Hydroelectricity and Other Renewable Resources

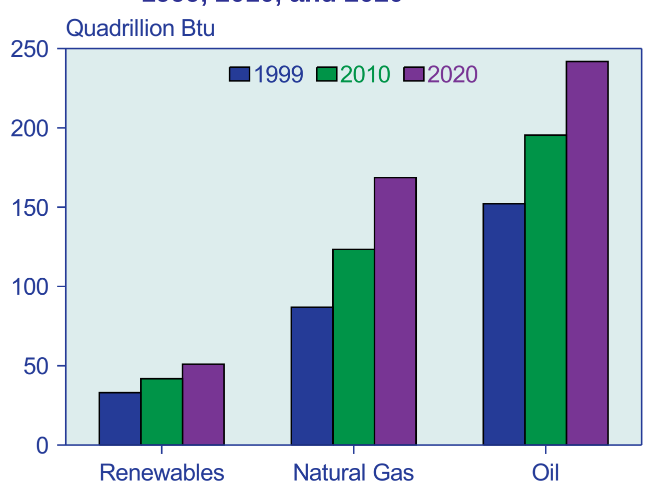
The renewable energy share of total world energy consumption is expected to decline slightly, from 9 percent in 1999 to 8 percent in 2020, despite a projected 53-percent increase in consumption of hydroelectricity and other renewable resources.

The use of hydropower and other renewable energy resources is projected to increase in the *International Energy Outlook 2002* (*IEO2002*) mid-term forecast. From 1999 to 2020, worldwide consumption of renewable energy is projected to increase by 53 percent, as compared with expected increases of 92 percent for natural gas and 58 percent for oil consumption (Figure 67). Growth in demand for renewable energy resources is expected to continue to be constrained by relatively moderate fossil fuel prices.

New, large-scale hydroelectric installations are expected to provide much of the growth in renewable energy use in the developing world. China, India, Malaysia, and other developing Asian countries continue to construct or plan large-scale hydropower projects. Construction on the largest project, China's 18,200-megawatt Three Gorges Dam, continued in 2001 despite reports of corruption and problems in the relocation of populations from the reservoir site. Malaysia continues to work on its 2,400-megawatt Bakun hydroelectric project, although to date only the mile-long underground river diversion tunnel has been completed [***1***].

The heavy reliance on hydroelectric power in many countries of Central and South America has become a burden for some, because drought has endangered the reliable supply of electricity. In Brazil, persistent drought in 2001 led to a substantial decline in reservoir levels and, therefore, the ability of hydroelectric power plants to provide electricity. Brazil's government enforced a 20-percent cut in power use as part of a rationing program, and considered other measures such as reducing the work week, in an effort to avoid blackouts [***2***]. In the fall of 2001, reservoir levels were 28 percent below capacity in key regions of the country. Brazil is responding by increasing the pace of natural-gas-fired power plant construction, a trend that many governments in the region see as necessary in order to diversify electricity supply sources and avoid shortages in the future.

Figure 67. Worldwide Consumption of Renewables, Natural Gas and Oil, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

In the industrialized world, Canada is among the only countries with plans to expand large-scale hydroelectric resources, such as the 2,000-megawatt Lower Churchill Project at Gull Island in Newfoundland Province. Many developed countries have already substantially exploited their hydroelectric resources, and increments to their renewable energy consumption are expected to come from wind, solar, and other nonhydroelectric renewable energy sources.

Worldwide, some 3,800 megawatts of new wind energy capacity were installed during 2000, and the American Wind Energy Association estimated that another 5,000 megawatts would be added in 2001 [***3***]. Wind remains the fastest-growing source of renewable energy in the industrialized world. Germany added 1,650 megawatts of wind capacity in 2000, making it the country with the largest annual increment in wind capacity worldwide, as it has been for the past several years. Germany's increase was followed by Spain's 795 megawatts of installed new wind capacity and Denmark's 588 megawatts [***4***]. The European Union (EU) finalized the agreement for a Renewable Directive in September 2001 [***5***]. The directive sets goals of doubling the renewable energy share of total energy consumption in the inland EU to 12 percent by 2010, and increasing the renewable energy share of electricity generation from 14 percent in 2001 to 22 percent by 2010.

New wind capacity additions in the United States decreased sharply in 2000, after a record increment of 565 megawatts in 1999, when the wind energy production tax credit expired. The credit was subsequently extended through 2001, and the Energy Information Administration's *Annual Energy Outlook 2002* (*AEO2002*) estimates that 1,872 megawatts of wind capacity was added in the United States in 2001. The credit has since been extended to December 31, 2003.

The *IEO2002* projections for hydroelectricity and other renewable energy sources include only on-grid renewables. Although noncommercial fuels from plant and animal sources are an important source of energy, particularly in the developing world, comprehensive data on the use of noncommercial fuels are not available and, as a result, cannot be included in the projections. Moreover, dispersed renewables (renewable energy consumed on the site of its production, such as solar panels used to heat water) are not included in the projections, because there are also few comprehensive sources of international data on their use.

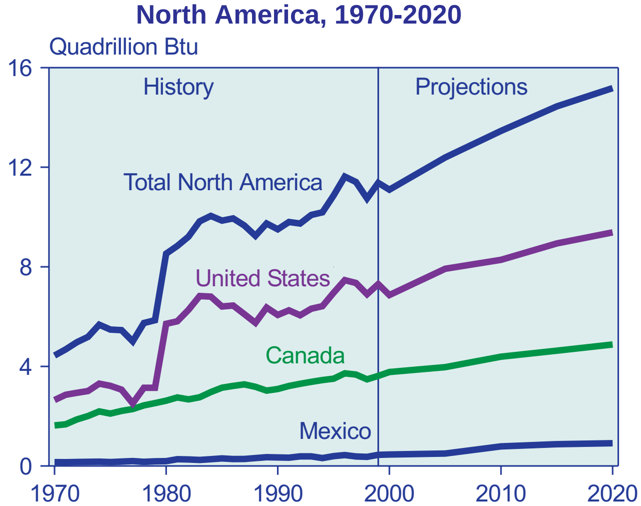
Regional Activity

North America

Hydroelectricity remains the predominant form of renewable energy use in North America, particularly in Canada. In 1999, hydroelectric power provided nearly 60 percent of the Canada's 551 billion kilowatthours of electricity generation [***6***], compared with 8 percent in the United States and 14 percent in Mexico.

In the *IEO2002* reference case forecast, renewable energy use in North America as a whole is projected to increase by 1.3 percent per year between 1999 and 2020 (Figure 68). Although Canada has announced some plans to expand its hydroelectric capacity over the next decade, hydropower consumption is expected to remain flat or decline slightly over the projection period for the region. Increases are expected for geothermal, wind, solar, biomass, and municipal solid waste (MSW) energy use.

Figure 68. Renewable Energy Consumption in North America, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

United States

Potential sites for hydroelectric dams have already been largely established in the United States, and environmental concerns are expected to prevent the development of any new sites in the future. EIA's *AEO2002* projects that U.S. conventional hydroelectric generation will decline from 316 billion kilowatthours in 1999 to 304 billion kilowatthours in 2020 as increasing environmental and other competing needs reduce the productivity of generation from existing hydroelectric capacity [***7***].

Nonhydroelectric renewables are expected to account for 3.9 percent of all projected additions to U.S. generating capacity between 2000 and 2020. Generation from geothermal, biomass, landfill gas, solar, and wind energy is projected to increase from 77 billion kilowatthours in 1999 to 160 billion kilowatthours in 2020. Biomass (which includes cogeneration and co-firing in coal-fired power plants) is expected to grow from 38 billion kilowatthours in 2000 to 64 billion kilowatthours in 2020. Most of the increase is attributed to cogenerators, with a smaller amount from co-firing. Few new dedicated biomass plants are expected to be constructed over the forecast period.

The reference case projects substantial increments in U.S. geothermal and wind power. High-output geothermal capacity could increase by 87 percent over the next two decades, to 5,300 megawatts, and could provide almost 35 billion kilowatthours of electricity generation by 2020. This will depend, however, on the success of several new, untested sites. Wind capacity in the United States is projected to grow by nearly 300 percent over the forecast period, from 2,400 megawatts in 2000 to 4,300 megawatts in 2001 and 9,100 megawatts by 2020. Wind capacity was installed or under construction in 28 States by the end of 2001 (Figure 69), and State mandates for increasing the development of renewable energy sources are expected to provide the impetus for the large increment in wind power over the forecast. State mandates are expected to have the greatest impacts on renewable capacity additions in Texas (2,279 megawatts), California (1,930 megawatts), Nevada (1,148 megawatts), and New Jersey (904 megawatts), and smaller increases are expected in Massachusetts, Minnesota, Iowa, Wisconsin, and Arizona.

Canada

At present, 60 percent of Canada's total installed electricity generation capacity consists of hydroelectric dams [***8***]. Canada is exploring ways to increase its hydroelectric capacity still further with several proposals that are currently under consideration. In the

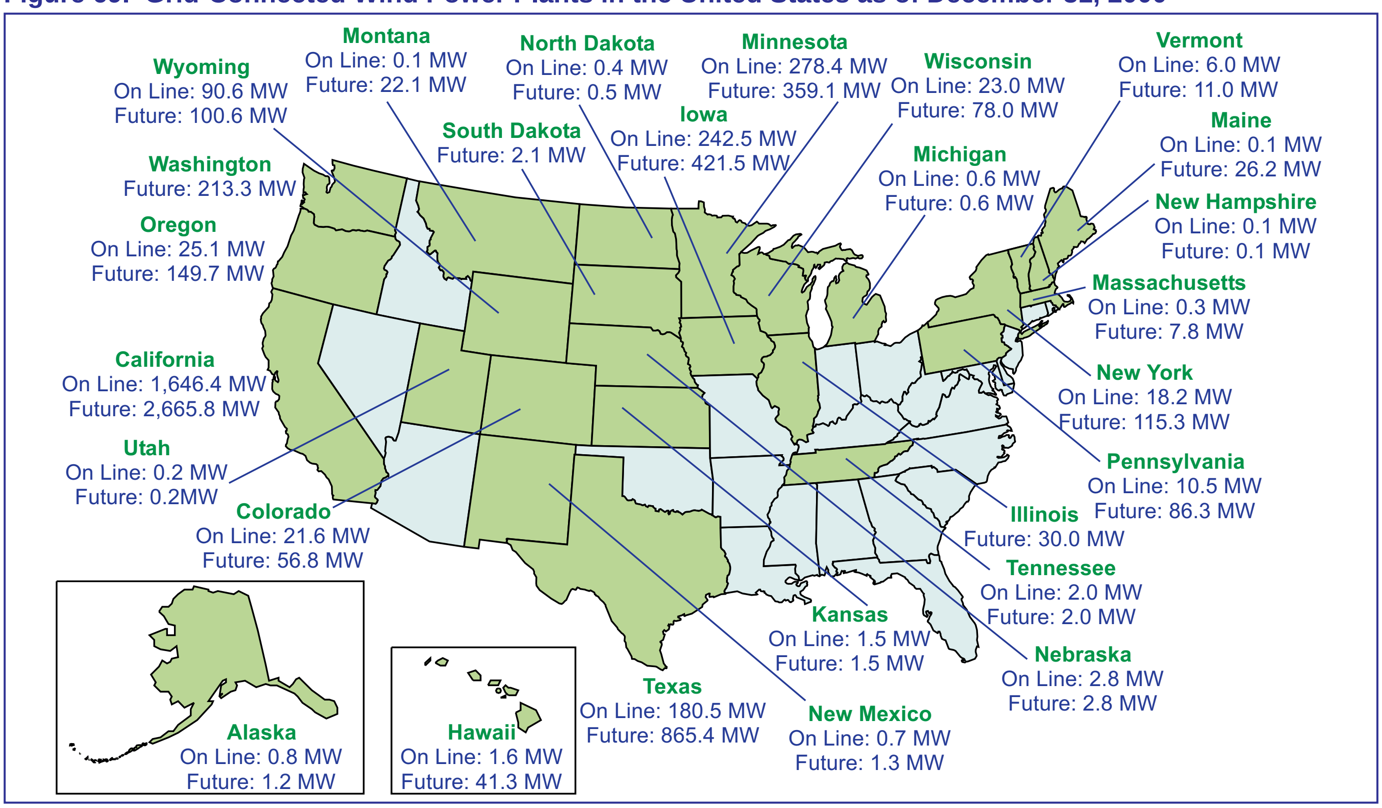
Northwest Territories there are proposals to develop hydroelectric projects that would total between 12,000 and 15,000 megawatts [*9*]. The projects would cost an estimated $17.5 billion and would be constructed in a sparsely populated part of the country on six separate rivers: the Mackenzie, Bear, Lockhart, Talston, Snare, and Lac la Marte. The government has identified 10,000 megawatts of potential development that could be exploited by developing sites on the Mackenzie River. The largest site on the Mackenzie, Ramparts, has a potential for 4,500 megawatts. Estimates are that the projects would take between 5 and 20 years to complete.

