RENEWABLES 2005

GLOBAL STATUS REPORT

REN21 Renewable Energy Policy Network for the 21st Century

www.ren21.net

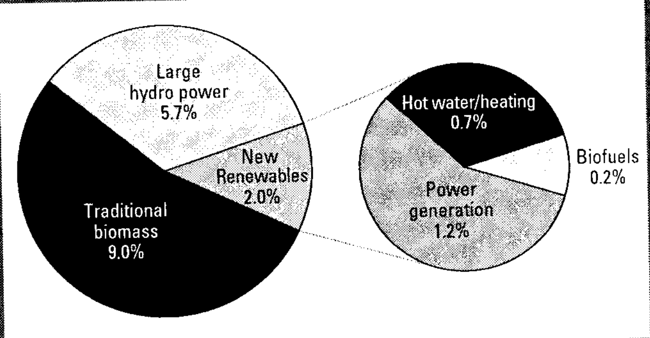
Paper prepared for
the REN21 Network by
The Worldwatch Institute

Lead Author: Eric Martinot

1. GLOBAL MARKET OVERVIEW

Renewable energy supplies 17 percent of the world's primary energy, counting traditional biomass, large hydropower and "new" renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels).*† (See Figure 1.) Traditional biomass, primarily for cooking and heating, represents about 9 percent and is growing slowly or even declining in some regions as biomass is used more efficiently or replaced by more modern energy forms. Large hydropower is slightly less than 6 percent and growing slowly, primarily in developing countries.‡ New renewables are 2 percent and growing very rapidly in developed countries and in some developing countries. Clearly, each of these three forms of renewable energy is unique in its characteristics and trends. This report focuses primarily on new renewables because of their large future potential and the critical need for market and policy support in accelerating their commercial use.§[N1, N2]**

Figure 1. Renewable Energy Contribution to Global Primary Energy, 2004



Renewable energy competes with conventional fuels in four distinct markets: power generation, hot water and space heating, transport fuels, and rural (off-grid) energy. (See Table 1.) In power generation, renewable energy comprises about 4 percent of power-generating capacity and supplies about 3 percent of global electricity production (excluding large hydropower). Hot water and space heating for tens of millions of buildings is supplied by solar, biomass, and geothermal. Solar thermal collectors alone are now used by an estimated 40 million households worldwide. Biomass and geothermal also supply heat for industry, homes, and agriculture. Biomass transport fuels make small but growing contributions in some countries and a very large contribution in Brazil, where ethanol from sugar cane now supplies 44 percent of automotive (non-diesel) fuel consumption for the entire country. In developing countries, 16 million households cook and light their homes from biogas, displacing kerosene and other cooking fuel; more than 2 million households light their homes with solar PV; and a growing number of small industries, including agro-processing, obtain process heat and motive power from small-scale biogas digesters.††[N3]

The fastest growing energy technology in the world has been grid-connected solar PV, with total existing capacity increasing from 0.16 GW at the start of 2000 to 1.8 GW by the end of 2004, for a 60 percent average annual growth rate during the five-year period. (See Figures 2 and 3, page 8.)

* Unless indicated otherwise, the use of "renewable energy" in this report refers to "new" renewables. There is no universally accepted definition of renewable energy, but referring to "new" renewables as "renewable energy" in written work is a generally accepted semantic practice. For example, BP in its annual statistical review of world energy defines "renewable energy" to exclude large hydro. And the landmark International Energy Agency book *Renewables for Power Generation* (2003) also excludes large hydro. Common practice is to define large hydro as above 10 MW, although small hydro statistics in this report include plants up to 50 MW in China and 30 MW in Brazil, as these countries define and report small hydro based on those thresholds.

† Depending on the methodology for how large hydro and other renewable power generation technologies are counted in the global energy balance, renewables' total contribution to world primary energy can also be reported as 13–14 percent rather than 17 percent. The basic issue is whether to count the energy value of equivalent primary energy or of the electricity; see Note 2 [N2] for further explanation.

‡ "Developing country" is not an exact term, but refers generally to a country with low per-capita income. One metric is whether it qualifies for World Bank assistance. Developing countries in this report are non-OECD countries plus OECD members Mexico and Turkey, but excluding Russia and other formerly planned economies in transition.

§ This report covers only renewable energy technologies that are in commercial application on a significant global scale today. Many other technologies are showing commercial promise for the future or are already being employed in limited quantities on a commercial basis, including active solar cooling (also called "solar assisted air conditioning of buildings"), concentrating solar electric power (with Fresnel lenses), ocean thermal energy conversion, tidal power, wave power, hot dry/wet rock geothermal, and cellulose-derived ethanol. Solar cookers were reportedly in use by almost one million households but data on current trends were not readily available. In addition, passive solar heating and cooling is a commercially proven and widespread building design practice, but is not covered in this report. Future editions of this report could cover more of these technologies and practices.

** Notes and references for this report are designated in brackets following the paragraph to which they refer, e.g. [N1]. Full notes and references can be found on the REN21 Web site, at www.ren21.net/globalstatusreport.

†† Solar PV for off-grid includes residential, commercial, signal and communications, and consumer products. In 2004 globally, there were 70 MW used for consumer products, 80 MW used for signal and communications, and 180 MW used for residential and commercial off-grid applications.

