9

Cutting Carbon Emissions in Half

When the Kyoto Protocol was negotiated in 1997, the proposed 5-percent reduction in carbon emissions from 1990 levels in industrial countries by 2012 seemed like an ambitious goal. Now it is seen by more and more people as being out of date. Even before the treaty has entered into force, many of the countries committed to carrying it out have discovered that they can do even better.[1]

National governments, local governments, corporations, and environmental groups are coming up with ambitious plans to cut carbon emissions. Prominent among these is a plan developed by the British government to reduce carbon emissions 60 percent by 2050, the amount that scientists deem necessary to stabilize atmospheric carbon dioxide (CO_2) levels. Building on this, Prime Minister Tony Blair and Sweden's Prime Minister Göran Persson are jointly urging the European Union to adopt the 60-percent goal.[2]

A plan developed for Canada by the David Suzuki Foundation and the Climate Action Network would halve carbon emissions by 2030 and would do it only with investments in energy efficiency that are profitable. And in early April 2003, the World Wildlife Fund released a peer-reviewed analysis by a team of scientists that proposed reducing carbon emissions from U.S. electric power generation 60 percent by 2020. This proposal centers on a shift to more energy-efficient power generation equipment, the use of more-efficient household appliances and industrial motors and other equipment, and in some situations a shift from coal to natural gas. If implemented, it would result in national savings averaging $20 billion a year from now until 2020.[3]

In Canada's most populous province, an environmental group—the Ontario Clear Air Alliance—has devised a plan to phase out the province's five coal-fired power plants, the first one in 2005 and the last one by 2015. The plan is supported by all three major political parties. Jack Gibbons, director of the Alliance, says of coal burning, "It's a nineteenth century fuel that has no place in twenty-first century Ontario."[4]

Germany, which has set the pace for reducing carbon emissions among industrial countries, is now talking about lowering its emissions by 40 percent by 2020. And this is a country that is already far more energy-efficient than the United States. Contrasting goals for cutting carbon emissions in Germany and the United States are due to a lack of leadership in the latter—not a lack of technology.[5]

U.S.-based Interface, the world's largest manufacturer of industrial carpeting, cut carbon emissions in its Canadian affiliate during the 1990s by two thirds from the peak. It did so by examining every facet of its business—from electricity consumption to trucking procedures. The company has saved more than $400,000 a year in energy expenditures. CEO Ray Anderson says, "Interface Canada has reduced greenhouse gas emissions by 64 percent from the peak, and made money in the process, in no small measure because our customers support environmental responsibility." The Canadian plan to cut carbon

emissions in half by 2030 was inspired by the profitability of the Interface initiative.[6]

Although stabilizing atmospheric CO_2 levels is a staggering challenge, it is entirely doable. Detailed studies by governments and by various environmental groups are beginning to reveal the potential for reducing carbon emissions while saving money in the process. With advances in wind turbine design and the evolution of the fuel cell, we now have the basic technologies needed to shift quickly from a carbon-based to a hydrogen-based energy economy. Cutting world carbon emissions in half by 2015 is entirely within range. Ambitious though this might seem, it is commensurate with the threat that climate change poses.

Raising Energy Productivity

The enormous potential for raising energy productivity becomes clear in comparisons among countries. Some countries in Europe have essentially the same living standard as the United States yet use scarcely half as much energy per person. But even the countries that use energy most efficiently are not close to realizing the full potential for doing so.[7]

In April 2001, the Bush administration released a new energy plan and called for construction of 1,300 new power plants by 2020. Bill Prindle of the Washington-based Alliance to Save Energy responded by pointing out how the country could eliminate the need for those plants and save money in the process. He ticked off several steps that would reduce the demand for electricity: Improving efficiency standards for household appliances would eliminate the need for 127 power plants. More stringent residential air conditioner efficiency standards would eliminate 43 power plants. Raising commercial air conditioner standards would eliminate the need for 50 plants.

Using tax credits and energy codes to improve the efficiency of new buildings would save another 170 plants. Similar steps to raise the energy efficiency of existing buildings would save 210 plants. These five measures alone from the list suggested by Prindle would not only eliminate the need for 600 power plants, they would save money too.[8]

Of course, each country will have to fashion its own plan for raising energy productivity. Nevertheless, there are a number of common components. Some are quite simple but highly effective, such as banning the use of nonrefillable beverage containers, eliminating the use of incandescent light bulbs, doubling the fuel efficiency of automobiles, and redesigning urban transport systems to raise efficiency and increase mobility.

