The Role of Alternative Energy in the US Supply

Peter Fox-Penner and Adam Schumacher
The Brattle Group
1133 20th St. NW, Suite 800
Washington, DC 20036

Synopsis:

1.01. Introduction

The energy industry of 2003 faces no shortage of challenges. In the wake of the California energy crisis of 2000 and 2001, industry and government alike have explored ways to ensure that power markets work well and the industry provides affordable, reliable service. In the light of current geopolitical events, America's dependence on oil for transportation has once again become a pressing national issue. Major new power plant emissions standards have been introduced in the United States, and global climate change (along with its competitive cousin, green trading markets) has become a top-tier issue everywhere in the world.

What is the role of renewable, alternative energy technologies in meeting these challenges? Are technologies such as wind, solar, biomass, and geothermal generators quaint proposals of environmentalists or meaningful contributors to the supply base? The answer is that these technologies are moving slowly but steadily from niche applications into the mainstream, especially in power generation. Within the lifetimes of our children, renewable energy sources will probably account for roughly half of the world's energy. The global transport system, so dominated by oil use, will also gradually shift, but the driving forces in this arena will be fuel cells and hydrogen as an energy carrier.

As this summary suggests, it is important to begin by distinguishing between two energy systems that together comprise the energy sector. Section 1.02 outlines important distinctions between these two systems that will inform the role of renewables in each. Section 1.03 provides three motivations for exploring the role of renewable energy in the United States energy supply.

Section 1.04 provides an analysis of the current and future role of renewables in the electric power industry while Section 1.05 documents specific policies being pursued to make renewable energy a part of the mainstream in electric power supply. Section 1.06 analyzes the role of renewable energy in the transportation energy sector and provides a broad outline of the evolution to a hydrogen transport economy. Finally, Section 1.07 offers conclusions.

1.02. The Existence of Two Distinct Energy Systems in the United States

An important dichotomy exists between the energy system that governs the supply of electricity to consumers and the energy system that provides fuel to our nation's transportation sector.

[1] The Flow-Based Electric Power System

The system that provides electricity to the country has witnessed the ups and downs of deregulation and ensuing re-regulation. Since the dawn of the industry, the US power system has been primarily supplied by coal-fired, oil, and nuclear generation, but the fuel of choice for new generation coming on-line is almost entirely natural gas. Conventional hydroelectric power has moved into the mainstream, and is a significant component of supply, particularly in the Pacific Northwest. Renewable energy sources, including wood, solar power, biomass, geothermal, and wind technologies have played a historically minor role; in 2001 these technologies contributed to approximately 2 percent of the total US net generation of electricity.[1]

[1] EIA Annual Energy Review 2001, Table 8.2a.

These characteristics describe a system fueled by predominately North American sources of supply. Because of the potentially close relationship between the upstream and downstream segments, regulatory attention has been relatively more focused than in the transport energy sector. After the California energy crisis, the pendulum that had swung in the direction of deregulation during the 1990s has swung back to a considerable degree. Today, the Federal Energy Regulatory Commission's (FERC) goal of promulgating a "standard market design" stands as the leading testament to the somewhat counterintuitive notion that power markets work well only when they are strongly and properly governed.

[2] The Transportation Energy System

In sharp contrast on many levels to the electric power sector is the energy system that provides the fuels for the US transportation sector. This system centers on a single, separable fuel whose supply is truly global. Petroleum sources provided 98 percent of total energy consumption by the US transport sector in 2001.[2] Most renewable sources of transportation fuel came from corn ethanol.

As recent events have brought into sharp focus, foreign sources of petroleum have a dominant role. The geopolitical risks of this phenomenon, from threats of regime uncertainty in the Middle East to economic uncertainty in South America influence US policymaking at many levels. The transportation energy industry is more akin to a commodity industry, rooted in the history and geopolitics of international resource conflicts.

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[2] EIA Annual Energy Review 2001, Table 2.1e.

Before an audience of lawyers, it would be foolish to ignore the large regulatory differences between these two systems. Whereas price and access regulation continue to dominate the utility sectors, the transport sector's government controls center on extraction rules, processing and emissions standards, and extensive control over the technologies that affect fuel demand.

1.03. The Need for Alternative Energy Sources

Before outlining the role of alternative energy sources, the significance of pursuing the question should be articulated. If, for example, the systems described above were capable of meeting US energy needs going forward, the question of renewable sources would be less important. However, a gradually decreasing source of domestic natural gas supplies, the increasing specter of oil dependence, and environmental risk linked with heavy usage of fossil fuel technologies provide a different answer.

[1] Waning Domestic Natural Gas Supplies

In 2001, the electric generation sector witnessed a boom in the historic boom-bust cycle associated with the building of new power plants. Of the 47.95 gigawatts of capacity coming on line during the year, 40.22 gigawatts or almost 84 percent of the total additions were natural gas-fired plants.[3] In one context this could be viewed as a positive move away from the high-pollutant coal-fired capacity that has historically been our nation's generator of choice. Placed in the

