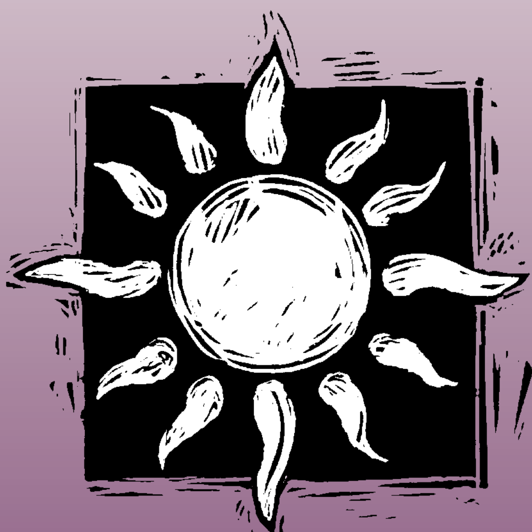
WORLDWATCH PAPER **169**

Mainstreaming Renewable Energy in the 21st Century



JANET L. SAWIN

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Thomas Prugh, *Editor*

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Contents

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SUMMARY

Wind and solar power are the world's fastest-growing energy sources, with capacity expanding at double-digit rates every year over the past decade. Globally, wind power already generates electricity equal to that used by 19 million European households. In 2003, an estimated $20.3 billion—about one-sixth of total global investment in power generation equipment—were invested in "new renewables" (all renewable energy sources except large-scale hydropower and traditional biomass). The effects of this rapid growth include impressive technology advances, dramatic cost reductions, and an increase in political support for renewable energy around the world.

These developments occur against a backdrop of rapidly rising demand for energy, as well as growing concerns about the security of energy supplies and the environmental and health dangers associated with the burning of fossil fuels. Indeed, the need for new, sustainable sources of energy has never been greater. Although new renewables currently meet only 2 percent of global energy demand, the technical potential of these inexhaustible and relatively benign energy sources far exceeds total energy use.

A mere six countries—Denmark, Germany, India, Japan, Spain, and the United States—account for about 80 percent of global photovoltaic (PV) and wind power capacity. In all cases, the advancement of renewables has been spurred by strong government policies designed to nurture nascent energy industries and to create demand for these technologies, often in markets dominated by mature, heavily subsidized

fossil fuels and nuclear power.

Experience shows that renewable energy can advance dramatically worldwide if governments enact the right mix of policies. Among the key policy lessons:

• Access to the market must be ensured. Pricing laws have proved most successful to date at creating markets, while also encouraging steady industry growth and private sector investment in R&D, and offering ease of financing. Quota systems (such as the renewable portfolio standards established in several U.S. states) have also been useful.

• Financial incentives (including tax credits, rebates, payments, and low-interest loans) are also important for encouraging investment in renewables by reducing investors' risks and compensating for high initial capital costs. Subsidies should be phased out as costs decline.

• Education and information dissemination are necessary to apprise potential investors and customers about the potential of renewables, dispel myths, and ensure that trained workers are available to produce, install, and maintain renewable energy equipment.

• Public participation and ownership in the renewables development process increase political support and the likelihood of success.

• Industry standards and permitting help prevent inferior hardware from entering the marketplace and eroding investor and customer confidence, while also addressing potential sources of opposition such as noise and visual impacts.

Governments also must rethink their relationships to the conventional energy industry. Reducing or eliminating the hundreds of billions of dollars in annual subsidies, incorporating all costs into the price of energy, and shifting government purchases from conventional to renewable energies would help to level the playing field for renewable technologies. Finally, policies enacted to advance the development and use of renewables must be consistent and long-term to avoid boom-and-bust environments that shake investor confidence and choke off the supply of capital.

Introduction

Renewable energy is poised for a global takeoff. Over the past decade, the installed capacity of solar power has increased seven-fold, and wind energy capacity has grown by more than a factor of 13. These 10-year annual growth rates (of 22 and 30 percent, respectively) are closer to the realm of computers and telecommunications than the single-digit growth rates common in today's energy economies. And their impact could be revolutionary. The immediate effects include rapidly declining costs, impressive technology advances, and growing economic power and broad-based political support, which in turn are leading to further policy reforms and even faster growth.

Those in the mainstream energy sectors tend to dismiss rapid growth in what they view as tiny industries. This thinking mirrors the attitude of IBM toward Microsoft in the early 1980s. Such high growth rates can rapidly vault a new industry from insignificance to market dominance and thus radically transform the status quo. The conventional wisdom is that the high growth rates will quickly decelerate. Yet the global capacity of both wind and solar photovoltaics (PV) has grown faster over the past five years than in the previous five. And in fact these industries are already far from tiny. For example, today's worldwide wind capacity is sufficient to power the equivalent of 19 million European households.

Although "new renewables" (which exclude large-scale hydropower and traditional biomass) still represent a modest 2-percent share of global energy use, and wind and solar represent less than 1 percent, these new energy sources are large enough to command attention in the marketplace. The estimated $20.3 billion spent on renewable energy development in 2003 was roughly one-sixth of total world investment in power generation equipment.[1*] And these industries are attracting some of the largest players in the world energy market, including BP, Royal Dutch/Shell, and General Electric.

The vast potential of these energy sources is shown by the fact that the past decade's growth in renewable energy has taken place mostly in six countries, which represent roughly 80 percent of the world's generation of wind and solar power. Unlike the markets for oil or coal, the dominant roles of Denmark, Germany, India, Japan, Spain, and the United States in renewables do not reflect a fortunate accident of geography and resource availability. They are instead the product of conscious policy decisions that have created demand for these technologies, including access to the electric grid at attractive prices, low-cost financing, tax incentives and other subsidies, standards, education, and stakeholder involvement. Public research and development investments are also important, but it is only by creating markets that the technological development, learning, and economies of scale in production can develop to further advance renewables and reduce their costs. The costs of these policies have been relatively minor compared to the leverage they have provided, spurring billions of dollars' worth of research and development and capital investment by the private sector.

These six countries have shown that it is possible to create vibrant markets for renewable energy and to do so rapidly. New laws to promote renewables are being introduced almost continually at the state and national levels worldwide. If more countries continue to board the renewable energy bandwagon, renewables could reach a tipping point that propels them toward dominance of the global energy system—much as oil passed a similar threshold a century ago—and provide humanity with a cleaner, safer, healthier, and more equitable world.

*Endnotes are grouped by section and begin on page 53.

For renewable energy to make a significant contribution to economic development, job creation, reduced fossil fuel dependence, improved human health, and lower greenhouse gas emissions, it is essential to improve the efficiency of the technologies, reduce their costs, and develop mature, self-sustaining industries to manufacture, install, and maintain renewable energy systems. The goal must be to establish the conditions for sustained and profitable industries. These in turn will boost renewable energy capacity and generation, and will drive down costs. Viable, clear, and long-term government commitments are critical to this end, along with policies that create markets and ensure a fair rate of return for investors.

The need for new energy sources has never been greater. Energy use is rising rapidly everywhere but particularly in the developing world, where up to 2 billion people still lack access to electricity and other modern energy services, and average per-person energy consumption is far below that in the industrial world.[2] For most developing countries that lack fossil fuels but are rich in renewable and human labor resources, renewable energy is a perfect match, making it possible to create millions of jobs while reducing the foreign exchange burden of imported fuels. The same holds true for much of the industrial world as well, where renewables can meet rising demand and replace obsolete systems.

On the other hand, if the world continues down the track of business as usual, it faces a fast-approaching train wreck. Oil is being consumed at ever more rapid rates, and the peak in world oil production could be less than a generation away. Not only are conventional fuels insufficient to meet rising energy needs through this century, but they also impose unacceptable economic, health, social, and security costs. For instance, the steady rise of atmospheric carbon dioxide levels—and the consequent risk of climate change, whether gradual or abrupt—is now receiving the attention of everyone from urban planners to Pentagon strategists.

Although a transition to renewable energy will require considerable upfront investment, numerous studies conclude that it would be cheaper over the long term, while also providing tremendous social, economic, security, and environmental advantages. Just as the United States dominated the petroleum economy of the last century, countries that invest in renewable energy technologies early on will be in a strong position to reap the economic rewards of a rapidly growing new sector.*

The Approaching Train Wreck—and How To Avoid It

During the past year, Shanghai's gleaming shopping malls have gone for hours without heat on winter days, while children study by candlelight and factories shut down for lack of power.[1] The lights are out across much of China because energy supply cannot keep up with rapidly rising energy demand, driven by extraordinary economic growth. Simultaneous shortages of oil, electricity, and coal have sparked concerns about an impending energy crisis and, ironically, are slowing further economic expansion.[2] At the same time, the World Bank estimates that the environmental and health costs of air pollution in China, due primarily to coal burning, could total 13 percent of China's gross domestic product (GDP) by 2020.[3]

China's electricity use has tripled since 1990.[4] In 2003 alone, power demand jumped 15 percent, and oil consumption increased more than 10 percent.[5] A decade ago, it was a net exporter of oil; in 2003, due primarily to a dramatic rise

* In June 2004, the German government will host the first major intergovernmental conference on renewable energy since the 1981 UN Conference on New and Renewable Sources of Energy in Nairobi. Major issues to be discussed will include barriers to the development and diffusion of renewable energy technologies, policy instruments for advancing their use, and financing to accelerate development. The purpose is to develop an international action plan with voluntary national and regional targets aimed at substantially increasing the global share of energy from renewable sources. The International Conference for Renewable Energies in Bonn will offer a historic opportunity for nations to unite toward the common goal of a more sustainable energy future, and to work together to bring renewables into the mainstream during the 21st century.

in private car ownership, China passed Japan to become the second largest consumer after the United States. Long a major exporter of coal, China could become a major importer within four years.[6]

And China is not alone. More and more people in the global South are using as much energy on average as people in the North do, and studies suggest that their incomes are rising faster than those in the industrial world.[7] Demand for energy will continue to rise as people in developing countries increasingly adopt the transportation systems, diets, and lifestyles of consumers in the world's richest nations. The International Energy Agency (IEA) projects that, between 2000 and 2030, global energy consumption will increase 66 percent and electricity use could double.[8] The largest share of this growth will likely occur in the developing world.

