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5

Building the Solar/Hydrogen Economy

In May of 2001, the Bush White House released with great fanfare a 20-year plan for the U.S. energy economy. It disappointed many people because it largely overlooked the enormous potential for raising energy efficiency. It also overlooked the huge potential of wind power, which is likely to add more to U.S. generating capacity over the next 20 years than coal does. The plan was indicative of the problems some governments are having in fashioning an energy economy that is compatible with the earth's ecosystem.[1]

Prepared under the direction of Vice President Dick Cheney, the administration's plan centered on expanding production of fossil fuels, something more appropriate for the early twentieth century than the early twenty-first. It emphasized the role of coal, but the authors were apparently unaware that world coal use peaked in 1996 and has declined some 7 percent since then as other countries have turned away from this fuel. Even China, which rivals the United States as a coal-burning country, has reduced its coal use by an estimated 14 percent since 1996.[2]

The energy future that I see is very different from the one outlined in the Bush energy plan. For example, the plan noted that the 2 percent of U.S. electricity generation that today comes from renewable sources, excluding hydropower, would increase to 2.8 percent in 2020. But months before the Bush energy plan was released, the American Wind Energy Association (AWEA) was projecting a staggering 60-percent growth in U.S. wind-generating capacity in 2001. Worldwide, use of wind power alone has multiplied nearly fourfold over the last five years, a growth rate matched only by the computer industry.[3]

Although the Bush energy plan does not reflect it, the world energy economy is on the edge of a major transformation. Historically, the twentieth century was the century of fossil fuels. Coal, already well established as a major fuel source in 1900, was joined by oil when the automobile came on the scene. It was not until 1967, however, that oil finally replaced coal as the workhorse of the world energy economy. Natural gas gained in popularity during the closing decades of the century as concern about urban air pollution and global climate change escalated, moving ahead of coal in 1999.[4]

As the new century begins, the Sun is setting on the fossil fuel era. The last several decades have shown a steady shift from coal, the most polluting and climate-disrupting fossil fuel, to oil, which is somewhat less environmentally disruptive, and then to natural gas, the cleanest and least climate-disrupting of the three. It is this desire for clean, climate-benign fuels—not the depletion of fossil fuels—that is driving the global transition to the solar/hydrogen age.[5]

In addition to world coal use peaking in 1996, oil production is expected to peak either in this decade or the next. Natural gas use will keep expanding somewhat longer because of its generous reserves and its popularity as a clean-burning, carbon-efficient fuel. Because it is a gas, it is also the ideal fuel for the transition from a carbon-based energy economy to one based on hydrogen. If it keeps expanding at 2 percent or so a year, as it has for the last decade, natural gas use will require the continued construction of pipelines and storage facilities—an infrastructure that can one day easily be adapted for hydrogen.[6]

Even the oil companies are now beginning to recognize that the time has come for an energy transition. After years of denying any link between fossil fuel burning and climate change, John Browne, the chief executive officer of British Petroleum (BP) announced his new position in a historic speech at Stanford University in May

1997. "My colleagues and I now take the threat of global warming seriously," said Browne. "The time to consider the policy dimensions of climate change is not when the link between greenhouse gases and climate change is conclusively proven, but when the possibility cannot be discounted and is taken seriously by the society of which we are a part. We in BP have reached that point." In February 1999, ARCO chief executive Michael Bowlin said at an energy conference in Houston, Texas, that the beginning of the end of the age of oil was in sight. He went on to discuss the need to shift from a carbon-based energy economy to a hydrogen-based one.[7]

Seth Dunn writes in *World Watch* magazine that a consortium of corporations led by Shell Hydrogen and DaimlerChrysler reached an agreement in 1999 with the government of Iceland to make that country the world's first hydrogen-powered economy. Shell is interested because it wants to begin developing its hydrogen production and distribution capacity, and DaimlerChrysler expects to have the first fuel cell–powered automobile on the market. Shell plans to open its first chain of hydrogen stations in Iceland.[8]

The signs of restructuring the global energy economy are unmistakable. Events are moving far faster than would have been expected even a few years ago, driven in part by the mounting evidence that the earth is indeed warming up and that the burning of fossil fuels is responsible.[9]

The Energy Efficiency Base

When the new Bush energy plan was announced, many were surprised at the near-exclusive emphasis on expanding production, with little attention given initially to the potential for using energy more efficiently. In response, the Washington-based Alliance to Save Energy issued a counterproposal, one that would eliminate the need to build most of the 1,300 proposed power plants. It would also be far less costly and less polluting.[10]

Bill Prindle, Director of the Alliance's building and utility programs, pointed out that adopting the household appliance efficiency standards agreed to by both the Clinton and the Bush administrations would eliminate the need for 127 power plants by 2020. If the more stringent residential air conditioner efficiency standard that was approved by the Clinton administration were adopted, this would do away with the need for another 43 power plants.