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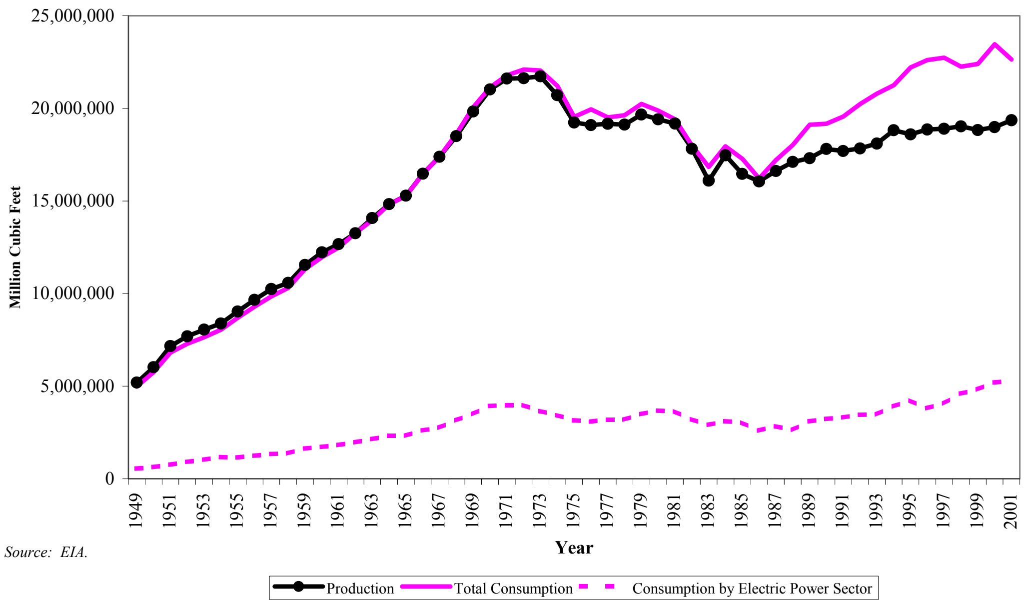
[3] Energy Information Administration, Form EIA-860A, "Annual Electric Generator Report - Utility" and Form EIA-860B, "Annual Electric Generator Report - Nonutility."

context of supply and demand, however, these additions highlight one factor contributing to the transition to alternative sources of power.

Figure 1
Trends in US Natural Gas Supply and Demand (1949 - 2001)



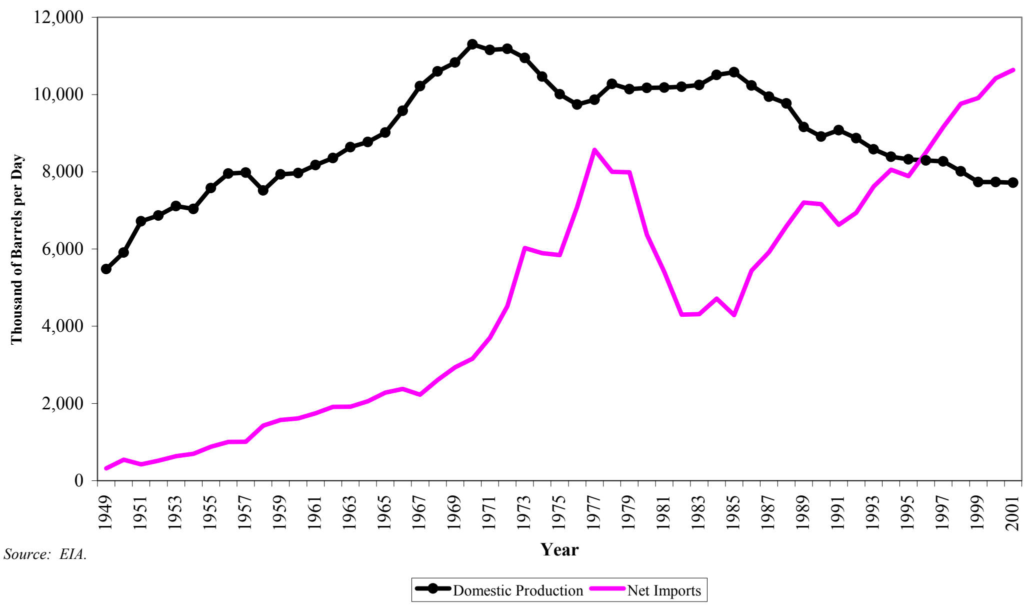
Source: EIA.

Figure 1 documents the trends in US natural gas supply and demand from 1949 – 2001, along with providing the specific consumption of natural gas by the electric utility sector. Consumption and domestic production were closely matched until 1986. In that year, consumption of natural gas by electric utilities was at low levels not seen since the mid-1960s. Going forward from that year, however, consumption of gas by utilities increased each year by 4.8 percent on average from 1986-2001. Not surprisingly, the unprecedented gap between overall annual production and consumption appears over this same time period.

This depiction of facts does not assert the United States is running out of natural gas as a source of supply. In fact, Section 1.06 will show that natural gas will continue to be a key transition fuel between the high-pollution worldview of yesterday and the hydrogen economy of tomorrow. Nevertheless, the fact that natural gas has become the fuel of choice for the power generation market and domestic production of natural gas is not keeping pace with consumption will foster the growth of alternative power generation sources.

[2] Oil Dependence

Figure 2
Trends in Petroleum Domestic Production vs. Imports (1949 - 2001)



Source: EIA.

Figure 2 provides a comparison of domestic production of petroleum versus net imports of the same product from 1949 – 2001. What is more telling than the expected drop in imports resulting from the oil shock of the 1970s is the inability of domestic resources to fill in the gap resulting from that same decline. The downward trajectory of domestic oil production that began when the industry reached its apex in 1970 continued through the mid-1990s, when imports of petroleum finally surpassed domestic production.