We know that it is possible to ban the use of nonrefillable beverage containers because Canada's Prince Edward Island has already done so. And Finland has a stiff tax on nonrefillables that has lead to 98-percent container reuse for soft drinks. These actions reduce energy use, water use, and garbage generation. A refillable glass bottle used over and over again requires about 10 percent as much energy per use as an aluminum can, even if the can is recycled. Cleaning, sterilizing, and relabeling a used bottle requires little energy, but recycling aluminum, which has a melting point of 660 degrees Celsius (1220 degrees Fahrenheit), is an energy-intensive process. Banning nonrefillables is a win-win policy initiative because it cuts both energy use and the flow of garbage.[9]

Another simple step is to replace all incandescent light bulbs with compact fluorescent bulbs (CFLs), which use only one third as much electricity and last 10 times as long. In the United States, where 20 percent of all electricity is used for lighting, if each household replaced commonly used incandescents with compact fluorescents, electricity for lighting would be cut in half. The combination of lasting longer and using less electricity greatly outweighs the higher costs of the CFLs, yielding a risk-free return of some 25–40 percent a year. Worldwide, replacing incandescent light bulbs with CFLs would save enough electricity to close hundreds of coal-fired power plants, and it could be accomplished easily within three years if we decided to do it.[10]

A third obvious area for raising energy efficiency is automobiles. In the United States, for example, if all motorists were to shift from their current vehicles with internal combustion engines to cars with hybrid engines, like the Toyota Prius or the Honda Insight, gasoline use could be cut in half. Sales of hybrid cars, introduced into the U.S. market in 1999, reached an estimated 46,000 in 2003. (See Table 9–1.) Higher gasoline prices and a tax deduction of up to $2,000 for purchasing a low-emission vehicle are boosting sales. With U.S. auto manufacturers coming onto the market on a major scale soon, hybrid vehicle sales are projected to reach 1 million in 2007.[11]

A somewhat more complex way to raise energy pro-

Table 9–1. *Sales of Hybrid Cars in the United States, 1999–2003*

Year	Sales (number)
1999	17
2000	9,350
2001	20,282
2002	35,835
2003 (est.)	46,000

Source: See endnote 11.

ductivity is to redesign urban transport systems. Most systems, now automobile-centered, are highly inefficient, with the majority of cars carrying only the driver. Replacing this with a more diverse system that would include a well-developed light-rail system complemented with buses as needed and that was bicycle- and pedestrian-friendly could increase mobility, reduce air pollution, and provide exercise. This is a win-win-win situation. Mobility would be greater, the air would be cleaner, and it would be easier to exercise. Fewer automobiles would mean that parking lots could be converted into parks, creating more civilized cities.

In order to begin shifting the mix away from automobiles, some cities now charge cars entering the city. Pioneered by Singapore many years ago, this approach is now being used in Oslo and Melbourne. And in February 2003, London introduced a similar system to combat congestion as well as pollution, charging $8 for any vehicle entering the central city during the working day. This immediately reduced traffic congestion by 24 percent.[12]

Harnessing the Wind

Shifting to renewable sources of energy, such as wind power, opens up vast new opportunities for lowering fossil fuel dependence. Wind offers a powerful alternative to fossil fuels—a way of dramatically cutting carbon emissions. Wind energy is abundant, inexhaustible, cheap, widely distributed, climate-benign, and clean—which is why it has been the world's fastest-growing energy source over the last decade.

The modern wind industry was born in California in the early 1980s as a result of a federal tax credit for renewable energy, combined with a generous state tax credit. For most of the industry's first 15 years, growth

was relatively slow, but in recent years, generating capacity has exploded. In 1995, world wind-generating capacity was 4,800 megawatts. By the end of 2002, it had increased sixfold to 31,100 megawatts. (See Figure 9–1.) World wind generating capacity today is sufficient to meet the residential needs of Norway, Sweden, Finland, Denmark, and Belgium combined.[13]

Germany, with over 12,000 megawatts of wind power at the end of 2002, leads the world in generating capacity. Spain and the United States, at 4,800 and 4,700 megawatts, are second and third. Tiny Denmark is fourth with 2,900 megawatts, and India is fifth with 1,700 megawatts. Today Denmark gets 18 percent of its electricity from wind. In Schleswig-Holstein, the northernmost state in Germany, the figure is 28 percent. And in Spain's northern industrial province of Navarra, it is 22 percent. Although a score of countries now generate elec-