Stronger standards for commercial air conditioning would take care of needing 50 plants. Increasing the energy efficiency of new buildings over the next 20 years using tax credits and energy codes would save another 170 plants. And improving the energy efficiency of existing buildings, including air conditioners, commercial lighting, and commercial cooling, would save 210 plants.[11]

Prindle's list goes on, but these five measures alone would eliminate the need for 600 power plants. The costs of the measures to avoid these plants would be far less than the cost of building them. All of these steps to save electricity are cost-effective, some of them offering 30 percent annual rates of return.[12]

Peter Coy, economics editor at *Business Week*, points out that time-of-day pricing of electricity, which would increase prices during the peak daytime hours and reduce them at night, would also greatly reduce the generating capacity needed. Although he did not calculate the number of plants that could be saved, it would undoubtedly eliminate the need for another large block.[13]

Amory Lovins of the Rocky Mountain Institute has gained a worldwide reputation selling the idea that it is cheaper to save energy than to buy it. In response to his persuasive presentations about the returns on investment in improved efficiency being often 30 percent or more a year, many companies have invested heavily in reducing their energy use. But even with the efficiency gains since the oil price hikes of the 1970s, Lovins believes that U.S. businesses could still cut their electric utility bills in half while making money doing so.[14]

Europe's example provides ample proof of the latent energy savings potential in the United States. Europeans routinely use 30 percent less energy per unit of gross national product than Americans do. The United States could easily meet its requirements for carbon reduction under the Kyoto Protocol by 2010 simply by moving to European efficiency levels, and these are far below the efficiency levels that are possible using state-of-the-art technologies.[15]

Although Europe is already well ahead of the United States in energy efficiency, individual countries are continuing to advance. In early August 2001, the British introduced a new tax scheme to encourage investment in energy-saving equipment. Expenditures on capital equipment can now be subtracted from taxable profits if the equipment meets established energy efficiency standards. Among the categories of equipment eligible for the tax break are cogeneration (combined heat and power), boilers, electric motors, lighting, and refrigeration. This plan was modeled on a similar system already operating successfully in the Netherlands.[16]

China is now setting the pace in increasing energy efficiency and reducing carbon emissions. Over the last four years, China has apparently reduced its carbon emissions, even while its economy grew 7 percent annually, using subsidy phaseouts for coal, market pricing for fuels, and new energy conservation initiatives. For example, China will soon start to produce a high-efficiency refrigerator that will use only half as much electricity as conventional models.[17]

Some of the worldwide potential for saving energy can be seen in the substitution of compact fluorescent lamps (CFLs) for traditional incandescent light bulbs. The compact fluorescent uses less than one fourth as much electricity, and though it costs more than an incandescent, it lasts 13 times as long. Over three years, using the light four hours a day, the electricity and bulb cost $19.06 for a compact fluorescent and $39.54 for an incandescent. Even excluding the labor costs of replacing the short-lived incandescent bulbs six times during the three years, the return on investing in a compact fluorescent lamp is still close to 30 percent a year.[18]

As I travel from country to country launching books and addressing conferences, I routinely check the light bulbs in hotel rooms. Some hotel chains use CFLs almost exclusively. Others use very few or none at all. The worldwide potential for investing in compact fluorescent lamps and closing power plants in the process is not only huge, it is also profitable.

Another area with enormous potential for efficiency improvements is automobile fuel. In the United States, which has one of the world's most inefficient vehicle fleets, the new 2001 models get an estimated 24.5 miles per gallon, down from the peak of 26.2 miles per gallon in 1987. Thus fuel efficiency dropped 6 percent when, given the advances in technology and growing concern about global warming, it should have been rising. Fortunately, at this writing, it appears that Congress may take the lead and establish new fuel efficiency standards for the next decade or so.[19]

The fuel efficiency among the 2001 models sold in the United States varies widely, ranging from the hybrid electric Honda Insight, which gets 68 miles per gallon on the highway and 61 in the city, to a Ferrari, with 13 miles per gallon on the highway and 8 in the city. Just above the Ferrari in the fuel ratings are several large sport utility vehicles. The more efficient cars on the market, such as the Honda Insight and the Toyota Prius, easily double the average fuel efficiency of the U.S. fleet, underlining the enormous potential for fuel savings.[20]

Regardless of the source of energy, it makes economic and environmental sense to make sure the energy is used efficiently. At a minimum, the world should be making all the investments in energy efficiency that are profitable with current prices. That alone would drop world energy use by a substantial amount.

Sometimes a simple measure can make a big difference. In Bangkok, the city government decided that at 9 p.m. on a given weekday evening, all major television stations would be co-opted in order to show a big dial with the city's current use of electricity. Once the dial appeared on the screen, everyone was asked to turn off unnecessary lights and appliances. As viewers watched, the dial dropped, reducing electricity use by 735 megawatts, enough to shut down two moderate-sized coal-fired power plants. For viewers, this visual experiment had a lasting effect, reminding them that individually they could make a difference and that collectively they could literally close power plants.[21]

The purpose of this section is simply to provide a sense of potential energy savings. A successful global effort in this direction would lower energy expenditures and help reduce air pollution and climate disruption while the new energy sources are coming online. Even as hydrogen-fueled engines are being developed, it would reduce vulnerability to oil price hikes—a matter of concern for many governments.

Harnessing the Wind

The modern wind industry was born in California in the early 1980s in the wake of the oil price hikes of 1973 and 1979. Under the leadership of Governor Jerry Brown, the state added its own tax incentive to an existing federal one to develop renewable energy resources, creating an investment climate that yielded enough wind-generating capacity statewide to satisfy the residential needs of San Francisco. But after a fast beginning in California, U.S. interest in wind energy lagged, almost disappearing for a decade.[22]

While interest in wind energy was sagging in the United States, it was continuing to advance in Europe, led initially by Denmark, which had built many of the wind turbines that were installed in

California. From 1995 to 2000, as noted earlier, wind energy worldwide expanded nearly fourfold, a computer industry growth rate. (See Figure 5–1.) And the United States got back into the race, with AWEA projecting 60 percent growth in U.S. wind generating capacity in 2001.[23]

Today Denmark gets 15 percent of its electricity from wind power. For Schleswig-Holstein, the northernmost state of Germany, the figure is 19 percent—with some parts of that state getting an impressive 75 percent. Spain's industrial state of Navarra, starting from scratch six years ago, now gets 22 percent of its electricity from wind. But in terms of absolute generating capacity, Germany has emerged as the world leader, with the United States in second place. (See Table 5–1.) Spain, Denmark, and India round out the top five.[24]