The successful development of these projects, as well as many others in Canada will depend on agreements with the local populations that will be displaced or otherwise affected by the projects. In the past, local concerns were not always taken into consideration, and Canadian aboriginal groups began to fight further developments through legal means, often successfully suing developers for reparations or to scale down proposed projects. The current trend is for governments and companies to work with the aboriginal tribes to reach consensus before construction begins, including offers of joint ownership and extensive environmental impact studies. The government of the Northwest Territories is meeting with the indigenous groups that would be affected by hydroelectric development and must reach an agreement with them before any construction begins.

One successful outcome of the new government strategy to gain approval for development from the indigenous people who will be affected by the construction of new hydroelectric infrastructure is the 1,200-megawatt Eastmain Rupert project [*10*]. In 2000, the provincial utility Hydro-Quebec paid the Grand Council of the Crees some $300,000 to conduct a 3-month study of the economic, commercial, and environmental aspects of the utility's proposal to construct the hydroelectric project. The project will cost an estimated $2.5 billion to construct and will involve the diversion of the Rupert River in the James Bay region of Quebec. Although an agreement has been reached between Quebec and the Crees, feasibility studies and environmental authorizations remain to be completed and are expected to take nearly 4 years. If all approvals are obtained, construction could be completed in 2011.

There are still other plans to construct large-scale hydroelectric projects in Canada. The governments of Newfoundland and Quebec provinces have proposed construction of a 2,000 megawatt Lower Churchill Project at Newfoundland's Gull Island. The project has been scaled back from 2,800 megawatts, because Newfoundland determined that it would be too expensive to construct a phase of the project that involved building an 800-megawatt powerhouse at Muskrat Falls. The government of Newfoundland is working with U.S. company Alcoa on a study of the Lower Churchill River on

Figure 69. Grid-Connected Wind Power Plants in the United States as of December 31, 2000



Source: National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 186.

Labrador that will determine the feasibility of constructing hydroelectric facilities at Gull Island and Muskrat Falls to support proposed aluminum smelters in Newfoundland and Labrador [*11*].

Quebec's government has also approved a plan by Hydro-Quebec for construction of a dam and 526-megawatt powerhouse on the Toulnustouc River, on the north shore of the St. Lawrence River about 60 miles north of Baie-Comeau [*12*]. The project's powerhouse is part of a larger project supported by the Betsiamites Innu-Montagnais aborigines that would include several river diversions. Authorization has not yet been obtained for some parts of the larger project. Construction of the 526-megawatt powerhouse that has been approved will take an estimated $400 million and will involve enlarging Lake Sainte-Anne reservoir, building a dam and a powerhouse, and connecting the powerhouse to the Micoua substation. Construction will not begin until the project has been approved by the Canadian federal government.

Hydro-Quebec has a number of plans for additional mid-size hydro power projects over the next decade. Quebec's government has authorized Hydro-Quebec to begin a draft design study for a dam and 220-megawatt powerhouse on the Romaine River near Havre-Saint-Pierre. If approved, construction of the $335 million La Romaine Project could begin in 2004. The station could be commissioned in 2007, generating 1,000 gigawatthours annually. Another technical and environmental study has been launched for the development of a 450-megawatt hydroelectric plant on the Peribonka River nearly 200 miles north of Quebec City [*13*]. The project would generate an average 2,200 gigawatthours of electricity annually. If all goes according to plan, the studies will be completed by mid-2003, with construction beginning in 2004 and commissioning set for 2009.

Along with mid- to large-scale hydro projects, Canada is showing increasing interest in smaller scale hydroelectricity and alternative renewable energy sources, such as wind, that have not previously been exploited in the country. The Canadian Renewable Energy Corporation announced in September 2001 that it would evaluate nearly a dozen potential sites for small, run-of-river hydroelectric development in Ontario [*14*]. The company plans to install 38 megawatts of new renewable capacity within the next 3 years, beginning with the 3-megawatt Misema power project on the Misema River in eastern Ontario. Construction on Misema began in 2001 and is scheduled for completion in November 2002 [*15*].

Another example of the development of smaller scale hydroelectric facilities is the construction of the Granite Canal hydroelectric project on Newfoundland Island. Construction on the 40-megawatt site began in May 2001. The project is being built by Newfoundland & Labrador Hydro company and should be operating by 2003 [*16*].

At the end of 2000, there was an estimated 137 megawatts of total installed wind capacity in Canada [*17*]. At present, the provinces of Quebec and Alberta have the largest shares of Canada's wind capacity. There are, however, new government incentives to increase wind power projects throughout the country and as a result several projects are expected to become operational over the next year. In December 2001, Canada implemented a wind power production incentive. Wind projects installed between April 1, 2002, and March 31, 2007, will be eligible for a government incentive payment of about 0.8 cents per kilowatthour of generation [*18*]. The payment will gradually decline to 0.5 cents per kilowatthour.

In Saskatchewan's Gull Lake, the first phase of the $12.8 million SunBridge Wind Power Project has begun generating electricity [*19*]. Three of the 17 wind turbines began generating in August 2001, and the remaining turbines should be operational by June 2002, when total installed capacity should reach 11.2 megawatts. The Canadian government has agreed to purchase electricity from emerging renewable sources in Saskatchewan and Prince Edward Island, and for the Gull Lake wind project this will mean an investment of around $7.9 million over a 10-year period [*20*]. Power from the project will be fed into the provincial power grid and used to supply electricity to federal government buildings in Saskatchewan, among other customers.

In June 2001, the Canadian government, the Prince Edward Island provincial government, and Maritime Electric Company, Ltd. announced that an agreement had been signed for the development of a wind farm at North Cape to be constructed by the Prince Edward Island Energy Corporation [*21*]. The project, which is expected to cost $5.9 million, will generate an estimated 16.6 million kilowatthours of electricity annually.

In August 2001, Ontario Power Generation commissioned North American's largest wind turbine at the Pickering Nuclear Generating Station [*22*]. The 1.8-megawatt turbine is supposed to generate enough energy to supply 600 average Canadian homes. The company is also planning a 10-megawatt wind farm near Lake Huron, which is scheduled for completion by summer 2002. Ontario Power Generation has committed to increasing its total renewable generating capacity to 500 megawatts by 2005, from a present 138 megawatts.

Mexico

In Mexico there are limited plans to expand the renewable energy resource base at the present time. Mexico has made some moves toward increasing the development of geothermal resources, including studies by the state-owned Comisión Federal de Electricidad (CFE) [*23*] and a government pledge to invest some $31 million in geothermal energy. There has been little activity in wind power development in Mexico, although by some estimates Mexico has wind resources that could support the installation of up to 5,000 megawatts of wind power capacity [*24*]. The country has about 3 megawatts of installed wind capacity but has not added any new capacity since 1998. Construction of a 54-megawatt wind power project proposed by CFE in 1996 has continued to be postponed. In addition, five other wind projects proposed by private companies are still being negotiated. Construction permits have been issued to four of the five projects, but no construction work has been started.

Western Europe

Expansion of renewable energy sources in Western Europe is expected to be mostly in the form of nonhydroelectric renewables. Most potential hydroelectric resources have already been developed in the region, and there are few plans to extend hydropower capacity over the next two decades. Among the other forms of renewable energy, wind has made the greatest gains over recent years and will probably contribute to much of the future growth in renewable energy use.

The EU has moved to increase the penetration of renewables in the European energy mix. In 2001, the European Parliament approved a Renewables Directive that would require the EU to double the renewable share of total energy consumption by 2010 [*25*]. According to the new law, the share of total inland energy consumption met by renewable energy resources will have to increase to 12 percent in 2010, from an estimated current level of about 6 percent. Furthermore, the share of electricity demand met by renewables will have to increase to 22 percent, from about 14 percent now.

Individual European countries have been implementing various strategies to increase their use of renewables. The United Kingdom has introduced a "renewables obligation," which will require electricity suppliers to derive 3 percent of their electricity from renewable resources beginning in 2002, rising to 10 percent in 2011. Germany's Gesetz für den Vorrang Erneuerbarer Energien law was enacted on April 1, 2000; it requires that electricity grid operators give "priority access to all renewable energy" and sets fixed rates for each renewable (the cost is passed to the consumer) [*26*]. France has also set rates for renewable energy in the wholesale market to ensure that a planned installation of 10,000 megawatts of wind power occurs by 2010 [*27*].

In contrast to the German and French strategies of ratesetting, the government of the Netherlands uses "green certificates" to create a market for renewables. Generators are given green certificates for their renewable power production that provide tax credits and can be traded. The resulting tax savings or the earnings made from the sale of the certificates are supposed to allow renewable generators to sell more of their power in the market. In the past, Denmark has required utilities to allow private renewable energy producers access to the grid and has required utilities to pay the producers a percentage of their production and distribution costs. Now the Danish government is also introducing renewable energy certificates, similar to the Dutch scheme.

Of all the renewable energy sources, wind is the most promising in Europe. Germany, Spain, and Denmark have been among the world's top wind capacity installers in recent years, and in 2000 Italy and the United Kingdom also saw sharp increases in wind power capacity installations.

In 2000, Germany expanded its total installed capacity by 1,668 megawatts, bringing its combined operating wind capacity to 6,113 megawatts. In August 2001, Europe's largest onshore wind farm, the 105-megawatt Sintfeld wind farm, began production near Paderborn, Germany [*28*]. The project is expected to provide enough electricity for 70,000 homes.

Denmark added 588 megawatts of wind capacity in 2000, twice as much new capacity as it has installed in recent years [*29*]. The country has one of the most mature wind power markets in the world and currently meets an estimated 12 percent of its total electricity demand with wind energy. Under the government's Energy 21 strategy, the national target is to have 1,500 megawatts of wind power installed by 2005 and 5,500 megawatts by 2030. The 2005 target has already been exceeded; however, most of the potential on-land sites available for wind facilities have already been exploited, and 4,000 of the 5,500 megawatts that must be in place by 2030 are supposed to be offshore (see box on page 110). Thus far, Denmark has only 50 megawatts of offshore installed wind capacity.

Like Germany and Denmark, Spain has seen substantial growth in wind power capacity over the past several years. In 2000, it added 795 megawatts of wind capacity, bringing the country's total installed wind generation capacity to 2,334 megawatts, nearly the level of the mature wind market in Denmark. The government encourages the development of renewable generation by offering producers a choice of incentives. Either the producer can opt to be paid a fixed price for the electricity it produces (the price varies by renewable energy source), or it can accept a variable price based on the average price of the market pool, plus a bonus based on the amount produced.

Development of Offshore Wind Power in Denmark

Over the past decade, wind power has moved from being a novel, unconventional technology to achieving significant, and in some cases substantial, market penetration. In many industrialized countries, governments and environmental planners view wind energy as a low-cost pathway to achieving substantial reductions in greenhouse gas emissions and addressing other environmental problems associated with conventional generation technologies. To achieve these goals, many countries have started to look beyond conventional land-based wind turbine technology, with its economic and physical limitations, and have set their sights on the windy expanses of coastal oceans and seas surrounding northwestern Europe.