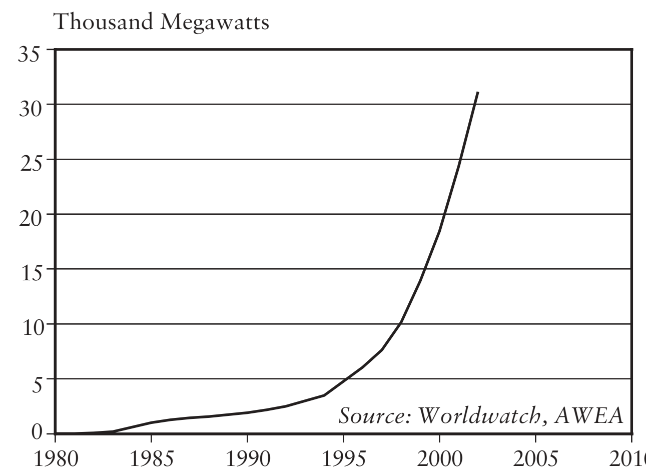

Figure 9–1. *World Wind Energy Generating Capacity, 1980–2002*

tricity from wind, a second wave of major players is coming onto the field, including the United Kingdom, France, Italy, Brazil, and China.[14]

Wind energy is both abundant and widely distributed. In densely populated Europe, there is enough easily accessible offshore wind energy to meet all of the region's electricity needs. China can easily double its current electricity generation from wind alone. In the United States, a national wind resource inventory published in 1991 indicated that there is enough harnessable wind energy in just three of the 50 states—North Dakota, Kansas, and Texas—to satisfy national electricity needs. But this now greatly understates U.S. potential. Recent advances in wind turbine design and size, enabling the turbines to operate at lower wind speeds and to harness the wind's energy more efficiently and at greater heights, have dramatically expanded the harnessable wind resource.[15]

Wind is also clean. Wind energy does not produce sulfur dioxide emissions or nitrous oxides to cause acid rain. Nor are there any emissions of health-threatening mercury that come from coal-fired power plants. No mountains are leveled, no streams are polluted, and there are no deaths from black lung disease. Wind does not disrupt the earth's climate.

One of the great attractions of wind is that it is inexhaustible. Once wind farms are developed, they can operate indefinitely simply by replacing equipment parts as they wear out. In contrast to oil, which is eventually depleted, wind is inexhaustible.

Wind is also cheap. Advances in wind turbine design, drawing heavily on the technologies of the aerospace industry, have dropped the cost of wind power from 38¢ per kilowatt-hour in the early 1980s to less than 4¢ at prime wind sites in 2001. Some recent long-term wind supply contracts were signed at 3¢ per kilowatt-hour. The

cost of wind-generated electricity is well below that of nuclear power. On prime wind sites, it can now undercut coal and compete with gas, currently the cheapest source of electricity generation.[16]

Even more exciting, with each doubling of world generating capacity, costs fall by 15 percent. With recent growth rates of 31 percent a year, costs are dropping by 15 percent every 30 months or so. While natural gas prices are highly volatile, the costs of wind are declining. And there is no OPEC for wind.[17]

Cheap electricity from wind brings the option of electrolyzing water to produce hydrogen, which offers a way of both storing wind energy and transporting it via pipelines. It can be stored and used in lieu of natural gas in power plants to provide electricity when the wind ebbs.

Hydrogen is also the fuel of choice for the new fuel cell engines that every major automobile manufacturer is now working on. Honda and Toyota both made it to the market with their first fuel cell–powered automobiles at the end of 2002. DaimlerChrysler plans to be in the market in 2003 and Ford in 2004. In a country like the United States, the advances in wind turbine design and the evolution of fuel cells hold out the hope that farmers and ranchers, who own most of the country's wind rights, could one day be supplying not only the country's electricity, but much of the fuel for its cars as well.[18]

Countries that are rich in wind could end up exporting hydrogen in liquefied form in the same way that natural gas is liquefied and exported today. Among the countries that are both richly endowed in wind and rather sparsely populated are Canada, Argentina (with world-class winds in Patagonia), and Russia. Eastern Siberia could supply vast amounts of hydrogen to densely populated, heavily industrialized China, South Korea, and Japan.