Advances in wind turbine technology, drawing heavily on the aerospace industry, have lowered the cost of wind power from 38¢ per kilowatt-hour in the early 1980s to less than 4¢ in prime wind sites in 2001. (See Figure 5–2.) In some locations, wind is already cheaper than oil or gas-fired power. With major corporations such as ABB, Royal Dutch Shell, and Enron plowing resources into this field, further cost cuts are in prospect.[25]

Wind is a vast, worldwide source of energy. The U.S. Great Plains are the Saudi Arabia of wind power. Three wind-rich states—North Dakota, Kansas, and Texas—have enough harnessable wind to meet

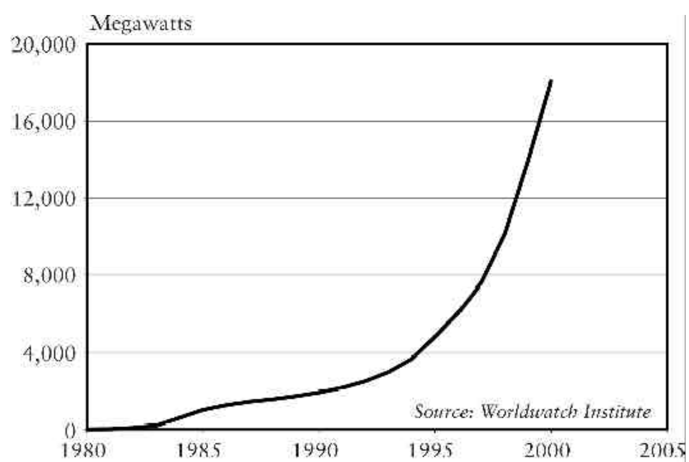

Figure 5–1. *World Wind Energy Generating Capacity, 1980–2000*

Table 5–1. *Wind Energy Generating Capacity in Selected Countries, 2000*

Country	Capacity (megawatts)
Germany	6,113
United States	2,554
Spain	2,250
Denmark	2,140
India	1,167

Source: See endnote 24.

national electricity needs. China can double its existing generating capacity from wind alone. Densely populated Western Europe can meet all its electricity needs from offshore wind power out to an ocean depth of 30 meters.[26]

As wind generating costs fall and as concern about climate change escalates, more and more countries are climbing onto the wind energy bandwagon. Beginning in December 2000, the scale of world wind energy development climbed to a new level. Early in the month, France announced it will develop 5,000 megawatts of wind power by 2010. Later in the month, Argentina announced a plan to develop 3,000 megawatts of wind power in Patagonia by 2010. Then in April 2001, the United Kingdom accepted offshore bids for 1,500 megawatts of wind power. In May, a report from Beijing indicated that China plans to develop some 2,500 megawatts of wind power by 2005.[27]

The actual growth in wind power is consistently outrunning earlier estimates. The European Wind Energy Association, which in 1996 had set a target of 40,000 megawatts for Europe by 2010, recently upped its goal to 60,000 megawatts.[28]

In the United States, wind power was once confined to California, but during the last three years wind farms coming online in Colorado, Iowa, Minnesota, Oregon, Pennsylvania, Texas, and Wyoming have boosted U.S. capacity by half—from 1,680 megawatts to 2,550 megawatts. (One megawatt of wind generating capacity typically supplies 350 homes.) The 1,500 or more megawatts to be added in 2001 will be located in a dozen states. A 300-megawatt wind farm under construction on the Oregon/Washington border, currently the world's largest, can supply 105,000

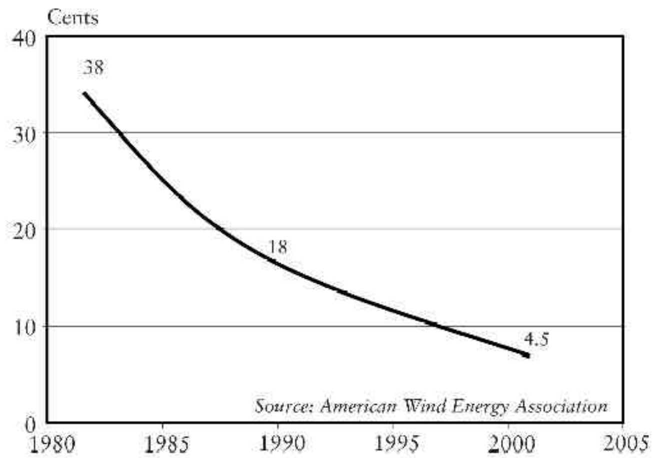

Figure 5–2. *Average Cost per Kilowatt-hour of Wind-powered Electricity in the United States, 1982, 1990, and 2001*

homes with electricity.[29]

But this is only the beginning. The Bonneville Power Administration (BPA), a U.S. federal agency power supplier, indicated in February that it wanted to buy 1,000 megawatts of wind-generating capacity and requested proposals. Much to its surprise, it received enough proposals to build 2,600 megawatts of capacity in five states, with the potential of expanding these sites to over 4,000 megawatts. BPA, which may accept most of these proposals, expects to have at least one site online by the end of 2001.[30]

A 3,000-megawatt wind farm in the early planning stages in east central South Dakota, near the Iowa border, is 10 times the size of the Oregon/Washington wind farm. Named Rolling Thunder, this proposed project—initiated by Dehlsen Associates and drawing on the leadership of Jim Dehlsen, a wind energy pioneer in California—is designed to feed power into the Midwest around Chicago. It is not only large by wind power standards, it is one of the largest energy projects of any kind in the world today.[31]

Income from wind-generated electricity tends to remain in the community, bolstering local economies by providing local income, jobs, and tax revenue. One large advanced-design wind turbine, occupying a quarter-acre of land, can easily yield a farmer or rancher $2,000 in royalties per year while providing the community with $100,000 of electricity.[32]

For farmers and ranchers, discovering the value of their wind resources is like striking oil—except that the wind is never depleted. One of wind's attractions is that the turbines scattered about a farm or ranch do not interfere with the use of the land for farming or cattle grazing. For ranchers with prime wind sites, income from wind can easily exceed that from cattle sales. The wind boom can rejuvenate rural communities throughout the world.