All else being equal, reliance on international trade for a good or service is not a reason to sound alarms and in most cases signals a more efficient employment of labor and capital. But geopolitical risk defines the regions of the world from which the US relies on for imports. Beyond the obvious instability over potential regime change in Iraq and resulting spillovers to the rest of the Middle East, and also the recent political turmoil in Venezuela, increasing reliance on imported oil ensures that the United States will face decades of geopolitical co-dependence on its major oil suppliers. These geopolitical risks, some new and some old, provide natural incentives for the transportation energy system to look for alternative sources of supply.

[3] Environmental Risk

Finally, the broad reliance on fossil fuels by both energy systems carries a commensurate environmental risk that has tangible consequences and costs. Regardless of individual or even corporate beliefs, there has been a steady (if perhaps inadequate) increase in environmental limits imposed on energy production and consumption worldwide since the 1970s. These limits impose costs on fossil fuels and improve the relative economics of most renewable energy sources. In combination with a domestic natural gas supply source that is no longer keeping pace with consumption and oil dependence on regions facing significant geopolitical risk, the benefits of lower emissions compel a serious analysis of the role of alternative energy sources in the US supply.

1.04. Prospects for Alternative Energy Sources in the Flow-Based Electricity System

Table 1
Installed US Renewable Electric Capacity, 1997 - 2001
(megawatts)

Source	*1997*	*1998*	*1999*	*2000*	*2001*	*Annual Growth*
Geothermal	2,893	2,893	2,846	2,793	2,793	-1%
Biomass	10,515	10,500	10,459	10,024	10,120	-1%
Solar	334	335	389	386	387	4%
Wind	1,610	1,720	2,252	2,377	4,062	26%
Total Renewables	15,352	15,448	15,946	15,580	17,362	3%

Source:
EIA, Office of Coal, Nuclear, Electric, and Alternate Fuels, Renewable Energy Annual 2001, November 2002.

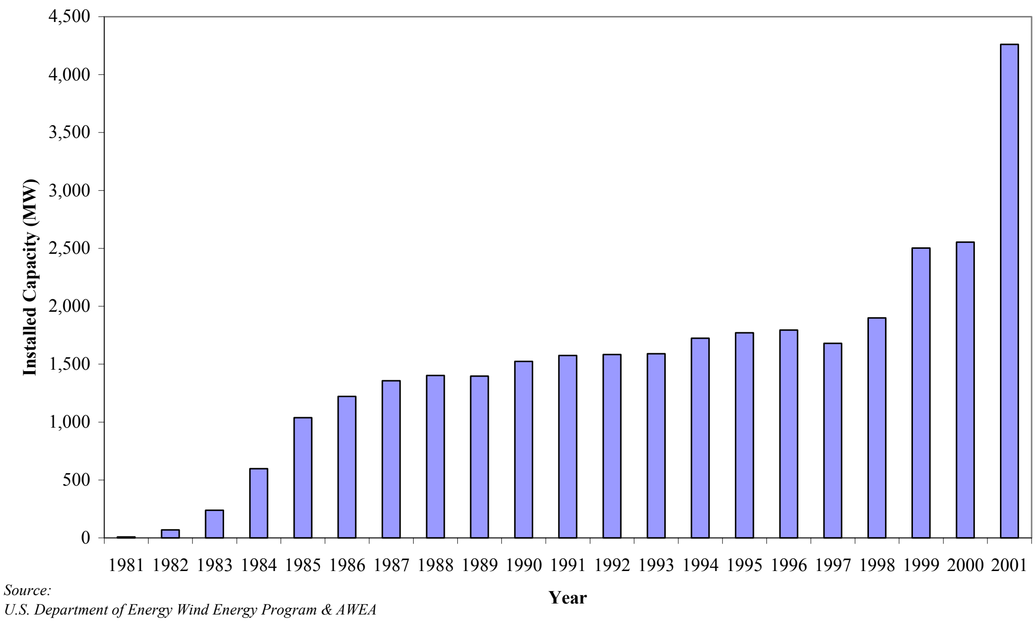
Table 1 provides the installed capacity of the major renewable technologies during the past five years. (Large-scale hydropower, while by far the nation's largest conventional renewable source, is excluded simply because its prospects for US growth are limited.)

The table shows that the role of renewable energy has increased over time but at widely varying rates. Geothermal and biomass technologies have maintained their levels over the five years displayed. Solar technology has exhibited modest growth over the time period, and the installed capacity of wind power has exploded with 26 percent average annual increases. As the following subsections will illustrate, each of the technologies has a unique potential for influencing the supply of electricity.

[1] Wind Power

The brightest star of the renewable technologies analyzed in this survey is wind power. Figure 3 displays a longer time series of the installed wind capacity base in the United States. The technology's role in the US supply has grown from a quaint niche source in the early 1980s to a significant role in the 21st century. Dramatic improvements in the economics of wind power technologies explain this increase.

Figure 3
Installed Wind Capacity in the United States



Source:
U.S. Department of Energy Wind Energy Program & AWEA

In 1981, the typical design for a wind turbine was a 25 kW peak-capacity turbine with a ten-meter rotor. The cost at the time was approximately $2,600 / kW, placing the technology far out of commercial competitiveness. At best, such applications could serve very small, niche energy purposes. By 2000, technology existed for 1.5 MW peak-capacity turbines with turbine length of over 70 meters. Exhibiting characteristics of classic economies of scale, this modern turbine comes in at an installed cost of $790 / kW.[4] It is important to note that these installed costs capture nearly all of the total costs of wind technology; there are no fuel costs to consider. The trend of improved competitiveness partly explains the dramatic picture displayed in Figure 3.