New conventional power plants will come on line in China by 2006, easing current shortages. But they will be only temporary fixes for an emerging challenge that developing and industrial nations alike must soon confront: how to satisfy the world's voracious and growing appetite for energy, which is relentlessly increasing the pressure on non-renewable resources, public health and welfare, international stability, and the natural environment.

Even at current global consumption rates, many analysts predict that world oil production will peak before 2020, and while the world will technically never run out, fossil fuels will become increasingly difficult and expensive to extract.[9] According to Harry Shimp, former president of BP Solar, "In 20 to 25 years the reserves of liquid hydrocarbons are beginning to go down so we have this window of time to convert over to renewables."[10] Of greater concern to many, however, is not when or if economically recoverable fossil fuel reserves will be depleted, but the fact that the world cannot afford to use all the conventional energy resources that remain.

Worldwide, there is a growing realization that climate change, caused primarily by the burning of fossil fuels, is a more serious threat to the international community than terrorism and that it "remains the most important global challenge to humanity."[11] The Intergovernmental Panel on Climate Change (IPCC), a body of 2,000 scientists and economists that advises the United Nations on climate change, has concluded that global carbon dioxide (CO_2) emissions must be reduced at least 70 percent over the next 100 years to stabilize atmospheric CO_2 concentrations at 450 parts per million, which would be 60 percent higher than pre-industrial levels.[12] There is evidence that effects of global warming are already being felt worldwide, as weather-related disasters grow more frequent and costly and associated death rates rise.[13] The sooner societies begin to reduce their emissions, the lower will be the impacts and associated costs of both climate change and emissions reductions.

Other environmental costs of conventional energy production and use include the damage wrought by resource extraction; air, soil, and water pollution; acid rain; and biodiversity loss. Conventional energy requires vast quantities of fresh water. Mining and drilling affect the way of life and very existence of indigenous peoples worldwide. Urban air pollution from burning fossil fuels is responsible for hundreds of thousands of premature deaths each year around the world.[14] In the European Union, the environmental and health costs associated with conventional energy (and not incorporated into energy prices) are estimated to equal 1–2 percent of the EU's GDP, excluding costs associated with climate change.[15] (See Table 1.)

The direct economic and security costs associated with conventional energy are also substantial. Nuclear power is one of the most expensive means of generating electricity, even without accounting for the risks of nuclear accidents, waste, and weapons proliferation. All conventional power plants face risks of conflict, sabotage, accidents, or even disruption of fuel supply. And massive and costly power blackouts are difficult to avoid in highly centralized systems of production and distribution based on fossil fuels and nuclear power.

Political, economic, and military conflicts over limited energy resources will intensify as global demand increases. Similarly, as demand rises and supply becomes further concentrated in the world's unstable, resource-rich regions, the prices of oil

TABLE 1

Costs of Electricity With and Without External Costs

Electricity Source	Generating Costs	External Costs	Total Costs
	(U.S. cents per kilowatt-hour)		
Coal/lignite	4.3–4.8	2.3–16.9	6.6–21.7
Natural gas (new)	3.4–5.0	1.1–4.5	4.5–9.5
Nuclear	10–14	0.2–0.8	10.2–14.8
Biomass	7–9	0.2–3.4	7.2–12.4
Hydropower	2.4–7.7	0–1.1	2.4–8.8
Photovoltaics	24–48	0.7	24.7-48.7
Wind	3–5	0.1–0.3	3.1-5.3

Notes: Generating costs are for the United States and/or Europe. External costs are environmental and health costs for 15 countries in Europe, and are converted to U.S. cents from eurocents at the 2003 average exchange rate of US$1=€0.8854.
Sources: See Endnote 15 for this section.

and gas will become increasingly erratic, affecting the stability of economies around the world. In fact, there is increasing evidence that a rise in fossil fuel prices or volatility leads to economic decline, even global recessions.[16] Further, the economic costs of relying on imported fuels are extremely high. African countries, for example, spend an estimated 80 percent of their export earnings on imported oil.[17] Conversely, the benefits of reducing imports can be significant. Brazil's 27-year-old ethanol program, which displaces about 220,000 barrels of oil daily, has saved Brazil more than $52 billion in avoided fuel imports, many times the total investments in ethanol production.[18]

Change is never easy, and there are strong forces (including politically powerful industries) acting to maintain the status quo. Yet while the world remains sharply divided over what kind of energy future must lie ahead, political support for renewable energy is on the rise as strong new legislation opens markets for renewable energy in a rapidly growing list of countries. Many nations view renewable energy as not only a credible alternative to fossil fuels, but also a necessity to meet growing energy needs without sacrificing quality of life, human health, the natural environment, and national security.

New renewable resources provide only a small share of global energy production today.[19] (See Figures 1 and 2.) Yet renewable energy technologies have the potential to meet world energy demand many times over and are ready for use on a large scale.[20] (See Table 2, page 16.) Renewable energy can generate electricity, heat and cool space, perform mechanical work such as water pumping, and produce fuels—in other words, everything that conventional energy does.

Moreover, the advantages of shifting from conventional energy to renewable energy are numerous and compelling. Renewable technologies impose significantly lower social, environmental, and health costs than do conventional fuels and technologies. They are generally domestic, pose far fewer fuel and transport hazards, and are much less vulnerable to terrorist attack. Generating power locally with solar or wind energy, for example, reduces or eliminates transmission and distribution losses, which range from 4 to 7 percent in industrial nations to more than 40 percent in parts of the developing world.[21] Renewable technologies can be installed rapidly and in dispersed small- or large-scale applications—getting power quickly to areas where it is urgently needed, delaying or avoiding investment in expensive new electric plants or power lines, reducing investment risk, and promoting economic development. All renewables except biomass energy avoid fuel costs and the risks associated with future fuel price fluctuations. It has been estimated that investments required over a 10-year period to make renewables competitive worldwide within two decades would be far lower than the economic costs of a single 10-percent increase in oil prices, and would be modest in comparison with existing flows for energy sectors worldwide.[22]

Renewables can provide reliable power for businesses in developing countries like China and India where power cuts are common. India's former minister for nonconventional energy sources, M. Kannappan, has declared that renewables have "enormous potential to meet the growing requirements of the increasing populations of the developing world, whilst offering sustainable solutions to the threat of global climate change."[23] Developing countries that invest

FIGURE 1

World Energy Use by Source, 2000

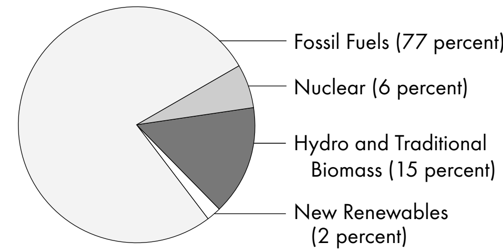
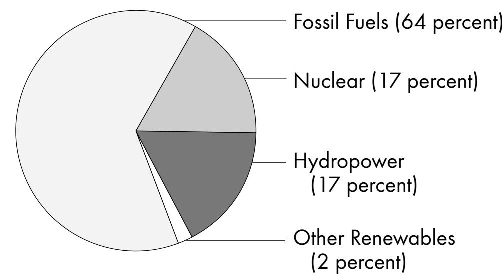


FIGURE 2

World Electricity Generation by Type, 2001



Sources, Figures 1 and 2: See Endnote 19 for this section.

in renewables will discover that they are energy-rich—that they can leapfrog over the dirty technologies relied on by early industrializing countries and can develop their economies with clean, domestic, secure sources of energy that avoid long-term and costly imports.

Further, "renewables [are] not just about energy and the environment but also about manufacturing and jobs." This ringing endorsement came from U.K. Energy Minister Brian Wilson in July 2002, after the commissioning of a new 30-megawatt wind farm in Argyll, Scotland. The Kintyre Peninsula of Argyll once thrived on its fisheries, whiskey production, and textile manufacturing. But these traditional sources of employment are in decline, and now wind power is breathing new life into the region's economy, generating power for 25,000 homes and producing new jobs.[24]

TABLE 2

Global Renewable Resource Base (Exajoules/year)

Resource	Current Use	Technical Potential
Hydropower	10	50
Biomass	50	>250
Solar	0.2	>1,600
Wind	0.2	600
Geothermal	2	5,000
Total Renewables	62.4	>7,500
Total Global Energy Use, 2000	422.4	–

Notes: Data are for late 1990s. Total global energy use includes traditional biomass. Technical potential is based on available technologies and will increase as technologies improve.
Sources: See Endnote 20 for this section.

Around the world, using renewables stimulates local economies by attracting investment and tourists (and their money) and by creating employment. Many of the jobs are high-wage and high-tech, and require a range of skills, often in rural or economically depressed areas.[25] A recent study concluded that increasing the use of renewable energy technologies in California would create four times more jobs than continued operation of natural gas plants, while keeping billions of dollars in California that otherwise would go for out-of-state power purchases.[26]

Many of the components, if not entire systems, for solar homes, wind farms, and other renewable technologies are now manufactured or assembled in developing countries, creating local jobs, reducing costs, and keeping capital investments at home. For example, China and India have both developed domestic wind-turbine manufacturing industries, with Indian firms producing about 500 MW of turbines annually for domestic use and export.[27]

The many advantages of renewables led the Task Force on Renewable Energy of the Group of Eight (G8) industrial countries to conclude in 2001 that "though there will be a higher cost in the first decades, measured solely in terms of the costs so far reflected in the market, successfully promoting renewables over the period to 2030 will prove less expensive than taking a 'business as usual' approach within any realistic range of discount rates."[28]