Once we get cheap electricity from wind, we can use it to electrolyze water, splitting the water molecule into its component elements of hydrogen and oxygen. Hydrogen is the simplest of fuels and, unlike coal or oil, is entirely carbon-free. It is the fuel of choice for the new, highly efficient fuel cell engine on which every major auto manufacturer is now working. DaimlerChrysler plans to market fuel cell–powered cars by 2003. Ford, Toyota, and Honda will probably not be far behind.[33]

Surplus wind power can be stored as hydrogen and used in fuel cells or gas turbines to generate electricity, leveling supply when winds are variable. Wind, once seen as a cornerstone of the new energy economy, is likely to become its foundation.

With the advancing technologies for harnessing wind and powering motor vehicles with hydrogen, we can now see a future in which U.S. farmers and ranchers supply not only much of the country's electricity, but much of the hydrogen for its fleet of automobiles as well. For the first time, the United States has the technology to divorce itself from Middle Eastern oil.

Within the United States, a new lobby is developing for wind power. In addition to the wind industry and environmentalists, U.S. farmers and ranchers are now also urging lawmakers to support development of this abundant alternative to fossil fuels.[34]

In manufacturing the turbines that convert wind into electricity, Denmark is the world leader. Sixty percent of all the turbines installed in 2000 were either manufactured by Danish companies or licensed by them. This illustrates how a country can translate foresight and a strong environmental commitment into a dominant position in the fast-emerging eco-economy. The United States, although now experiencing an extraordinary growth in wind energy development, is struggling to get back into the race in the manufacturing of wind energy turbines. The first utility-scale wind turbine manufacturing facility to be built in the United States outside of California has recently started operation in Champaign, Illinois, in the heart of the Corn Belt.[35]

The world is beginning to recognize wind for what it is—an energy source that is both vast and inexhaustible, an energy source that can supply both electricity and hydrogen for fuel. In the United States, farmers are learning that two harvests—crops and energy—are better than one. Political leaders are realizing that harnessing the wind can contribute to both energy security and climate stability. And consumers opting for green electricity are learning that they can help stabilize climate. This is a winning combination.

Turning Sunlight into Electricity

After wind power, the second fastest growing source of energy—solar cells—is a relatively new one. In 1952, three scientists at Bell Labs in Princeton, New Jersey, discovered that sunlight striking a silicon-based material produced electricity. The discovery of this photovoltaic or solar cell opened up a vast new potential for generating electricity.[36]

Initially very costly, solar cells could be used only for high-value purposes such as providing the electricity to operate satellites. Another early economical use was powering pocket calculators. Once run on batteries, pocket calculators now typically rely on a thin strip of silicon for power.

The next use to become economical was providing electricity in remote sites, such as summer mountain homes in industrial countries and villages in developing countries not yet linked to an electrical grid. In the more remote villages, it is already more economical to install solar cells than to build a power plant and connect the villages by grid. By the end of 2000, about a million homes worldwide were getting their electricity from solar cell installations. An estimated 700,000 of these were in Third World villages.[37]

As the cost of solar cells continues to decline, this energy source is becoming competitive with large, centralized power sources. For many of the 2 billion people in the world who do not have access to electricity, small solar cell arrays provide a shortcut, an affordable source of electricity. In villages in the Peruvian highlands, for example, village families spend roughly $4 a month on candles. For just a bit more, they can have much higher quality lighting from solar cells. In some Third World communities not serviced by a centralized power system, local entrepreneurs are investing in solar cell generating facilities and selling the energy to village families.[38]

Perhaps the most exciting technological advance has been the development of a photovoltaic roofing material in Japan. A joint effort involving the construction industry, the solar cell manufacturing industry, and the Japanese government plans to have 4,600 megawatts of electrical generating capacity in place by 2010, enough to satisfy all of the electricity needs of a country like Estonia.[39]

With photovoltaic roofing material, the roof of a building becomes the power plant. In some countries, including Germany and Japan, buildings now have a two-way meter—selling electricity to the local utility when they have an excess and buying it when they do not have enough.[40]

Newly constructed office buildings in the United States, Germany, and Switzerland have incorporated photovoltaic materials in their facades to generate electricity. Nothing in the appearance of these buildings would indicate to the casual observer that their glass walls and windows are in fact small power plants.