Progressive policies that mitigate some of the costs inherent to intermittent technologies such as wind power also will be key to their potential success. An example of this type of effort is typified by a recent FERC order approving a modification to the California Independent System Operator (ISO) tariff.[5] Wind technologies and other intermittent resources are generally unable to respond to the ISO's dispatch instructions. In addition, forecasts for these same technologies are rarely accurate beyond a couple of hours into the future.

If a generation resource in the California ISO performs an uninstructed deviation from its schedule, it is typically assessed a charge. The ISO recognized the inherent uncertainty behind an intermittent resource's operation, and in an effort to encourage diversity of supply in California, proposed a rule allowing intermittent resources to "net out" their deviations on a monthly basis, rather than requiring standard settlements. Generators such as wind turbines would still need to pay for a net negative deviation over a month, but this FERC-approved change in market rules removed a technicality that would have inhibited the commercial viability of wind power in California.

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[4] Matthew H. Brown, National Conference of State Legislatures, "State Policy Options for Renewable Energy."
[5] See order in FERC Docket No. ER02-922 on March 27, 2002.

[2] Other Renewable Energy Sources

The key to understanding the relevance of renewable sources of energy is to gain a full appreciation of the unique role a particular energy source can play. If one naïvely compares the economics of a 600 MW combined-cycle power plant to a photovoltaic fuel cell, the immediate result would place the renewable technology on the shelf as a quaint but impractical concept. Total installed costs of solar technologies have fallen over the years, but they are still in the ostensibly noncompetitive range of $4,000 - $10,000 / kW.[6] A closer inspection, however, reveals that many of these technologies offer competitive solutions for very specific purposes.

A prime example of this assertion is the ability of solar power applications to provide peak-shaving opportunities to price-sensitive customers. Figure 4 illustrates the basic premise of peak shaving. If a commercial customer can utilize a technology to reduce its peak demand, it can realize savings by lowering the demand component of its bill, which is tied to the maximum kilowatts of usage over a time period. This example argues for greater potential benefits from solar applications accruing to individual customers as opposed to utilities.

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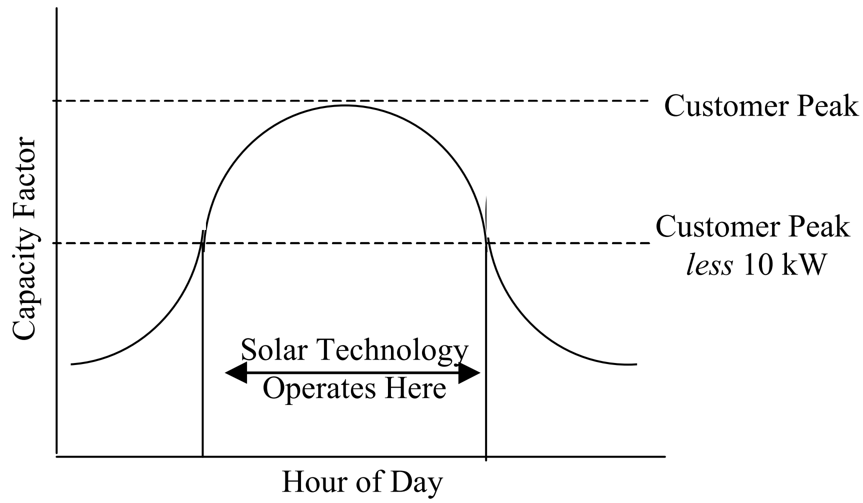
[6] Matthew H. Brown, National Conference of State Legislatures, "State Policy Options for Renewable Energy."

Figure 4
Graphical Depiction of Solar Peaking Application



A study analyzing the prospects for solar peak shaving applications in Delmarva Power and Light's service territory confirmed this anecdotal finding, but also suggested that a utility-customer partnership may be required to speed the development of this application. A utility, armed with a lower cost of capital, would provide the financing to purchase the technology, and the end-use customer would repay the loan through some of the bill savings and tax benefits accruing from the use of the application. The study notes that this arrangement has been used before in the context of utilities subsidizing investments in end-use efficiency.[7]

This example of an innovative use of renewable technologies for cost-effective supply is one of many. Capacity fueled by biomass sources is developed almost exclusively as a byproduct of another industrial or agricultural process. Wood and wood wastes account for over 60% of the biomass capacity documented in Table 1, with municipal solid waste and other waste products accounting for most of the remaining balance. Almost exclusively located in the Western United States, geothermal resources have received increased scrutiny because of their ability to provide round-the-clock generation to a region that has not forgotten the power crisis of 2000 – 2001. The Department of Energy's GeoPowering the West program has stated goals of doubling the number of states producing geopower to eight by 2006 and promoting research to lower the levelized cost of power to 3 – 5 cents per kWh by 2007.[8]

[3] Outlook for the Future

This section has provided a closer look at the improving role of renewable energies in the U.S. supply. Based on this analysis, one would expect forecasts of the growing prominence of renewables in the US supply. Several sources confirm this expectation.