During the same period, other renewable energy technologies grew rapidly (annual average) as well: wind power 28 percent (see Figure 4, page 9), biodiesel 25 percent, solar hot water/heating 17 percent, off-grid solar PV 17 percent, geothermal heat capacity 13 percent, and ethanol 11 percent. Other renewable energy power generation technologies, including biomass, geothermal, and small hydro, are more mature and growing by more traditional rates of 2–4 percent per year. Biomass heat supply is likely growing by similar amounts, although data are not available. These growth rates compare with annual growth rates of fossil fuel-based electric power capacity of typically 3–4 percent (higher in some developing countries), a 2 percent annual growth rate for large hydropower, and a 1.6 percent annual growth rate for nuclear capacity during the three year period 2000–2002.[N3]

Existing renewable electricity capacity worldwide totaled 160 GW in 2004, excluding large hydro. (See Figure 5, page 9.) Small hydro and wind power account for two-thirds of this capacity. This 160 GW compares to 3,800 GW installed capacity worldwide for all power generation. Developing countries as a group, including China, have 70 GW (44 percent) of the 160 GW total, primarily biomass and small hydro power. The European Union has 57 GW (36 percent), a majority of which is wind power. The top five individual countries are China (37 GW), Germany (20 GW), the United States (20 GW), Spain (10 GW), and Japan (6 GW).[N4, N5]

Large hydropower remains one of the lowest-cost energy technologies, although environmental constraints, resettlement impacts, and the availability of sites have limited further growth in many countries. Large hydro supplied 16 percent of global electricity production in 2004, down from 19 percent a decade ago. Large hydro totaled about 720 GW worldwide in 2004 and has grown historically at slightly more than 2 percent per year (half that rate in developed countries). Norway is one of several countries that obtain virtually all of their electricity from hydro. The top five hydropower producers in 2004 were Canada (12 percent of world production), China (11.7 percent), Brazil (11.4 percent), the United States (9.4 percent), and Russia (6.3 percent). China's hydro growth has kept pace with its rapidly growing power sector. China installed nearly 8 GW of large hydro in 2004 to become number one in terms of installed capacity (74 GW). Other developing countries also invest significantly in large hydro, with a number of plants under construction.

Small hydropower has developed worldwide for more than a century. More than half of the world's small hydropower capacity exists in China, where an ongoing boom in small hydro construction added nearly 4 GW of capacity in 2004. Other countries with active efforts include Australia, Canada, India, Nepal, and New Zealand. Small hydro is often used in autonomous (not grid-connected) village-

Table 1. Renewable Energy Indicators

Indicator	Existing Capacity End of 2004	Comparison Indicators
Power generation	**(GW)**	
Large hydropower	720	World electric power capacity=3,800
Small hydropower	61	
Wind turbines	48	
Biomass power	39	
Geothermal power	8.9	
Solar PV, off-grid	2.2	
Solar PV, grid-connected	1.8	
Solar thermal power	0.4	
Ocean (tidal) power	0.3	
Total renewable power capacity (excluding large hydropower)	160	
Hot water/space heating	**(GWth)**	
Biomass heating	220	
Solar collectors for hot water/heating (glazed)	77	
Geothermal direct heating	13	
Geothermal heat pumps	15	
Households with solar hot water	40 million	Total households worldwide=1,600 million
Buildings with geothermal heat pumps	2 million	
Transport fuels	**(liters/yr)**	
Ethanol production	31 billion	Total gasoline production=1,200 billion
Biodiesel production	2.2 billion	
Rural (off-grid) energy		
Household-scale biogas digesters	16 million	Total households off-grid=360 million
Small-scale biomass gasifiers	n/a	
Household-scale solar PV systems	2 million	
Solar cookers	1 million	

power applications to replace diesel generators or other small-scale power plants or to provide electricity for the first time to rural populations. In the last few years, more emphasis has been put on the environmental integration of small hydro plants into river systems in order to minimize environmental impacts, incorporating new technology and operating methods.

Wind power markets are concentrated in a few primary countries, with Spain, Germany, India, the United States, and Italy leading expansion in 2004. (See Figure 6, page 10.) Several countries are now taking their first steps to develop large-scale commercial markets, including Russia and other transition countries, China, South Africa, Brazil, and Mexico. In the case of China, most wind power investments historically have been donor- or government-supported, but a shift to private investment has been underway in recent years. Several other countries are at the stage of demonstrating wind farm installations, looking to develop commercial markets in the future.[N6]

Offshore wind power markets are just emerging. About 600 MW of offshore wind exists, all in Europe. The first large-scale offshore wind farm (170 MW) was completed in 2003 in Denmark, and ambitious plans exist for over 40 GW of development in Europe, particularly in Germany, the Netherlands, and the United Kingdom.[N6]

Biomass electricity and heat production is slowly expanding in Europe, driven mainly by developments in Austria, Finland, Germany, and the United Kingdom. A boom in recent years in converting waste wood in Germany is now levelling off, as the resource base is mostly used. The United Kingdom has seen recent growth in "co-firing" (burning small shares of biomass in coal-fired power plants). Continuing investments are occurring in Denmark, Finland, Sweden, the United States, and several other OECD countries. The use of biomass for district heating and combined heat-and-power has been expanding in some countries, including Austria and Germany. In Sweden, biomass supplies more than 50 percent of district heating needs. Among developing countries, small-scale power and heat production from agricultural waste is common, for example from rice or coconut husks. The use of sugar cane waste (bagasse) for power and heat production is significant in countries with a large sugar industry, including Brazil, Columbia, Cuba, India, the Philippines, and Thailand. Increasing numbers of small-scale biomass gasifiers are finding application in rural areas (and there are also demonstrations of biomass gasification for use in high-efficiency combined-cycle power plants in developed countries). Interest in bioenergy "coproduction," in which both energy and non-energy outputs (for example, animal feed or industrial fiber) are produced in an integrated process, is also growing.[N6]