Technology and Market Development

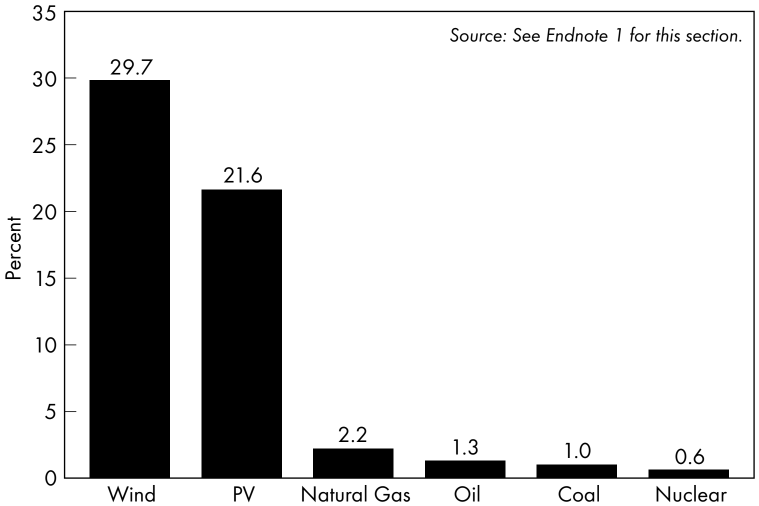
Since the 1980s, renewable technologies have improved significantly in both performance and cost, with some undergoing rates of growth and technology advancement comparable to the electronics industry. Wind and solar power are the fastest-growing energy sources in the world.[1] (See Figure 3, page 18.) By some estimates, new renewables already account for well over 100,000 megawatts (MW) of grid-connected electric capacity. Globally, new renewable energy supplies the equivalent of the residential electricity needs of more than 300 million people.[2]

In 1999, the International Energy Agency noted that "the world is in the early stages of an inevitable transition to a sustainable energy system that will be largely dependent on renewable resources."[3] This is a bold statement for an organization that represents North America, Europe, and Japan—areas that depend so heavily on fossil fuels. But it seems logical, given the many problems associated with the use of conventional energy and the tremendous surge in renewable energy investments over recent years.

Global investment in renewable energy exceeded $20.3 billion in 2003, and cumulative investments totaled at least $100 billion between 1995 and 2003.[4] Markets for new renewable energy are expected to approach $85 billion annually within the next decade.[5] The technical progress of many renewable technologies has been faster than anticipated even a few years ago, and this trend is expected to continue. While costs are still a concern with some technologies, they are falling rapidly due to technological advances, automated manufacturing, economies of scale through increased production volumes, and learning by doing.[6]

FIGURE 3

Average Annual Increase in Installed Capacity, 1993–2003



Solar and wind are the best-known renewables, but inexhaustible energy supplies are also offered by biomass, geothermal, hydropower, ocean energy (from tides, currents, and waves), and ocean thermal energy. The remainder of this paper focuses on wind power and photovoltaics for electricity generation because they are the fastest-growing renewables, they share the challenges of being intermittent and having high up-front capital costs, solar and wind resources are nearly ubiquitous, and they have the greatest potential for helping all countries to achieve a more sustainable energy future.

During the past two decades, wind energy technology has evolved to the point where it can compete with conventional forms of power generation at good sites. Costs have declined 12–18 percent for each doubling of global capacity.[7] As a result, the average cost of wind-generated electricity has fallen from about 46 cents per kilowatthour (kWh) in 1980 to 3–5 cents/kWh at good wind sites today.*[8] Costs vary from one location to the next due primarily to variations in wind speed and different institutional frameworks and interest rates. By 2010, onshore wind generation costs will likely be lower than natural gas costs, and offshore wind costs could fall by 25 percent.[9] As costs fall, it will become economical to site turbines in regions with lower wind speeds, increasing the global potential for wind-generated electricity.

* 1980 costs are for United States only. All costs are in 2003 U.S. dollars.

The main trends in wind technology development are toward lighter and more flexible blades, variable speed operation, direct-drive generators, and taller machines with greater capacity.[10] The average turbine size has increased from 100–200 kilowatts (kW) in the early 1990s to more than 1,200 kW today, making it possible to produce more power with fewer machines.[11] (One 1,200 kW machine can provide the electricity needed by about 720 European homes.) Larger machines are available for use on land, and turbines with capacity ratings as high as 5,000 kW (5 MW) are being manufactured for use offshore.[12] Small wind machines that can be installed close to the point of demand (atop buildings, for example) are also under development.[13] Advances in turbine technology and power electronics, along with a better understanding of siting needs and wind energy resources, have combined to extend the lifetime of today's wind turbines, improve performance, and reduce costs.[14] (See Sidebar 1, page 20.)

Global wind capacity has grown at an average annual rate of nearly 30 percent during the past decade.[15] (See Figure 4, page 21.) An estimated 8,250 MW of wind capacity were added worldwide in 2003, bringing the total to nearly 40,290 MW—enough to provide power to more than 19 million average European households.[16] It has taken 25 years to reach this total; if the industry's projections hold true, another 110,000 MW could be added in only nine years.[17] Wind is now generating electricity in at least 48 countries.[18] However, Europe accounts for more than 70 percent of total global capacity, and most of these installations are in only three countries (Germany, Denmark, and Spain) where onshore markets have begun to peak due to some market saturation, and offshore projects have experienced slow starts. But the overall health of the industry is good, and

SIDEBAR 1

Examples of Advances in Wind Technology

The U.S. Department of Energy's Sandia National Laboratory is developing turbines with lighter, larger, slower-rotating blades to reduce costs and produce power at less windy sites. These next-generation turbines could expand wind development potential as much as 20 times.

Mathematical climate models have been developed in Germany and Denmark to predict wind resources 24–36 hours in advance with reasonable accuracy. This will be important for managing wind power capacity as it reaches a high percentage of the total electric system.

Vestas now equips offshore turbines with sensors to detect wear and tear on components, along with backup systems to cope with electronic system power failures.

Sources: See Endnote 14 for this section.

significant projects are in the pipeline in the United Kingdom and other countries that could become wind powerhouses of the future.[19] Global sales of wind power worldwide exceeded $9 billion in 2003 and are predicted to reach $49 billion annually by 2012.[20] It is estimated that more than 100,000 people are now employed in the wind industry worldwide.[21]

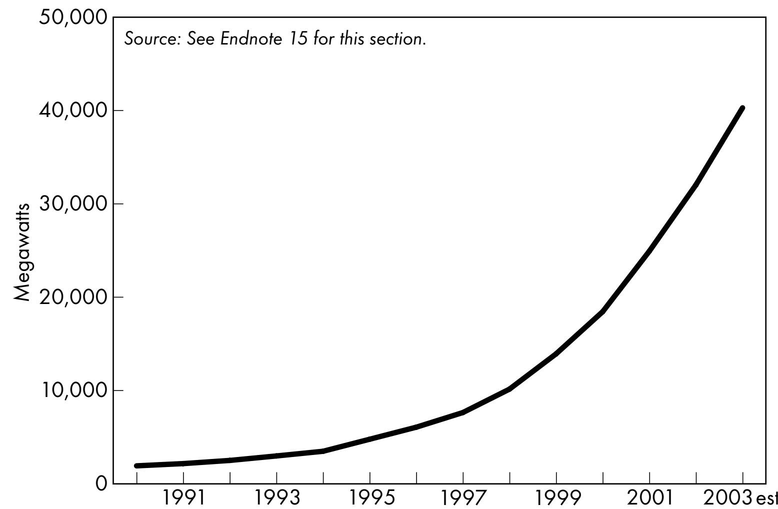
The majority of turbines operating today are on land, but new markets are opening for wind power offshore, mainly in Europe, because the resource is huge and wind speeds at sea are considerably higher and more consistent. (Stronger winds generate more electricity, while consistency reduces wear and tear on machines.) By the end of 2003, turbines with a combined capacity of 529 MW were spinning offshore, all of them in Europe, with an additional 8,600 MW planned for construction through 2008.[22]

Resource analysis shows that onshore wind resources could supply more than four times as much electricity as is now consumed worldwide. Offshore resources are substantial as well. While some of that potential is too costly to exploit over the near term, the promise of large amounts of wind power at competitive prices is enormous.[23]

As with all energy technologies, there are disadvantages

FIGURE 4

Cumulative Global Wind Capacity, 1990–2003



associated with wind power. The environmental factor that has caused the most controversy and concern is bird mortality. This is a site-specific problem, however, and it is far less significant than other hazards to birds, such as vehicles, buildings, cell phone towers, and (the primary threat) habitat loss. Progress has been made in reducing bird strikes through the use of painted blades, slower rotational speeds, tubular turbine towers, and careful siting of projects.[24]

Both wind and sun are intermittent resources; they cannot be turned on and off as needed. But there is no guarantee that any resource will be available when it is required, and utilities must have backup power for generation every day. Assessments in Europe and the United States have concluded that intermittent sources can account for up to 20 percent of an electric system's generation without posing technical problems; higher levels might demand minor changes in operational practices.[25] Wind power's contribution already exceeds 20 percent in regions of Germany, Denmark, and Spain, and distributed generation—for example, the use of solar panels on rooftops, or clusters of turbines along the path of a power line—

can improve electric system reliability.