Given the enormous wind-generation potential and the associated benefits of climate stabilization, it is time to consider an all-out effort to develop wind resources. Instead of doubling every 30 months or so, perhaps we should be doubling wind electric generation each year for the next several years, much as the number of computers linked to the Internet doubled each year from 1985 to 1995. If this were to happen, then costs would drop precipitously, giving wind-generated electricity an even greater advantage over power from fossil fuels.[19]

Energy consultant Harry Braun made an interesting proposal at a Hydrogen Roundtable in April 2003 for quickly shifting to a wind/hydrogen economy. From a manufacturing point of view, he noted, wind turbines are similar to automobiles: each has a brake, a gearbox, an electrical generator, and an electronic control system. Braun noted that if wind turbines are mass-produced like automobiles, the capital costs of wind-generated electricity would drop from $1,000 a megawatt to roughly $300, reducing the cost of electricity to 1¢ or 2¢ per kilowatt-hour.[20]

Rather than wait for fuel cell engines, Braun suggests using hydrogen in internal combustion engines of the sort developed by BMW. He notes that converting a gasoline engine to hydrogen is relatively simple and inexpensive. This would also facilitate the early development of hydrogen stations in wind-rich areas while waiting for the mass production of fuel cell cars. Braun calculates that the electrolysis of water to produce hydrogen and its liquefication, along with the high efficiency of a hydrogen-fueled internal combustion engine, would bring the cost of hydrogen down to $1.40 per equivalent gallon of gasoline. Assembly-line production of wind turbines at "wartime" speed would quickly end urban air pollution, oil spills, and the need for oil wars.[21]

The incentives for such a growth could come in part

from simply restructuring global energy subsidies—shifting the $210 billion in annual fossil fuel subsidies to the development of wind energy, hydrogen generators, and the provision of kits to convert engines from gasoline to hydrogen. The investment capital could come from private capital markets but also from companies already in the energy business. Shell, for example, has become a major player in the world wind energy economy. BP has also begun to invest in wind power. Other major corporations now in the wind power business include General Electric and ABB. BP's planned investment of $15 billion in developing oil resources in the Gulf of Mexico could also be used to develop 15,000 megawatts of wind-generating capacity, enough to satisfy the residential needs of 15 million people in industrial countries.[22]

These goals may seem farfetched, but here and there around the world ambitious efforts are beginning to take shape. As noted earlier, Germany announced at international climate discussions in India in October 2002 that it wants to cut its greenhouse gas emissions 40 percent by 2020. It is proposing a 30-percent cut throughout Europe by that date. Developing the continent's offshore and onshore wind energy resources will be at the heart of this carbon reduction effort.[23]

In the United States, a 3,000-megawatt wind farm is in the early planning stages. Located in South Dakota near the Iowa border, it is being initiated by Dehlsen Associates, led by James Dehlsen, a wind energy pioneer in California. Designed to feed power into the industrial Midwest around Chicago, this project is not only large by wind power standards, it is one of the largest energy projects of any kind in the world today.[24]

Cape Wind is planning a 420-megawatt wind farm off the coast of Cape Cod, Massachusetts. And a newly formed energy company, called Winergy, has plans for some 9,000 megawatts in a network of wind farms stretching along the Atlantic coast. These are but a few of the more ambitious wind energy projects that are now beginning to emerge in the United States, a country rich in wind energy.[25]

The question is not whether wind is a potentially powerful technology that can be used to stabilize climate. It is. But will we develop it fast enough to head off economically disruptive climate change?

Converting Sunlight into Electricity

When a team of three scientists at Bell Labs discovered in 1952 that sunlight striking a silicon surface could generate electricity, they gave the world access to a vast new source of energy. No country uses as much energy as is contained in the sunlight that strikes its buildings each day, writes Denis Hayes, former Director of the U.S. government's Solar Energy Research Institute.[26]

Solar cells were initially used to provide electricity in remote sites in industrial countries, such as in national forests or parks, offshore lighthouses, and summer homes in remote locations. In recent years, a vast new market has opened up in developing-country villages that are not yet linked to an electrical grid. In many such situations, the cost of building a centralized power plant and a grid to deliver relatively small amounts of electricity is prohibitive, which helps explain why 1.7 billion people in developing countries still do not have electricity. As the cost of solar cells has declined, however, it is now often cheaper to provide electricity from solar cell installations than from a centralized source.[27]

In Andean villages, solar installations are replacing candles as a source of lighting. For villagers who are paying for the installation over 30 months, the monthly payment is roughly the same as the cost of a month's supply

of candles. Once the solar cells are paid for, the villagers then have an essentially free source of power—one that can supply electricity for decades. In villages in India, where light now comes from kerosene lamps, kerosene may cost more than solar cells.[28]

At the end of 2002, more than 1 million homes in villages in the developing world were getting their electricity from solar cells. If families average six members, then 6 million people are getting their residential electricity from solar cells. But this is less than 1 percent of the 1.7 billion who do not yet have electricity. The principal obstacle to the spread of solar cell installations is not the cost per se, but the lack of small-scale credit programs to finance them. As this credit shortfall is overcome, village purchases of solar cells could climb far above the rate of recent years.[29]