Figure 2. Average Annual Growth Rates of Renewable Energy Capacity, 2000–2004

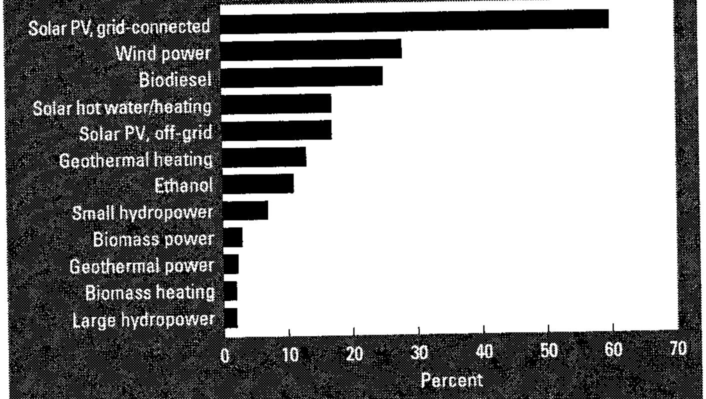
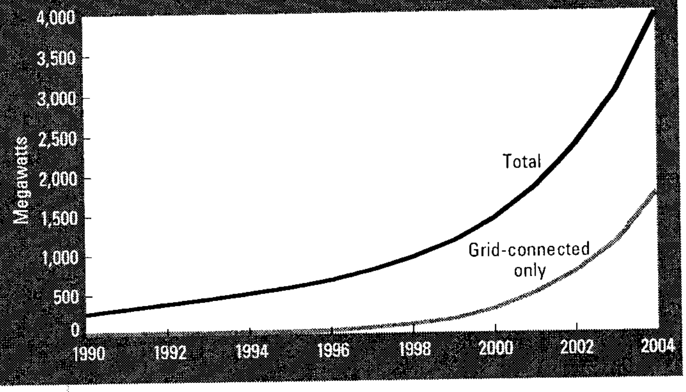


Figure 3. Solar PV, Existing World Capacity, 1990–2004



Like small hydro, geothermal energy has been used for electricity generation and heat for a century. There are at least 76 countries with geothermal heating capacity and 24 countries with geothermal electricity. More than 1 GW of geothermal power was added between 2000 and 2004, including significant increases in France, Iceland, Indonesia, Kenya, Mexico, the Philippines, and Russia. Most of the geothermal power capacity in developed countries exists in Italy, Japan, New Zealand, and the United States.[N6]

Geothermal direct-heat utilization capacity nearly doubled from 2000 to 2005, an increase of 13 GWth, with at least 13 new countries using geothermal heat for the first time. Iceland leads the world in direct heating, supplying some 85 percent of its total space-heating needs from geothermal. Turkey has increased its geothermal direct-heating

Figure 4. Wind Power, Existing World Capacity, 1990–2004

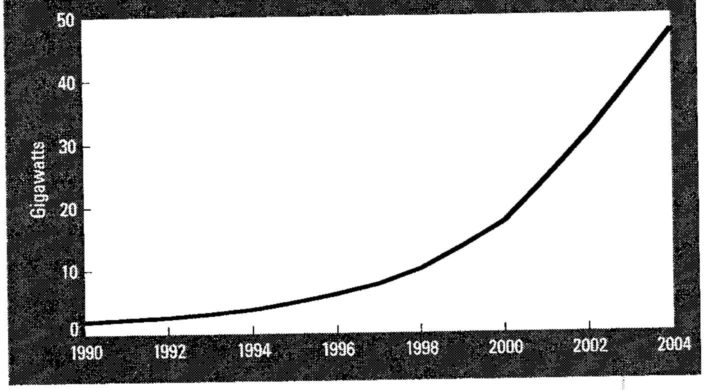
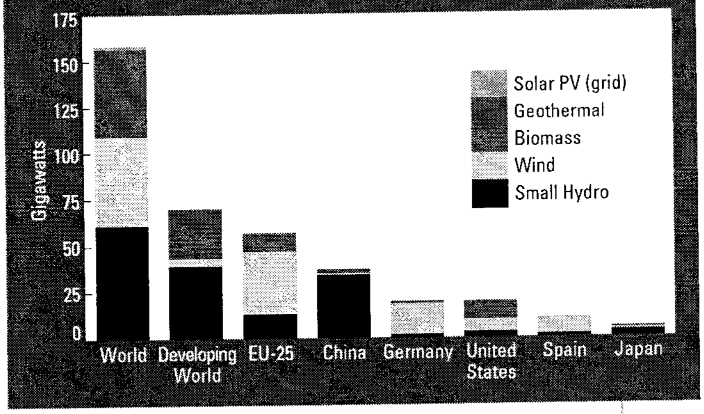


Figure 5. Renewable Power Capacities, EU, Top 5 Countries, and Developing World, 2004



capacity by 50 percent since 2000, which now supplies heat equivalent to the needs of 70,000 homes. About half of the existing geothermal heat capacity exists as geothermal heat pumps, also called ground source heat pumps. These are increasingly used for heating and cooling buildings, with nearly 2 million heat pumps used in over 30 countries, mostly in Europe and the United States.

Grid-connected solar PV installations are concentrated in three countries: Japan, Germany, and the United States, driven by supportive policies. By 2004, more than 400,000 homes in these countries had rooftop solar PV feeding power into the grid. This market grew by about 0.7 GW in 2004, from 1.1 GW to 1.8 GW cumulative installed capacity. Around the world, there are also a growing number of commercial and public demonstrations of building-integrated solar PV. Typical examples include a subway station (100 kW), gas station (30kW), solar PV manufacturing plant (200kW), fire station (100kW), city hall (50kW), exhibition hall (1000 kW), museum (10kW), university building (10kW), and prison (70kW).[N7]

The concentrating solar thermal power market has remained stagnant since the early 1990s, when 350 MW was constructed in California due to favorable tax credits. Recently, commercial plans in Israel, Spain, and the United States have led a resurgence of interest, technology evolution, and potential investment. In 2004, construction started on a 1 MW parabolic trough in Arizona, the first new plant anywhere in the world since the early 1990s. Spain's market is emerging, with investors considering two 50 MW projects in 2005. Some developing countries, including India, Egypt, Mexico, and Morocco, have planned projects with multilateral assistance, although the status of some of these projects remains uncertain.