In 1998, an unlikely prognosticator of renewable energy trends stepped forward with a bold prediction. Royal/Dutch Shell Group Chairman Cor Herkstroter forecast that renewables would meet 10 percent of world energy needs by 2020 and 50 percent of needs by 2050.[9] This prediction foreshadowed a significant shift among the world's petroleum producers toward investments in renewable energy opportunities. In late 1997, Royal/Dutch Shell founded the Shell International Renewables business, and predicted global market sales of $43

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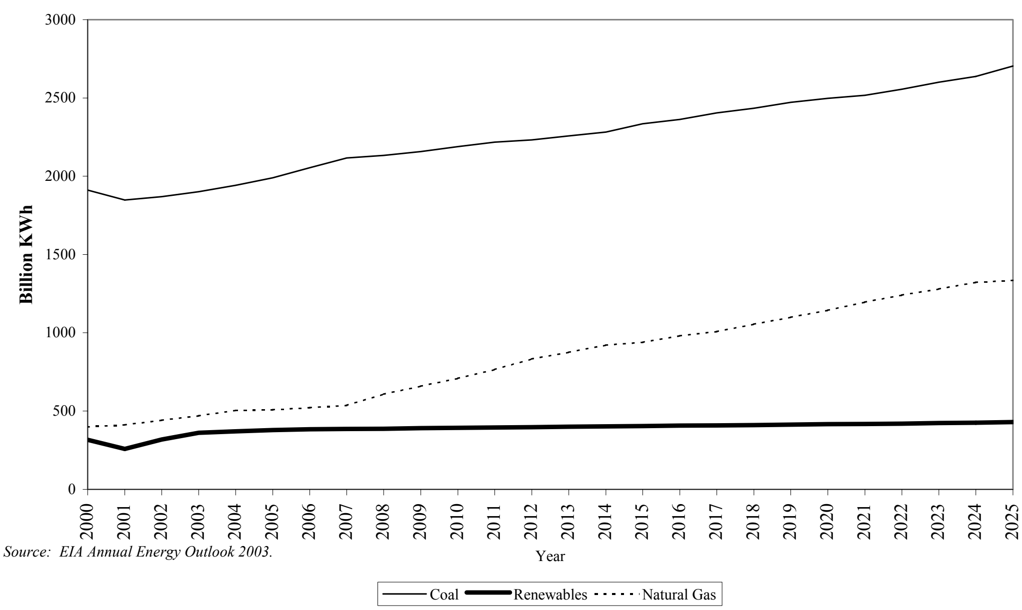
[7] John Byrne, *et al.,* "Photovoltaics: a Dispatchable Peak-Shaving Option," *Public Utilities Fortnightly,* September 1, 1995.

[8] See http://www.eren.doe.gov/geopoweringthewest/aboutgeopowering.html for a description of the program.

[9] "Shell Exec Addresses Renewables," *Utility Environment Report*, June 5, 1998.

billion or generation of 766 terawatt-hours by 2010 and sales of $248 billion or generation of 4,915 terawatt-hours by 2020.[10] In 2000, Shell's competitor BP Amoco projected a doubling of its investments in renewable energy technologies to approximately $500 million per year within three years.[11] This revealed preference by key players in the petroleum industry to increase their exposure to renewables flows from the increasing competitiveness of these applications, and their certain large role in the energy business of the rest of this century.

Figure 5
Forecast of US Electricity Supply by Fuel (2000 - 2025)



Source: EIA Annual Energy Outlook 2003.

Closer to home, the EIA produces a widely referenced forecast of US energy trends in its Annual Energy Outlook. Figure 5 provides the most recent forecast of US electricity supply by fuel. At a glance, it does not seem to depict a significantly improving role for renewables, but a closer look provides more

[10] "Shell Goes for Growth in Renewable Energies," Dow Jones Energy Service, October 16, 1997.

positive trends. First, the growth rate of renewable energy production (excluding combined heat and power) is 2.1 percent and is 30 percent greater than that of production from coal technologies. Second, the EIA classifies conventional hydroelectric resources as a renewable, and forecasts a growth rate of 1.4 percent for that technology over the time period. This means that generation from the key alternative energy sources discussed in this paper is forecast to grow at much higher rates. Wind is expected to grow at 7.9 percent; solar thermal and photovoltaic are expected to grow at a combined 5.7 percent; combined waste resources are expected to grow at 2.8 percent; and, geothermal is expected to grow at a rate of 4.2 percent.[12] Thus, evidence from industry forecasts of greater investment, and government forecasts of increased generation confirm the analysis that renewable energy sources are moving into the mainstream.

1.05. Promotion of Renewable Energy in the Electric Power Sector

The nature of renewable energy technologies has evolved to the point where forecasts from government and industry alike predict an increased role. EIA forecasts, however, include explicit assumptions that policies in place to promote renewable energy will continue into the future. Specific policies that promote renewable energy in the electric power sector provide another reason for optimistic projections.