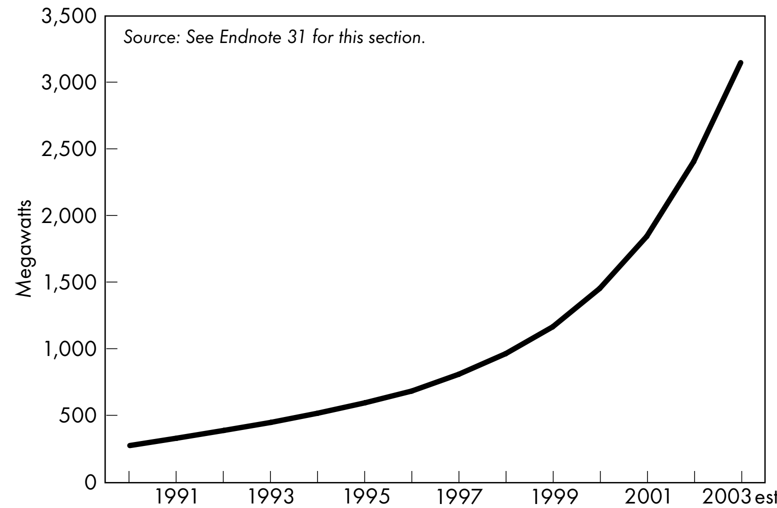
The challenges posed by intermittency are not of immediate concern in most countries, where the share of electricity from the sun and wind are far from 20 percent. Where necessary, they will be addressed via hybrid systems (for example, a mix of wind- and hydropower), improvements in wind forecasting technology, and further development of storage technologies.[26] New storage technologies could also help tap renewable resources that are far from demand centers. Furthermore, what is most significant is the cost of electricity generated. Wind power costs continue to fall, and at good locations are competitive with all conventional technologies. Solar PVs are likely to see dramatic cost reductions, and they produce power in the middle of hot summer days when demand is greatest and electricity costs are highest. High-tech solutions now under development, such as "smart grids" (which use advanced computer controls to enable more efficient, resilient, and safe distribution of power) can provide renewable energy with easier access to energy markets while improving the performance and cost of renewable energy systems.[27]

According to the U.S. National Renewable Energy Laboratory, PV technologies have the "potential to become one of the world's most important industries." The potential PV market is enormous, ranging from consumer products (such as calculators and watches) and remote stand-alone systems for electricity and water pumping to grid-connected systems on buildings and large-scale power plants.[28] Today, 60–70 percent of solar electric power is fed to electric grids.[29]

Each year the sun delivers to Earth more than 10,000 times the energy that humans currently use.[30] While PV systems account for a small share of global electricity generation, they have undergone dramatic growth over the past decade. Since 1993, global PV production has increased at an average annual rate exceeding 28 percent, and growth rates have risen almost every year. It took nearly 30 years, until 1999, for the world to produce its first gigawatt (GW) of PV capacity; by the end of 2003, this total had tripled.[31] (See Figure 5.) The PV industry generated sales worth more than $5.2 billion in

FIGURE 5

Cumulative Global Photovoltaic Production, 1990–2003



2003, and provides tens of thousands of jobs.[32] It is projected that the industry will surpass $27.5 billion in annual sales (including components and installation) by 2012.[33] More than a million households in the developing world now have electricity for the first time from PVs, while well over 100,000 households in industrial countries supplement their utility power with PV systems.[34]

PV technology has advanced significantly over the years, primarily through incremental improvements. Crystalline silicon cells and modules, which now dominate the market, have achieved commercial efficiencies of 12 to 15 percent; they could reach 20 percent by 2010 and 30 percent or higher in the longer term.[35] Sanyo has developed a technology combining amorphous silicon and crystalline silicon that has achieved module efficiencies of 17 to 19 percent, and other major players are developing single-crystal silicon modules with similar efficiency rates. As a result, even the typically small rooftops in Japan can generate as much power as the average Japanese household consumes, allowing for "zero-energy" homes.[36] The industry is now highly competitive with a host of technologies, including multi-crystalline and triple-junction cells, amorphous thin films, polymers, dyes, concentrating lens PV hybrids, and nanotechnology.[37] (See Sidebar 2.)

Solar cell production is concentrated in Japan, Europe, and the United States, but there are growing markets and manufacturing bases in developing countries as well, including China and India. Global PV output is expected to increase by 25 percent per year through 2010.[38] As larger factories come into operation, manufacturers can increase the degree of automation.

Such evolving industrial processes, along with technological advances and economies of scale, have led already to significant cost reductions. Since 1976, costs have dropped 20 percent for every doubling of installed PV capacity, or about 5 percent annually.[39] Module prices have declined from about $30 per watt ($/W) in 1975 to below $4/W today, with some bulk purchases costing less than $3/W.[40] Globally, total system costs—including balance-of-system components such as inverters, and installation—range from a low of $5.25–5.50/W in Japan, to $6–8/W in California, to a high of $20/W for remote, off-grid systems.[41]

As with wind energy, actual generating costs are determined by capital costs (for modules, other system components, and installation), interest rates, and the available resource. Generating costs worldwide now range from $0.11 to $1.00 per kWh, which is still extremely high at the upper end, and cost remains the primary barrier to more widespread use.[42] Yet PVs are the cheapest option for many remote or off-grid functions. When used for building facades, they can be cheaper than other materials such as marble or granite, with the added advantage of producing electricity.[43] And PV systems are now competitive on-grid at all times in Japan, and at peak demand times in California, where government policies and private investments have led to reduced costs through economies of scale in production and experience with installation.[44] Around the world, companies are racing to create future generations of products to make PVs cost-competitive for on-grid use elsewhere as well. Many manufacturers aim for a module price of $1 per peak watt.[45]

SIDEBAR 2

The Solar Race

The U.S. National Renewable Energy Laboratory (NREL) and Spectrolabs have developed a Triple-Junction Terrestrial Concentrator Solar Cell that is 34 percent efficient and can be manufactured for less than $1 per watt, according to NREL.

"Spheral Solar" technology developed in Canada will bond tiny silicon beads into an aluminum foil, allowing for flexible, lightweight, dramatically cheaper solar cells for a broad range of new PV uses. Plans were announced in late 2003 to commercialize the technology and build a 20-MW production facility.

U.S. Evergreen Solar, Inc. has successfully produced a prototype technology that enables the growth of four silicon ribbons from one furnace. String ribbon technology can yield more than twice as many solar cells per unit of silicon than conventional methods, reducing costs and waste.

German solar cell manufacturer Sunways recently released "Solar Blinds," a product that can protect buildings against bad weather, sun, and burglary while also producing electricity.

Sources: See Endnote 37 for this section.

Costs have already declined faster than many believed possible, using existing technologies.[46] Sharp reduced per-unit costs 30–35 percent by scaling up to a 200 MW manufacturing plant that allowed for increased automation and bulk purchases of inputs such as glass.[47] Future PV cost reductions are expected to occur primarily through continued incremental improvements in materials and module efficiency, reduced costs and increased lifetime of balance-of-system components, experience with installation, and economies of scale in production.[48] Experts believe that on-grid rooftop systems could be competitive with conventional generation in the United States within a decade, even without incentives.[49]

In addition to cost, one of the primary concerns regarding PV's ability to meet a major portion of global electricity demand is the length of time cells must operate to produce as much energy as was used to manufacture them. The energy "pay-back" period for today's modules in rooftop systems is 4–6 years, depending on the technology, with expected lifetimes of up to 30 years. Payback periods will decline as the energy efficiency of production increases.[50] PV manufacture also requires hazardous materials, including many of the chemicals and heavy metals used in the semiconductor electronics industry. There are techniques and equipment to reduce the environmental and safety risks, however, and these problems are minimal compared with those associated with conventional energy technologies.[51]

According to the International Energy Agency, buildings in industrialized nations offer enough suitable surfaces for PV to generate 15–50 percent of current electricity needs.[52] Other surfaces, such as parking lots and brownfields, could increase this share. Most on-grid PV today is used in rooftop systems, but several large, centralized PV power plants are in the works. There are plans for at least two major projects (of 5 MW and 18 MW) to be built in Germany during 2004.[53] And such projects pale in comparison to other possibilities for PV. An IEA study concluded that very-large-scale PV systems installed on 4 percent of the world's deserts could produce enough electricity annually to meet world power demand, while helping to prevent further desertification. The Gobi Desert area between western China and Mongolia could generate as much electricity as current world primary energy supply.[54]

Global markets for renewables are only just beginning a dramatic expansion, starting from relatively low levels. It is useful to point out, however, that despite increasing concerns regarding safety and high costs, it took fewer than 30 years for nuclear power to develop into an industry that supplies 17 percent of global electricity demand. The same can happen with renewable technologies. In fact, since 1993 the nuclear power industry has added only 59 percent as much capacity to the world's electric grid as the wind industry.[55] If the average annual market growth rates of PV (37 percent) and wind (26 percent) over the past five years were to continue to 2020, the world would have nearly 570,000 MW of installed solar PV capacity and more than 2 million MW of wind capacity. Wind alone could supply one-fifth the electricity projected to be used worldwide in 2020.[56] Such continued growth is unlikely, but recent industry reports have concluded that if the necessary institutional framework is put in place, it is feasible for wind to meet 12 percent of global electricity demand by 2020 and for PVs to meet 26 percent by 2040.[57]

The rapid expansion of renewable technologies over the past decade has been fueled by a handful of countries that have adopted ambitious, deliberate government policies aimed at advancing renewable energy through sustained and orderly market growth. These successful policy innovations have been the most important drivers in the advancement and diffusion of renewable technologies. By examining the policies that have succeeded over the past two decades, as well as those that have failed, we can better understand what is required to launch a global takeoff in renewables in the decade ahead.

Two Success Stories: Germany and Japan

Since the early 1990s, Germany and Japan have achieved dramatic successes with renewable energy and today lead the world in the use of wind and solar power, respectively. The common elements to their stories are long-term commitments to advancing renewable energy, effective and consistent policies, the use of gradually declining subsidies, and an emphasis not only on government R&D but also on market penetration.

When the 1990s began, Germany had virtually no renewable energy industry and seemed unlikely ever to be in the forefront of these technologies. Yet within 10 years Germany had transformed itself into a renewable energy leader. With a fraction of the potential in wind and solar power as the United States, Germany now has more than twice as much installed wind capacity (more than one-third of global capacity) and is a world PV leader as well. In the space of a decade, Germany created a new, multibillion-dollar industry and tens of thousands of new jobs.