Solar hot water/heating technologies are becoming widespread and contribute significantly to the hot water/heating markets in China, Europe, Israel, Turkey, and Japan. Dozens of other countries have smaller markets. China accounts for 60 percent of total installed capacity worldwide. (See Figure 7, page 10, and Figure 8, page 11). The European Union accounts for 11 percent, followed by Turkey with 9 percent and Japan with 7 percent (all figures are for glazed collectors only). Total sales volume in 2004 in China was 13.5 million square meters, a 26-percent increase in existing capacity. Vacuum tube solar water heaters now dominate the Chinese market, with an 88-percent share in 2003. In Japan, existing solar hot capacity continues to decline, as new installations fall short of retirements. In Europe, about 1.6 million square meters was installed in 2004, partly offset by retirements of older existing systems. The 110 million square meters of installed collector area (77 GWth of heat production capacity) worldwide translates into almost 40 million households worldwide now using solar hot water. This is 2.5 percent of the roughly 1,600 million households that exist worldwide.*[N8]

Space heating from solar is gaining ground in several countries, although the primary application remains hot water. In Sweden and Austria, more than 50 percent of the annually-installed collector area is for combined hot water and space heating systems. In Germany, the share of com-

* Solar hot water/heating is commonly called "Solar Heating and Cooling" to emphasize that solar cooling (solar-assisted air conditioning) is also a commercial technology. This report uses solar hot water/heating because hot water alone constitutes the vast majority of installed capacity. Some capacity worldwide, particularly in Europe, does serve space heating, although space heating is a small share of total heat even in combined systems. Solar cooling is not yet in widespread commercial use but many believe its future is promising.

bined systems is 25–30 percent of the annual installed capacity. Less than 5 percent of systems in China provide space heating in addition to hot water.

Biofuels production of 33 billion liters in 2004 compares with about 1,200 billion liters annually of gasoline production worldwide. (See Figure 9, page 11.) Brazil has been the world's leader (and primary user) of fuel ethanol for more than 25 years. It produced about 15 billion liters of fuel ethanol in 2004, contributing slightly less than half the world's total. All fueling stations in Brazil sell both pure ethanol (E95) and gasohol, a 25-percent ethanol/75-percent gasoline blend (E25). In 2004, almost as much ethanol as gasoline was used for automobile (non-diesel) fuel in Brazil; that is, ethanol blended into gasohol or sold as pure ethanol accounted for 44 percent of total automobile fuel sold in Brazil. Demand for ethanol fuels, compared to gasoline, was very strong in 2005. In recent years, significant global trade in fuel ethanol has emerged, with Brazil being the leading exporter. Brazil's 2.5 billion liters of ethanol exports accounted for more than half of global trade in 2004.[N9]

Figure 6. Wind Power Capacity, Top 10 Countries, 2004

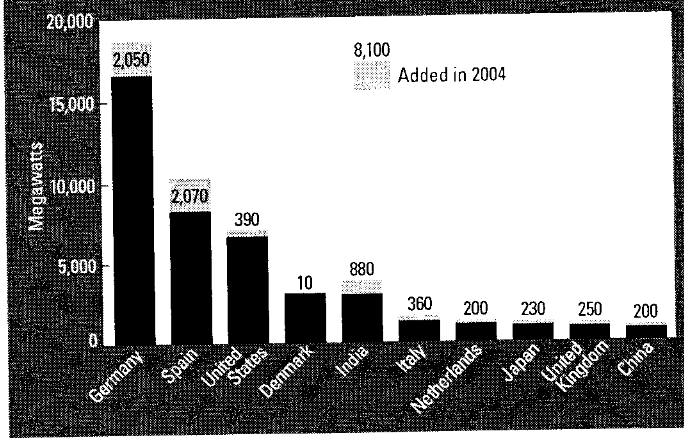
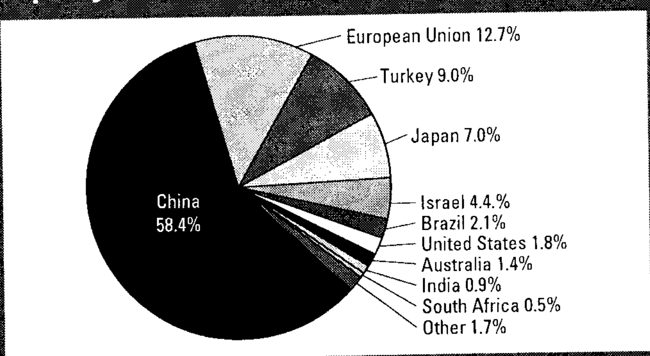


Figure 7. Share of Existing Solar Hot Water/Heating Capacity, Selected Countries, 2004



Brazil's transport fuels and vehicle markets have evolved together. After a sharp decline in the sales of pure-ethanol vehicles during the 1990s, sales were climbing again in the early 2000s, due to a significant decline in ethanol prices, rising gasoline prices, and the introduction of so-called "flexible fuel" cars by automakers in Brazil. These cars can operate on either pure ethanol or ethanol/gasoline blends. By 2003, these cars were being offered by most auto manufacturers at comparable prices to pure ethanol or gasohol cars. Flexible-fuel cars have been widely embraced by drivers, some out of concern for fuel-supply uncertainties (such as an ethanol shortage that happened in 1989 or future oil shocks). Sales increased rapidly, and by 2005 more than half of all new cars sold in Brazil were flex-fuel cars.[N10]

