Energy Sector Report

Technology Roadmap Project

Prepared by:

The information contained in this document is not warranted or guaranteed in any way and is provided "as is." Rensselaer does not warrant or guarantee, express or implied, the accuracy, adequacy, quality, validity, completeness, or suitability of any information contained in this document for any purpose. In no event shall Rensselaer be liable to anyone for any inaccuracies, errors or omissions with respect to the information or any part thereof, or for any damage arising from, or occasioned by, the use of the information.

© 2004 Center for Economic Growth and the Lally School of Management and Technology

ENERGY

1. Segments and sub sectors

The energy sector can be classified broadly based upon the primary *sources*: fossil, nuclear, hydroelectric, and renewable categories. The nonrenewable energy sources are exhaustible and comprise more traditional sectors such as coal, natural gas, and petroleum. As the name suggests, the renewable energy sources emphasize recycling energy gained from sources such as wind, wave, solar, geothermal, biomass, and waste. These energy categories have spawned a whole range of products and services that can be viewed as making up the value chain in the respective sub sectors. In terms of economic activity, a major difficulty in identifying energy sectors is represented by the fact that the boundaries between energy goods and services are blurred. This unified approach to energy is probably explained by the market structure of the sector. Until recently the energy sector has been dominated by state-owned, vertically integrated companies, which performed all energy related economic activities, from the production of energy to its distribution to the final consumers. In recent years, privatization of public suppliers and complete or partial deregulation in the sector has led to a separation of energy related economic activities and to the identification of energy services as distinct form energy goods. Following is a qualitative description of the various sub sectors in the energy industry [1].

- *Coal:* This sector includes the extraction of all types of coal (hard coal, lignite, peat) as well as associated preparation processes including cleaning, crushing, screening and sizing of coal.
- *Petroleum:* Activities in this sector include exploration and extraction of crude oil, drilling, completing and equipping wells services activities in support of oil exploration and production and the manufacture of refined petroleum products (gasoline, kerosene, distillate fuel oils, residual fuel oils, lubricants, and so forth).
- *Electricity:* The supply of electricity involves several activities including: purchasing of fuel; constructing power stations and generating electricity; expanding, operating and maintaining transmission and distribution networks; trading bulk electricity (both nationally and internationally); supplying and metering; and operating customer billing and accounting systems.
- *Gas:* Exploration and production of natural gas is closely linked to exploration and production of oil and the establishments involved in these activities are often also involved in transmission and distribution.
- *Nuclear energy:* Nuclear energy activities involve: (a) production of uranium from open pit or underground mining methods; (b) the conversion of uranium oxide into uranium hexafluoride (representing 3% of the total cost of the fuel), which possesses the required chemical purity for enrichment and fabrication; (c) enrichment by means of gas diffusion or centrifugal separation (25% of total cost); (d) fuel fabrication, where the enriched uranium is used to produce the final fuels elements to be placed into the reactors (11% of

[1] World Trade Organization, *Background Note by the Secretariat*, Energy Services, C/W/52, Council for Trade in Services (98-3480). 1998.

total cost); (e) production of secondary energy from nuclear reaction; (f) storage (disposal) and reprocessing of discharged fuels.

- *Renewable energies:* Renewable energy sources are not depleted by their exploitation to produce electricity, heat or liquid fuels. Renewable energies include: hydroelectric power, biomass, geothermal energy, wind power and solar energy. With the exception of biomass (the conversion of wood, wood residues and crops into heat, electricity or liquid fuels), renewable energy is almost free of pollution.

The North American Industry Classification (NAIC) for the energy sector is summarized in Table 1. This classification is consistent with the aforementioned description of sectors within the energy industry.