The residential use of solar cells is also expanding in some industrial countries. In Japan, where companies have commercialized a solar roofing material, some 70,000 homes now have solar installations. Consumers in Germany receive low-interest loans and a favorable guaranteed price when feeding excess electricity into the grid. In industrial countries, most installations are designed to reduce the consumer's dependence on grid-supplied electricity, much of it from coal-fired power plants.[30]

The governments with the strongest incentives for the use of solar cells are also those with the largest solar cell manufacturing industries. In Japan, for example, residential installations totaled roughly 100 megawatts in 2001. The comparable figure for Germany was 75 megawatts. The United States, a far larger country, was third—with 32 megawatts of installations. India was fourth with 18 megawatts. Japan leads the world in solar cell manufacturing, with some 43 percent of the market. The European Union, led by Germany's vigorous program, has moved into second place with 25 percent of output. The United States, with 24 percent, is now third.[31]

The cost of solar cells has been dropping for several decades, but the falling cost curve lags wind by several years, making solar-generated electricity much more costly than power from wind or coal-fired power plants. Industry experts estimate that with each doubling of cumulative production, the price drops roughly 20 percent.[32]

Over the last seven years, solar cell sales have expanded an average of 31 percent annually, doubling every 2.6 years. (See Table 9–2.) Since there is little doubt that solar cells will one day be an inexpensive source of electricity as the scale of manufacturing expands, the challenge for governments is to leapfrog into the future by accelerating growth of the industry. Only very modest government incentives are needed to do that. If we can quickly reduce the cost of solar cells, they will join wind as a major player in the world energy economy.[33]

Table 9–2. *Trends in Energy Use by Source, 1995–2002*

Energy Source	Annual Rate of Growth (percent)
Solar Photovoltaics	30.9
Wind Power	30.7
Geothermal Power[1]	3.1
Natural Gas	2.1
Oil	1.5
Hydroelectric[2]	0.7
Nuclear Power	0.7
Coal	0.3

[1]Data available through 2000. [2]Data available through 2001.
Sources: See endnote 33.

Energy from the Earth

When we think of renewable energy, we typically think of sources derived from the sun, either directly or indirectly, such as solar heating, solar electricity, wind power, and hydropower, or sources of biological origin, such as wood and crop residues. But the earth itself is a source of heat energy (mostly from radioactivity within the earth), which gradually escapes either through conduction or through hot springs and geysers that bring internal heat to the earth's surface. The use of geothermal energy is sustainable as long as its use does not exceed the rate of generation. It is also inexhaustible and will last as long as the earth itself.

Geothermal energy is used both to generate electricity and as a source of heat for direct use, such as with space heating for greenhouses, aquaculture, and industrial processes, and with heat pumps. After Italy pioneered the use of geothermal energy to generate electricity in 1904, the practice spread to some 22 countries. The global capacity of 8,000 megawatts in 2000 represents a 37-percent growth over the 5,800 megawatts available in 1990.[34]

Two countries—the United States with 2,200 megawatts and the Philippines with 1,900 megawatts—account for half of world generating capacity. (In the Philippines, geothermal provides 27 percent of the country's electricity supply.) Most of the remainder is concentrated in five countries: Italy, Mexico, Indonesia, Japan, and New Zealand.[35]

The direct use of geothermal heat for various purposes is even larger, equivalent to 12,000 megawatts of electricity generation. Some 30 countries account for most of the world's direct use of geothermal energy. Its use in heat pumps, which extract and concentrate heat from warm water for various uses, is the largest single use.[36]

Iceland and France dominate the use of geothermal energy for space heating. In Iceland, 85 percent of the country's 290,000 people use geothermal energy to heat their homes, saving $100 million per year from avoiding oil imports. Geothermal energy accounts for more than one third of Iceland's energy use. During the decade following the two oil price hikes in the 1970s, some 70 geothermal heating facilities were constructed in France, providing both heat and hot water for some 200,000 housing units. In the United States, individual homes are supplied directly with geothermal heat in Reno, Nevada, and in Klamath Falls, Oregon. Other countries that have extensive geothermally based district-heating systems include China, Japan, and Turkey.[37]

Geothermal energy is an ideal source of heat for greenhouses, particularly in northern climes. Russia, Hungary, Iceland, and the United States all use geothermally heated greenhouses to produce fresh vegetables in winter.[38]

Some 16 countries use geothermal energy for aquaculture. Among these are China, Israel, and the United States. In California, for example, 15 fish farms produce tilapia, striped bass, and catfish with warm water from underground. This enables farmers to produce larger fish in a shorter period of time and to produce without interruption during the winter. Collectively these California farms produce 4.5 million kilograms of fish per year.[39]