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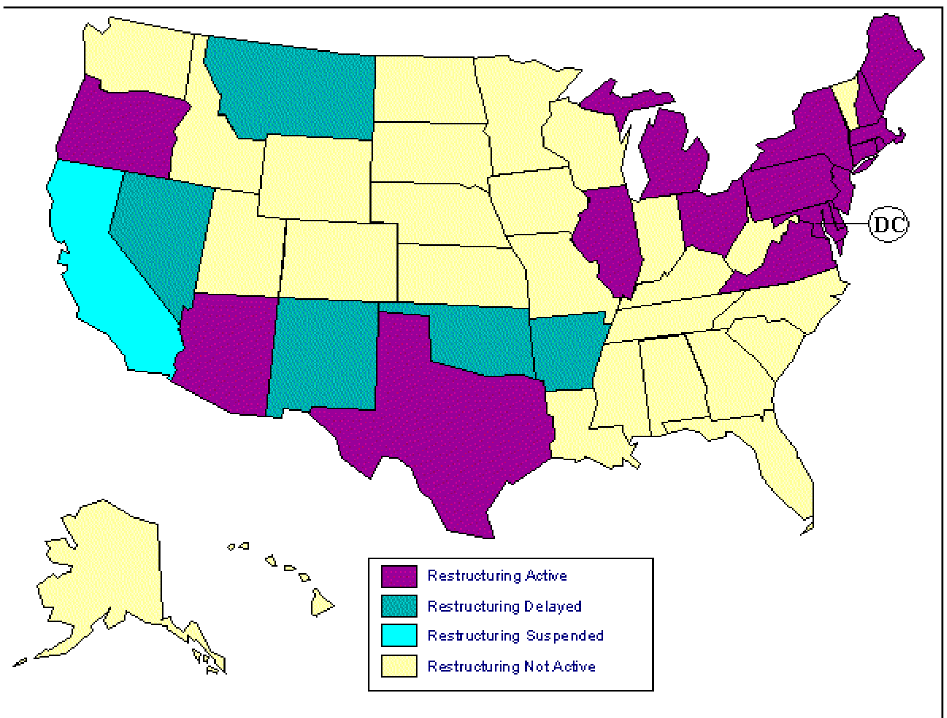
[11] Paul Merolli, "BP Amoco Jumps Headfirst into Expansion," *The Oil Daily*, July 12, 2000.
[12] EIA Annual Energy Outlook 2003, Table 17 [as reported in early release of report.]

[1] Renewable Portfolio Standards

Figure 6 provides a map prepared by the EIA documenting the status of state deregulation of electricity markets. This figure shows that "retail choice" has taken root primarily in the Northeastern United States, Texas, and a few Midwestern industrial states. The displacement of the incumbent utility as sole provider of electricity needs means customers in these regions have been introduced to the concept of choosing their provider of electricity.

Figure 6
Status of Retail Restructuring by State



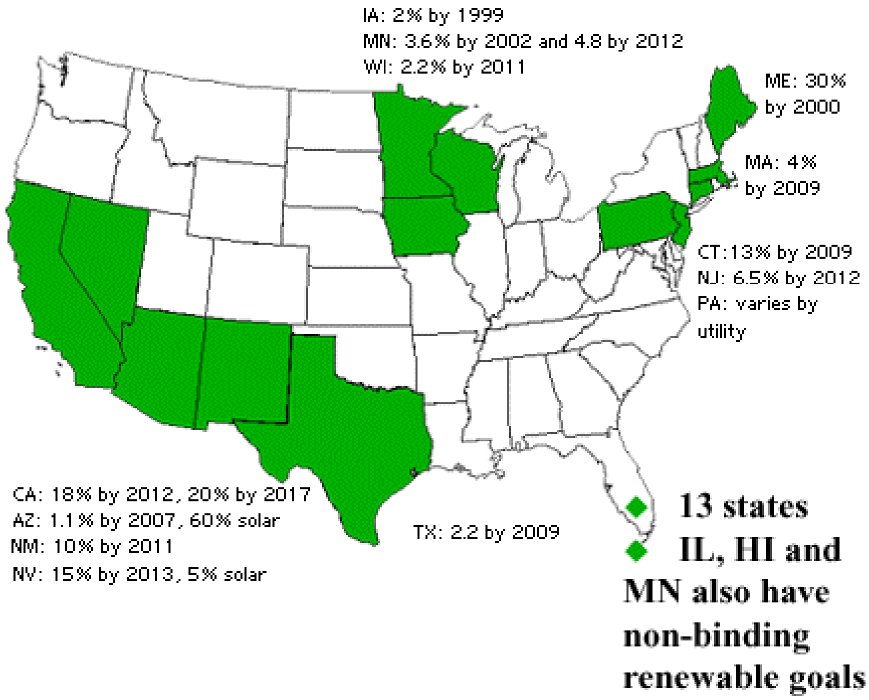
Source: EIA.

In the states where retail competition has taken hold, customers have greater incentives to understand the business strategies employed by utilities. In some cases opportunities for price responsive demand programs have been started as consumers see linkages between wholesale and retail prices. More importantly for renewable energy, the advent of retail competition has spawned a movement to allow consumers to choose how electricity is provided. The most striking example of this trend is the advent of the renewable portfolio standard in soon to be fourteen states.

Figure 7 provides the Union of Concerned Scientists' map of renewable portfolio standards in place across the country.[13] The standards are not simply mandates to utilities to meet a certain percentage of their procurement needs through green power. Rather, they are an innovative blend of market incentives and state guidelines which seek to increase the role of renewable energy. In many of the states, utilities can choose to either meet the requirements through self-generation using renewable technologies or through purchase of green credits which are sold by entities exceeding the requirements of generation through renewable sources. The allure of choice has empowered customers to move from simply choosing a provider to choosing how power is being supplied.

[13] This map does not reflect the recent announcement by Governor George Pataki that New York will require 25 percent of its electricity to come from renewable sources by 2013.