The Danish government has set substantial targets for growth in wind-powered electricity generation and expects it to account for 50 percent of domestic generation by 2030. In the country's Energy 21 plan, a target for installed wind capacity of 5,500 megawatts has been set, of which 4,000 megawatts is to be offshore.[a] This means that, with wind energy currently at about 12 percent of electricity demand, much of the remaining land-based wind resource in Denmark is believed to be unsuited for development. Limitations include:

- Poor remaining resources: Denmark has never been rich in high-quality wind resources, and most of the suitable land resource is already utilized.[b]
- Competing land uses: Denmark is a densely populated country, with correspondingly high land costs.
- Landscape impacts: Although the Danish people seem largely to have shared in their government's commitment to wind power, there is some evidence of growing resistance to further visual intrusion by the increasingly tall wind turbines in rural areas.[c]

Denmark already has several pilot-scale offshore wind facilities and in 2000 commissioned what is, for now, the largest commercial offshore operation, a 20-turbine, 40-megawatt facility on the Middelgrunden shoal off of Copenhagen. Other recent European installations include a 10-megawatt facility near Blyth, England, and another 10-megawatt facility on the Utgrunden shoal in Swedish waters.

There are substantial additional costs associated with the offshore development of wind resources, and it might be asked, "Why build offshore at all?" For much of northwestern Europe, the answer is simple: that's where the wind is. Denmark has been an early adopter of wind energy, and its industry remains the global leader in the field. Not surprisingly, much of the early offshore development has occurred in Danish waters as suitable unused land sites in the country have become increasingly scarce. Although Germany has significant inland resources, many other countries, such as the United Kingdom, the Netherlands, and Belgium, find themselves with few easily developed land sites but ample coastlines.

Although concepts for offshore wind power have existed longer than there has been a commercial wind industry, realization of those visions had to wait for both the technology and the economic necessity to catch up. Enabling technologies have come, naturally, from the wind industry itself and have also benefited from the engineering expertise of the offshore oil industry. Even with technological advances, however, offshore wind power remains substantially more expensive than land-based wind power in good resource areas. As economically viable wind power opportunities on land are exhausted, offshore wind becomes an increasingly attractive proposition.

A key enabling technology for offshore wind is the turbine foundation.[d] Foundation design and engineering concepts are based on offshore oil rig foundations. Unlike land-based foundations, offshore wind turbines face additional loading from wave action, sea-bed scouring, and (in northern climates) pack ice. Oil rig designs, made for largely static above-water loads, must be modified to face the additional dynamic loading imposed by the turbine itself. Additionally, while oil rig technology has progressed to ever-deeper waters, wind turbines will likely be limited, at least in the near term, to waters near shore with smaller critical wave heights, shorter distances to lay power transmission cables, and closer maintenance facilities.[e] Of course, placement of turbines too close to shore will start to limit the offshore benefits, including

(continued on page 111)

[a]International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual 2000* (Golden, CO, May 2001), p. 69.

[b]The *IEA Wind Energy Annual 2000*, p. 69, indicates that in 2000 approximately 2,300 megawatts of onshore capacity was installed, with a "realistic" maximum capacity of about 2,600 megawatts.

[c]J. Samuelsberg, "Analysis—Offshore Wind Power Swirls Through Europe," web site www.climateark.org/articles/2000/2nd/offswind.htm (April 13, 2000). See also web site http://rotor.fb12.tu-berlin.de/windfarm/offshore.vindeby.html.

[d]See various topics in *OWEN Workshop on Structure and Foundation Design of Offshore Wind Installations* (Offshore Wind Energy Network, March 2000), web site www.owen.eru.rl.ac.uk/workshop_3/ws3_final.pdf.

[e]B. Standing, "Wave and Current Characterization Modeling," *OWEN Workshop on Structure and Foundation Design of Offshore Wind Installations* (Offshore Wind Energy Network, March 2000), web site www.owen.eru.rl.ac.uk/workshop_3/ws3_final.pdf.

Development of Offshore Wind Power in Denmark (Continued)

low-turbulence winds found over the relatively smooth ocean surfaces and less visibility from populated areas.

Because a major additional expense of offshore turbines compared to land-based turbines is in the foundation construction, the key development in turbine technology has been larger turbines. With larger turbines (2- to 5-megawatt turbines are currently under development for the offshore market, compared with 1 to 2 megawatts for onshore installations), fewer foundations have to be constructed to achieve comparable output, which reduces overall construction costs. Although the offshore foundations will be exposed to much rougher conditions from ocean waves than are land-based foundations, which are essentially static, the turbines themselves should encounter less turbulent winds (because the surface of the sea is not as rough as the trees, hills, and mountains on land) and may benefit from higher blade-tip speeds (because there is less concern over noise pollution from offshore turbines than there is for land-based turbines).

Some believe that reduced wind turbulence will increase the life of offshore turbines relative to land-based turbines; however, additional operations and maintenance expenses will also be incurred, resulting from the additional costs of transporting personnel to the facility and protecting against corrosion in the salt-water environments.[f] The industry, still not mature, is effectively still building "first-of-a-kind" commercial units; but early indications show a 50- to 100-percent capital cost penalty compared to land-based units ($1,500 to $2,000 per kilowatt of capacity for offshore, around $1,000 for land-based),[g] as well as a significant maintenance penalty (also in the range of 50 to 100 percent, although the numbers are less reliable).

Over the past 15 years, the Danish government has encouraged the growth of a vibrant domestic wind power industry through "grassroots" development. Individual farmers, or small farmer cooperatives, have been given incentives to develop small wind clusters on their lands, and the utilities in turn have been required to accommodate this new power source on the distribution grid. In the early years of the developing Danish wind industry, regulations required local ownership and consumption of wind power.[h] Tax breaks and direct subsidies have also played an important role in spurring new installations.[i] Finally, Danish utilities are required not only to connect wind turbines to the distribution grid but also to upgrade distribution facilities where required to accommodate the resources.[j]

To achieve their ambitious 2030 wind generation target, the Danes have, in some cases, turned to the American model of large "wind farms" of hundreds of megawatts of capacity built, owned, and operated by a utility or corporate third party.[k] The Danes have recognized that development on the scale envisioned will inevitably require them to look to the ocean as an alternative to increasingly low-quality, high-cost, and unattractive resources onshore. Such development will not likely result from the grassroots efforts of independent farmers, but will require the capital and technological resources of established wind turbine manufacturers, developers, and utilities.

In much of the rest of Western Europe, offshore wind is also seen as an attractive generation technology, for much the same reasons: a political commitment to greenhouse gas reduction, limited land-based wind resources, high population density, and negative public reaction to the tall wind towers. In addition, Western Europe has a relatively shallow continental shelf, allowing placement of wind turbines farther offshore without encountering water that is too deep. As a result, the mid-term outlook for offshore wind seems largely focused on ocean shallows surrounding Western Europe.

[f]G. Siefert, "5 Years of Ascension Island Wind Farm Operations," *WindPower 2001 Conference Proceedings* (June 2001).

[g]See, for example, web sites http://rotor.fb12.tu-berlin.de/windfarm/offshore.vindeby.html and www.windpower.dk/tour/econ/offshore.htm.

[h]F. Tranaes, "Danish Wind Energy Cooperatives" (Danish Wind Industry Association, 1997), web site www.windpower.dk/articles/coop2.htm.

[i]International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual 2000* (Golden, CO, May 2001), p. 70.

[j]F. Tranaes, "Danish Wind Energy Cooperatives" (Danish Wind Industry Association, 1997), web site www.windpower.dk/articles/coop2.htm.

[k]International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual 2000* (Golden, CO, May 2001), p. 72.

Even some European countries that have been slow in developing wind programs heretofore are beginning to make plans for expanding this renewable energy source. Offshore wind is allowing European countries that do not have the land area to devote to wind turbines a chance to begin exploiting wind energy. TotalFinaElf plans to build a large wind farm off the coast of Belgium [*30*]. The company is currently seeking a license from the Belgian Electricity and Gas Regulatory Commission to construct and operate the wind farm. The project would consist of 40 wind turbines installed at a distance of 5 to 10 miles from shore. Upon completion, the facility would have a combined capacity of 100 megawatts, which TotalFinaElf estimates would provide enough power to supply some 150,000 households.

The United Kingdom experienced a jump in wind installations in 2000, after many years of lackluster activity. Ten projects with a combined capacity of 63 megawatts were completed in 2000. The greatest obstacle to new growth in the country's wind capacity remains the difficulty developers have in obtaining planning approvals. In 2001, ScottishPower announced plans to construct what will be the United Kingdom's largest wind farm at Eaglesham Moor south of Glasgow [*31*]. The $213.8 million project will consist of 140 turbines and will have a combined capacity of 240 megawatts. The project could be completed by 2003; however, ScottishPower has yet to obtain the necessary regulatory approval.

There are also some plans to expand solar power in Western Europe. In anticipation of future growth in solar energy, BP Solar committed to constructing Europe's largest solar equipment manufacturing plant in Spain in 2001 [*32*]. The plant will be able to produce 60 megawatts per year of high-efficiency solar cells (with an aim to expand that amount to 100 megawatts). BP plans to invest $101.7 million to expand existing facilities in the plant to be located north of Madrid. The project should be complete by 2002 [*33*].

Industrialized Asia

The countries of industrialized Asia (Australia, Japan, and New Zealand) have markedly different electricity energy mixes. Japan is the only one of the three countries with a nuclear generation program, supplying one-third of its electricity from nuclear power plants. Hydroelectricity and other renewable energy sources supply about 12 percent of Japan's electricity. Renewables also account for about 10 percent of Australia's electricity supply, and thermal generation (predominantly coal) accounts for nearly 90 percent. In contrast, renewable energy sources provide 73 percent of New Zealand's electricity supply.

Between 1999 and 2020, the use of hydroelectricity and other renewables is projected to increase by 1.4 percent per year in the region of Australasia (which includes Australia and New Zealand, along with the U.S. Territories). Much of this modest increase is expected to be in the form of nonhydroelectric renewables, most notably wind.

Australia

On December 21, 2000, the Australian government passed the Renewable Energy (Electricity) Act 2000 in an effort to encourage renewable energy development [*34*]. The legislation, enacted on April 1, 2001, sets mandatory targets for renewable energy. It requires wholesale purchasers of electricity to contribute to the generation of an additional 9,500 gigawatthours of renewable energy each year by 2010. Interim targets are to be enforced, and penalties are to be assessed against electricity purchasers who do not attain their individual targets.

The Renewable Energy (Electricity) Act 2000 already appears to be having an impact on renewable energy markets in Australia. The country added 20 megawatts of its total installed wind capacity of 33 megawatts in 2000 alone. Several wind farms are either in the planning stage or currently under construction. The government has estimated that another 300 megawatts of wind capacity is expected to be operational by the end of 2002 [*35*]. In July 2001, the first wind power project in Victoria (and the largest to date in Australia) came online near Warmambool [*36*]. The 18.3-megawatt Codrington project cost an estimated $15 million to construct. Pacific Hydro, which built and operates the project, is completing environmental impact statements for another four wind farms to be located in the Portland region. The company plans to complete construction of the combined 150 megawatts of new wind capacity before the end of 2002.

The 21-megawatt Toora wind farm is currently under construction in Victoria's South Gippland region. Upon completion, its electricity generation is to be sold to CitiPower, an electricity retailer. Queensland's state-owned Stanwell Corporation plans to install 450 megawatts of wind capacity before 2006 [*37*]. Stanwell is looking to expand at a number of sites in South Australia, Western Australia, New South Wales, and Queensland.

Japan

Japan's wind energy development also increased sharply in 2000, when 50 megawatts of wind capacity was installed, bringing total installed capacity to 121 megawatts [*38*]. Tomen Corporation, a wind energy developer, is investing some $64 million in a 32-megawatt wind plant. Two sites are also planned for the northern part of the country, with installed capacities of 25 megawatts and 15 megawatts.