Driven by growing public concerns about the safety of nuclear power, the security of energy supplies, and the environmental impacts (including climate change) of energy use, the German government passed an energy law in 1990 that required utilities to purchase the electricity generated from all renewable technologies in their supply areas, and to pay a minimum price for it—at least 90 percent of the retail price, in the case of wind and solar power. The "Electricity Feed-in Law" was inspired in part by similar policies that had proved effective in neighboring Denmark. The preferential payments for renewable energy are intended to help internalize the costs of conventional energy and compensate for the benefits of renewables.[1]

This pricing law has been adjusted many times since it took effect in 1991. Most significantly, in 2000 the German Bundestag required that renewable electricity be distributed among all suppliers based on their total electricity sales, ensuring that no one region would be overly burdened. With scientific input and advice from the various renewables industries, the Bundestag established specific per-kilowatthour payments for each renewable technology, based on the real costs of generation. The tariffs are paid for 20 years, while the rate for new projects is adjusted regularly to account for changes in the marketplace and technological advances. Electric utilities also qualify for these tariffs, thus reducing utility opposition while further stimulating the renewable energy market.[2]

Soon after the first pricing law was established, farmers, small investors, and start-up manufacturers started to create a new industry from scratch, and wind energy development in Germany began a steady and dramatic surge. Some barriers to renewables remained, but as each new hurdle arose the government enacted laws or established programs to address it. Obstacles to wind, for example, included lengthy, inconsistent, and complex siting procedures. The government responded by encouraging communities to zone specific areas for wind. As of 2000, grid operators were required to connect plants at the most suitable location and pay for necessary upgrading, eliminating barriers that arose when utilities discouraged wind development through inflated connection-related charges.[3]

Germany addressed the challenge of renewables' high initial capital costs through low-interest loans offered by major banks and refinanced by the federal government.[4] Until mid-2003, the "100,000 Roofs" program provided 10-year low-interest loans for PV installation (it ended early when all targets were met). In addition, income tax credits granted for projects and equipment that meet specified standards have provided tax deductions against investments in renewable energy projects. Over the years, these credits have drawn billions of dollars to the renewables industries.[5]

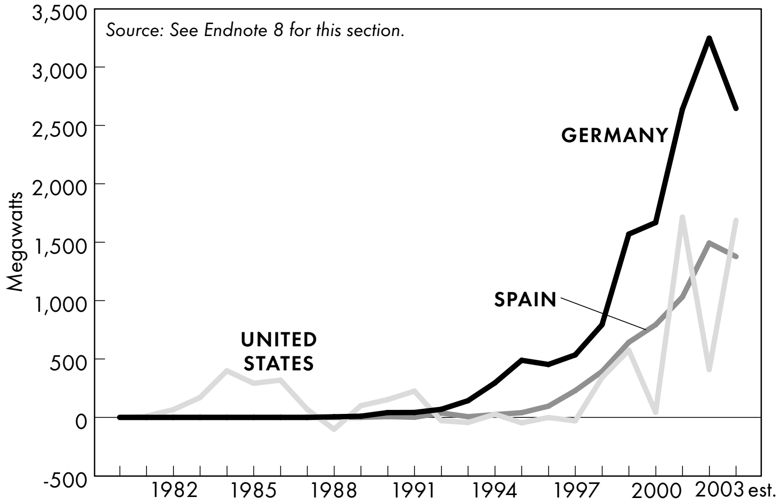
In addition, the federal and state governments have funded renewable resource studies on- and off-shore, have established institutes to collect and publish data, and have advanced awareness about renewable technologies through publication of subsidies and through architectural, engineering, and other relevant vocational training programs.[6]

Of all these policies, the pricing law has had the greatest impact. It ended uncertainties regarding whether, and at what price, producers could sell electricity into the grid. It also boosted investor confidence, making it easier for even small producers to obtain bank loans and drawing money into the industries. Increased investment drove improvements in technology, advanced learning and experience, and produced economies of scale that have led to dramatic cost reductions. The average cost of manufacturing wind turbines in Germany fell 43 percent between 1990 and 2000, and the cost of total PV systems declined 39 percent between 1992 and 2002.[7]

Not surprisingly, German wind capacity has mushroomed, from 56 MW in 1990 to more than 14,600 MW in 2003.[8] (See Figure 6, page 30.) Germany passed the United States to become the world's leading wind energy producer in 1997. Wind power now meets more than 6 percent of Germany's total electricity demand, up from 3 percent in late 2001.[9] In the northern reaches of the country, where most of the development is concentrated, wind power provides as much as 29 percent of annual electricity needs, close to nuclear power's share for Germany as a whole.[10] As for PV, since 1992 it has grown at an average annual rate of nearly 47 percent. Germany ended

FIGURE 6

Wind Power Capacity Additions in Germany, Spain, and the United States, 1980–2003



2003 with 417 MW of PV capacity, mostly on-grid, and is now second only to Japan in PV capacity.[11] To meet rapidly rising demand, major German manufacturers plan to expand PV manufacturing facilities significantly over the next few years, which will further reduce costs and increase employment.[12]

In 2002 alone, the sales in German renewable energy industries totaled nearly $11 billion.[13] Some 45,000 people worked in Germany's wind industry by early 2003, one-fifth of them hired the previous year.[14] The 100,000 Roofs program alone created an estimated 10,000 new jobs, at a cost of $27,000 per position, and Germany accounts for most of Europe's PV installations.[15] Germany also boasts Europe's largest shares of biogas capacity and solar thermal water heaters.[16] With so many Germans employed in renewables industries or owning shares in wind turbines, solar, or other projects, renewable energy enjoys broad support.

Germany has pledged to reduce its CO_2 emissions 21 percent below 1990 levels by 2010, and plans to accomplish much of this through increased use of renewable energy.[17] To date, renewable energy is responsible for 50 million tons (6.25 percent) of Germany's total CO_2 emissions reductions.[18] The government aims for wind power to meet 25 percent of national electricity needs by 2025, with a target of 25,000 MW of wind capacity offshore, and also considers solar PV as a viable long-term option for large-scale power generation.[19] By 2050, Germany intends to meet at least half of its total energy needs with renewable sources.[20] The total costs of market development programs for all new energy technologies through 2050 appear to be significantly lower than the total spent over all years on coal.[21]

Japan's story with PV is similar to Germany's experience with renewables. It rose from a minor player in the early 1990s, manufacturing PV units primarily for use in calculators and watches, to become the world's largest producer and user in less than a decade. With far less land area and about half the solar insolation of California, Japan now has three times as much PV capacity as the entire United States.[22]

Driven by concerns about energy security and climate change, Japan has enacted effective and consistent policies to promote PV, and has retained them even through major budget crises. The "New Sunshine" program was established in 1992 to introduce renewable energy throughout the country. Targets were set and a new net metering law enacted to require utilities to purchase excess PV power at the retail rate.[23] Two years later, Japan launched the "Solar Roofs" program to promote PV through low-interest loans, a comprehensive education and awareness program, and rebates for grid-connected residential systems in return for data about systems operations and output. At the time, Japan had about 31 MW of installed PV and accounted for less than one-fourth of global PV manufacture.[24]

The residential rebates started at 50 percent of installed costs and declined gradually over time. In 1997, rebates were extended to owners and developers of housing complexes as well, and Japan became the world's largest supporter of PV with a seven-fold increase in funding for the expanded program, which became known as the "70,000 Roofs" program. The budget for the residential PV dissemination program increased from $20 million in 1994 to a peak of $219 million in fiscal year 2001; the FY 2004 budget is just under $49 million.[25]

Government promotion of PV has included publicity on television and in print media.[26] The national government has also encouraged the use of PV in government office buildings, and many local governments provide PV subsidies and low-interest loans.[27] As a result of Japan's net metering law, between April 2001 and March 2002 alone, Japanese electric power companies bought more than 124 GWh of surplus PV power at retail rates.[28]

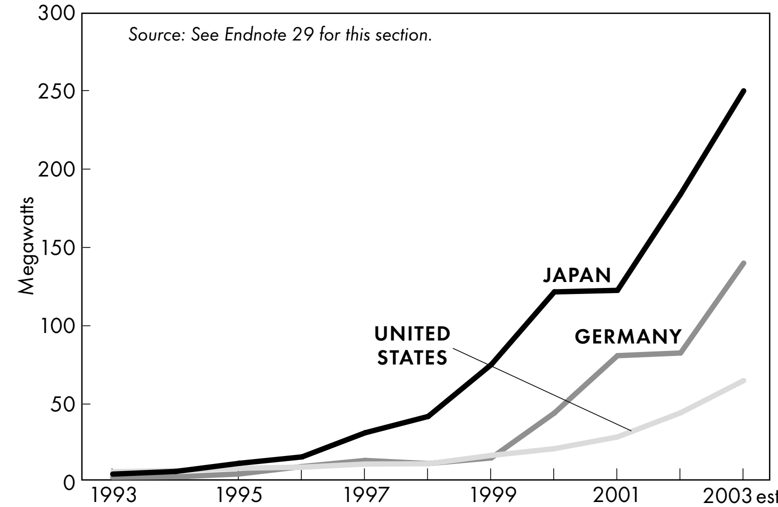
The goal of Japan's PV program has been to create market awareness and stimulate production in order to reduce costs through economies of scale and technology improvements, and thereby enable large-scale power generation and the export of PV products to the rest of the world. Japan is now the world's leader in the manufacture and use (i.e., capacity) of solar PV, having surpassed the United States in both respects in the late 1990s.[29] (See Figure 7 regarding capacity.)

A number of policies have contributed to PV's success in Japan, but the 70,000 Roofs program is considered by some to be the most important government PV program in history.[30] While some subsidies remain at the national, state, and municipal levels, the Solar Roofs program ended officially in 2002 after exceeding all objectives.[31] The program resulted in the installation of more than 144,000 residential systems, with capacity totalling 424 MW.[32] Nearly 43,000 households applied for program funding in 2002 alone, when subsidies were down to about $1/W.[33] Primarily due to the residential program, total installed PV capacity in Japan has increased an average of more than 43 percent annually since 1993, totalling 887 MW by the end of 2003.[34] The government aims for total PV installations to reach 4,820 MW by 2010.[35]

Despite the decline in subsidies, new home installations continue to rise as costs fall, and Japan's PV market is expected to continue growing by 20 percent annually over the next several years.[36] By some accounts, small-system costs in Japan have dropped more than 80 percent since 1993, far more rapidly than the decrease in global module costs over this period.[37] Installed

FIGURE 7

Photovoltaic Capacity Additions in Japan, Germany, and the United States, 1993–2003



costs of residential grid-connected systems have fallen from $11/W in 1995 to about $5.50/W in 2003, not including subsidies.[38] As a result, on-grid PV-generated power in Japan, at 11–15 cents/kWh, is now cheaper than retail electricity.[39]

To keep up with rising demand, Japanese PV manufacturers have invested significantly in plants and equipment, increasing their production capacity by nearly 47 percent in 2002 and 45 percent in 2003.[40] Japan was responsible for half of global PV production in 2003, and Sharp has been the world's leading producer of solar cells since 2000.[41]

Policy Lessons From Around the World

It is difficult to claim that something is impossible once it has already occurred. This is why it is globally significant that two of the world's largest economies transformed themselves from laggards to leaders in renewable technologies in less than a decade. What Germany and Japan have accomplished can be replicated elsewhere—with the right mix of policies.