Growth in the sales of photovoltaic cells averaged 20 percent a year from 1990 to 2000. Then in 2000, sales jumped by 43 percent. Over the last decade, worldwide sales of photovoltaic cells have increased more than sixfold—from 46 megawatts of capacity in 1990 to 288 megawatts in 2000. (See Figure 5–3.)[41]

The big three in solar cell manufacturing are Japan, the United States, and the European Union. In 1999, production of solar cells in Japan alone jumped to 80 megawatts, pushing it into first place ahead of the United States. A large share of the solar cells produced

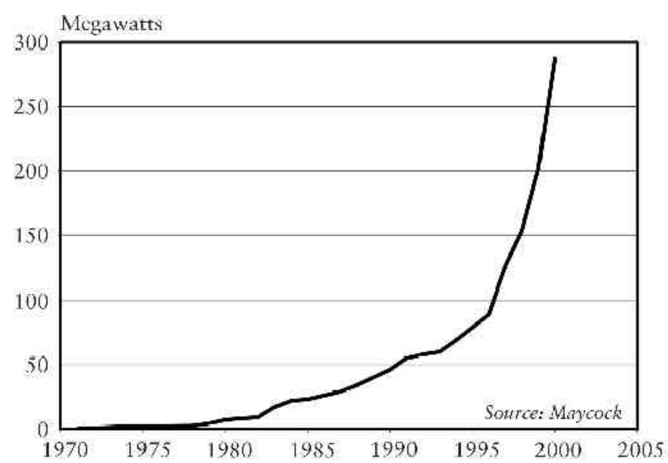

Figure 5–3. *World Photovoltaic Shipments, 1971–2000*

in the United States, which reached 60 megawatts in 1999, was exported to developing countries. Europe is currently in third place, with 40 megawatts of production in 1999, but its capacity expanded by more than half when Royal Dutch Shell and Pilkington Glass opened a 25-megawatt solar cell manufacturing facility in Germany.[42]

When BP merged with Amoco, it also acquired Solarex, the solar cell arm of Amoco, making BP overnight the world's third-ranking manufacturer of solar cells after Sharp and Kyocera, both of Japan. Siemens/Shell is in fourth place. The world solar cell market is marked by intense competition among companies and among countries. One reason leading industrial countries have ambitious solar roof programs is to help develop their solar cell manufacturing industries.[43]

Japan, Germany, and the United States all have strong programs to support this industry. The new Shell/Pilkington manufacturing facility in Germany was built in response to a vigorous German program to increase the use of solar energy, particularly on rooftops. In contrast to the Japanese, which rely on a cash subsidy to the buyers of solar roofing systems, the German government offers a bonus price for solar cell electricity and uses low-interest loans to encourage investment. Germany has a 100,000 Roofs program, with a goal of installing 300 megawatts of solar cells by 2005. The U.S. Million Solar Roofs program was launched in 1997. Although it is an impressive goal, government financial support is not nearly as strong as in Japan and Germany. Italy, too, has begun to move forward on the solar front, with a 10,000 Solar Roofs program.[44]

The potential in the solar arena is enormous. Aerial photographs show that even in the notoriously cloudy climate of the British Isles, putting solar cells on the country's existing roofs could generate 68,000 megawatts of power on a bright day, about half of Britain's peak power demand.[45]

The costs of solar cells has fallen from more than $70 per watt of production capacity in the 1970s to less than $3.50 per watt today. And it is expected to continue dropping, possibly falling to only $1 per watt as technologies advance and as manufacturing capacity expands by leaps and bounds. Research designed to improve photovoltaic technology is under way in literally hundreds of laboratories. Scarcely a month goes by without another advance in either photovoltaic cell design or manufacturing technology.[46]

Tapping the Earth's Heat

In contrast to other sources of renewable energy, such as wind power, solar cells, and hydropower, which rely directly or indirectly on sunlight, geothermal energy comes from within the earth itself. Produced radioactively within the earth and by the pressures of gravity, it is a vast resource, most of which is deep within the earth. Geothermal energy can be economically tapped when it is relatively close to the surface, as evidenced by hot springs, geysers, and volcanic activity.

This energy source is essentially inexhaustible. Hot baths, for example, have been used for millennia. It is possible to extract heat faster than it is generated at any local site, but this is a matter of adjusting the extraction of heat to the amount generated. In contrast to oil fields, which are eventually depleted, properly managed geothermal fields keep producing indefinitely.

Geothermal energy is much more abundant in some parts of the world than in others. The richest region is the vast Pacific Rim. In the East Pacific, geothermal resources are found along the coastal regions of Latin America, Central America, and North America all the way to Alaska. On the west side, they are widely distributed in Eastern Russia, Japan, the Korean Peninsula, China, and island countries such as the Philippines, Indonesia, New Guinea, Australia, and New Zealand.[47]

This buried energy source is used directly both to supply heat and to generate electricity. When used for heat, hot water or steam is typically pumped from underground, heat is extracted, and then the water is re-injected into the earth. Electricity can be generated from hot water pumped from beneath the earth's surface, from steam extracted directly, or from steam produced by circulating water into fissures in hot rock below the surface. Geothermal energy extracted directly can be used for space heating, as in Iceland, where it heats some 85 percent of buildings; for hot baths where springs bring geothermal energy to the surface, as in Japan; and for generating electricity, as in the United States.[48]

First harnessed for electricity generation in Italy in 1904, geothermal energy is now used in scores of countries, although in many cases it is used primarily to supply hot water to bath houses. During the first seven decades of the twentieth century, the growth in geothermal electrical generating capacity was modest, reaching only 1,100 megawatts in 1973. With the two oil price hikes in 1973 and 1979, however, use of geothermal energy began to grow. By 1998, it had expanded nearly eightfold, to 8,240 megawatts. (See Figure 5–4.)[49]

The United States, with more than 2,800 megawatts of capacity, is the world leader in tapping this energy source. But as a share of national electricity generation, other, smaller countries are far ahead. Whereas the United States gets only 1 percent of its electricity from geothermal energy, Nicaragua gets 28 percent and the Philippines, 26 percent.[50]