Figure 7
Renewable Energy Standards



Source:
Union of Concerned Scientists
http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=895#res

[2] Emissions Trading Systems

Incentives flowing from the development of more robust emissions trading markets are closely related to incentives for renewable energy technologies arising from renewable portfolio standards. The sulfur dioxide trading program put into place as a result of the Clean Air Act contributed to a reduction of national emissions of SO_2 of 22 percent since 1990, without any significant price changes to consumers or disincentives for coal-fired generation to produce electricity.[14]

A four-pollutant cap and trade program would extend this system and provide a strong incentive for expansion of renewable installed capacity. This program has been proposed in various pieces of legislation, but the general approach is to establish firm caps for SO_2, NO_x, CO_2, and airborne mercury emissions, and allow emitters a reasonable timeframe to reach compliance. Evidence exists that auctioning off allowances is the most efficient method for initiating such a program, with subsequent resale of allowances being encouraged.[15]

This policy at once provides a valuable mechanism to reduce emissions in the most flexible and efficient manner possible for the energy industry. At the same time it offers strong incentives for developers to pursue clean, renewable energy technologies. As outlined in Section 1.03, the environmental profile of renewable technologies demonstrates that most renewable plants would not require the purchase of credits to offset any emissions. Other incentives to build renewable technologies will undoubtedly evolve, but renewable portfolio standards and robust emissions trading markets are the most prominent of those currently being pursued.

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[14] Peter Fox-Penner, *Clean Growth: A Balanced Energy Policy for the 21st Century,* Progressive Policy Institute Policy Report, October 2001.

[15] *Ibid.*

[3] Distributed Generation (DG)

One final area of policies and technical developments is encouraging alternative power technologies. The ability to make power plants progressively smaller and cheaper, along with the political reluctance to build more large power lines in the United States, is causing US electric regulators to enact policies that encourage many small power plants closer to customers rather than large plants in remote areas. Renewable power plants are inherently suited to such a "distributed" power grid design. Transmission and distribution policies that encourage DG tend to reduce renewable power costs, and technological change and production economies will reduce them further.

1.06. Prospects for Alternative Energy Sources in the Transportation Energy System

The transport sector's transition to renewable fuels will occur not by making oil from renewable sources – although this will remain an important niche – but rather by a momentous shift away from internal combustion vehicles to those powered partly and completely by fuel cells and electric motors. These changes in power plant will eventually make hydrogen rather than oil the dominant transport fuel. Since hydrogen can be made by renewable and fossil sources with equal technical ease, the hydrogen feedstock industry will be an economics- and environment-driven mix of renewable and non-renewable fuels.

[1] Bio-Based Transportation Fuel

A variety of transport fuels can be made from biomass sources, including ethanol from corn and cellulosic biomass and diesel fuels from food and agricultural wastes as well as soybeans. Most of these processes are niche applications, but they have enough support and promise to continue to grow.

For example, ethanol's prospects gained some prominence through the renewable fuel standard (RFS) component of the Energy Policy Act of 2002 (H.R. 4.) This piece of legislation phases out the more environmentally controversial use of the gasoline oxygenate methyl tertiary butyl ether (MTBE) and increases renewable fuel use to 5 billion gallons by 2012. Because corn is the predominant source of ethanol, a study by the US Department of Agriculture forecast significant indirect benefits to the farm economy from this move, due to a large increase in demand for corn.[16]

Many experts believe the positive benefits from ethanol can be multiplied by exploring production of the fuel from sources other than corn. Cellulosic ethanol produced from woody or herbaceous biomass requires a technology that will cogenerate electricity. One study, sponsored by the Department of Energy, suggests that taking into account this potential displacement of utility-generated electricity greatly supplements the basic environmental benefit of replacing petroleum use with ethanol.[17]

Critics of ethanol argue that the energy used by conventional methods to produce this gasoline substitute must be weighed against the end-use applications heralded by advocates. In addition, the forecast benefits of cellulosic ethanol are based on technology that has yet to be deployed on a broad commercial scale.

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[16] *Effects on the Farm Economy of a Renewable Fuels Standard for Motor Vehicle Fuel,* US Department of Agriculture, August 1, 2002.

[2] The Hydrogen Transportation Economy

The concept of employing hydrogen as the key building block for energy needs has been in the public eye since the 1970s. Developing technologies that are based solely on hydrogen simultaneously relieves the environmental pressures associated with the use of fossil fuels and the oil dependence described in Section 1.03. While the Bush administration has laid out a comprehensive vision of a hydrogen economy that encompasses both transportation and energy efficiency in buildings, this section focuses on the potential for the hydrogen transportation economy.

Even though hydrogen is the most abundant element in the universe, it does not naturally occur and must be produced through some process. Ninety-five percent of the nine million tons of hydrogen produced each year is produced using steam methane reforming. This method reacts natural gas or some other hydrocarbon with steam to produce a mixture of hydrogen and carbon that is subsequently separated.[18] While this method represents the most cost-efficient, commercially viable technology available, it relies on the gradually decreasing domestic source of natural gas. This is the first of two examples where natural gas is the transition fuel to the hydrogen economy.

