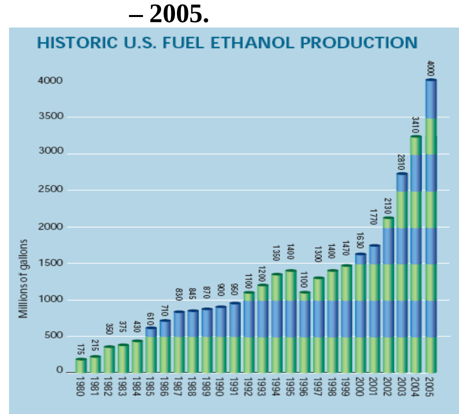
Figure 8. Global Ethanol Production, 2000 and 2005



Source: REN21 Renewables Global Status Report 2006

As the name suggests, cellulosic ethanol is derived from plant-based cellulose, a polymer of the disaccharide molecule found in the cell walls of mosses, seaweeds, annual and perennial plants, and trees. This is compared with starc-based polysaccharides that come from the fruits, seeds and roots of plants, and constitute a much lower fraction of global vegetable matter.[63] This speaks to the fact that cellulosic material is much more widely available than starch-based material, and can be derived from many more resources in many regions of the world. Additionally, better yield of energy per ton of feedstock from cellulosic biomass is possible, in the order of up to 10 tons versus 4 or 5 tons for even the most efficient grain crop yields.[64]

Figure 9. U.S. Ethanol Production 1980 – 2005.



As mentioned earlier, ethanol production from cellulosic resources is still in the development stage. There are few commercial operations in place across the globe, none of them in the US. The ethanol industry, domestically and abroad, is still largely focused on non-cellulosic biomass sources.

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[61] Department of Energy, EERE www.eere.gov/biomass_news

[62] Department of Energy, EERE www.eere.gov/biomass_news

[63] McAloon, A., Taylor, F. and Yee, W. (2000) 'Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks'. A Joint Study Sponsored by: U.S. Department of Agriculture and U.S. Department of Energy

[64] Sims, R., Hastings, T., Schlamadinger, B. Taylor, G. and Smi, T. (2006) 'Energy crops: current status and future prospects' *Global Change Biology.* 12, 2054–2076.

Growth, Demand and the Future

Brazil has historically led the world in ethanol production, producing over 4 billion gallons per year (mmgy) in 2005 from sugar cane. However, the US now exceeds Brazil in total production capacity, and has the capacity to produce 5.3 mmgy of ethanol, over 80 percent from corn, in over 110 refineries across the country. Furthermore, 79 more refineries, adding 6 mmgy to that capacity, are in some stage of planning or construction.[65] China, with capacity over 1,000 mmgy, is the closest to Brazil and the US, followed by India at 450 mmgy based on 2005 year end estimates.

The Energy Policy Act 2005 (EPACT 2005) set a national Renewable Fuel Standard for the US, requiring that the domestic production of ethanol increase from 4 mmgy in 2006 to 7.5 mmgy by 2012. This policy also established a provision that requires production of 250 million gallons of cellulosic ethanol by the end of 2012. Tax credits for the installation of biofuel infrastructure were also included in the EPACT of 2005.

Production-based incentives have also been created to spur further development in the ethanol industry, such as the Federal Volumetric Ethanol Excise Tax Credit (VEETC).[66] Passed in 2004, the VEETC provides a partial federal excise tax exemption of 51 cents per gallon for ethanol blended into gasoline. In 2005, the use of ethanol reduced the US trade deficit $8.7 billion by eliminating the need to import 170 million barrels of petroleum oil.[67]

Global production of ethanol is increasing. In addition to growth in the US, at least eight countries now possess ethanol blending mandates.[68] Most nations producing ethanol have done so to increase domestic consumption while reducing transportation costs. Countries like Brazil are now capitalizing on growing global demand by exporting fuel to countries such as the US and Japan. This is generating activity across the globe, inspiring many nations to develop incentives to grow their local industries for both domestic demand and export. To encourage domestic production, many nations' impose import taxes on ethanol and biofuels. For example, the US imposes $0.54 per gallon tariffs on the import of ethyl alcohol for fuel production.[69] These tariffs are sufficiently low to encourage imports and therefore act as significant barriers to market entry for domestic producers.[70] Even with the $0.54 per gallon tariff, the US imported over 653.3 million gallons of ethanol from Central and South America in 2006, a 383 percent increase over