The number of countries turning to geothermal energy both for electricity and for direct use is increasing rapidly. So, too, is the range of uses. Once the value of geothermal energy is discovered, its use is often quickly diversified. Romania, for example, uses its geothermal energy for district heating, for greenhouses, to produce hot water for dwellings, and to supply industrial hot water for factories. With heat pumps, it is now possible to treat the earth as both a heat source and a sink to provide heating in winter and cooling in summer.[40]

Geothermal energy is widely used for bathing and swimming. Japan, for example, has 2,800 spas, 5,500 public bathhouses, and 15,600 hotels and inns that use hot geothermal water. Iceland has some 100 public swimming pools heated with geothermal energy. Most are open-air pools used the year-round. Hungary heats 1,200 swimming pools with geothermal energy.[41]

The potential of geothermal energy is extraordinary. Japan alone has an estimated geothermal electric-generating capacity of 69,000 megawatts, enough to satisfy one third of its electricity needs. Other countries bordering the Pacific with a vast potential—in the so-called Ring of Fire—include Chile, Peru, Ecuador, Colombia, all of Central America, Mexico, the United States, and Canada in the East Pacific and Russia, China, South Korea, the Philippines, Indonesia, Australia, and New Zealand in the West Pacific. Other geothermally rich countries include those along the Great Rift of Africa and the Eastern Mediterranean. Fortunately, many countries now have enough experience and engineering capacity to tap this vast resource.[42]

Building the Hydrogen Economy

The evolution of the fuel cell—a device that is powered by hydrogen and uses an electro-chemical process to convert hydrogen into electricity, water vapor, and heat—is setting the stage for the evolution of a hydrogen-based economy. The fuel cell is twice as efficient as the internal combustion engine and it is clean, emitting only water vapor.[43]

The great attraction of the fuel cell is that it facilitates the shift to a single fuel, hydrogen, that neither pollutes the air nor disrupts the earth's climate. Stationary fuel cells can be installed in the basements of buildings, for example, to generate electricity and heat that can be used both for heating and cooling. Mobile fuel cells can be used to power cars and portable electronic devices, such as cell phones and laptop computers.

Hydrogen can come from many sources, including the electrolysis of water or the reformulation of natural gas or gasoline, a process that extracts the hydrogen from these hydrocarbons. If the hydrogen comes from water, then electricity from any source can be used to electrolyze the water. If the electricity comes from a wind farm, hydropower station, geothermal power station, or solar cells, the hydrogen will be clean—produced without carbon emissions or air pollutants.

One country, Iceland, already has a plan to convert from fossil fuels to hydrogen. The government, working with a consortium of companies led by Shell and DaimlerChrysler, is taking the first step in 2003 as DaimlerChrysler begins converting Reykjavik's fleet of 80 buses from internal combustion to fuel cell engines. Shell has built a hydrogen station to service the buses, using cheap hydroelectricity to electrolyze water and produce hydrogen. This is clean hydrogen. In the next stage, Iceland's automobiles will be converted to fuel cell engines. And in the final stage, the Icelandic fishing fleet—the centerpiece of its economy—will also convert to fuel cells. Already heating most of its homes and buildings with geothermal energy and getting most of its electricity from hydropower and geothermal power, Iceland plans to be the first modern economy to declare its independence from fossil fuels.[44]

On the other side of the world, in Japan, retired corporate executive Masatsugu Tanaguichi is also planning to create a hydrogen economy. He is working on 875-square-kilometer Yakushima Island off the southern tip of Japan whose principal defining characteristic is 8 meters of rainfall a year. Much of the island is part of a huge nature preserve. Tanaguichi plans to build a series of small dams on the island to convert its abundant hydropower into electricity to power hydrogen generators, electrolyzing water to produce hydrogen. The first goal will be to meet the needs of the 14,000 residents of the island. Once that is done, he plans to ship the excess hydrogen to mainland Japan, transporting it in liquefied form aboard tankers, much as natural gas is transported. He believes the island can export enough hydrogen to run 500,000 automobiles.[45]

Elsewhere, some 30 hydrogen stations have opened. In the Munich airport, for example, a hydrogen station fuels 15 airport buses that have hydrogen-burning internal combustion engines. California now has at least two hydrogen stations—one, built by Honda, uses solar cell electricity to electrolyze water. This station was built to service the five fuel cell cars Honda has sold to the city of Los Angeles. The other hydrogen station in California uses wind-generated electricity to produce the hydrogen. Both are clean-hydrogen stations.[46]