TABLE 1. North American Industry Classification System (NAICS) codes for various sub sectors in the energy industry

2002 NAICS	1987 SIC	Corresponding Index Entries
237130	1629	All energy power plant construction except hydroelectric
237990	1629	Power plant, hydroelectric, construction
221119		Electric power generation, (except fossil fuel, hydroelectric, nuclear) solar, tidal, wind, electric

Source: US Census Bureau

2. Industrial life cycle

2.1 Market growth

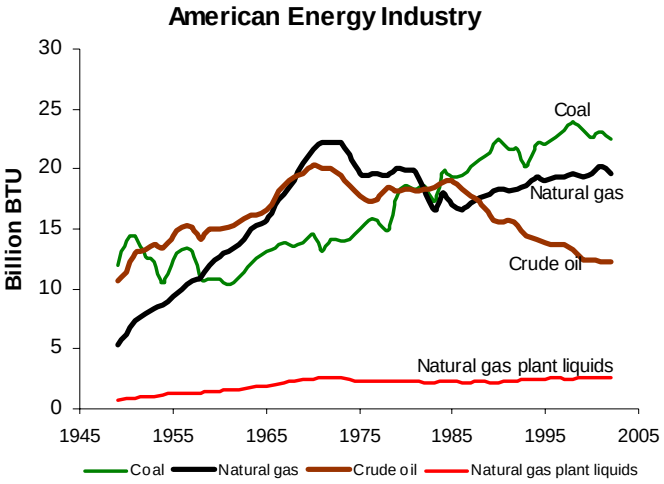
The energy industry is relatively large and global – of the order of trillions of dollars annually. Corresponding to the massive size of the energy industry, growth rates for the conventional forms of energy are relatively modest – in the range of 1-3% per year. This is to be expected: these segments of industrial activity are so mature that they simply cannot grow much faster than population or economic growth. North America is the largest consumer of oil in the world, accounting for more than one-fourth of total demand in 2001. Oil consumption in the transportation sector currently represents 66 percent of North America's total oil demand [2]. That share is expected to continue to increase as oil use declines in other end-use sectors (for example, natural gas is expected to displace most oil use for electricity generation).

Even though the absolute values for the renewables are much smaller in magnitude several of the renewable energy sectors within the industry are growing at a very rapid rate. It is likely that such robust growth rates for renewable energy markets will continue in the future. Markets for renewable energy could grow by close to 30% per year for the remainder of this decade .

[2] Energy Information Administration (EIA), 2004. Report #: DOE/EIA-0484 (2003).

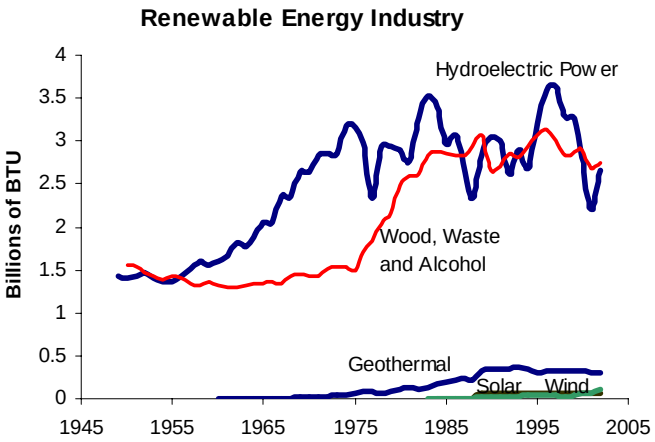
2.2 Market size

As seen in Figures 1A and 1B, the market size for conventional energy sources is much larger than that for renewable energy sources. The energy production for coal and natural gas shows a slight decline though they are the largest sources of energy production while the production from crude oil exhibits a declining trend. In the case of renewable energy sources, the production from hydroelectric power has been a major source up until 1975 and thereafter shows upward and downward swings. Energy production from wood, waste, and alcohol grew until around 1985 and shows a convergence with the production from hydroelectric power. While geothermal energy production has been in progress for some time, wind and solar energy production is relatively new and emerging.



Source: Department of Energy Annual Energy Review 2002

Figure 1A. Energy production (in BTU) for conventional energy sources



Source: Department of Energy Annual Energy Review 2002 (Table 1.2)

Figure 1B. Energy production market (in US$ Billions) for renewable energy sources

Figure 1. Market size in terms of energy production for various sub sectors from 1949 to present

2.3 Technology trends in industry

Some of the dominant technological trends in the energy industry are across the value chain, developing and modifying the industry structure constantly. Table 2 highlights the commercial applications and technology trends for various energy sources, likely to emerge within the next few years across the four stages of the value chain: extraction, processing and transformation, transmission, and retail and services. The technological innovations are primarily focused on the development of affordable energy that reduces costs and improves energy efficiencies. The general technological trend in the mature traditional sectors (such as, coal and gas) is visible on the services side of the value chain, although efforts are being made in the coal industry to improve processes in the front end of the value chain. On the other hand, several opportunities exist for development of new technologies at various stages in the value chain for renewable energy sources.