Some effort has also been made to expand Japan's micro-hydroelectric capacity. In September 2001, Japan's Ministry of Economy, Trade, and Industry

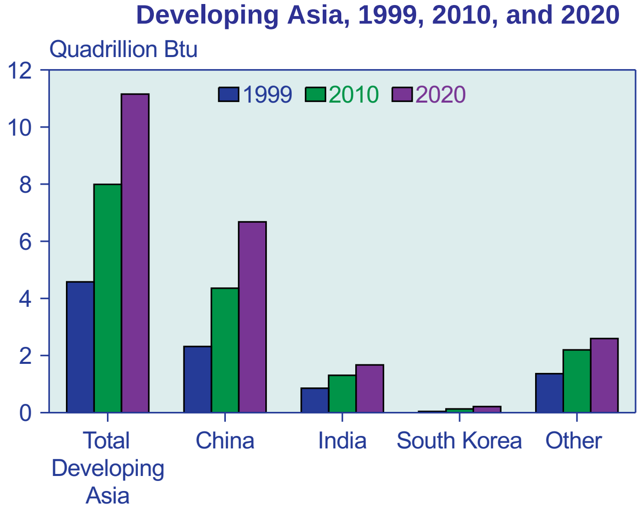
(METI) approved plans to build three new small hydroelectric projects, with a combined generation of capacity of 14.2 megawatts [***39***]. The projects are Chugoku Electric Power Company's 11-megawatt plant in western Japan, Kyushu Electric Power Company's 0.5-megawatt plant on the western island of Kyushu, and the Electric Power Development Company's 2.7-megawatt project in northern Japan. All three plants are scheduled to come online before 2004.

In 2001, the Electric Power Development Company canceled plans to build a large-scale pumped storage hydroelectric station in northern Japan because of the lack of growth in electric power demand. The electricity wholesaler had planned to construct four 450-megawatt generators, with a total capacity of 1,800 megawatts, at Ynotani, Niigata Prefecture, for a total cost of around $3 billion. The projects were supposed to come online in 2011 and 2012, but Tokyo Electric Power Company and Tohoku Electric Power Company requested the delay because electricity demand for 2011 is now expected to lag far behind the forecast made 4 years ago.

Developing Asia

Support for the construction of large-scale hydroelectric dams remains strong in many countries of developing Asia, and large-scale hydropower projects in China, India, Malaysia, and Vietnam, among others in the region, are expected to provide most of the 4.3-percent annual growth in renewable energy consumption worldwide in the *IEO2002* reference case forecast (Figure 70). There are more modest efforts to increase nonhydroelectric renewable energy use, primarily wind and solar, in China, India, and other developing Asian countries, as well as generation from biomass in Bangladesh (see box on page 114). The projects are often aimed at reaching small, rural communities that would otherwise not have access to electricity through the national grid.

Figure 70. Renewable Energy Consumption in Developing Asia, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

China

In China, work progresses more or less on schedule on the 18,200-megawatt Three Gorges Dam project, the largest hydroelectric project in the world. The dam is being built on China's Yangtze River. It is scheduled to begin producing electricity in 2003 and to be fully operational by 2009. The Three Gorges Dam project has encountered problems with accusations of corruption, and there have been difficulties in relocating the estimated 1.13 million residents who will have to move before the dam's reservoir can be flooded. Since 1993, more than 350,000 residents have been relocated [***40***].

The Chinese government has also announced that work will begin on another large-scale dam on the Hongshui River in Guangxi Province [***41***]. The Longtan hydroelectric project has a proposed capacity of 5,400 megawatts and is scheduled to begin generating electricity in 2007, with completion by 2009. The project will cost an estimated $3.2 billion. Upon completion, Longtan will be the second largest hydroelectric project in Asia, exceeded in size only by Three Gorges Dam.

Beyond the expansion of large-scale hydropower, several other projects are underway to develop China's other renewable resources, notably, wind and solar. The Global Environment Facility (GEF) and the World Bank have begun a 10-year project to increase China's nonconventional renewable energy use by 14,300 megawatts by 2010 [***42***]. The goal of the China Renewable Energy Scale-Up Program (CRESP) is to begin to reduce China's dependence on coal-fired electricity, as well as to bring electrification to the remote, rural parts of China that do not have access to the national grid. The project is expected to cost billions of dollars. Thus far, the World Bank has committed $100 million in a series of loans that give the country flexibility on meeting deadlines and targets. Another $80 million in the first phase is to come from other donors and the Chinese government, along with $190 million throughout the program's duration. The public investments are expected to encourage up to $212 million in private investments in the first phase and as much as $10 billion in indirect investments over the 10-year period.

One example of the donors that are being attracted to China because of the CRESP is the Asia Development Bank donation of $58 million in 2000 for wind power development, in support of the World Bank project [***43***]. The loan is being used to construct three 26-megawatt wind farms in China. Shell Renewables has also

Biomass Resource Utilization in Bangladesh

On many levels, Bangladesh is a country that is ideally suited for the development of small-scale biomass energy systems. Because the economy is largely dependent on agriculture, the residues needed for such projects are available. Approximately 75 percent of the 130 million people in the country live in rural areas, and for all practical purposes they are not able to benefit from the national electricity transmission grid. The country is relatively poor, with a per capita annual income of $266 (1997 U.S. dollars), as compared with $493 per person in neighboring India. As a result, it is difficult to attract the investment needed to expand the national energy infrastructure.

The lack of infrastructure in Bangladesh's rural areas has resulted in an increase in the migration of rural populations to the country's urban areas, putting enormous pressure on urban infrastructures that are ill-equipped to deal with the influx. As a result, the Bangladeshi government is interested in finding economical ways to bring electricity to the rural areas, both to improve economic development and to stem the migratory trend. Small-scale renewable energy systems fueled by biomass may offer Bangladesh a way to accomplish these goals.

The technologies that have been most popular in terms of development are biogas digesters running on animal or human wastes; turning agricultural wastes into solid fuel briquettes (similar to charcoal); and direct combustion of agricultural waste for household cooking. The main need for energy in rural Bangladesh is for cooking, although biomass is also used as housing material and animal feed. A limited amount of biomass is used as feedstock for recycled paper and in pulp mills. Sources of biomass include rice husks, jute stalks, sugarcane stalks, and peanut shells.

The patterns of biomass usage in developing countries such as Bangladesh could not be more different from those in industrialized countries such as the United States. In industrialized countries there is an abundance of waste biomass material that has only been used once and is contained in landfills, forests, or agricultural lands. A waste stream that may be attractive in the United States, such as municipal solid waste, is fraught with problems in developing countries. In the United States, wastes are carefully entombed in landfills and generally left undisturbed. In developing countries, entire communities of rag pickers, perhaps for several generations, live on and alongside the dumps and earn their living by scavenging materials and selling them to small industries that turn them into a myriad of products ranging from combs to shoes to paper. Consequently, attempts to divert streams of municipal solid waste in developing countries can affect entire classes of people and the small industries that depend on them. Although large quantities of "waste" are generated in a country like Bangladesh due to the agricultural nature of the economy, relatively little of that biomass may be available for use in energy generation. As long as competing uses of biomass material fetch a higher price, or are easier to accomplish, the material will find use in non-energy applications. Two examples illustrate the opportunities and pitfalls for biomass commercialization in a developing country like Bangladesh.

A thriving business in Bangladesh is biomass briquetting or "densification." Briquetting processes require heat and pressure to produce fuel pellets from rice husks and wood chips. There are approximately 900 briquetting machines in operation in Bangladesh, the overwhelming majority of which are locally manufactured. Their capital cost is about $1,080 to $1,180, equipment costs are $500 to $670, land costs are about $360, and installation costs are about $150.[a] Production costs range from $0.78 to $0.93 per pound, and the briquettes can be sold for about $1.04 per pound. The machines produce briquettes at the rate of about 180 pounds per hour and have payback periods of 7.5 months to 18 months.

Briquettes have become popular as a fuel for heating urban hotels and tea shops. In addition, briquettes are in demand as a fuel for melting bitumen, which is used in road paving operations. Brick manufacturing industries can also use the briquettes as a fuel in their ovens. Overall, the prospects for growth of this industry in Bangladesh appear to be bright.

Another example of biomass use in Bangladesh is biodigesters. Unlike briquetting, biodigesters have a mixed record of success. In Faridpur District, a school with about 350 students and 50 staff members uses a biodigester to generate a methane-based cooking fuel.[b] Sludge from the digester is used for fertilizer. The replacement cost for a plant of this type is estimated to range from $515 to $825. The Government of

(continued on page 115)

[a]Institute of Appropriate Technology, *Proceedings of Workshop on Reverse Engineering* (Bangladesh University of Engineering and Technology, Dhaka, Bangladesh, May 2001). Assuming an exchange rate of 70 Taka for 1 U.S. dollar.

[b]A. Jimenez and T. Lawand, *Renewable Energy for Rural Schools* (Golden, CO: National Renewable Energy Laboratory, November 2000).

committed to supply solar power systems to 78,000 homes before 2006 [44]. Shell signed an agreement with Sun Oasis Company in Beijing to supply the systems (to be installed and maintained by Sun Oasis) in the western China Autonomous Region of Xinjiang.

India

The Indian government continues to pursue large-scale hydroelectric power, although the projects frequently face difficulties in obtaining financing, as well as protests from environmental and human rights activists. The Narmada Valley Development Project has been planned to include up to 30 large dams, in addition to numerous medium and small ones [45]. The 1,450-megawatt Sardar Sarovar hydroelectric project is only one of the large-scale dams to be constructed as part of the Narmada Valley plan.

In October 2000, India's Supreme Court dismissed a petition filed by the Narmada Bachao Andolan (NBA) movement to stop completion of Sardar Sarovar. Work on the project was halted in 1995 when the NBA filed the suit. NBA argued that the dam developers had not made adequate plans for relocating hundreds of thousands of people who would be displaced by the project. The court did rule that the dam may only be constructed to a height of 295 feet, although developers had planned for a height of 453 feet. For every 16-foot height addition beyond the 295 feet, the developers are required to obtain additional planning permission, including the approval of the environmental subgroup of the environment and forestry ministry. In August 2001, the developers gained permission to raise the height of Sardar Sarovar to 328 feet [46]. Upon completion, Sardar Sarovar will provide power to Madhya Pradesh and will offer irrigation and food production benefits to Gujarat, Rajasthan, and other arid areas along the north and south banks of the Narmada River, some 600 miles south of New Delhi. In August 2001, project managers announced that Rajasthan should begin receiving its share of water from Sardar Sarovar by June 2004.

India continues to encourage the development of renewable energy sources beyond hydroelectricity. In 2002, Indian Prime Minister Atal Bihari Vajpayee stated he would like renewable energy to account for at least 10,000 megawatts of the 100,000 megawatts of new electricity capacity to be added between 2001 and 2012 [47]. The renewable resources that would be counted in this plan are small hydroelectricity, wind, solar, and biomass. The government expects that up to 2,000 megawatts of new wind capacity could be added to the current 1,340 megawatts before 2007, with biomass contributing 1,000 megawatts, small hydropower 800 megawatts, solar thermal 140 megawatts, waste-to-energy 100 megawatts, and grid-connected solar photovoltaic 15 megawatts. In recent years, bagasse (crushed sugar cane) cogeneration potential in cooperative and public-sector sugar mills has looked promising. Currently India has about 213 megawatts of installed bagasse cogeneration capacity, and another 263 megawatts is under construction at 29 plants.

Malaysia

Malaysia is another developing Asian country pursuing the development of large-scale hydropower. The country's Bakun hydroelectric project has been plagued by controversy and financial difficulties since it was first approved in 1994 [48]. The 2,400-megawatt project was scaled back in 1998, because the Asian economic crisis made the project too expensive to pursue, particularly given the sharp drop in electricity demand associated with the recession; however, the government recently announced that it would return to the original capacity of 2,400 megawatts. Bakun is expected to cost around $2.4 billion, and it is scheduled for completion in 2005. Environmentalists argue against the dam, which will require that more than 172,000 acres of farm land—an area larger than Singapore—be flooded to serve as a reservoir for the 670-foot dam. The reservoir will submerge 15 villages of the indigenous Iban people in central Sarawak state, as well as destroying the habitat of some 100 endangered species [49].