For renewable energy to make as large as possible a contribution to economic development, job creation, lower oil dependence, and reduced greenhouse gas emissions, it is essential to improve the efficiency of technologies, reduce their costs, and develop mature, self-sustaining industries. Today's energy markets frustrate efforts to achieve these goals because of lack of access to the electric grid at reasonable prices, high initial costs compared to conventional energy sources, and widespread ignorance about the scale of resources available, the pace of development of renewable technologies, or the potential economic advantages of renewable energy.

The dramatic successes seen in Germany and Japan stem from a range of policies introduced to address these barriers. They demonstrate that policies play a far greater role than a nation's resource base in determining its renewable energy generation. They also demonstrate that, in addition to the global learning curve that is driving down technology costs, there is a national learning curve that drives domestic costs down even faster and further as countries develop domestic industries to manufacture, install, and maintain renewable systems using local equipment and labor. The experiences of Germany, Japan, and other countries provide an array of promising policy options that can be disseminated around the world.

There are five major categories of relevant policies:

1. Market Access and Obligations. As Germany's experience demonstrates, access to the market is imperative for renewables to gain a foothold. Two main types of regulatory policies have been used to open the electric grid to renewables. The first is pricing laws, which guarantee renewable producers fixed, minimum prices and obligate electric utilities to provide grid access to renewable energy plants. Fixed payments, or tariffs, are paid over several years, and often decline over time to reflect cost reductions. The costs of the pricing system are covered by energy taxes or an additional per-kilowatthour charge on electricity consumers.

Spain, Denmark, and several other countries have enacted similar pricing laws. Before Spain passed a pricing law in 1994, few wind turbines were spinning in the Spanish plains and mountains, but by the end of 2000 the country ranked third in the world in wind installations.[1] Spain generated 5 percent of its electricity from wind in 2003 and is now home to some of the world's largest turbine manufacturers.[2] Denmark now generates more than 20 percent of its electricity from wind and has long been the world's wind-turbine leader.[3]

The marriage of a guaranteed market and long-term minimum payments has reduced investment risks, making it profitable to invest in renewable technologies and easier to obtain financing. By creating demand for renewable electricity, the pricing law has attracted private investment for R&D, spread the costs of technology advancement and diffusion relatively evenly across populations, and enabled the production scale-ups and the installation, operation, and maintenance experience needed to bring down the costs of renewable technologies and generation.

The second type of regulatory access policy, the quota system, works in reverse of pricing laws: governments set targets and let the market determine prices. Typically, governments mandate a minimum share of capacity or generation to come from renewable sources. As with pricing systems, the additional costs of renewable energy are borne by taxpayers or electricity consumers.

With the most common form of quota system (such as the Renewables Portfolio Standard, or RPS, used in several U.S. states), investors and generators comply with the quota by installing capacity, purchasing renewable electricity through a bidding process, or buying "green certificates" or "renewable energy credits." Generally certificates are awarded to producers for the renewable electricity they generate, and add flexibility by enabling utilities and customers to trade, sell, or buy credits to meet obligations. They can add value to renewable installations by creating a paper market separate from electricity sales, and can allow for trading and expanding renewable energy markets between states or countries.

Texas's RPS is primarily responsible for wind energy's rapid growth there since 1999, when the state required that 2,000 MW of additional renewable capacity be installed within a decade. Texas was more than halfway there with wind alone by mid-2002, and the target will likely be met long before 2009.[4] But the mandates alone have done little to encourage the use of more expensive technologies such as PV, despite vast solar resources in Texas. About one-fourth of U.S. states have enacted RPS laws, many of them experiencing less success than Texas.[5] RPS systems with enforced penalties for noncompliance and specific technology quotas are most effective at ensuring that targets are met and a range of technologies is developed. Mandated quotas are now used in several other countries as well, including Japan, the United Kingdom, Italy, and Australia.

Under tendering systems, another type of quota system, potential project developers bid to a public authority for contracts to fulfill their government mandate. Projects that are considered viable and that compete successfully on price terms against other bidders are offered contracts to receive a guaranteed price per unit of electricity generated. The government often covers the difference between the market reference price and the winning bid, and contracts are generally awarded for a period of several years.

The United Kingdom enacted a tendering system in 1989, and between 1990 and 1998 renewable developers competed for contracts in a series of bidding rounds. While this system made it easier to obtain financing, it created flurries of activity followed by long lulls with no development, making it difficult to build a domestic turbine manufacturing industry and infeasible for small firms or cooperatives to take part. Competition to reduce costs and win contracts led developers to seek sites with the highest wind speeds, often areas of scenic beauty, which increased public opposition to wind energy and made it harder to obtain project permits. The lack of deadlines allowed winning contractors to wait years for costs to fall before building projects.[6] When the program ended in 1999, more than 2,670 MW of wind capacity were under contract, but only 344 MW had been installed.[7] A new quota system based on renewable certificates has since been established, and capacity reached 649 MW by the end of 2003.[8] This system is expected to provide a significant boost for wind power, but it is still too early to tell what the impacts will be.

A variation on pricing laws, net metering, can be used in conjunction with quota systems. Net metering permits consumers to install small renewable systems and sell excess electricity into the grid at wholesale market prices. It differs from pricing laws primarily in scale and implementation, and is available in several countries, including Japan, Thailand, and Canada. At least 38 U.S. states, including California and Texas, have enacted such laws.[9] Success in attracting new renewable energy investments and capacity depends on the limits set on participation (capacity caps, number of customers, or share of peak demand); the price paid, if any, for net excess generation; the existence of grid-connection standards; enforcement mechanisms; and other available incentives.

Of these regulatory options, pricing laws have consistently proved to be the most successful to date. Although they have not succeeded in every country that has enacted them, those countries with the most significant growth and the strongest domestic industries have had pricing laws. While at least 48 countries have installed wind capacity, just three—Germany, Denmark, and Spain, all with pricing laws—account for more than 84 percent of total wind capacity installed in the European Union, and 59 percent of global capacity.[10]

Pricing laws can be designed to account for changes in the marketplace, encourage steady growth of small- and medium-scale producers, encourage private sector investment in R&D, offer ease of financing, and enable even average citizens to benefit from investments in renewable energy projects. Although some argue that pricing systems are more costly than quota systems, costs depend more on policy details than system type, and several studies have concluded that the average additional costs per household of the German pricing law have been minimal.[11] Further, both system types involve subsidies as they create protected markets for renewables. Quota systems have not been in use as long, so there is a lack of experience with them, but to date the record of such systems is more uneven and reveals a tendency toward boom-and-bust markets. However, success is determined by system details and by other policy mechanisms enacted in parallel.

2. Financial Incentives. Market compensation mechanisms (tax credits, rebates, loans, or payments) that subsidize investment in a technology or the production of power have been used extensively in Europe, Japan, the United States, and India. To encourage investment in renewables in the 1980s, the U.S. government and California offered investors credit against their income taxes, allowing them to recoup a significant share of their money in the first few years and reducing their risk. The credits played a major role in a wind boom that many called California's second gold rush. The lessons learned and economies of scale gained through this experience advanced wind technology and reduced its costs.[12] But enormous tax breaks and a lack of technology standards encouraged fraud and the use of untested and substandard equipment, some of which never generated a kilowatthour of electricity.[13]

India saw a similar boom a decade later, sparked by a combination of investment tax credits, financing assistance, and accelerated depreciation.[14] India is now the world's fifth-largest producer of wind power and has developed a domestic manufacturing industry. As in California, however, investment-based subsidies and a lack of standards or production requirements led wealthy investors to use wind farms as tax shelters, and several projects performed poorly despite the significant technology advancements since the early 1980s.[15]

Some countries, like Japan, have subsidized investment through rebates and have seen dramatic successes, with PV in particular. Twenty-four U.S. states offer PV rebates that cover a large share of the costs—up to 50 percent in California and Massachusetts, and 70 percent in New Jersey and New York.[16] Due to rebates and resulting cost reductions, some California builders now include PV on homes in entire subdivisions.[17] (See Sidebar 3.)

Since 1994, the U.S. government has offered a production tax credit to those who supply wind-generated electricity

SIDEBAR 3

Public Benefit Funds and Bond Initiatives

Fifteen U.S. states have established accounts to finance renewable energy projects, funded through small per-kilowatthour surcharges on electricity consumption. In early 2004, 15 such public benefit funds from 12 states announced formation of the Clean Energy States Alliance; CESA will invest $3.5 billion over the next decade to create larger markets than each fund could promote individually, thereby spurring innovation and producing more jobs.

California has the largest fund, created in 1996 as part of the state's electricity restructuring legislation. It has enabled California to provide production payments for existing and new renewable energy projects, as well as rebates for consumers who buy certified green power and for people investing in "emerging renewables" (PV, small-scale wind, solar thermal electric, and fuel cells powered with renewable hydrogen). Since 1998, California's PV program has helped reduce system costs by 50 percent, has dramatically increased grid-connected capacity, and has increased the number of in-state PV manufacturing, distribution, and installation companies. California is now the third-largest PV market in the world, with 10 times more installed PV capacity than any other U.S. state.

Another California program driving PV is the San Francisco Solar Bond Initiative. In 2001, city voters overwhelmingly approved a $100-million bond program to purchase renewable energy for public facilities. A combination of bulk purchasing and bundling of PV with wind energy and efficiency measures means that energy savings will cover the additional costs associated with PV. The program aims to increase public awareness, create jobs, drive down PV costs through economies of scale, and to make the city a world leader in the use of clean energy. Several other U.S. cities and states are considering following San Francisco's lead.