TABLE 2. Emerging or key technologies in various energy sub sectors and segments

Energy Source	Emerging or key technologies and trends by value chain segment			
	Extraction	**Processing and transformation**	**Transmission**	**Retail/Services**
Coal	Underground coal gasification. Coal and biotechnology	Integrated coal gasification cycle ; A combination of fluidized bed and gasification technologies; Direct coal combustion gas turbines; Ultra-supercritical steam Kalina cycle; Humid air turbine	Supercritical Pulverized Fuel (PF). Magneto-hydrodynamics (MHD)	Hydrogen – electrochemical Battery technology for electric and hybrid vehicles High speed rails
Gas			Fuel cells	Liquefied petroleum gas (LPG). Compressed natural gas (CNG). Methanol-powered flexible-fuel vehicles; Hydrogen; Fuel cells
Nuclear	Improved reactor and fuel management systems are being developed.		Reactor design concepts are being improved	
Wave		Further R&D is needed on the hydrodynamics	Ocean thermal energy conversion (OTEC)	.
Biomass	Development in the clean-up process, vessel sizes, the fuel-handling systems and the agricultural infrastructure needed to produce the energy crops			Sunflower, soya, groundnut, cottonseed, rapeseed, palm oil and castor oil. Biomass utilization technologies
Photo-voltaics	Cadmium telluride (CdTe) thin films and other materials. Copper-indium-diselenide materials			
Wind	Trends: Locating wind turbines in offshore locations.			
Solar thermal	Continuing R&D			
Hydro-electric	Hot dry rock used for geothermal energy…			

3. Value chain

The energy industry continues its transformation, driven by business imperatives to enhance customer value, meet industry-restructuring standards, and realize the benefits of economic and technological advances. As shown in Table 2, the energy value chain can be described using four segments, which are continually evolving through the combination of previously separate segments and the splitting of previously single segments into multiple segments. In the case of the oil and natural gas sector value chain, shown in Figure 2A (generated using publicly available data), a majority of the establishments in the value chain in 2002 are concentrated at the front and back ends of the value chain. However, although not shown in the figure, the retail segment is split into two to three markets, one focused on large customers, another focused on the mass market (both typically involving choice of retail energy supplier) and possibly a third market focused on the remaining regulated retail (including utility provider of last resort).

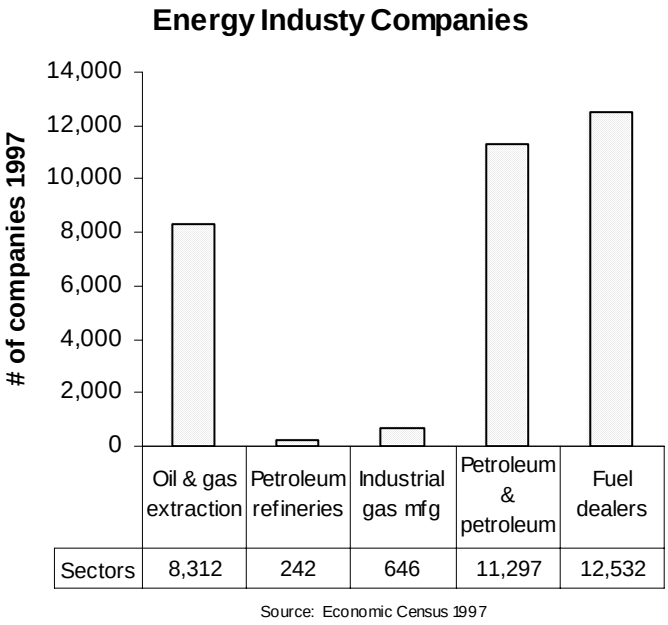


Figure 2A. Number of companies in the oil and natural gas value chain for the year 2002