On the other hand, the Malaysian government argues that electricity from the Bakun dam will be necessary to support expanded industrial activity in the region, as well as to diversify the Malaysian electricity fuel mix, which is dominated by natural gas. The government announced that three resource-based industries (oil

Biomass Resource Utilization in Bangladesh (Continued)

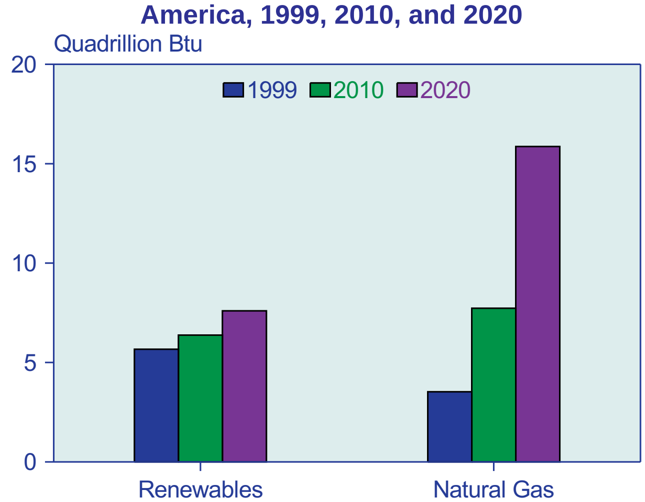
Bangladesh's Local Government Engineering Department provided the initial funding and paid for the entire system. The school pays for the operating and maintenance costs, which have been negligible. Although there have been successful installations of other biodigesters in the community, the school has not expanded its own biodigester program. The principal barriers to further commercialization of the technology are high capital costs and lack of financing options.

Despite the potential for problems associated with high capital costs, competing uses of biomass, availability of adequate quantity and quality of feedstocks, and lack of financing mechanisms, it is expected that biomass will continue to play a key role in supplying the energy needs of Bangladesh. The major question is how quickly more efficient biomass-using technologies can be introduced to allow the people of Bangladesh to obtain maximum benefit from the resource.

palm, cocoa, and wood) and four non-resource-based industries (electronics and engineering, manufacturing, petrochemicals, and steel) in Sabah and Sarawak will be the primary consumers of the electricity generated by Bakun [***50***]. The Sabah government has said it will open three industrial parks—Kudat Industrial Estate, the Integrated Timber Complex, and Palm Oil Industrial Cluster—that will consume an estimated 600 megawatts of electricity to be supplied by Bakun. Sarawak is expected to take about 500 megawatts of Bakun's electricity and neighboring country Brunei up to 500 megawatts; Kalimantan province in Indonesia is expected to take 100 megawatts. Upon completion, Bakun's capacity will be 1,700 megawatts, 700 megawatts below the full design capacity of 2,400 megawatts, because water levels are not expected to be sufficient initially to operate the generator at maximum capacity.

In addition to the large-scale hydroelectric expansion of Bakun, the Malaysian government has indicated an interest in developing the country's less controversial renewable resources. In 2001, the Malaysian government announced that it would like renewable energy to account for 5 percent of total power generation by 2005 [***51***]. The government hopes to support the development of renewables with its new Small Renewable Energy Power (SREP) program. Under the program, small power producers using renewable energy will be given a license for a 21-year period (from the date by which a plant is commissioned) to sell their power through the national power grid. The renewable energy sources permissible under the SREP program include biomass, biogas, municipal waste, solar, mini-hydro, and wind.

Figure 71. Renewable Energy and Natural Gas Consumption in Central and South America, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

While the plant size can be greater than 10 megawatts, the maximum capacity for power exports to the national distribution grid cannot exceed 10 megawatts.

Vietnam

Vietnam also proposes expanding its large-scale hydroelectric power over the next several years. In 2001, Vietnam's National Assembly approved construction of the 3,600-megawatt Son La hydropower project to be constructed on the Da River, about 200 miles west of Hanoi [***52***]. The project is the subject of some dispute, even among members of the National Assembly, because it has been sited for an area known to have frequent seismic disturbances, and it opposed by human rights activists because it would require the relocation of up to 700,000 people, mostly of ethnic minorities. Estimates for the cost of constructing Son La (which is scheduled for completion in 2016) have run as high as $5.1 billion. Proponents of the project have argued that it is needed to help improve Vietnam's electricity fuel mix, reduce flood damage, and improve irrigation in the Red River Delta.

Pakistan

In Pakistan, several smaller hydroelectric and non-hydroelectric renewable projects were initiated in 2001. Work began on the Malakand III hydroelectric power project in September. Malakand is located at Dargai, Northwest Frontier Province, about 50 miles north of the Peshawar, which is considered the gateway to the Khyber Pass [***53***]. The project, which is being built by the Canadian Southern Electric Power Company, is scheduled for completion in 2005. In addition to the electricity to be generated by the dam, it should provide irrigation for some 20,000 acres of barren land.

Central and South America

Hydroelectricity is an important source of electricity generation in Central and South America. (In Brazil, the region's largest economy, hydropower typically supplies more than 90 percent of the country's electricity generation.) As a result, drought can have a devastating impact on electricity supply, and many countries of Central and South America are initiating projects to diversify the mix of electricity supply. Much of the diversification will consist of adding natural-gas-fired electricity capacity to reduce dependence on hydropower. As a result, although there is some projected growth in the use of hydroelectric and other renewable resources in the forecast, it is expected to be much less than the growth in natural gas consumption. In the *IEO2002* reference case forecast, demand for hydroelectricity and other renewables in Central and South America increases by only 1.4 percent per year between 1999 and 2020, whereas natural gas use in the region grows by 7.4 percent per year (Figure 71).

Rural electrification has also become an important issue for many Latin American countries. An estimated 75 million people in Latin America live without electricity [54]. In remote, rural locations where national electricity grids do not reach, renewable resources other than hydroelectricity are increasingly being used by government to bring electricity and telecommunications to the residents. Brazil, Chile, and Argentina, for instance, all have federal programs in place to improve access to electricity through off-grid renewable resources.

Brazil

In 2001, Brazil faced its worse drought in decades, which had a major impact on electricity supply (see also box on page 118). The country's reservoirs were, on average, 28 percent below normal capacity and in June the government was forced to initiate energy conservation and rationing measures in an effort to reduce electricity consumption by 20 percent [55]. The effort was largely successful in the first 2 months, with many regions meeting or exceeding their 20-percent demand reduction goal, but in August consumption was reduced by only 15 to 18 percent [56]. In an effort to improve the conservation effort, the government expanded an existing bonus scheme to benefit 75 percent of families living in energy rationing areas, as opposed to the previous 60 percent. Those who achieve a 20-percent savings and consume less than 225 kilowatthours per month will receive 1 real credit (about $0.37) for every 1 real of energy saved. Previously, only those consuming up to 100 kilowatts were eligible for a bonus.

Although the country missed its targets in August, the Brazilian government announced that there was no risk of blackouts for the remainder of the year because water levels were about 3 percent higher than had been projected. In addition, according to the government, even in a worst case scenario—where rainfall was only 61 to 63 percent of normal levels—rationing would be extended into 2002, but at the lower rate of 5 percent of consumption.

In addition to the rationing and conservation strategies, Brazil is rushing to add additional capacity. By the end of 2002, Brazil plans to add 9,034 megawatts of natural-gas-fired electricity generation capacity, 6,381 megawatts of hydroelectric capacity, and 400 megawatts of mini-hydro capacity [57]. One of the hydroelectric projects included in the plans is the 112-megawatt Porto Estrela project on the Santo Antonio River, which began operating in October 2001 [58]. The project was constructed by a consortium led by Brazil's Cemig power company at a cost of $50 million. It was built in record speed, with only a 26-month construction period.

In June 2001, Brazil's electricity regulator, Aneel, sold eight licenses to build and operate hydroelectric facilities in six southern Brazilian states. The licenses netted the government about $1.1 billion [59]. The six plants will add a total of 2,282 megawatts of power to the national energy grid. The largest project, which will be constructed by a consortium led by mining company Companhia Vale do Rio Doce (CVRD), is an 840-megawatt plant in the southern state of Rio Grande do Sul. Other plants will be located in the states of Santa Catarina, Parana, Rio Grande do Sul, Minas Gerais, Goias, and Tocantins. Brazil's southern region is not suffering from the drought that has hit other parts of the country, and the plants are expected to be completed between 2006 and 2008. Licenses were awarded in November for 11 additional hydroelectric power plants in Brazil, which are expected to add 2,700 megawatts of generating capacity by 2007 [60].

The government of Brazil is also working to develop nonhydroelectric renewables, especially in remote areas of the country that do not have access to the electricity grid. In 1998, the country started the National Program for Energy Development of States (PRODEEM) in an effort to install 20,000 megawatts of renewable energy capacity, with an investment of about $25 billion in photovoltaic and other renewable energy technologies [61]. The project's aim was to expand electricity capacity through hundreds of community projects—each expected to reach about 200 people living in rural communities that would not be connected to an expanding electricity grid before 2003. In addition to photovoltaics, the PRODEEM program included aero-generators and wind turbines, small central hydroelectric plants, biomass-derived fuels (alcohol, vegetable oils, forest and farm wastes), and biodigesters.

Brazil is now launching a successor program to PRODEEM called ALVARADO, which will focus on increasing access to electricity in the northeastern part of the country. Starting in 2002, ALVARADO is expected to begin establishing small renewable energy systems. Like PRODEEM, ALVARADO will involve both local and international private-sector developers in its effort to install off-grid renewable energy projects.

Another Brazilian scheme to promote the development of renewable energy resources involves electricity produced from sugar cane. The second-largest distributor of electricity in São Paulo state, CPFL, has set a target to increase its marginal power purchases from sugar cane industries to 7 percent of its total demand by 2003. Further, the Pernambuco state power company (owned by Spain's Iberdrola) has agreed to purchase all the electricity that is produced by the Cruangi sugar refinery through 2006.

Chile

In Chile, the controversial and much-delayed 570-megawatt Ralco hydroelectric project was delayed for another 6 months. The $540 million project being developed by

Energy Crisis in Brazil: Implications for Hydropower

Brazil is currently in the midst of an energy crisis that has exposed the risk that accompanies its high level of dependence on hydroelectric power. After the worst drought in 70 years, water levels in many of Brazil's hydroelectric reservoirs fell to critical lows by the summer of 2001. To avert impending blackouts and power interruptions, the Brazilian government introduced a series of emergency measures intended to cut electricity consumption and diversify supply sources.

As of June 1, 2001, industries and commercial businesses were required to reduce their power consumption by 15 to 25 percent.[a,b] They were also barred from undertaking any major new expansion works requiring new electricity connections from the main system.[c] Households that consume more than 100 kilowatthours of electricity per month were required to cut their consumption by 20 percent or face a 3- to 6-day cut in their electricity supply.[d] The electricity rationing plans were initially implemented in areas of the South East, North East, and Center West regions of the country, then extended to three more states (Pará and Tocantins in the North, and Maranhão in the North East) as of July 1 (see map below).

Electricity consumption dropped during the first few months of the rationing program, but reduction levels did not reach the 20-percent target in most regions.[e] The program was initially expected to conclude in November, but the government announced in October that it would extend the rationing and initiate further demand-side measures. The government ordered a 4-day work week in several states and created three new "holidays" (October 22 and November 16 and 26) in North Eastern states, intended to help spur electricity consumption reductions in the manufacturing and buildings sectors.[f] The new measures also required that power be cut off to residential customers using more than 500 kilowatthours of energy per month. Daylight savings measures were also introduced in most regions of the country.

(continued on page 119)

[a]"Brazil: Power Rationing Begins," *World Markets Online*, web site www.worldmarketsonline.com (June 4, 2001).

[b]"Brazil: Government Loosens Electricity Penalties," *World Markets Online*, web site www.worldmarketsonline.com (June 6, 2001).

[c]With the exception of residential and rural projects.

[d]Initially, the noncompliance penalty for residential customers included surcharges. Under mounting public pressure, the government eliminated the surcharge penalties and relaxed the conditions for supply cuts. Power will now be cut off only for households that fail to meet their target for two consecutive months (3 days for the first offense, 6 days for the second offense).

[e]"Electricity Rationing Extended to April," *Latin America Monitor*, Vol. 18, No. 8 (August 2001).

[f]"Extra Holidays To Help North East Meet Power Saving Target," *World Markets Online*, web site www.worldmarketsonline.com (October 11, 2001).