Most countries have barely begun to tap their wealth of geothermal energy. For countries rich in geothermal energy, such as those on the Pacific Rim, bordering the Mediterranean Sea, and along Africa's Great Rift, geothermal heat is potentially a huge source of energy—and one that does not disrupt the earth's climate. In Japan, an abundance of geothermal energy is close to the surface, as the thousands of hot spring spas throughout the country attest. It is estimated that the potential electrical generating capacity of geothermal energy in Japan could meet 30 percent of the country's needs. Some countries are so well endowed that they can run their economies entirely on geothermal energy.[51]

In a time of mounting concern about climate change, many governments are beginning to exploit the geothermal potential. The U.S. Department of Energy, for example, announced in 2000 that it was launching a program to develop the rich geothermal energy resources in the western United States. The goal is to have 10 per-

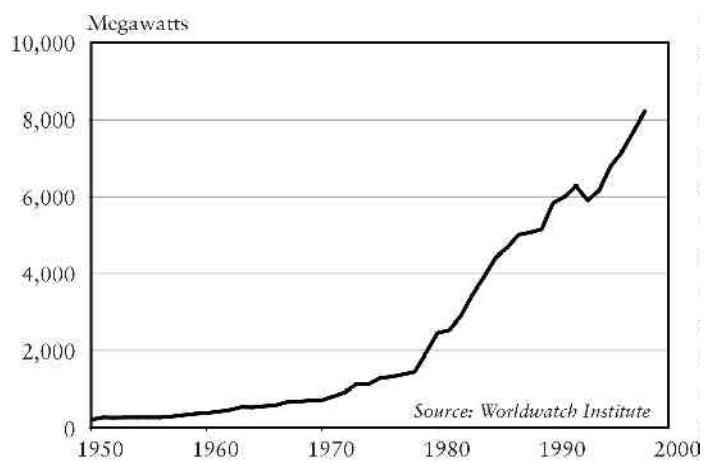

Figure 5–4. *World Geothermal Power, 1950–98*

cent of the electricity in the West coming from geothermal energy by 2020.[52]

Natural Gas: The Transition Fuel

Over the last half-century, the use of natural gas has increased 12-fold. Indeed, in 1999 natural gas eclipsed coal as a world source of energy, making it second only to oil. (See Figure 5–5.) This growth in natural gas use is fortuitous, because as this energy source grows, the storage and distribution system—whether long-distance pipelines or the detailed distribution networks within cities that supply natural gas to individual residences—is also expanding, setting the stage for the eventual switch to a hydrogen economy.[53]

Natural gas could overtake oil as the world's leading source of energy within the next 20 years, particularly if an anticipated downturn in oil production comes in this decade rather than the next. Natural gas has gained in popularity both because it is a clean-burning source of energy and because it is less carbon-intensive than either coal or oil. It emits scarcely half as much carbon as coal does for each unit of energy produced. In contrast to both coal and oil, which often emit sulfur dioxide and nitrous oxides when burned, gas burns cleanly.[54]

It is this clean-burning quality that has appealed to governments as a way of reducing air pollution. In China, for example, shifting from coal to natural gas for both industrial and residential uses is

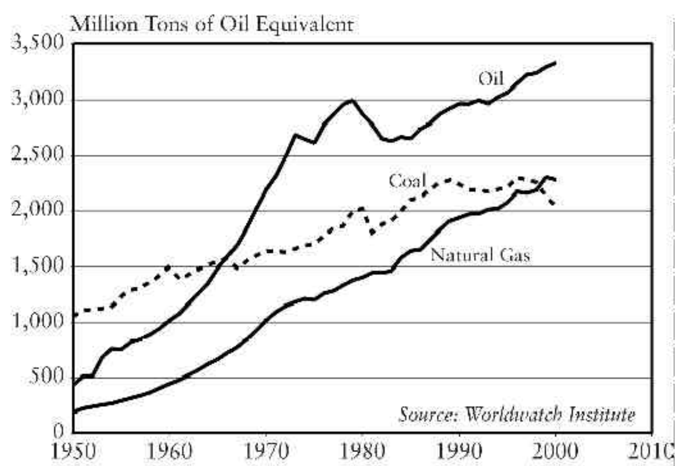

Figure 5–5. *World Fossil Fuel Consumption, 1950–2000*

reducing the urban air pollution that has claimed literally millions of lives in recent years. As part of its long-term planning, China is building a new pipeline from gas fields discovered in its far northwest to the city of Lanzhou in Gansu Province. The government has also approved the import of natural gas and is now planning to build a pipeline linking Russia's Siberian gas fields with Beijing and Tianjin, both leading industrial cities.[55]

Natural gas's potential to play a central role in the transition from the fossil fuel era to the solar/hydrogen era has not escaped the more progressive leaders in this industry. For example, Gasunie, the Netherlands natural gas utility, expects to be a major player in this transition. Although Gasunie now transports natural gas from the North Sea gas fields across the Netherlands to other countries in Europe, the firm plans eventually to use offshore wind power to generate electricity, converting it into hydrogen that will then be moved through the pipeline system now used for natural gas.[56]

In the United States, Enron, a Texas-based natural gas company that in recent years has become a global energy company, is also keenly aware of the part it can play in the transition to the new energy economy. In recent years, it has purchased two wind companies, which gives it the capacity to exploit the vast wind resources of Texas. This abundance of wind to generate cheap electricity and produce hydrogen gives Enron the option of one day feeding the hydrogen into the same distribution network of pipelines that it now uses to distribute natural gas in the Northeast and Midwest.[57]

A similar situation exists in China, where the development of natural gas fields in the northwest and the pipelines used to carry the gas eastward to industrial cities could one day be used to carry hydrogen produced with the region's wealth of wind resources. (The installation of wind turbines along with the more traditional windbreaks of trees in areas where soil is vulnerable to wind erosion could also help control erosion and the dust storms that blow across the country to Beijing and other cities.)