The United States is the world's second-largest consumer and producer of fuel ethanol. The growth of the U.S. market is a relatively recent trend; ethanol production capacity increased from 4 billion liters per year in 1996 to 14 billion liters per year in 2004. Recent annual growth has been in the 15–20 percent range. By 2005, there were nearly 400 fueling stations (mostly in the upper Midwest) that sold E85, an 85-percent ethanol/15-percent gasoline blend, and many more selling gasohol (E10). By 2005, about 3 percent of the 140 billion gallons of vehicle fuel (non-diesel) consumed annually in the U.S. was ethanol. In addition, 30 percent of all gasoline sold in the United States was being blended with ethanol (E10) as a substitute oxygenator for MTBE (methyl tertiary-butyl ether), which more and more states were requiring be discontinued. Other countries producing fuel ethanol include Australia, Canada, China, Columbia, the Dominican Republic, France, Germany, India, Jamaica, Malawi, Poland, South Africa, Spain, Sweden, Thailand, and Zambia.[N9]

Biodiesel production grew by 50 percent in Germany in 2004, bringing total world production to more than 2 billion liters. Pure biodiesel (B100) in Germany enjoys a 100-percent fuel-tax exemption, and the country now has over 1,500 fueling stations selling B100. Other primary biodiesel producers are France and Italy, with several other countries producing smaller amounts, including Austria, Belgium, the Czech Republic, Denmark, Indonesia, Malaysia, and the United States. Several countries are planning to begin biodiesel production or to expand their existing capacity in the coming few years.[N9]

Costs of the most common renewable energy applications are shown in Table 2 (page 12). Many of these costs are

Figure 8. Solar Hot Water Existing per 1,000 Inhabitants

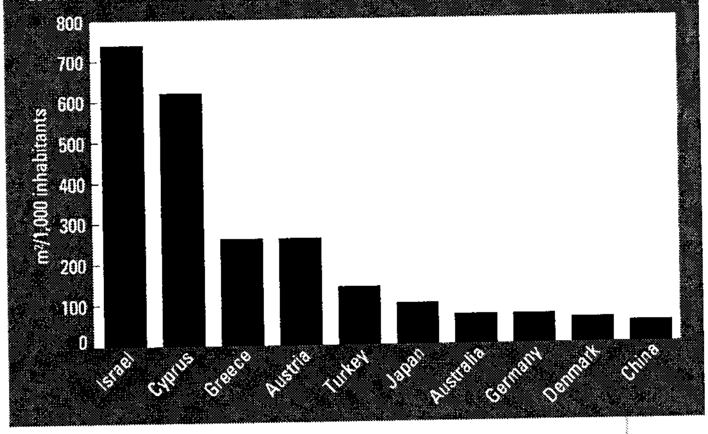
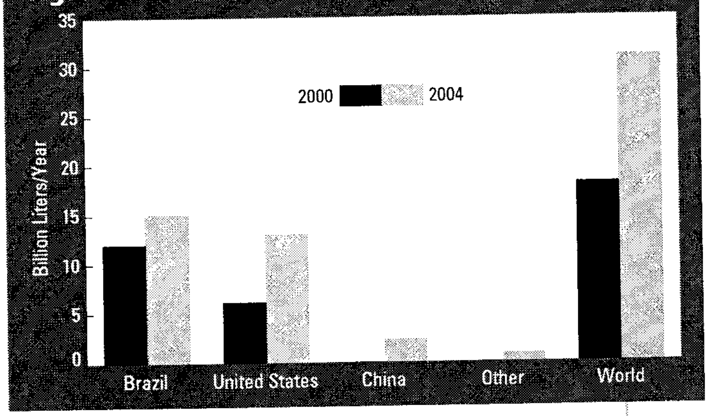


Figure 9. Fuel Ethanol Production, 2000 and 2004



still higher than conventional energy technologies. (Typical conventional power generation costs are in the US$ 2–5 cents/kWh range for baseload power, but can be considerably higher for peak power and higher still for off-grid diesel generators.*) Higher costs and other market barriers mean that most renewables continue to require policy support. However, economic competitiveness is not static: just as renewables' costs are declining, conventional technology costs are declining as well (for example with improvements in gas turbine technology). The fundamental uncertainty about future competitiveness relates to future fossil fuel prices, which affect conventional power costs but not the costs of renewables.

For the present, the International Energy Agency has portrayed the cost-competitiveness of renewables in this way: "Except for large hydropower and combustible renewables and waste plants, the average costs of renewable electricity are not widely competitive with wholesale electricity prices. However, depending on the technology, application and site, costs are competitive with grid [retail] electricity or commercial heat production. Under best conditions—optimized system design, site and resource availability—electricity from biomass, small hydropower, wind and geothermal plants can produce electricity at costs ranging from 2–5 cents/kWh. Some biomass applications are competitive as well as geothermal heat production in specific sites." In regions where the technology is well-established, solar water heaters are fully competitive with conventional water heaters, although less so in cooler climates where the solar resource is poorer and heating demand is higher. Grid-connected solar PV is not yet competitive, except in locations with extremely high retail power rates (i.e., exceeding 20–25 cents/kWh). Ethanol in Brazil is now fully competitive with gasoline.†[N11]

* Unless otherwise noted, all dollar figures are in U.S. dollars.