Energy Crisis in Brazil: Implications for Hydropower (Continued)

In December 2001, regional energy rationing targets (with the exception of heavy industry in each region) were lowered.[g] In January 2002 the Brazilian government eased the power rationing targets for heavy industry to 10 percent of mid-2001 consumption,[h] and all energy rationing was discontinued on March 1, 2002. According to the Brazilian national grid operator, ONS, water reservoir levels had increased sufficiently to guarantee power supply through 2002 and 2003, given the long-term forecasts for rainfall.[i]

Although more than 90 percent of Brazil's generating capacity and production currently comes from hydroelectric plants, the drought was not the sole factor behind the country's energy crisis. The demand for electricity in Brazil has been growing by almost 5 percent per year, on average, since 1990. Demand growth has been driven particularly by industrial use in the South East and Center West regions, where most of the country's population live. However, investments in new electricity generation and transmission capacity have not kept pace with demand. The Brazilian government now plans to build 49 new thermoelectric generators by 2003, fueled primarily by Bolivian natural gas; only a handful have come online so far. The absence of power line connections to regions of the South and the North of Brazil, as well as from Argentina, has prevented electricity from reaching the areas facing electricity shortages.

Factors such as private investors' increased perception of risk since the devaluation of the Brazilian real in 1999, the contractual terms of supply offered for natural gas by Petrobras (the federal oil and gas monopoly), and the electricity tariff controls set by Aneel (Brazil's power regulator) are believed to have impeded the capital investments needed to finance new generation and transmission projects in the country.[j] The slowdown in efforts to privatize the electricity sector in recent years has also contributed to the current energy crisis, because some planned capacity additions were to occur after privatization.

Changes that have occurred since the onset of the rationing program have helped to remove some of the financial and regulatory barriers to electricity sector investment in Brazil.[k] Specifically, the National Development Bank of Brazil made several billion dollars worth of public funds available to companies wishing to enter partnerships in natural-gas-fired or hydroelectric power stations. The bank will provide up to 60 percent of the financing needed by private investors. A formula has also been established to protect investors against exchange rate risk. Furthermore, Petrobras has agreed to a set of supply terms that are considered more favorable by thermoelectric power plant investors, with natural gas to be provided at fixed prices for periods of 12 full months. On the transmission side, the Inter-American Development Bank has approved $243.9 million in financing to build an additional 1,000-megawatt line connecting the electricity grids of Argentina and Brazil.

Substantial governmental effort on the supply side has focused on natural-gas-fired generating plants, which can be brought online faster and at less expense than most other comparable options. Despite the difficulties associated with depleted reservoirs, a significant expansion of Brazil's hydropower infrastructure is also considered a key element of the government's overall plan to shore up the country's electricity supply. Aneel awarded licenses for the construction and operation of 8 new hydroelectric power plants in June 2001, and licenses for another 11 were awarded in November.[l] These new builds alone would add some 5,000 megawatts to Brazil's total generating capacity. The government has also expressed its intention to increase capacity from the country's third largest power generator, CESP Parana, in advance of its privatization. The reservoir quota for Itaipu—the world's largest hydroelectric plant—may also be increased in order to boost generation.[m] Both CESP Parana and Itaipu serve the energy-starved South East region of Brazil.

Although expansion of the hydroelectric infrastructure may serve to alleviate electricity shortages in Brazil, it is not without controversy. The development of Brazil's existing hydroelectric facilities has given rise to

(continued on page 120)

[g]"Power Rationing Reduced," *World Markets Online*, web site www.worldmarketsonline.com (November 23, 2001).

[h]Power-Saving Targets for Industry Reduced," *World Markets Online*, web site www.worldmarketsonline.com (January 25, 2002).

[i]"Power Rationing To End on 1 March," *World Markets Online*, web site www.worldmarketsonline.com (February 20, 2002).

[j]A. de Oliveira, "The Changing Brazilian Electricity Market," Roundtable / Conference Reports, Institute of the Americas (March 27, 2000); "Brazil Stares Electricity Rationing in the Face," *Financial Times: Power in Latin America*, No. 70 (April 2001); "Biting the Hand That Electrifies," *Financial Times: Power in Latin America*, No. 71 (May 2001).

[k]"Investing in Brazil Is Anything But Boring," *Financial Times: Power in Latin America*, No. 74 (August 2001).

[l]"Government Sells Licenses for New Hydroelectric Power Plants," *World Markets Online*, web site www.worldmarketsonline.com (June 29, 2001); "Brazil: Aneel Sells Licenses to Build 11 New Hydroelectric Plants," *World Markets Online*, web site www.worldmarketsonline.com (December 3, 2001).

[m]"Brazil Stares Electricity Rationing in the Face," *Financial Times: Power in Latin America*, No. 70 (April 2001).

Endesa España has been the subject of much criticism from environmentalists and human rights activists for its treatment of the indigenous Pehuenche people. Construction of Ralco will include flooding of some sacred Pehuenche land and will dislocate 91 families that currently live there [***62***]. In 2001, the problems were compounded by heavy rains in the late spring that caused the Bio Bio River to rise to five times its normal level. The dike constructed to reroute the river above the construction site collapsed, and the river reestablished its original course. As a result, construction was halted and did not resume until December, when river levels were low enough to allow reconstruction of the diversion dike. The project has been under construction for some 7 years, and the original completion date has been delayed for at least a year; it is now expected to be completed by January 2004 at the earliest.

Chile's National Energy Commission is planning to implement several projects that will involve nonhydroelectric renewable energy resources [***63***]. The government has passed legislation promoting the development of 120 new geothermal projects by independent power producers. The National Electricity Commission has initiated an aggressive rural electrification program aimed at providing electricity to communities that lack access to the national electricity grid. Since 1992, Chile has invested $112 million in the program, which is expected to run until 2004, with the goal of supplying electricity to 100 percent of the population.

Other Central and South America

Other Central and South American countries are also attempting to address the problem of getting electricity to remote, rural areas. Costa Rica has one of the most ambitious programs for renewable energy in Latin America. The country instituted a policy mandating that by 2025 all forms of energy consumed in the country be derived from renewable sources. In Honduras the Inter-American Development Bank has estimated that almost 40 percent of the population does not have access to electricity. The Bank has approved a $5 million loan for a study to determine whether combining education and health assistance with telecommunications and energy technology for low-density populations is feasible [***64***]. The study will begin with two villages, providing solar thermal and photovoltaic home systems. If it is deemed a success, the Bank has indicated that it would allow as many as 100 villages to take part in the project.

In Argentina, the government and the World Bank are implementing a project that is to provide electricity to roughly 70,000 rural households and 1,100 provincial public service institutions, principally through the use of renewable energy systems [***65***]. Total cost of the project has been estimated at $120.5 million. Energy sources will be principally photovoltaic and wind, with biomass used to make up any shortfalls. Argentina has expressed a particular interest in developing its wind resources. The country has passed legislation that requires all utilities to purchase wind power if it is available. This should help cover the costs of building the necessary transmission infrastructure from the wind turbines to the power distributors. Further, with approval of the Argentine government, Spanish companies Endesa and Elecnor are developing 3,000 megawatts of wind energy capacity, to be completed by 2010.

In a region like Latin America, where the grid is often underdeveloped and a large number of people live in rural areas without access to electricity, photovoltaics are promising because they can be installed and operated at the point of energy consumption. Roughly 75 million people in Latin America live without electricity because of inadequate transmission infrastructure. It can cost between $1,000 and $2,000 per mile to extend low-voltage distribution lines to the transmission grid. As a result, in areas where the population is so dispersed that load density can be as small as one customer per mile of line, the cost of extending remote sites to the transmission grid can be prohibitive. On the other hand, off-grid, individual photovoltaic systems average $647

Energy Crisis in Brazil: Implications for Hydropower (Continued)

some economic, social, and environmental problems. The construction of large hydroelectric projects in particular, often beset by long delays and significant cost overruns, has contributed to the country's debt burden since the 1970s. Reservoir and dam development for large facilities has also disrupted the culture and sources of livelihood for many communities. Studies have indicated that the majority of people uprooted from their existing settlements as a result of dam development are poor and / or members of indigenous populations or vulnerable ethnic minorities.[n] The displaced populations have also had to bear a disproportionate share of the social and environmental costs of large hydroelectric projects without gaining a commensurate share of the economic benefits. Reservoir and dam development for hydroelectric facilities has also led to loss of forests, wildlife habitats, species populations, aquatic biodiversity, upstream and downstream fisheries, and services provided by downstream flood plains and wetlands.

[n]World Commission on Dams, *Dams and Development: A New Framework for Decision-Making* (London, UK: Earthscan Publications, 2000).

per installed household unit, assuming a system of 50 watts per household. As a result, the more remote the site, the more financially attractive photovoltaic systems can be.

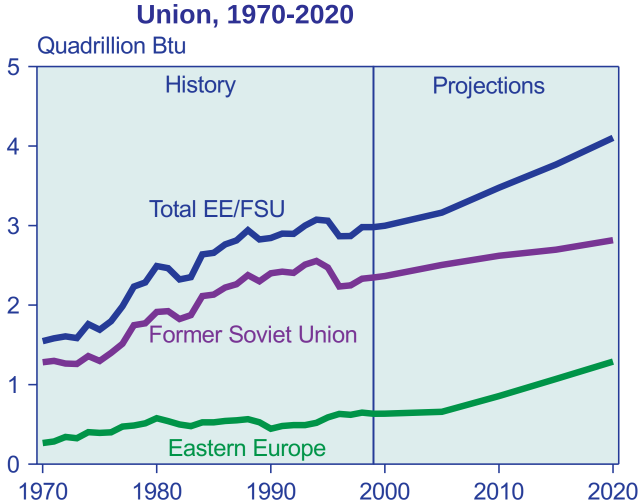
Eastern Europe/Former Soviet Union

There are only a few plans to expand the use of renewable resources in the countries of Eastern Europe and the former Soviet Union (EE/FSU). Much of the increment in hydroelectricity from 1999 to 2020 is expected to be in the form of repairing and expanding existing facilities that suffered from a lack of maintenance during the Soviet era. In general, renewables are not competitive in the FSU, where fossil fuel resources are abundant and demand for clean forms of electricity can be met with cheaper natural-gas-fired capacity. FSU renewable energy demand is projected to increase by 0.8 percent per year. In Eastern Europe, the growth rates projected for hydroelectricity and other renewables are four times those for the FSU at 3.4 percent per year, reflecting the relatively small amount of renewable capacity currently installed in the region. By 2020, the reference case projects that use of hydropower and other renewables in Eastern Europe will be 55 percent of the current level in the FSU (Figure 72).

Former Soviet Union

Azerbaijan is one of the few former Soviet republics that has added new, large-scale hydroelectric power capacity. In May 2000, the 4,000-megawatt Yenikand hydroelectric facility was completed [*66*]. The project, originally begun in 1985, was later suspended and could only be started again in 1996 with the help of a $53 million loan from the World Bank. The country's 360-megawatt Mingechaur hydroelectric power station is currently undergoing rehabilitation and should begin operation in the near future.

Figure 72. Renewable Energy Consumption in Eastern Europe and the Former Soviet Union, 1970-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Georgia also plans to add hydroelectric capacity and repair some of the country's existing hydropower facilities. There are plans to construct two hydroelectric plants on the Rioni River, the 250-megawatt Namakhvani and the 100-megawatt Zhoneti [*67*], and a 40-megawatt Minadze hydroelectric plant on the Kura River. In November 2002, Georgia announced a tender for work to be done on the country's largest hydropower project, the Inguri. The estimated $62 million project is designed to increase the facility's capacity to 1,300 megawatts from the current level of around 400 megawatts. The project will be funded in part by a long-term credit from the European Bank for Reconstruction and Development, along with funds from the European Union and Japan and the Georgian government.

In 2001 there were some modest attempts to increase the use of nonhydroelectric renewables in a few countries of the FSU. In July, Ukraine's parliament passed the Ukrainian Wind Power Development Project in an attempt to encourage the development of wind power and make wind power a "significant source" of electric power by 2020 [*68*]. Ukraine has extensive wind resources, although the development of a wind power industry would require technological and financial support.

A Malaysian company, Ideal Fortune Holdings Sdn. Bhd., has been awarded a 25-year concession to build, own, operate, and transfer wind and hydroelectric power projects in Kazakhstan [*69*]. A combined capacity of 500 megawatts is to be added in Kazakhstan. The wind facilities are to be located in the Chilik Corridor, a valley 90 miles north of the city of Almaty. They will cost an estimated $500 million and should be completed by 2006.

Eastern Europe

Much of Eastern Europe has been experiencing drought conditions over the past year, which has constrained electricity generation from the region's hydroelectric facilities. To counteract the decline in reservoir levels, there are some plans to expand the capacity of existing hydroelectric facilities throughout the region, as well as some plans to construct new facilities.