Natural gas companies are well positioned to be leaders in building the solar/hydrogen economy. They may someday invest in wind electric generation in remote regions that have a wealth of wind, and then use that electricity to electrolyze water and produce hydrogen. This could then be exported in liquid form, much as natural gas is now compressed into liquid form for shipping in tankers.

Getting to the Hydrogen Economy

The transition from fossil fuels to a solar/hydrogen energy economy can be seen in the widely differing growth rates among the various sources of energy. (See Table 5–2.) During the 1990s, wind power grew by a phenomenal 25 percent annually, expanding from 1,930 megawatts in 1990 to 18,449 megawatts in 2000. Sales of solar cells, meanwhile, grew at 20 percent a year, while geothermal energy grew by 4 percent annually. Hydropower, the fourth renewable energy source, grew at 2 percent a year.

Table 5–2. *Trends in Energy Use, by Source, 1990–2000*

Energy Source	Annual Rate of Growth (percent)
Wind power	25
Solar cells	20
Geothermal power	4
Hydroelectric power	2
Natural Gas	2
Oil	1
Nuclear Power	0.8
Coal	– 1

Source: Worldwatch Institute, *Vital Signs 2001* (New York: W.W. Norton & Company, 2001), pp. 40–47.

Among the fossil fuels, natural gas grew the fastest, at 2 percent annually, followed by oil at 1 percent. Coal use declined by 1 percent a year, with the actual decline coming after 1996. Nuclear power continued to grow, but just barely, averaging less than 1 percent a year during the decade.

The contrasting growth rates among the various energy sources were even greater in the year 2000 than during the 1990s. World wind generating capacity grew by 32 percent and sales of solar cells by 43 percent. The burning of coal, the fossil fuel that launched the industrial era, declined by 4 percent in 2000; natural gas increased by 2 percent; and oil increased by 1 percent. Nuclear power expanded by less than 1 percent. These data for the latest year—with the dramatic gains in wind and solar combined with the sharp decline for coal—indicate that the restructuring of the energy economy is gaining momentum.[58]

Coal is the first fossil fuel to peak and begin to decline. After reaching a historic high in 1996, production dropped 7 percent by 2000 and is expected to continue declining as the shift to natural gas and renewables gains momentum. Coal consumption is declining sharply in both the United Kingdom, the country where the Industrial Revolution began, and in China, the world's largest user.[59]

The shift in the fortunes of nuclear power could hardly be more dramatic. In the 1980s, world nuclear generating capacity expanded by 140 percent; during the 1990s, it expanded by 6 percent. Confronted with decommissioning costs of power plants that could rival the original construction costs, the energy source that was to be "too cheap to meter" is now too costly to use. Wherever electricity markets are opened to competition, nuclear power is in trouble. With a number of older plants scheduled to close, its worldwide use is likely to peak and start declining in a matter of years.[60]

Nuclear power plant closings are now under way or slated in the years immediately ahead in many countries, including Bulgaria, Germany, Kazakhstan, the Netherlands, Russia, the Slovak Republic, Sweden, and the United States. In three countries once solidly committed to this energy source—France, China, and Japan—nuclear power is losing its appeal. France has extended its moratorium on new plants. China has said it will not approve any additional plants for the next three years. Japan's once ambitious program is in trouble. A serious accident in September 1999 at a nuclear fuel fabrication plant north of Tokyo has reinforced rising public concerns about nuclear safety in Japan.[61]

Meanwhile, the use of wind and solar cells is growing by leaps and bounds. The spectacular growth in wind-generated electricity is driven by its falling cost. With the new advanced-design wind turbines, electricity is being generated at less than 4¢ per kilowatt-hour in prime wind sites—down from 18¢ a decade ago. Surpluses of wind-generated electricity on long-term contracts can guarantee the price, something those relying on oil or natural gas cannot do. With annual additions of wind capacity during the late 1990s exceeding those of nuclear power, the torch is passing to a new generation of energy technologies.[62]

In contrast to the old energy economy, in which a handful of countries control the supply, the new energy sources are widely dispersed. The economic opportunity for developing countries to develop their indigenous energy sources promises a strong boost to their overall development. New coalitions are evolving in support of the new energy sources, such as the one between U.S. environmental and agricultural groups in support of wind power development.

Satisfying the local demand for electricity from wind is not the end of the story. As noted earlier, cheap electricity produced from wind can be used to electrolyze water, producing hydrogen. At night, when electricity demand falls, electricity from wind farms can be used to power hydrogen generators to produce fuel for automobiles, trucks, and tractors.

With the first automobiles powered by fuel cell engines expected on the market in 2003 and with hydrogen as the fuel of choice for these new engines, a huge new market is opening up. As noted earlier, Royal Dutch Shell is already opening hydrogen stations in Europe. William Ford, the youthful chairman of the Ford Motor Company board, has said he expects to preside over the demise of the internal combustion engine.[63]

The economic benefits of developing local low-cost renewable sources of energy are obvious. In a community, for example, that gets its electricity from wind power, the money spent for electricity stays largely in the region. Developing wind resources thus promises to help rural communities in many countries, providing a welcome supplemental source of income and employment.

As the world energy economy is restructured, so, too, will the rest of the economy change. The geography of economic activity will be altered, in some cases dramatically. The traditional siting of heavy industry, such as steel production, in areas where coal and iron ore are found in close proximity will no longer be necessary. In the future, energy-intensive industries will be located in wind-rich regions rather than coal-rich regions. Countries that were once importers of energy may become self-sufficient, even exporting electricity or hydrogen.