The large oil and gas companies, with subsidiary operations in extraction, processing/wholesale, transmission, distribution, large customer retail, and mass-market retail, are representative of large players who seek to participate in most or all segments of the value chain. During 2001-05, despite the recent slow-down in deregulation and restructuring efforts in the U.S. market, a continued move toward separation in each segment of the energy value chain is expected to occur, with each segment forming a distinct business model. Although companies may choose to operate in some or all of these segments, the era of vertically integrated monopolies is phasing out gradually.

A dramatically opposite business strategy of horizontal specialization, where companies choose to focus on one or two segments of the value chain and possibly extend their capabilities to other similar industries, is pursued by the emerging companies in the renewable sub sector. As seen in Figure 2B, the renewable photovoltaic industry shows a simultaneous growth in almost all the value chain segments for both 2001 and 2002. However, the number of establishments in all the segments is relatively much smaller than those for oil and natural gas. The phenomenon of vertical integration evident in conventional energy sectors is markedly absent in the photovoltaic industry. Other strategies, which could be combined with either vertical or horizontal specialization, include convergence (a focus on multiple commodities such as electricity, gas, water, and telecommunication) and geographic reach (regional, national, and international). Each segment will focus on a primary value discipline as the basis for strategy.

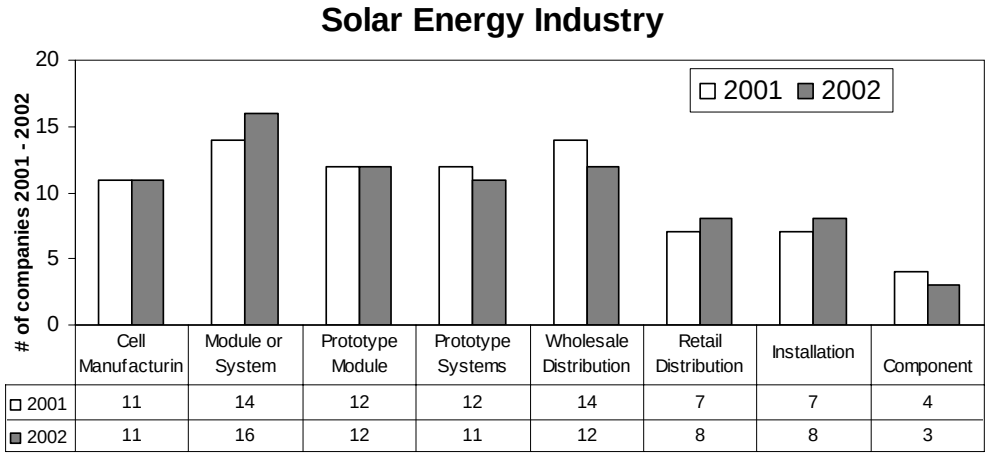


Figure 2B. Number of companies for segments in the photovoltaics value chain

4. Target for economic development

Defining a target for economic development in the energy sector is to choose between: a) expanding conventional natural gas power plants with or without inclusion of environmental costs (for example, whether CO_2 extraction is carried out or not), and b) renewable energy resources with virtually nonexistent environmental impacts. Natural gas power with CO_2 extraction will not be economically competitive (in price) compared to conventional production of gas power without calculation of these costs. Carbon extraction increases the costs of generating power with the use of fossil fuels and contributes to more realistic conditions of competition for renewable energy [3].

On the other hand, renewable energy sources enjoy the benefits of reduced energy costs, risk management by diversifying generation options, job creation and economic benefits, and environmental benefits. These benefits are well documented in the literature [4]. Electricity generated from oil is the most expensive of all forms of electricity from fossil fuel. As a result, if coal and natural gas are readily available, a very low fraction of electricity is produced from oil. Most renewable energy sources have little or no fuel cost. These include wind, hydro, solar, geothermal, Ocean Thermal Energy Conversion (OTEC), and wave. There may be costs associated with some types of biomass, but these costs tend to be more predictable and controllable [5].