† Cost comparisons are based on economic costs excluding external costs. Financial cost comparisons can be fairly complex, as they must take into account policy support, subsidies, tax treatment, and other market conditions. Historical cost reductions are due to an array of factors beyond the scope of this report. As one example. Brazil's ethanol costs have declined over more than two decades with increases in production efficiency and market growth.

Table 2. Status of Renewables Technologies—Characteristics and Cost

Technology	Typical Characteristics	Typical Energy Costs (cents/kWh)	Cost Trends and Potential for Cost Reduction
Power Generation			
Large hydro	*Plant size:* 10 MW–18,000 MW	3–4	Stable.
Small hydro	*Plant size:* 1–10 MW	4–7	Stable.
On-shore wind	*Turbine size:* 1–3 MW *Blade diameter:* 60–100 m	4–6	Costs have declined by 12–18% with each doubling of global capacity. Costs are now half those of 1990. Turbine size has increased from 600–800 kW a decade ago. Future reductions from site optimization, improved blade/generator design, and electronics.
Off-shore wind	*Turbine size:* 1.5–5 MW *Blade diameter:* 70–125 m	6–10	Market still small. Future cost reductions due to market maturity and technology improvement.
Biomass power	*Plant size:* 1–20 MW	5–12	Stable.
Geothermal power	*Plant size:* 1–100 MW *Type:* binary, single-flash, double-flash, or natural steam	4–7	Costs have declined since the 1970s. Costs for exploiting currently-economic resources could decline with improved exploration technology, cheaper drilling techniques, and better heat extraction.
Solar PV (module)	*Cell type and efficiency:* single-crystal: 17%, polycrystalline: 15%, thin film: 10–12%	—	Costs have declined by 20% for each doubling of installed capacity, or by about 5% per year. Costs rose in 2004 due to market factors. Future cost reductions due to materials, design, process, efficiency, and scale.
Rooftop solar PV	*Peak capacity:* 2–5 kW	20–40	Continuing declines due to lower solar PV module costs and improvements in inverters and balance-of-system components.
Solar thermal power (CSP)	*Plant size:* 1–100 MW *Type:* tower, dish, trough	12–18 (trough)	Costs have fallen from about 44 cents/kWh for the first plants in the 1980s. Future reductions due to scale and technology.
Hot Water/Heating			
Biomass heat	*Plant size:* 1–20 MW	1–6	Stable.
Solar hot water/heating	*Size:* 2–5 m² *Type:* evacuated tube/flat-plate *Service:* hot water, space heating	2–25	Costs stable or moderately lower due to economies of scale, new materials, larger collectors, and quality improvements.
Geothermal heat	*Plant capacity:* 1–100 MW *Type:* binary, single- and double-flash, natural steam, heat pumps	0.5–5	See geothermal power, above.
Biofuels			
Ethanol	*Feedstocks:* sugar cane, sugar beets, corn, or wheat (and cellulose in the future)	25–30 cents/liter gasoline equivalent	Declining costs in Brazil due to production efficiencies, now 25–30 cents/equivalent-liter (sugar), but stable in the United States at 40–50 cents (corn). Other feedstocks higher, up to 90 cents. Cost reductions for ethanol from cellulose are projected, from 53 cents today to 27 cents post-2010; modest drops for other feedstocks.
Biodiesel	*Feedstocks:* soy, rapeseed, mustard seed, or waste vegetable oils	40–80 cents/liter diesel equivalent	Costs could decline to 35–70 cents/liter diesel equivalent post-2010 for rapeseed and soy, and remain about 25 cents (currently) for biodiesel from waste oil.

Table 2. *continued*

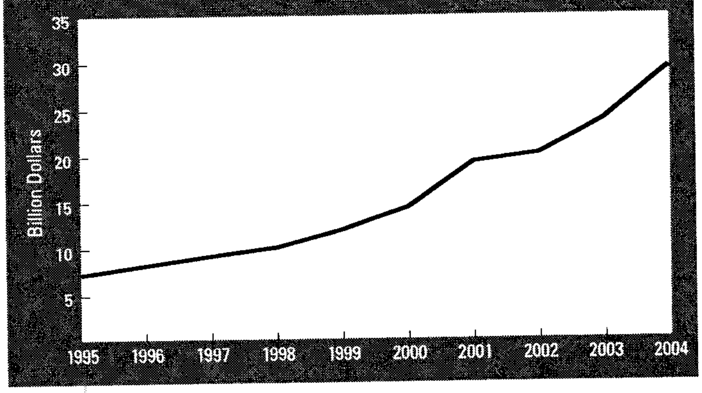
Technology	Typical Characteristics	Typical Energy Costs (cents/kWh)	Cost Trends and Potential for Cost Reduction
Rural (off-grid) Energy			
Mini-hydro	*Plant capacity:* 100–1,000 kW	5–10	Stable.
Micro-hydro	*Plant capacity:* 1–100 kW	7–20	Stable to moderately declining with efficiency improvements.
Pico-hydro	*Plant capacity:* 0.1–1 kW	20–40	Stable to moderately declining with efficiency improvements.
Biogas digester	*Digester size:* 6–8 m^3	n/a	Stable to moderately declining with economies of construction and service infrastructure.
Biomass gasifier	*Size:* 20–5,000 kW	8–12	Excellent potential for cost reduction with further technology development.
Small wind turbine	*Turbine size:* 3–100 kW	15–30	Moderately declining with technology advances.
Household wind turbine	*Turbine size:* 0.1–1 kW	20–40	Moderately declining with technology advances.
Village-scale mini-grid	*System size:* 10–1,000 kW *Options:* battery back-up or diesel	25–100	Declining with reductions in solar and wind component costs.
Solar home system	*System size:* 20–100 W	40–60	Declining with reductions in solar component costs.