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[65] Renewable Fuels Association Press Release December 2006: October Ethanol Production Ties All Time High: http://www.ethanolrfa.org/media/press/rfa/2006/view.php?id=918

[66] Renewable Fuels Association, Biofuel Outlook 2006 http://www.ethanolrfa.org/objects/pdf/outlook/outlook_2006.pdf

[67] United States Department of Agriculture

[68] Renewable Energy Policy Network for the 21st Century: Renewable Energy Global Status Report, 2006 Update. http://www.renewableenergyaccess.com/rea/news/story?id=41508

[69] Ethanol subsidies (2007). Econbrowser. Retrieved 6/11/2007 from: http://www.econbrowser.com/archives/2007/02/ethanol_subsidi.html

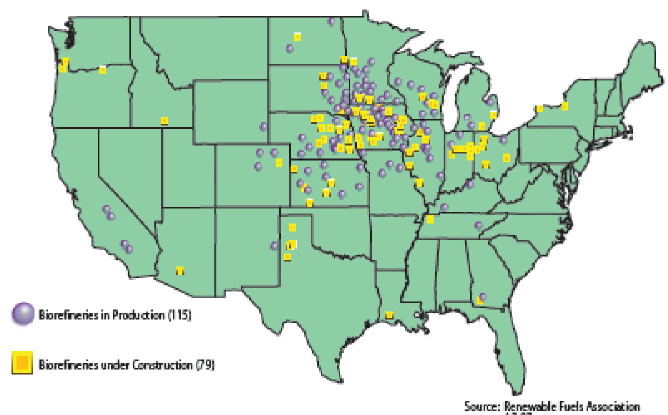
[70] Renewable Fuels Association, Biofuel Outlook 2006 http://www.ethanolrfa.org/objects/pdf/outlook/outlook_2006.pdf

2005.[71] It is necessary to stress that the rapid growth in global ethanol production is primarily sugar- and starch-based production from food crops.

Industry Activity

Unlike its renewable energy counterparts in the wind and solar industries, the ethanol industry has a large base of activity in the US. Though initially an industry dominated by farmer-owned production facilities, large chemical and energy companies like DuPont, BP, Archer Daniels Midland, Cargill, and Monsanto are becoming major players and are deeply engaged in this thriving market. Some of these companies are buying into cooperatively-owned ethanol plants while others, such as BP, are investing in research for cellulosic ethanol. Each of these different players has a varying degree of influence on an American bioeconomy.

Figure 10. US Ethanol Refinery Locations,



As the ethanol refinery map demonstrates, the US industry is based primarily in the Midwestern region of the country. Where the ethanol industry has historically been concentrated within the hands of only a few firms, new entrants into the market are increasing. Most notably, the Federal Trade Commission recently announced that, with 15 new firms entering the market in 2006 (raising the total in the industry to 90), ethanol production is no longer 'highly' concentrated.[72] According to the FTC and the Renewable Fuels Association, the number of firms and the locations of biorefineries are expected to increase further through 2007.

The first commercial cellulosic facility was scheduled to begin construction in the fall of 2006 in Spain. Though only in its early stages of development, expectations are this technology will be widely deployed over the next decade and grow to become a dominant resource in the biofuel arena.

Challenges to Industry Growth

Absentee ownership structures alter the flow of resources into and out of the communities producing the feedstocks as well as the fuel. The current trajectory for development of ethanol suggests that large industry will continue to dominate this sector unless other priorities are considered. The shape of this emerging sector will depend on the social

[71] Renewable Fuels Association "Industry Statistics" 2005 Retrieved 5/16/07 from: http://www.ethanolrfa.org/industry/statistics/#F
[72] Renewable Fuels Association, Press Release December, 2006: New Producers Increase Competition in US Ethanol Market: http://www.ethanolrfa.org/media/press/rfa/2006/view.php?id=912

organization of the involved corporations, regulatory bodies, federal initiatives, environmental organizations, farmers and commodity groups.

The future bioeconomy will depend, to a great degree, on the resolution of social, environmental, and economic impacts of biofuel production. Given the growing recognition of environmental impacts of agriculture and concern about the effects of agricultural restructuring on rural livelihoods and communities, the landscape and social changes possible in a transition to increased production of energy feedstocks from agriculture deserve further examination. In particular, it is relevant to ask whether such production will support or undermine economic and environmental sustainability.