Albania has been particularly hard hit by the drought, and other countries have attempted to alleviate the resulting electricity shortages with exports or by increasing water flow at Albania's hydropower projects. In 2000, Macedonia allowed waters from Lake Ohrid to drain into the Black Drin River to increase the flow at Albanian hydroelectric projects downriver [*70*]. Croatia announced plans to construct a new hydroelectric project on the Drava River that would be able to provide power to Albania. Likewise, Italy's Enelpower announced plans to construct a 100-megawatt hydroelectric project on the Vjosa River in Albania that would be able to supply power to Albania, Greece, or Italy (by submarine cable) as needed. China has agreed to build a hydropower plant on the Drini River that is expected to produce 350 million kilowatthours of electricity each year.

At the end of July 2001, Albania's state-owned electric utility, Korporata Elektroenergjetika Shqiptare (KESH) imposed daily power cuts of up to 10 percent on electricity consumption to conserve water reserves until the rainy season arrived. The International Monetary Fund urged the government to act quickly to avoid the blackouts that occurred in the previous year when summer droughts led to 12-hour-a-day blackouts during the winter.

KESH also signed an agreement with Croatia's largest electrical equipment manufacturer, Koncar Inzinjering, to repair and upgrade two hydroelectric facilities on the Mat River in central Albania [***71***]. The agreement will include the upgrade of generators, transformers, and switchgear at the 25-megawatt Ulza and 25-megawatt Shkopeti power plants. The $2.9 million project is being financed by the European Bank for Reconstruction and Development and should be completed by the end of 2003. Koncar will also work with Bosnian Croat power utility Elektropivreda HZ Herceg Bosne (EP HZ HB) to complete Bosnia's Pec-Mlin and Mostarsko Blato hydropower plants, at an estimated cost of around $87.9 million [***72***].

Romania's Hidroelectrica is in the process of completing, upgrading, and restoring 14 of its hydroelectric facilities [***73***]. The plants, in various stages of construction, would add a combined 780 megawatts of installed capacity. One project, the Siriu-Surduc-Nehoiasu hydroelectric project on the Buzau River in eastern Romania, is being handled by United Power Company, a joint venture between Hidroelectrica and U.S. Harza. The project was to be completed in the first quarter of 2002. The expansion of the Iron Gates I (located on the Danube River) refurbishment project began in 1999. The $154 million contract includes restoration of six turbines and should boost capacity of the facility to 1,290 megawatts from the present 1,070 megawatts. The project is scheduled for completion by 2005.

There are a few plans to develop nonhydroelectric renewable energy resources in Eastern Europe. In 2001, a German renewable energy company, P&T Technology, announced plans to construct a series of wind power plants in Poland [***74***]. P&T has already reached agreements to construct 150 megawatts of wind power capacity and has obtained the approval of the local Polish communities. The projects are located in the northwestern coastal area of the country. The first, a 4-megawatt wind farm, is being constructed near Kolobrzeg, Poland.

Hungary has also begun looking toward developing wind power. A 600-kilowatt wind turbine in the Hungarian village of Kulcs (about 40 miles south of Budapest) began operating at the end of August 2001 and will supply electricity to the public electricity grid [***75***]. The project is expected to provide around 1.2 million kilowatthours of electricity annually, enough to supply 750 households. The $700,000 project is owned by Emszet (First Hungary Windpower), majority owned by Eon Hungaria, and was subsidized by government grants that covered 40 percent of the installation costs. The Hungarian government has established a target of having renewables supply 6 percent of the country's total energy production by 2010, from an estimated 2 to 3 percent currently. The Emszet wind generator is the second working unit in Hungary. The first was a 250-kilowatt unit built by Bakony Power in Inota, western Hungary. The Inota project cost $428,000 and began operating in December 2000. Electricity from the project is fed into the local power station before being sold onto the national grid.

Africa/Middle East

In Africa and the Middle East, hydroelectricity and other renewable energy sources have not been widely established, except in a few countries. In the Middle East, only Turkey and Iran have extensively developed their hydroelectric resources. In Africa, Egypt and Congo (Kinshasa) have the largest volumes of hydroelectric capacity. Other countries, including Ivory Coast, Kenya, and Zimbabwe, are almost entirely dependent on hydropower for their electricity, not because they have extensively developed hydropower resources but rather because of a lack of development of electricity infrastructure. Renewable energy use in Africa and the Middle East is projected to rise from 1.2 quadrillion Btu in 1999 to 2.7 quadrillion Btu in 2020 in the *IEO2002* reference case (Figure 73).

In Africa, a number of hydroelectric projects moved forward in 2001. The Japanese government approved implementation of the delayed Sondu Miriu hydroelectric project in Kenya [***76***]. Funding for the 60-megawatt project in Nyakach had been partially withheld because of environmental concerns from local residents and nongovernment organizations. The Japanese Ministry of Foreign Affairs and representatives from the Japanese Bank for International Cooperation reviewed the project and met with those opposing it to reach consensus as to whether the project should continue. An agreement was reached in June 2001, and the $52 million Sondu Miriu is expected to be completed by the end of 2003.

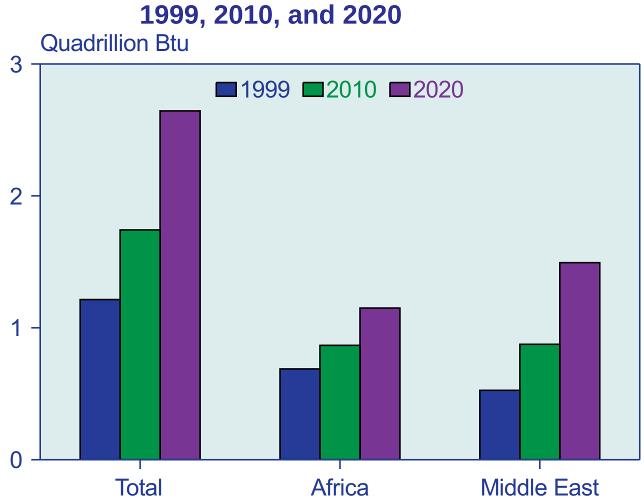
Uganda is also expected to see some hydroelectric projects begin operation over the next several years. A consortium of companies led by U.S. AES is constructing the 200-megawatt Bujagali hydroelectric project, to be located about 2.5 miles south of the source of the White Nile River at Lake Victoria [77]. The project is expected to cost an estimated $500 million to build and is scheduled for completion before the end of 2005. Bujagali will increase Uganda's electricity capacity by more than 40 percent, and a portion will be exported to neighboring Kenya and Tanzania.

There is also a move to increase the use of small-scale hydroelectric power in Uganda. In 2001, the country issued tenders for the development of a 5-megawatt hydropower station at Nyagak Falls in the Nebbi District and a 1.5-megawatt plant at Olewas Falls (the latter to be financed by the World Bank). The two projects will cost an estimated $18 million. No construction schedule has been released.

The River Senegal Basin Development Organization (OMVS) announced that all three member nations, Senegal, Mali, and Mauritania, should begin receiving electricity from the long-awaited Manantali hydroelectric project in Senegal by April 2002 [78]. The dam portion of the project was actually completed in 1987, but funding problems and military tensions between Mauritania and Senegal stopped the completion of the power station and transmission lines [79]. The 200-megawatt project cost a total of $267 million to construct.

Other African hydropower projects that moved forward in 2001 include the Zambian 120-megawatt Itezhi-Tezhi, to be located in the southern part of the country [80]. Tenders were issued in July 2001 for construction of this $105 million project, which should be completed by July 2003.

Figure 73. Renewable Energy Consumption in Africa and the Middle East, 1999, 2010, and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

Mozambique's proposed Mepanda Uncua project—to be located downstream from the existing Cahora Bassa dam on the Zambezi River—also moved forward in 2001 [81]. The 1,200-megawatt Mepanda Uncua project will cost an estimated $1.25 billion. In April 2001, the Mozambican government released results from its environmental impact study. The study indicated that potential environmental damage from the new project would be minimal, and that the project should proceed.

Finally, the Saudi Fund for Economic Development, the Abu Dhabi Fund for Development, the Arab Fund for Economic and Social Development, and the Kuwaiti Fund for Economic Development have jointly decided to fund the construction of a 1,250 megawatt hydroelectric project in Sudan [82]. The Merowe dam project is to be constructed at a cost of about $780 million and will be located about 220 miles north of Khartoum on the Nile River. Tenders are scheduled to be issued for construction of the project in 2002.

There were also several advances in the development of nonhydroelectric renewable energy projects in Africa. Morocco continued its pursuit of installing wind power. The state-owned utility Office Nationale d'Electricite (ONE) is planning to construct 200 megawatts of wind power at Tangiers and Tarfaya. The country's first wind power plant, the 50-megawatt Koudia al-Baida, began operating in May 2000 and is generating an estimated 200 million kilowatthours of electricity annually. Egypt also has made some advances in wind power, installing 30 megawatts of wind capacity on the Red Sea coastline south of Cairo in 2000, with plans to add another 60-megawatt build-own-operate-transfer (BOOT) wind project at Zafrana [83]. The Egyptian New and Renewable Energy Authority (affiliated with the state-owned Egyptian Electricity Holding Company) hopes that wind will supply some 600 megawatts of electricity capacity to the national grid by 2007.

In the Middle East, much of the new development in renewable energy, particularly hydroelectricity, is centered in Turkey. The country has ambitious plans to construct a system of 21 dams and 19 hydroelectric plants, called the Southeast Anatolia Project (GAP) [84]. It is a joint hydroelectric power and irrigation project. Upon completion, the $32 billion project will have a combined installed capacity of 7,500 megawatts. As of 2000, six of the hydropower plants had been completed (Karakaya, Ataturk, Kralkizi, Dickle, Batman, and Karkamis); three were under construction (Birecik, Kayacik, and Sanliurfa); and six others were in the planning phase (Erkenek, Garzan, Silvan, Adiyaman, Ilisu, and Cizre).

In recent years, Ilisu has been the most controversial project in the GAP scheme. The proposed 1,200-megawatt project would be the largest hydropower project on the Tigris River in the southern part of Turkey. The UK government was asked to provide export credit guarantees for construction of the $1.8 billion project by Balfour Beatty, a British civil engineering company, which has a contract worth nearly $290 million for construction work on Ilisu [***85***]. Environmentalists oppose the dam on the grounds that it will mean that more than 90 villages will be submerged by the reservoir that is to support the dam, and that it will force the relocation of up to 78,000 people, mostly of the minority ethnic Kurds [***86***]. The British government initially granted Balfour Beatty's guarantees, but amidst substantial protests it indicated that it might withdraw its support for the dam because of environmental concerns, leading Balfour Beatty to pull out of the project in November 2001 [***87***].

In a similar development, the UK government is considering whether to guarantee Turkey's $844 million Yusefeli hydropower project [***88***]. The British construction firm Amec, which is part of a consortium seeking to build the Yusefeli hydroelectric dam, has applied to the British Export Credit Guarantee Department for a loan of $96 million. Detractors of the project argue that up to 15,000 people—largely minority Georgians—would have to be relocated to construct Yusefeli.

Other hydroelectric projects are progressing in Turkey. In October 2001, a consortium of companies led by the Washington Group International announced that it had been awarded a planning contract to provide geotechnical exploration, engineering, and design for the first phase of the Hakkari dam, to be constructed on the Zap River in Southern Anatolia [***89***]. The $600 million project will consist of a 558-foot dam, a 7-mile tunnel, and a 208-megawatt hydroelectric power station. Construction of the first phase is scheduled for completion by mid-2002.