One of the challenges for fuel cell vehicles is how to store the hydrogen. It can be stored in compressed form, liquefied form, or chemically with metal hydrides. It is also possible to store natural gas or gasoline on board and then use reformers to extract the hydrogen. The pros and cons of these various approaches are numerous. In the end, the central question is whether the hydrogen that is used in fuel cell vehicles is clean hydrogen made using renewable energy to electrolyze water or climate-disrupting hydrogen made using fossil fuels.[47]

Fuel cells are initially being used more widely in buildings simply because hydrogen storage is much simpler with stationary fuel cells than with those used in vehicles. Fuel cells will probably proliferate rapidly in larger structures, such as office and apartment buildings, and then, as the technology matures, be installed in private homes. These fuel cells will provide buildings with electricity, heating, and cooling.

Natural gas will likely be the main source of hydrogen in the near term, but, given its abundance, wind is likely to become the principal source in the new energy economy, as mentioned earlier. The hydrogen storage and distribution system, most likely an adaptation of existing natural gas systems, provides a way of both storing wind energy and transporting it efficiently. It is a natural marriage.

One of the big questions today is which of the companies involved in today's multidimensional energy economy will be the principal players in the hydrogen economy? Will it be the oil companies, the natural gas companies, and gas utilities? Will wind companies invest in hydrogen generators and become major hydrogen suppliers? Will companies that control today's natural gas pipelines be the dominant players, delivering hydrogen both to individual buildings and to fueling stations for vehicles?

These are but a few of the questions emerging as the world faces the need to move quickly into the new economy, one in which wind farms replace coal mines and where hydrogen generators replace oil refineries. In making technological choices, there will be winners and there will be losers. A century ago, some automobile companies opted for steam engines and others opted for the newer, less well understood internal combustion engine. Today steam-powered vehicles are found only in museums.

The stakes in this competition are high. The aircraft industry faced a similar situation in the late 1960s as the world appeared to be moving toward supersonic air transport (SST). There were three entries in the race: Russian, Anglo-French, and American. The United States withdrew under pressure from the environmental community, which cited an economic analysis by the Environmental Defense Fund that concluded the technology was too fuel-inefficient to be economically viable. The Russians dropped out of the competition, leaving Europe alone to build the first SST, the Concorde. In the United States, Boeing decided to go with size rather than speed and built the 747. Today, 35 years later, not a single Concorde has been sold commercially. Only the national airlines of the two countries that developed the SST—Air France and British Airways—have bought them. And in April 2003, these companies announced they would ground the Concorde by the end of October 2003. Boeing, meanwhile, has sold more than 1,300 of its 747s.[48]

Today's corporations also will be choosing among various energy sources and technologies as they move into this new energy era. Some companies will underestimate the political pressures to phase out fossil fuels that will likely develop as the costs of climate change become more apparent. Some will choose wisely; others will not. Some will prosper; others will disappear.

Cutting Carbon Emissions

The accelerating rise in the earth's temperature calls for simultaneously raising efficiency and shifting to renewables in order to cut carbon emissions in half, recognizing that the initial large gains are likely to come in efficiency improvements. An important government measure is to mandate efficiency standards for household appliances, automobiles, and the construction of new buildings—taking advantage of recent technological advances.

Moving away from auto-centered urban transport to a system that would prominently feature public transport in a bicycle- and pedestrian-friendly environment would cut fuel use in cities. It would also reduce air pollution and increase the opportunities for exercise—something much needed in a world where 3 million people die each year from urban air pollution and where half or more of the adults in exercise-deprived, affluent societies are overweight.[49]

At the corporate level, firms are now looking at the expense of traffic congestion when deciding where to locate offices and plants. Similarly, young people deciding where to settle down are looking for communities that have bicycle-friendly transportation systems with jogging and hiking trails.

In looking at new energy sources, wind seems certain to be the centerpiece in the new energy economy for the reasons outlined earlier. Its wide distribution offers an alternative to the current heavy global dependence on one region for oil. The wind energy industry has now evolved to the point where it has the requisite technological capacity to expand wind electric generation dramatically over the next decade, making it the world's leading electricity source.