Wages in the unconventional energy industry are bid above the national average for the energy industry as a result of rapid growth in labor demand [6]. As can be seen in the case of the photovoltaics industry (figure 2B) value chain, most of the local jobs would come from the installation, operation and maintenance, and marketing of the renewable systems. Jobs could arise indirectly from businesses that supply renewable energy companies with raw materials, transportation, equipment, and professional services, such as accounting and clerical services. The wages and salaries generated from these jobs provide additional income in the local economy. The National Renewable Energy Laboratory (NREL) reports that renewable energy is already bringing important economic benefits to the United States. For example, in 1996 the photovoltaic industry generated more that $800 million of revenues and employed 15,000 people at over 800 companies, most of them in high quality jobs, such as manufacturing, engineering, sales, installation, servicing and maintenance [7]. Renewable energy companies also contribute more tax revenue locally than conventional energy sources. In 1997, the United States spent about $65 billion dollars outside the country to pay for fossil fuels. But as one of the world's leading manufacturers of renewable energy systems, the United States can bring in more money with the increased use of renewable energy sources around the world. Currently, for example, the United States manufactures about two-thirds of the world's photovoltaic (PV)

---

[3] Palm, T, Buch, C., Kruse, B., Sauar, S., *Green Heat and Power, Report* 3:1999

[4] GDS Associates, Inc., *Analysis of Renewable Portfolio Standard Options For Hawaii*. 2001.

[5] Energy Information Administration. *Electric Power Monthly*, December 2000 and HECO and MECO *FERC Form 1* and HELCO and KE *Annual Reports* for 1999.

[6] Sterman, John D., *The Energy Transition and the Economy: A System Dynamics Approach* (MIT PhD Thesis, Volume I., Sloan School of Management), pp. 2-3, 8-24, 352-369. December 1981.

[7] National Renewable Energy Laboratory, *Choices for a Brighter Future: Perspectives on Renewable Energy*. DOE/GO-1099-878. September 1999.

systems. U.S manufacturers export about 70% of these PV systems, mostly to developing nations, resulting in annual export sales of more than $300 million [8].

5. Conclusion

The analysis of the energy sector based on publicly available data indicates that the sector consists of a mix of both conventional and upcoming sources, which have led to the development of several sub-sectors. Major trends in the overall political and economic environment that are shaping this new global energy system include globalization, the information revolution, liberalization of national economies, and privatization of the industry. The conventional sectors are relatively saturated. The growth in the conventional arena is more likely to be related to the use of information technology to coordinate processes across the supply chain. The value in the conventional sector will result from providing more responsive services to customers at competitive prices. The energy efficiencies will result from a streamlined flow of goods and services throughout the value chain.

There could also be opportunities for economic development in integrating the two types of technologies related to conventional and renewable sources. For example, a distributed energy systems consisting of a combination of the two types of technologies will enable one to offset some of the economic disadvantages of the emerging renewable technologies. However, under the current energy services company (ESCO) model, a combination of the two types of technologies is not likely to be feasible. While utility (electricity and gas) companies can potentially become a major engine for change helping the adoption of renewable energy technologies, they also, in many cases, become a barrier to adoption of new technologies. This is inevitably an outcome of the size of large integrated utility companies.

Another way to integrate the various technologies to meet the energy demand is to integrate incremental and radical changes irrespective of the conventional and renewable sources. For example, in the near term, for electricity generation systems, the incremental technologies related to ultra clean coal testing, industrial gas turbines, photovoltaic, wind, and biomass can be integrated with the development of fuel cells, distributed energy production system introduction, wave and tidal power evaluation, and geothermal resource definition. Similarly, in the long run, for natural gas systems, disruptive technologies such as high pressure consumer gas, high (>15%) hydrogen additions, methane hydrates fuel resource, hydrates (transport, storage), and gas storage technologies can be combined with incremental development of thermo-photovoltaic appliances. Cross-sectoral spillovers across biotechnology and nanotechnology in the case of renewables like photovoltaics and biomass can drive economic growth.

[8] National Renewable Energy Laboratory web site. *Jobs and the Economy*. (http://www.nrel.gov).