References

1. "Surprise, Surprise! Ting Gets Bakun Contract," *Financial Times: Power in Asia*, Vol. 331 (June 28, 2001), p. 12.
2. P. Gall, "Brazil's Natural Gas Market Simultaneously Beckons, Threatens," *The Oil Daily*, Vol. 51, No. 169 (August 31, 2001), p. 4.
3. American Wind Energy Association, "Global Wind Energy Market Report: Wind Energy Growth Was Steady in 2000; Outlook for 2001 Is Bright," press release (May 2001), web site www.awea.org/faq/global200.html.
4. International Energy Agency and National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 46.
5. "Europe Launches Its (Half-Hearted) Push for Renewable Energy," *World Gas Intelligence*, electronic edition (September 19, 2001).
6. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), p. 95.
7. Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383(2002) (Washington, DC, November 2001), pp. 71 and 72.
8. Energy Information Administration, *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001), p. 98.
9. "Canadian News: Northern Province Proposes More Than 12,000 MW on Six Rivers," *Hydro•Wire*, Vol. 22, No. 15 (August 6, 2001), p. 2.
10. "Crees Consent to Quebec's 1,200-MW Eastmain-Rupert," *Hydro•Wire*, Vol. 22, No. 21 (October 29, 2001), p. 405.
11. "Alcoa Joins Newfoundland Study of 2,800-MW Lower Churchill," *Hydro•Wire*, Vol. 22, No. 15 (August 6, 2001), pp. 2-3.
12. "Quebec Approves 526-MW Toulnustouc," *Hydro•Wire*, Vol. 22, No. 18 (September 16, 2001), p. 4.
13. "Quebec Begins Studies of 450-MW Peribonka Project," *Hydro•Wire*, Vol. 22, No. 20 (October 15, 2001), p. 1.
14. "Canadian Renewable Energy Evaluates Hydro Development Sites," *Hydro•Wire*, Vol. 22, No. 18 (September 16, 2001), p. 4.
15. Acres International Limited, "Misema: Small Hydro Development," press release (August 2001).
16. "News Briefs: St. John's, Newfoundland," *Hydro•Wire*, Vol. 22, No. 18 (September 16, 2001), p. 7.
17. American Wind Energy Association, "Global Wind Energy Market Report: Wind Energy Growth Was Steady in 2000; Outlook for 2001 Is Bright," press release (May 2001), web site www.awea.org/faq/global200.html.
18. "Canada Implements Production Tax Credit," *Wind Energy Weekly*, electronic edition, Vol. 20, No. 975 (December 21, 2001).
19. "First Phase of SunBridge Wind Project Starts Sending Electricity to SaskPower," *Solar & Renewable Energy Outlook*, Vol. 27, No. 17 (September 1, 2001), p. 197.
20. Natural Resources Canada, "Saskatchewan's First Large-Scale Wind Power Project Planned for Gull Lake," press release (April 18, 2001), web site www.nrcan.gc.ca.

21. Natural Resources Canada, “Backgrounder: Wind Power Project in Prince Edward Island,” press release (June 1, 2001), web site www.nrcan.gc.ca.

22. “Ontario Power Generation Starts Up Largest Turbine in N. America,” *Wind Energy Weekly*, electronic edition, Vol. 20, No. 960 (August 17, 2001).

23. “Renewable Energy Enters Latin America Supply Mix,” *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.

24. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 129.

25. “Europe Launches Its (Half-Hearted) Push for Renewable Energy,” *World Gas Intelligence*, electronic edition (September 19, 2001).

26. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), pp. 95-96.

27. “Europe Launches Its (Half-Hearted) Push for Renewable Energy,” *World Gas Intelligence*, electronic edition (September 19, 2001).

28. “Germany Starts Up Europe’s Largest Onshore Wind Farm,” *Wind Energy Weekly*, electronic edition, Vol. 20, No. 960 (August 17, 2001).

29. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), pp. 67-69, 29, and 46.

30. “Today in Brief: TotalFinaElf Plans Wind Farm in Belgium,” *World Markets Online* (July 11, 2001).

31. “ScottishPower Unveils Plans for UK’s Largest Wind Farm,” *Wind Energy Weekly*, electronic edition, Vol. 20, No. 957 (August 10, 2001).

32. BP p.l.c., “BP Announces a Five-Fold Expansion of Solar Production in Spain: Acquisition of Agere Systems’ Plant in Madrid Offers Platform for Rapid Growth,” press release (July 4, 2001), web site www.bp.com.

33. “BP To Invest in Solar in Spain,” *The Oil Daily*, Vol. 51, No. 126 (July 6, 2001), p. 9.

34. “Overview of the Mandatory Renewable Energy Target,” Office of the Renewable Energy Regulator, web site www.orer.gov.au (June 1, 2001).

35. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 50.

36. “Victoria Wind Farm On Line,” *Financial Times: Power in Asia*, Vol. 332 (July 8, 2001), p. 20.

37. “Q’ld Seeks Big Wind Power,” *Financial Times: Power in Asia*, No. 336 (September 4, 2001), pp. 18-19.

38. National Renewable Energy Laboratory, *IEA Wind Energy Annual Report 2000* (Golden, CO, May 2001), p. 119.

39. “Plans for Hydropower Units,” *Financial Times: Power in Asia*, No. 337 (September 18, 2001), pp. 19-20.

40. N. Guu, “Zhu Urges Speeding Up Resident Relocation,” *China Daily* (July 19, 2001), p. 1.

41. M. Hurle, “Energy Sector Analysis: China: Construction of Longtan Hydro Plant Begins,” *World Markets OnLine*, web site www. worldmarketsonline. com (July 2, 2001).

42. J. Monahan, “WB Move To ‘clean Up’ China,” *Financial Times: Power in Asia*, No. 330 (June 14, 2001), pp. 2-3.

43. “ADB Power Lending Bounces Back,” *Financial Times: Power in Asia*, Vol. 331 (June 28, 2001), pp. 4-5.

44. “Shell To Provide Solar Power,” *Financial Times: Power in Asia*, Vol. 332 (July 8, 2001), p. 16.

45. “Narmada Oustees Still To Get a Home,” *The Statesman* (New Delhi) (May 18, 2001).

46. “India: Water for Rajasthan by June 2004,” *The Hindu* (Madras) (August 20, 2001).

47. “Delhi Stresses Renewables in Five-Year Plan,” *Financial Times: Power in Asia*, Vol. 331 (June 28, 2001), pp. 9-10.

48. H. Thompson, “The Bakun Dam Is Back,” *Earth Island Journal*, Vol. 16, No. 3 (Autumn 2001), p. 23.

49. R. Sullivan, “Giant Dam Plan Swamps Life in Longhouses,” *The Herald* (Glasgow) (September 17, 2001), p. 12.

50. “Potential Bakun Power Customers ‘Identified’ at Last,” *Financial Times: Power in Asia*, No. 336 (September 4, 2001), p. 11.

51. “KL Sets Renewable Target,” *Financial Times: Power in Asia*, No. 330 (June 14, 2001), p. 9.

52. “Assembly Ok’s Hydro Scheme,” *Financial Times: Power in Asia*, Vol. 331 (June 28, 2001), pp. 18-19; and “Hanoi Looks at Dam Project,” *Power in Asia*, Vol. 332 (July 8, 2001), pp. 14-15.

53. “New Boost For Hydro, Coal,” *Financial Times: Power in Asia*, No. 337 (September 18, 2001), p. 10.

54. “Renewable Energy Enters Latin America Supply Mix,” *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.

55. P. Gall, “Brazil’s Natural Gas Market Simultaneously Beckons, Threatens,” *The Oil Daily*, Vol. 51, No. 169 (August 31, 2001), p. 4.

56. “Brazil Widens Bonus Plan,” *Financial Times: Power in Latin America*, No. 75 (September 2001), p. 17.

57. J. Prates, “Brazil’s Energy Crisis Complicates Progress in Gas, Power Markets, But Outlook Brightening,” *Oil & Gas Journal*, Vol. 99, No. 42 (October 15, 2001), pp. 77-84.

58. "Briefly Noted—Hydro," www.SolarAccess.com, weekly edition (posted October 24, 2001).

59. "Sale of Hydroelectric Concessions Brings R2.5 Billion," *Financial Times: Power in Latin America*, No. 73 (July 2001), p. 15.

60. J. Kerr, "Aneel Sells Licences To Build 11 New Hydroelectric Plants," *World Markets OnLine*, web site www.worldmarketsonline.com (December 3, 2001).

61. "Renewable Energy Enters Latin America Supply Mix," *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.

62. "Ralco Delayed Another Six Months," *Financial Times: Power in Latin America*, No. 73 (July 2001), p. 16.

63. "Renewable Energy Enters Latin America Supply Mix," *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.

64. "Rural Areas Get Electricity Aid From the IDB," *Financial Times: Power in Latin America*, No. 73 (July 2001), pp. 20-21.

65. "Renewable Energy Enters Latin America Supply Mix," *Financial Times: Power in Latin America*, No. 75 (September 2001), pp. 9-12.

66. Energy Information Administration, "Country Analysis Brief: Azerbaijan," web site www.eia.doe .gov (May 2001).

67. Energy Information Administration, "Country Analysis Brief: Georgia," web site www.eia.doe. gov (April 2001).

68. "Today in Brief: FSU: Ukraine: Renewable Energy Bill Passed," *World Markets Online*, web site www.worldmarketsonline.com (July 9, 2001).

69. "Capital LTD Intends To Acquire Kazakhstan Renewables Developer," *Solar & Renewable Energy Outlook*, Vol. 27, No. 16 (August 15, 2001), p. 187.

70. Energy Information Administration, "Country Analysis Brief: Balkans Region," web site www.eia.doe.gov (July 2001).

71. "Koncar Signs Hydro Upgrade Deals," *Financial Times: Power in East Europe*, No. 63/64 (August 6, 2001), p. 11.

72. "Koncar To Develop Hydro With Bosnia's EP HZ HB," *Financial Times: Power in East Europe*, No. 63/64 (August 6, 2001), p. 12.

73. Energy Information Administration, "Country Analysis Briefs: Romania," web site www.eia.doe. gov (November 2000).

74. "Electricity in Brief," *Financial Times: East European Energy Report*, No. 117 (June 2001), p. 28.

75. "Eon Hungaria Moves into Wind Power," *Financial Times: East European Energy Report*, No. 120 (September 2001), pp. 23-24.

76. "Energy Sector Analysis: Kenya: Financiers Approve Hydro Project," *World Markets OnLine*, web site www.worldmarketsonline.com (June 20, 2001).

77. G. Alaran, "Energy Sector Analysis: Uganda: Nile Power Project Divides Ugandans," *World Markets Online*, web site www.worldmarketsonline.com (August 15, 2001).

78. "Energy Sector Analysis: Senegal: Manatali Hydro Project To Supply Three Countries by 2002," *World Markets Online*, wen site www. worldmarketsonline.com (August 1, 2001).

79. P. Bosshard, "An Act of Economic and Environmental Nonsense," International River Network, web site www.irn.org (March 1999).

80. "Energy Sector Analysis: Zambia: Tenders for Itezhi-Tezhi Hydro Power Project Ready in July," *World Markets Online*, web site www. worldmarketsonline.com (June 21, 2001).

81. "Energy Sector Analysis: Mozambique: Mepanda Dam Gets Favourable Environmental Report," *World Markets Online*, web site www. worldmarketsonline.com (April 24, 2001).

82. "Energy Sector Analysis: Sudan: Arab States Pledge Financial Assistance for Hydroelectric Plant," *World Markets Online*, web site www. worldmarketsonline.com (August 15, 2001).

83. "Energy Sector Analysis: Egypt: Zafrana Wind Farm Project Moves Forward," *World Markets Online*, web site www.worldmarketsonline.com (March 1, 2001); and American Wind Energy Association, "Global Wind Energy Market Report: Wind Energy Growth Was Steady in 2000; Outlook for 2001 Is Bright," press release (May 2001), web site www.awea.org/faq/global200.html.

84. Energy Information Administration, "Country Analysis Briefs: Turkey," web site www.eia.doe. gov (July 2001).

85. "Hewitt Consults on Controversial Dam," *BBC News Online*, web site www.bbc.co.uk (July 3, 2001).

86. International River Network, "Beyond Big Dams: An NGO Guide to the WCD," web site www.irn.org (2000).

87. "Turkey: Disputed Dam Loses Builder," *The New York Times* (November 14, 2001), p. A6.

88. R. Evans and D. Hencke, "Anger at Plea for Dam Funds," *The Guardian* (July 12, 2001), p. 1.1.

89. "Turkish State Hydraulic Works Signs Deal for Hydroelectric Power Plant," *Solar & Renewable Energy Outlook*, Vol. 27, No. 20 (October 15, 2001), p. 237.