In considering this prospect, it is instructive to look at the recent adoption of other popular new technologies, such as cellular phones. In 1990, there were 11 million cell phones in use in the world, compared with 519 million fixed-line phones. Just six years later—in 1996—sales of cell phones reached 53 million, eclipsing the sales of 51 million fixed-line phones. Within another six years—by 2002—the cell phones in use had reached 1.2 billion, outnumbering the 1.1 billion fixed-line phones. In 12 years cell phones went from being a novelty to dominating the market.[50]

Although the capital requirements for cell phones are small compared with those for electrical generating capacity, their sales growth nonetheless illustrates how market forces can drive the adoption of an appealing new technology. The cell phone market grew by 50 percent a year during the 1990s; wind power has been growing at 31 percent a year since 1995.[51]

If we decided for climate stabilization reasons that we wanted to double wind electric generation each year, it would not be long before wind would be the dominant source of electricity. The United States, for example, now has nearly 5,000 megawatts of wind-generating capacity. Doubling that each year would take it to 640,000 megawatts in seven years, making it the leading source of electricity. Again, this is not beyond the capacity of the industry. In 2001, the strongest year to date in the United States, wind electric-generating capacity grew by 67 percent. The total investment to reach this level of generation, using the rule of thumb of $1 million per megawatt (which is now on the high side), would be $640 billion over a seven-year span, or roughly $90 billion a year. For perspective, Americans currently spend $190 billion each year on gasoline.[52]

There are many policy instruments for accelerating the shift from a carbon- to a hydrogen-based energy economy, including the shift of subsidies from fossil fuels to wind, solar, and geothermal energy sources. Some of these subsidies might also be used for investments in efficiency. For example, each car with a gasoline/battery hybrid engine purchased in the United States currently is eligible for a federal tax deduction of up to $2,000. This helps to make these cars more competitive price-wise, since they are still being manufactured on a relatively small scale. Thus far, the only companies that are marketing hybrid cars are Toyota and Honda, both Japanese. U.S. automakers are scrambling to get on the bandwagon so as not to miss out on this fast-growing market.[53]

While subsidies are being shifted from fossil fuels to renewables and the hydrogen economy infrastructure, it would make eminent sense to reduce income taxes and raise those on climate-disrupting energy sources at the same time. This tax shifting, already under way in several countries in Europe, helps consumers of energy—both individuals and corporations—to understand the full costs of burning fossil fuels. (See also Chapter 11.)

Although shifting subsidies and taxes are at the heart of the energy transformation that is needed, other policy tools can either increase efficiency or accelerate the shift to renewables and the hydrogen-based economy. These include formal as well as informal procurement policies. National and local governments, corporations, universities, and individual homeowners can buy green power. In the United States, even if green power is not offered locally, there is a national Green Power Partnership electricity market operated by the U.S. Environmental Protection Agency (EPA) that enables anyone to buy green power. As more users sign up, the incentive to produce green power at premium rates increases.[54]

The Earth Policy Institute, for example, purchased Green Tags for new wind-generated electricity from wind farms in Washington and Oregon. This electricity will not be delivered to our office in Washington, D.C., but that is not necessary, since each Green Tag matches a seller and a buyer, all cleared through EPA's national computer databank. For every buyer there must be a seller. Green power marketing makes it easy for anyone to contribute to the energy transformation. Some churches are now buying green power, for example, and urging their members to do the same.[55]

One approach adopted by several countries and by 36 states in the United States is known as two-way or net metering. Whenever consumer-owned solar cells or wind turbines produce more electricity than is needed, a two-way electric meter enables individual homeowners to sell electricity back to the utility. Net metering has the added advantage of putting back into the system clean energy produced from the sun, which can displace electricity

generated from more traditional sources. It also promotes energy efficiency, as users are in effect paid for electricity that they generate but do not use.[56]

As wind electric generation expands, the first step would be to back out coal-fired power plants, either closing them or using them as a backup for wind. Coal-fired plants are the most climate-disruptive energy source simply because coal is almost pure carbon. Coal burning is also the principal source of the mercury deposits that contaminate freshwater lakes and streams. The prevalence of mercury-contaminated fish has led 44 state governments in the United States to issue warnings to consumers to limit or avoid eating fish because of the effect of mercury on the central nervous system. The Centers for Disease Control and Prevention issued a warning in 2001 indicating that an estimated 375,000 babies born each year in the United States are at risk of impaired mental development and learning disabilities because of exposure to mercury.[57]

While it is fashionable for some industries and industry groups to complain that reducing carbon emissions, even by the very modest 5 percent required by the Kyoto Protocol, would be costly and a burden on the economy, the reality is that reducing carbon emissions is one of the most profitable investments that many companies can make. Study after study has concluded that it is possible to reduce carbon emissions while making money in the process.

The experience of individual companies confirms this. Dupont, one of the world's largest chemical manufacturers, has already cut its greenhouse gas emissions from their 1990 level by 65 percent. In an annual report, CEO Chad Holliday, Jr., proudly reports savings of $1.5 billion in energy efficiency gains from 1990 to 2002.[58]