Note: All costs are economic costs, exclusive of subsidies and other policy incentives. Typical energy costs are under best conditions, including system design, siting, and resource availability. Some conditions can yield even lower costs, e.g. down to 2 cents/kWh for geothermal and large hydro and 3 cents/kWh for biomass power. Less-optimal conditions can yield costs substantially higher than the typical costs shown. Typical solar PV grid-connected costs are for 2,500 kWh/m^2 per year, typical for most developing countries. Costs increase to 30–50 cents/kWh for 1,500 kWh/m^2 sites (i.e., Southern Europe) and to 50–80 cents for 1,000 kWh/m^2 sites (i.e., UK).

2. INVESTMENT FLOWS

In 2004, about $30 billion was invested in renewable energy capacity and installations. (See Figure 10.) An additional $4–5 billion in new plant and equipment was invested in 2004 by the solar PV manufacturing industry, and at least several hundred million dollars was invested by the ethanol industry in new production plants. These numbers compare to roughly $110–150 billion invested annually in power generation worldwide. Thus, renewables are now 20–25 percent of global power-sector investment. Indeed, the International Energy Agency, in its most recent *World Energy Investment Outlook*, estimates that fully one-third of new power generation investment in OECD countries over the next thirty years will be renewable energy. Annual renewable energy investment has grown steadily from about $7 billion in 1995. Investment shares in 2004 were roughly $9.5 billion for wind power, $7 billion for solar PV, $4.5 billion for small hydro power, $4 billion for solar hot water/heating, and $5 billion for geothermal and biomass power and heat. In addition to these investments, an estimated $20–25 billion is being invested in large hydropower annually.[N12]

Figure 10. Annual Investment in Renewable Energy, 1995–2004



Renewable energy investments now come from a highly diverse range of public and private sources. Investment flows are being aided by technology standardization and growing acceptance and familiarity by financiers at all scales, from commercial finance of hundred-million-dollar wind farms to household-scale micro-financing. One of the most recent trends is that large commercial banks are starting to notice renewable energy investment opportunities. Examples of large banks that are "mainstreaming" renewable energy investments are HypoVereins Bank, Fortis, Dexia, Citigroup, ANZ Bank, Royal Bank of Canada, and Triodos Bank, all of which are very active in financing renewable energy. Investments by traditional utility companies, which historically as a group have been slow to consider renewables investments, are also becoming more "mainstreamed." Examples of utilities active in renewable energy include Electricité de France, Florida Power and Light (USA), Scottish Power, and Endesa (Spain).*

Other large investors are entering the renewable energy market, including leading investment banks. There is a growing belief in the mainstream investment community that renewable energy is a serious business opportunity. For example, Morgan Stanley is now investing in wind power projects in Spain. Goldman Sachs, one of the world's largest investment firms, bought Zilkha Renewable Energy, a wind-development firm currently developing 4 GW of wind capacity in the United States. GE commercial and consumer finance arms have started financing renewable energy. And commercial re-insurers are developing new insurance products targeting renewable energy.

Venture capital investors have also started to notice renewable energy. Venture capital investments in U.S.-based clean energy technology companies totaled almost $1 billion in 2004. In particular, solar PV saw a 100-percent compound annual growth in venture capital and equity investment from 2001 to 2004. Venture capital is being driven partly by future market projections, some of which show the solar PV and wind industries growing to $40–50 billion each sometime during 2010–2014.[N13]

Financing by public banking institutions has played an important role in stimulating private investments and industry activity. The European Investment Bank is the leading public banking institution providing finance for renewable energy, with finance averaging $630 million per year during the three-year period 2002–2004 (almost all for projects in the EU). The European Investment Bank plans to double its share of energy-sector loans to renewables between 2002 and 2007, from 7 percent to 15 percent by 2007. The bank also plans to increase renewable power-generation lending to 50 percent of total financing for new electricity-generation capacity in the EU by 2008–2010, up from the current 15 percent.[N14]

Multilateral, bilateral, and other public financing flows

* This report does not cover carbon finance or Clean Development Mechanism (CDM) projects. Subsequent editions can hopefully address these emerging financing vehicles. There were plans for renewable energy projects incorporating these financing vehicles in several countries, and countries were establishing administrative rules and procedures.

SIDEBAR 1. Bonn Action Programme in International Context

An analysis of the Bonn Action Progamme adopted in 2004 gives five key metrics for the program's content. Below, these metrics are compared with the existing global context. [N15b]

Metric	Bonn Action Programme Content	Global Context (2004)
1. Installed capacity	Adds 163 GW of renewable electricity capacity if fully implemented.	Existing global capacity of renewable energy was 160 GW (plus 720 GW for large hydro).
2. Investments	Implies total investment of $326 billion.	Global annual investment in renewable energy was $30 billion (plus $20–25 billion for large hydro).
3. CO_2 emissions	Implies CO_2 reductions totaling 1.2 billion tons/year by 2015.	CO_2 reduction from renewable energy was 0.9 billion tons/year (plus 3.7 billion tons/year from large hydro).
4. Donor financing	Donor funding pledged and needed totals 16% of financing, or about $52 billion.	Almost $500 million/year in donor financing flowed to developing countries.
5. Access to electricity in rural areas	Endorses Millennium Development Goal estimates that up to 1 billion people could have access to energy services from renewables by 2015.	Tens of millions of rural homes served by small hydro, 16 million using biogas, 2 million with solar home lighting, and many others served by biomass gasifiers.