The nine million tons of hydrogen produced annually would be sufficient to supply approximately 20 – 30 million hydrogen-fueled cars. It is estimated that approximately 40 million tons of hydrogen would be required to supply 100

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[17] M. Wang, *et al.*, Center for Transportation Research, Energy Systems Division, Argonne National Laboratories, *Effects of Fuel Ethanol Use on Fuel-Cycle Energy and Greenhouse Gas Emissions*, January 1999.

million hydrogen-fueled cars.[19] Renewable energy technologies such as wind, solar, or biomass are capable of producing hydrogen, but technology does not currently exist to produce the quantities described. Development of technologies to produce hydrogen from renewable resources is the first challenge for achieving a hydrogen transport economy.

Assuming an adequate supply of hydrogen is in place, how can this new fuel be converted to use for the transport sector? The National Aeronautics and Space Administration (NASA) employs the most visible method of hydrogen conversion through the use of hydrogen in the space shuttle's main engines. For the more down-to-earth needs of the transportation sector, hydrogen-based fuel cells remain the ultimate final answer.

A fuel cell is a flexible technology that combines a fuel and an oxidant to produce electricity, with water and heat being the only by-products. In a world where hydrogen could be supplied and stored in a convenient form, the ideal fuel would be hydrogen, yielding an emissions-free transport fuel that recycles itself through the cell's own emission of water. In today's world, a common method is to "reform" hydrocarbons such as alcohol fuels or natural gas to provide the required hydrogen input.[20] This is the second example of natural gas serving as the key transition fuel to the hydrogen economy.

Regardless of the fuel used by the cell as input, a variety of fuel cell technologies are used for conversion to energy. For the transportation sector, the

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[18] United States Department of Energy, *National Hydrogen Energy Roadmap*, November 2002.
[19] *Ibid.*

most accepted technology that is being employed by manufacturers in concept cars is the polymer-electrolyte membrane (PEM) fuel cell. Evidence exists, however, that no technology currently meets basic criteria for performance, durability, and cost.[21]

Figure 8

The Hydrogen Transportation Economy

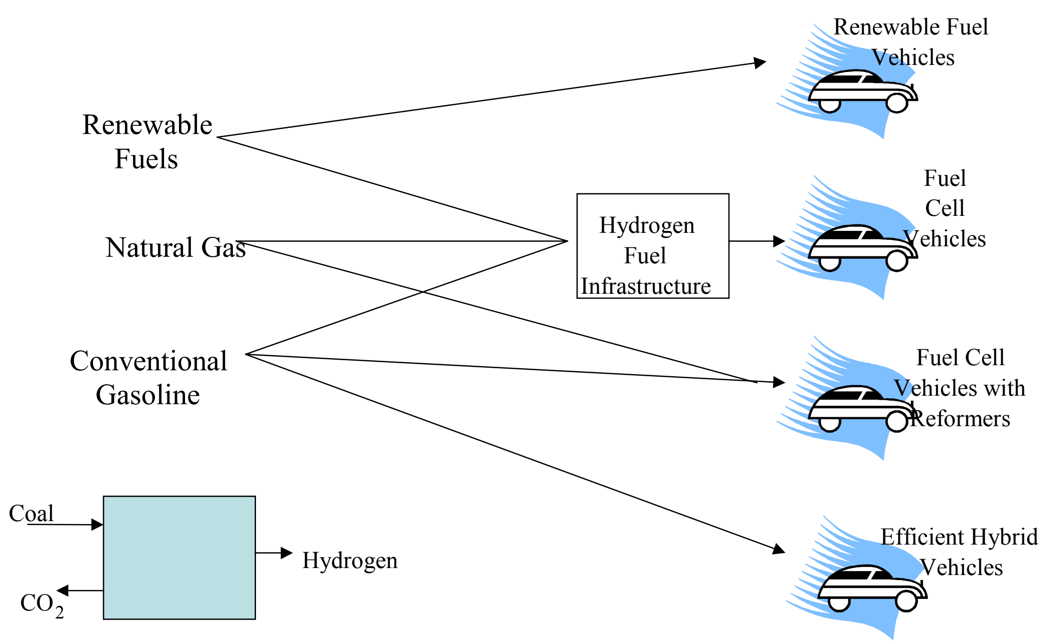

Figure 8 illustrates the main energy pathways in the hydrogen transport economies of the future. Hydrogen will be produced from every renewable and non-renewable source that is economic, with ultimate percentages changing from nearly 100 percent from natural gas to perhaps 50 percent renewable by the mid- to late 21st century.

[20] Robert Rose, *Fuel Cells and Hydrogen: The Path Forward,* September 5, 2002, available at http://www.fuelcellpath.org.

[21] United States Department of Energy, *National Hydrogen Energy Roadmap*, November 2002.

1.07. Conclusions

The broad conclusion of this survey supports the viability of renewable energy in both the electric power and transportation sectors. Natural gas has been shown to be a clear transition fuel from the heavily polluting days of old to a new renewable-based hydrogen economy. For the electric power sector, natural gas-fired generation was the technology of choice for the generation boom of late 2000 and early 2001. For the transportation sector, natural gas plays an important role in serving as a method for producing hydrogen, as well as being one of the few viable methods for powering fuel cell vehicles. However, renewable fuels will eventually take a large share of this market.

Ultimately, the surest sign that renewable energy sources represent a large segment of the future is the fact that most of the largest global oil companies are investing heavily in this area. BP has gone so far as to put solar cells on its filling stations and call itself "Beyond Petroleum." But many conservative utility and energy companies correctly see renewable energy as a major business opportunity, as well as a source of clean power essential for clean growth and development all over the world.