One of the characteristics of the new energy economy is that it will rely much more on decentralized small-scale power sources rather than a few large, centralized systems. Small-scale energy systems designed to satisfy the needs of individual homes, factories, or office buildings will become much more common. Instead of a few highly concentrated energy sources, the world will be turning to vast numbers of small individual sources of energy. Fuel cells powered with hydrogen and the highly efficient combined-cycle gas turbines that are powered by either natural gas or hydrogen will become common. Fuel cells can be used to generate electricity for office buildings, factories, or individual homes or to power automobiles.

In the eco-economy, hydrogen will be the dominant fuel, replacing oil, much like oil replaced coal and coal replaced wood. Since hydrogen can be stored and used as needed, it provides perfect support for an energy economy with wind and solar power as the main pillars. If this pollution-free, carbon-free energy source can be developed sooner rather than later, many of our present energy-related problems can be solved. Electricity and hydrogen can together provide energy in all the forms needed to operate a modern economy, whether powering computers, fueling cars, or manufacturing steel.

On first reflection, such an energy system may seem a farfetched idea. But two decades ago, the idea of desktop or laptop computers and Internet communication seemed equally farfetched. As Seth Dunn of Worldwatch Institute notes, what is most inconceivable is that an information-age economy should be powered by a primitive, industrial-age energy system. As corporate and government decisionmakers begin to understand the need to restructure the energy economy, and just how economical and practical a zero-emissions, carbon-free energy system can be, then they may finally summon the sort of effort that supported the last great energy transition—the one from wood to fossil fuels a century ago.[64]

If the goal is to expand wind electric generation fast enough to accelerate the phaseout of coal, it would mean extraordinarily rapid growth in wind energy. Is such growth possible? Yes. The growth in the Internet provides a model. Between 1985 and 1995, the number of host computers on the Internet more than doubled each year. In 1985, there were 2,300 host computers on the Internet. By 1995, there were 14,352,000.[65]

A back-of-the-envelope calculation indicates what kind of growth would be needed for wind to become the foundation of the global energy economy, and how much it would cost. What would happen if wind electric generation doubled each year for the next 10 years, as adoption of the Internet did? Assume for the sake of calculation that in 2000 the world had 20,000 megawatts of wind-generating electricity online and that in 2001 this doubled to 40,000 megawatts, then in 2002 to 80,000 megawatts, and so forth. At this rate, by 2005, it would be 640,000 megawatts—nearly enough to meet all U.S. electricity demand. By 2010, it would reach 20.4 million megawatts of wind generating capacity, far beyond today's 3.2 million megawatts of world generating capacity or the projection of 4 million or so megawatts of capacity needed by 2010. This would not only satisfy world electricity needs, it could meet other energy needs as well—including those for transportation and heavy industry as well as residential uses.[66]

How much would this cost? Assuming generously that it would take $1 million of investment per megawatt of electricity, 10 million megawatts of wind power capacity would require an investment over the next 10 years of $10 trillion. This would amount to roughly $1 trillion a year—about double what the world spent for oil in 2000, or just 2.5 percent of the gross world product of $40 trillion. Another financial reference point, which is in some ways more relevant, is the $700 billion that the world's governments have been spending each year on environmentally destructive activities, such as coal mining, excess fishing capacity, and overpumping of aquifers. (See Chapter 11.) Shifting these subsidies into investment in wind development would accelerate the evolution of an eco-economy on several fronts simultaneously. This calculation simply illustrates that if the world wants to move quickly to eliminate excessive carbon emissions, it can do so.[67]

The transition from a fossil-fuel- or carbon-based economy to a high-efficiency, hydrogen-based economy will provide enormous investment and employment opportunities across the globe. The question is not whether there will be an energy revolution. It is already under way. The only questions are how rapidly it will unfold, whether it will move fast enough to prevent climate change from getting out of hand, and who will benefit most from the transition.

Realistically, how fast could wind generation expand during this decade? During the 1990s it expanded at 25 percent a year, with only a half-dozen countries accounting for most of the growth. If all countries with commercially viable wind sites began developing their wind, how fast could it expand? Could it double each year? That would be tough, requiring a mobilization akin to that during World War II. There might be a few annual doublings early in the decade while the base is still small, but then the rate of expansion would slow. How fast the world develops wind resources will depend in part on how fast climate changes and how alarmed we become by record heat waves, rapid ice melting, and more destructive storms. Although predicting the rate of future growth is not possible, it is clearly safe to assume that the world could be getting much of its electricity from wind by 2010 if it becomes important to do so.[68]

In his Worldwatch Paper *Hydrogen Futures*, Seth Dunn quotes President John F. Kennedy: "There are risks and costs to a program of action. But they are far less than the long-range risks and costs of comfortable inaction." Dunn then goes on to establish the parallel between Kennedy's cold war observation and the current energy transition. "There are risks and costs involved in rapidly building a hydrogen economy, but they are far less than the long-range risks and costs of remaining comfortably committed to the hydrocarbon economy."[69]

The key to accelerating the transition to a hydrogen economy is to get the market to incorporate ecological costs in the prices. *The Economist* argues that there is a need to level the playing field and then let the market take it from there: "That means, for example, dismantling the many subsidies that prop up coal and other fossil fuels. It also means introducing a carbon tax or similar mechanism to ensure that prices for fossil fuels reflect the harm they do to human health and to the environment." More and more analysts are reaching this same conclusion. A recent study by the Organisation for Economic Co-operation and Development also argues for restructuring taxes in order to reduce carbon emissions. Phasing in a carbon tax so that the burning of fossil fuels would reflect their full cost to society would accelerate the transition to wind energy, solar cells, and geothermal energy, expanding them far faster during this decade than during the last.[70]