Sources: See Endnote 17 for this section.

to the grid. The credit has encouraged wind development, but only in states with additional incentives, and it provides greater benefit to producers with higher income levels and tax loads.[18] California has enacted a per-kilowatthour production payment, rather than a tax credit, for some existing and new renewable projects. It is financed through a small charge on electricity use, meaning that Californians share the cost of the program according to their consumption level. Provided that such payments are high enough to cover the costs of renewable generation and are guaranteed over a sufficient period, such a policy integrates several key elements of a pricing law and may be similar in effect (and perhaps more politically feasible in some countries).[19]

Experience to date demonstrates that payments and rebates are preferable to tax credits. Unlike tax credits, the benefits of payments and rebates are equal for people of all income levels. Further, production incentives are generally preferable to investment subsidies because they promote the desired outcome, energy generation. However, policies must be tailored to particular technologies and stages of maturation, and investment subsidies can be helpful when a technology is still relatively expensive, as with PV in Japan.[20] All subsidies should be gradually reduced and phased out to encourage cost reductions.

Financing assistance in the form of low-interest, long-term loans and loan guarantees is also essential to address the high up-front capital costs of renewables. Lowering the cost of capital can reduce the average cost of electricity and the risk of investment, as seen in Germany. Even in the developing world, all but the very poorest people are able and willing to pay for reliable energy services, but they need access to low-cost capital. According to PV companies in South Africa, Indonesia, India, and the Dominican Republic, up to 50 percent of prospective purchasers can afford systems if reasonable third-party financing is available; otherwise, only 2–5 percent can buy them.[21] Thus the availability of financing could increase PV use in some countries by 10-fold or more, and the impacts could be similar with other renewables.

One of the most successful means for disseminating household-scale renewable technologies in rural China has been local public-private bodies that offer technical support, materials sales, subsidies, and government loans for locally manufactured technology. They frequently provide revolving credit, with repayment linked to the timing of a household's income stream.[22] In India, the terms of long-term, low-interest loans vary by technology, with the most favorable for PV. In addition, the national government has obtained bilateral and multilateral funding for large-scale projects, particularly wind.[23]

3. Education and Information Dissemination. Even if governments offer generous incentives and low-cost capital, people will not invest in renewable energy if they are uninformed—or misinformed—about resource availability, technology development, the advantages and potential of renewables, the fuel mix of the energy they use, and the incentives themselves. During the 1980s, several U.S. states offered substantial subsidies for wind energy, including a 100-percent tax credit in Arkansas, a state with enough wind to generate half of its electricity. But these subsidies evoked little interest due to ignorance about wind resources.[24] By contrast, it was wind resource studies in California, Hawaii, and Minnesota that generated interest in wind energy there.[25] Cloudy Germany has more solar water heaters than sunnier Spain and France, mostly because public awareness of the technology is so much higher in Germany.[26]

Inexperience (or bad experiences) have left many with a perception that renewables do not work, are inadequate to meet their needs, are too expensive, or are too risky as investments. Above all, it is essential that government leaders recognize the inherent value of renewable energy. Then governments, nongovernmental organizations, and industry must work together to educate labor organizations about employment benefits, architects and city planners about ways to incorporate renewables into building projects and their value to local communities, agricultural communities about their potential to increase farming incomes, and so on.

Training and certifying workers are also essential, to ensure that people are available to manufacture, install, and maintain renewable energy systems. Austrian students learn about renewable energy in schools and universities, and many German vocational schools have renewable energy programs.[27] The Indian government has also established training programs, and has used print, radio, songs, and theater to educate the public about the benefits of renewable energy and government incentives. The Solar Finance Capacity Building Initiative educates Indian bank officials about solar technologies and encourages them to invest in projects.[28]

The problems thwarting renewables (and their solutions) are not necessarily unique to particular countries or settings.[29] Thus it is essential to share information at all levels regarding technology performance and cost, capacity and generation statistics, impacts of renewable energy on society, and policy successes and failures in order to increase awareness and avoid reinventing the wheel each time. While several countries do this on a national level, a centralized global clearinghouse for such information is clearly needed.

4. Stakeholder Involvement. Public participation in policymaking, project development, and ownership also increases the odds of success. In Germany and Denmark, where individuals (singly or as members of cooperatives) still own many of the turbines installed, there is strong and broad public support for wind energy. As of 2002, about 85 percent of the installed wind capacity in Denmark was owned by farmers or cooperatives, and at least 340,000 Germans had collectively invested nearly $14 billion in renewable energy projects.[30] Through cooperatives, people share in the risks and benefits of renewable energy; often avoid problems associated with obtaining financing and paying interest; play a direct role in the siting, planning, and operation of equipment; and gain a sense of pride and community.[31]

Public participation and a sense of ownership are as important in the South as in the North. When technologies are forced on people without consultation regarding their needs or are donated as part of an aid package, people often place little value on them and feel they have no stake in maintaining them. But when individuals and communities play a role in decision making and ownership, they are literally empowered and become invested in the success of the technologies. Local participation in and ownership of solar minigrid projects in Nepal and the Indian islands of the Sundarbans have helped ensure the projects' success and have eliminated electricity theft.[32]

5. Industry Standards, Permitting, and Building Codes. Standards are essential to prevent inferior technologies from entering the marketplace and generate greater confidence in products, thereby reducing risks and attracting investors. Technology standards for wind turbines, for example, can apply to everything from turbine blades, electronics, and safety systems to performance and compatibility with the transmissions system. Largely due to pressure from the wind industry, Denmark adopted wind turbine standards in 1979. These standards are credited with playing a major role in Denmark's becoming the world's leading turbine manufacturer.[33] Germany established an investment tax credit for wind energy in 1991, and turbine standards and certification requirements prevented the quality control problems experienced in California and India. Eventually, technology standards for all renewable technologies should be established at the international level.

Standards and planning requirements can reduce opposition to renewables if they address potential concerns such as noise and visual or environmental impacts. Such laws can be used to reserve specific locations for development or to restrict areas at higher risk of environmental damage or injury to birds, for instance, reducing uncertainty about project siting and speeding the planning process.[34] The United Kingdom provides the best example of how the lack of planning regulations can paralyze an industry: despite the best wind resources in Europe, the nation added little wind capacity under its early quota system, largely because a lack of planning regulations virtually halted the permitting process.[35]

Building codes and standards can also be designed to require renewables' incorporation into building designs and planning processes. London Mayor Ken Livingstone spearheaded a proposed strategy that, if enacted, will require major developments there to incorporate solar energy or be designed for easy future installation.[36] Including wiring and other hardware in new buildings to make them solar-ready adds little to construction costs while making it easier and far cheaper to install such systems later. And efficiency standards can facilitate the use of renewable energy by making the scale more manageable (so renewables can more easily satisfy energy needs), and by reducing the load so that it is easier to bear higher costs per unit of output.

Changing Government Approaches to Energy Policy

Energy markets are not now and never have been fully competitive and open. Discriminating standards, regulations, government purchases, past investments in infrastructure and long-term subsidies for conventional energy, and the failure to internalize external costs and benefits all act as obstacles to the advancement of renewable energy. Thus, perhaps the most important step governments can take to advance renewables is to transform their perspectives and approaches to energy policy. Governments must eliminate inappropriate, inconsistent, and inadequate policies that favor conventional fuels and technologies and that fail to recognize the social, environmental, and economic advantages of renewable energy.

One of the most important steps governments can take to level the playing field is to eliminate subsidies for conventional energy. Mature technologies and fuels should not require subsidization, and every dollar spent on conventional energy is a dollar not invested in clean, secure, and sustainable renewable energy. In the mid-1990s, governments worldwide were handing out $250–300 billion annually to subsidize fossil fuels and nuclear power.[1] Since then, several transitioning and developing countries have reduced energy subsidies significantly, but global subsidies for conventional energy remain many magnitudes higher than those for renewable energy.[2]

At the international level, the Global Environment Facility allocated $650 million to renewable energy projects in developing countries between 1992 and 2002.[3] This is a small fraction of global investments in carbon-intensive energy projects through international financial institutions like the World Bank and taxpayer-funded export credit agencies. Over

the past decade, World Bank funding for fossil fuel projects (totalling $26.5 billion) has exceeded that for renewable energy and efficiency by a factor of 18.[4]

In most cases, it is less a matter of finding new money to invest in renewable energy than of transferring money flows from conventional energy to renewables. Each year, an estimated $200–250 billion are invested in energy-related infrastructure to replace existing capital stock and meet ever-rising demand, and another $1.5 trillion is spent on energy consumption; nearly all of this goes to conventional energy.[5] Hundreds of millions of people in the developing world spend about $20 billion every year on makeshift solutions such as candles, kerosene lamps, and batteries.[6] The International Energy Agency projects that $16 trillion will be invested worldwide in energy-supply infrastructure between 2001 and 2030.[7] Even small shifts in these expenditures would have a tremendous impact on renewable energy markets and industries.

Next, pricing structures must account for the significant external costs of conventional energy and the advantages of renewable energy. Germany has begun to do this through its pricing law and other countries do so with energy or carbon taxes. And as the single largest consumers of energy in most or all countries, governments should purchase ever-larger shares of energy from renewables and thereby set an example, increase public awareness, reduce perceived risks associated with renewable technologies, and reduce costs through economies of scale.

Finally, policies designed to advance renewable energy can fail if they are not well formulated or are inconsistent, piecemeal, or unsustained. For example, because early investment credits in California were short-lived and extensions were often uncertain, many equipment manufacturers could not begin mass production for fear that credits would end too soon.[8] When the incentives expired, interest waned and the industries and markets died with them. The U.S. Production Tax Credit for wind energy has expired several times, only to be extended months later. As a result, the credit has stimulated wind capacity growth but has created cycles of boom and bust in the market, with busts causing suspension of projects, worker layoffs, and loss of momentum in the industry.

This on-and-off approach to renewables has made the development of a strong U.S. industry a challenge, at best. In India, uncoordinated and inconsistent state policies, and bottlenecks imposed by state electricity boards, have impeded renewable energy development.[9] Even in Denmark, years of steady wind-energy growth ended in 1999 when the government changed course and doubt overtook years of investor confidence. The future of some planned offshore wind farms is now uncertain, as is Denmark's target to produce half its electricity with wind by 2030. The number of jobs in the domestic industry will probably decline over the next few years.[10] These changes are due not to the technologies themselves but to inconsistencies and failures in policy.

Consistent policy environments are necessary for the health of all industries. Consistency is critical for ensuring continuous market growth, enabling the development of a domestic manufacturing industry, reducing the risk of investing in a technology, and making it easier to obtain financing. It is also cheaper, because higher incentives might be required to coax investors back into the market as uncertainty increases the perception of risk, and because stop-and-go policies force funds to be reappropriated, new programs administered, information distributed to stakeholders, and so on.[11] Government commitment to developing renewable energy markets and industries must be strong and long-term, just as it has been with fossil fuels and nuclear power. (See Sidebar 4.)

Unlocking Our Energy Future

In early January 2004, the U.S. unmanned rover *Spirit* touched down on the surface of Mars and within days began relaying to Earth dramatic photographs of a red, rock-strewn surface, distant hills, and a rust-colored sky from 170 million kilometers (106 million miles) away.[1] Humanity has clearly

SIDEBAR 4

Forging a New Energy Future

- Enact renewable energy policies that are consistent, long-term, and flexible, with enough lead time to allow industries and markets to adjust.
- Emphasize renewable energy market creation.
- Provide ready access to the electric grid at prices that reflect full costs of conventional energy and supply sufficient incentive to stimulate renewable energy market growth.
- Provide financing assistance to reduce up-front costs through long-term, low-interest loans, through production payments for more advanced technologies, and through investment rebates for more expensive technologies such as PV, with gradual phaseout.
- Disseminate information regarding resource availability, the benefits and potential of renewable energy, capacity and generation statistics, government incentives, and policy successes and failures at local, national, and international levels.
- Encourage individual and cooperative ownership of renewable energy projects and ensure that all stakeholders are involved in the decisionmaking process.
- Establish standards for performance, safety, siting, and buildings.
- Incorporate all costs into the price of energy and shift government subsidies and purchases from conventional to renewable energies.

established a presence on two planets—and one of them is powered primarily by renewable energy. PV modules enable *Spirit* and its twin, *Opportunity*, to roll across the planet's surface, operate sophisticated cameras and rock abrasion tools, analyze materials, and send valuable data and photographs back to Earth. In fact, without energy from the sun and high-tech, reliable, renewable technologies such as PV, space exploration itself would be impossible.

It will be a long time before renewables achieve the penetration level on Earth that they currently enjoy on Mars, but renewable energy is coming of age even on our planet. After more than a decade of double-digit growth, renewable energy is a multibillion-dollar global business. Wind power is leading the way in many nations, supplying more than 20 percent of the electricity needs in some regions and countries. It represents almost half of global investment in renewable technologies, and is now cost-competitive with conventional energy technologies. Solar cells are already the most affordable option for getting modern energy services to hundreds of millions of people in developing countries and are competitive on-grid in Japan today. Their costs continue to fall rapidly.

Renewable technologies are attracting the funds of venture capitalists and multinational corporations alike. The major oil companies BP and Royal Dutch/Shell have invested hundreds of millions of dollars in renewable energy development. While this is a fraction of what they devote to oil and gas, it is a move in the right direction. General Electric has also become a large player, supplying 15 percent of the global wind turbine market in 2003, and is beginning to enter the PV market.[2] In early 2004, the largest U.S. financial institution, Citigroup, announced plans to begin investing in renewable energy.[3] Worldwide, investment in new renewable energy technologies is expected to increase more than four-fold between 2003 and 2012, to $85 billion annually.[4]

Whether renewable energy capacity and investment continue to grow at current levels will hinge largely on policy decisions by governments around the world. Expansion during the past decade has occurred because of substantial policy changes in a half-dozen countries, and those nations alone are not large enough to sustain the growth required to propel renewables into the mainstream worldwide. But recent developments suggest that political support for renewables is rising around the world.

One example is Europe, the engine of growth for the global wind industry. In the United Kingdom, which until recently was a European straggler on renewables, Prime Minister Tony Blair has called his nation's investment in renewable energy "a major down-payment in our future" that will "open up huge commercial opportunities."[5] The European Union aims for renewables to generate 22 percent of Europe's electricity by 2010.[6] Elsewhere, China has upped its wind energy targets and

TABLE 3

Renewable Energy Targets and Recent Totals in Selected Countries/Regions

Country/Region	Targets for Renewable Energy	Recent Totals
California, U.S.	20% electricity from new renewables by 2017	12% (2002)
China	4,000 MW wind by 2010; 20,000 MW wind by 2020	568 MW (2003)
European Union	22.1% electricity by 2010; 12% total energy by 2010	14% electricity (1999); 6% energy (1997)
Germany	20% electricity by 2020; 50% total energy by 2050	6.8% electricity (2002)
Japan	4,830 MW of PV by 2010	887 MW (2003)
Latin America, Caribbean	10% total energy from new renewables by 2010	NA
Navarra, Spain	97% electricity by 2005	55% (2002)
Thailand	21.2% total energy by 2011	19.8% (2001)

Notes: Values are for all types of renewables unless otherwise noted. For California, RPS mandate for investor-owned utilities only; credit for existing but not new small hydropower plants. For Latin America and Caribbean countries above target must maintain their current share.
Source: See Endnote 9 for this section.

plans to invest $1.2 billion in PV over the next five years.[7] India has proposed that 10 percent of annual additions to electric capacity come from renewables by 2012.[8] In Latin America, Brazil is leading the way with a comprehensive and ambitious renewable energy law.[9] (See Table 3.)

Even in the United States, despite an oil-oriented White House, nearly half the members of Congress have joined the Renewable Energy and Energy Efficiency Caucus.[10] Although this political support has not yet translated into the needed federal legislation, many states—including Arizona, California, Nevada, New York, and Texas—have enacted pioneering laws, and more and more governors are professing the benefits of renewable energy for their states, from energy security and jobs to reduced dependence on imported oil.[11]

Despite the substantial strides being made in technology, investment, and policy, renewables continue to face a credibility gap. Many people remain unconvinced that renewable energy can one day be harnessed on a scale that would meet most of the world's energy needs. Renewable energy sources appear too ephemeral and sparsely distributed to provide the energy required by a modern post-industrial economy. But those assumptions are outdated. In the words of Paul Appleby, formerly with BP's solar division, "the natural flows of energy are so large relative to human needs for energy services that renewable energy sources have the technical potential to meet those needs indefinitely."[12]

The G8 Renewable Energy Task Force projects that in the next decade up to a billion people could be served with renewable energy.[13] BP and Shell have predicted that renewable sources could account for 33 to 50 percent of world energy production by 2050, with stable regulatory frameworks.[14] And David Jones of Shell has forecast that renewables could emulate the rise of oil a century ago, when it surpassed coal and wood as the primary source of energy.[15]

Not only is renewable energy alone sufficient to meet all of today's energy needs thousands of times over, harnessing it is not particularly land- or resource-intensive. Theoretically, all U.S. electricity could be provided by wind turbines in Kansas, North Dakota, and South Dakota, or with solar energy on a plot of land 100 miles square in Nevada.[16] Farming under the wind turbines could continue as before, while farmers enjoyed the supplementary revenues from spinning wind into electricity. In cities around the world, much of the local power needs could be met by covering existing roofs with solar cells—requiring no land at all. Additional energy will be provided by wind and ocean energy installations located several kilometers offshore, where the energy flows are abundant.

The other credibility gap that must be bridged is how to provide renewable energy when and where it is needed. How do you get wind or sunshine into a gas tank, for example, and on a still, dark night? That question may have been answered by automobile and energy companies around the world. Just as electricity enables us to use and transport renewable energy today, hydrogen offers a promising option—once costs have

dropped significantly and infrastructure is in place—for producing fuel from renewable energy, storing it underground, and carrying it by pipeline to cities and factories. Major automobile manufacturers are developing hydrogen internal combustion engines and fuel cell-powered cars that will emit only water from their tailpipes. DaimlerChrysler, Honda, Toyota, and GM now expect to have their first commercial fuel-cell cars available by 2010.[17]

The next challenge for renewables will be how to enter the mainstream and overtake fossil fuels in light of investments already made in conventional infrastructure that will be operable for decades to come. But infrastructure and power capacity are being replaced or added continuously, and this is where a significant shift toward renewable energy must begin in the developing and industrial worlds alike. A recent study determined that renewables could supply 20 percent of Europe's energy demand and 33 percent of its electricity by 2020. To meet the EU's targets for 2010 and proposed goals for 2020, 52.5 percent of new power capacity installed from 2001 through 2010 and 61 percent installed from 2011 through 2020 would need to be renewable. It is estimated that avoided fuel and environmental costs could equal the projected costs of investment.[18] Another study concluded that Europe could phase out nuclear power and reduce carbon emissions 80 percent by 2050 through a transition to renewable energy that, if external costs were incorporated, would be far cheaper than continuing with business as usual and would provide new jobs as well. However, this transition will be possible only if the necessary steps down this road are begun as soon as possible.[19]

In early 2001, the Intergovernmental Panel on Climate Change released its most recent report, confirming that in order to stabilize the world's climate, "eventually CO_2 emissions would need to decline to a very small fraction of current emissions"—meaning close to zero.[20] If the world is to achieve this goal—which it must—countries must begin today, not tomorrow, to make the transition to a renewable, sustainable energy future. We have a brief window of opportunity to start down the path to a more sustainable world—one in which rising demand for energy is met without sacrificing the needs of current and future generations and the natural environment.

We still have a long way to go to achieve this vision. Today most of the world is locked into a carbon-based energy system that is neither better nor necessarily cheaper than renewable energy, but merely the legacy of past policies and investment decisions. Breaking with this past will not be easy. But Germany, Japan, and other countries are proving that change is indeed possible and that it can happen rapidly. The key is ambitious, forward-looking, consistent government policies that drive demand for renewable energy, create a self-reinforcing market, and propel renewables into the energy mainstream during the 21st century.

Endnotes

Introduction

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