for new renewables in developing countries have reached almost $500 million per year in recent years. A significant portion of these funds supports training, policy development, market facilitation, technical assistance, and other non-investment needs. The three largest sources of funds have been the German Development Finance Group (KfW), the World Bank Group, and the Global Environment Facility (GEF). KfW approved about $180 million for renewables in 2004, including $100 million from public budgetary funds and $80 million from market funds. The World Bank Group committed an average of $110 million per year to new renewables during the three-year period 2002–2004.* The GEF allocated an average of $100 million each year from 2002 to 2004 to co-finance renewable energy projects implemented by the World Bank, United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), and several other agencies. Indirect or associated private-sector financing is often equal to or several times greater than the actual public finance from these agencies, as many projects are explicitly designed to catalyze private investment. In addition, recipient-country governments also contribute co-financing to these development projects.[N15]

Other sources of public financing include bilateral assistance agencies, United Nations agencies, and the contributions of recipient-country governments to development assistance projects. Several agencies and governments are providing aid for new renewables in the range of (typically) $5–25 million per year, including the Asian Development Bank (ADB), the European Bank for Reconstruction and Development (EBRD), the Inter-American Development Bank (IDB), UNDP, UNEP, the U.N. Industrial Development Organization (UNIDO), Denmark (Danida), France (Ademe and FFEM), Germany (GTZ), Italy, Japan (JBIC), and Sweden (SIDA). Other donors contributing technical assistance and financing on an annual basis include the U.N. Food and Agriculture Organization (FAO), Australia (AusAid), Canada (CIDA), the Netherlands (Novem), Switzerland (SDC), and the United Kingdom (DFID). Some of these donors are establishing specific-purpose investment funds and credit lines that combine additional private financing.[N15]

These public investment flows have remained relatively constant over the past few years, although recent commitments by a number of organizations suggest the total will increase in the coming years. In 2004, at the Renewables 2004 conference in Bonn, Germany, 170 countries adopted the Bonn Action Programme, with many future commitments by governments, international organizations, and non-governmental organizations. (See Sidebar 1.) At the same time, the German government committed 500 million euros over five years to KfW for renewable energy and energy efficiency investments in developing countries. Also in 2004, the World Bank Group committed to double financing flows for new renewables and energy efficiency within five years, which would add another $150 million in annual financing for renewable energy. The EU, together with the Johannesburg Renewable Energy Coalition (JREC), will establish a "Global Renewable Energy Fund of Funds" to provide patient equity capital, with initial financing of

* World Bank Group financing for new renewables plus average GEF co-financing of $45 million per year for World Bank Group projects (2002–2004) made total World Bank Group/GEF financing more than $155 million per year. The World Bank Group also committed an average of $170 million per year during the three-year period 2002–2004 to large hydropower (without GEF co-financing), bringing average annual World Bank Group/GEF financing for all renewables to more than $325 million.

about 75 million euros.

Local financing sources for renewable energy in developing countries, once the province of international development agencies, have also been growing. There is an increasing emphasis by donors and market facilitators on helping to increase these local financing sources for renewable energy and finding ways to mitigate financing risks for private investors. One of the best examples is the India Renewable Energy Development Agency (IREDA), which has provided almost $1.5 billion in financing for 2.5 GW of renewables since its inception in 1987. On the rural side, Grameen Shakti in Bangladesh, a local purveyor of credit and sales of rural solar home systems, is one of the best known examples. There are many others. The Development Bank of Uganda is providing rural micro-loans with support of the Shell Foundation. UNEP, the U.N. Foundation, and E+Co are experimenting with approaches to financing small- and medium-scale renewable energy enterprises through the Rural Energy Enterprise Development (REED) program in Africa, Brazil, and China. Triodos Bank's "Renewable Energy for Development Fund" provides seed capital, loans, and business development support for renewable energy entrepreneurs in Asia and Africa. In 2003, two of the largest commercial banks in India, Canara and Syndicate Banks, together with their regional associate banks, started to provide thousands of loans for rural households to use renewable energy, offered through 2,000 participating bank branches in two states. In general, capacity building for financial services for households and businesses has become a higher priority of many agencies.

These financing flows are augmented and facilitated by the efforts of many other industry associations, non-governmental organizations, international partnerships and networks, and private foundations. These so-called "market facilitation organizations" number in the hundreds and are active worldwide and locally. (See Note 45 for a listing of websites.) Five examples of international partnerships are the Global Village Energy Partnership (GVEP), the Renewable Energy and Energy Efficiency Partnership (REEEP), the Global Network on Energy for Sustainable Development (GNESD), the UNEP Sustainable Energy Finance Initiative, and the REN21 Renewable Energy Policy Network.

Government support for renewable energy was on the order of $10 billion in 2004 for the United States and Europe combined. Such support can take several forms. "On-budget" support includes such mechanisms as research and development funding, direct investment, capital-cost subsidies, tax credits, and export credits.* Research and development is a significant part of on-budget support, averaging $730 million per year during 1999–2001 for all International Energy Agency countries. "Off-budget" support includes the costs of market-based incentives and regulatory mechanisms that do not materially affect government budgets (for example, feed-in laws and renewables portfolio standards). The European Environment Agency estimated at least $0.8 billion in on-budget support and $6 billion in off-budget support for renewable energy in Europe in 2001. A large share of the off-budget support was due to feed-in tariffs, with purchase obligations and competitive tendering representing other forms of off-budget support. In the United States, federal on-budget support for renewables was $1.1 billion in 1999, including federal ethanol tax exemptions of $720 million and $330 million in RD&D. By 2004, RD&D spending declined but ethanol tax exemptions increased to $1.7 billion, which along with the production tax credit (perhaps another $200 million) increased total on-budget support to over $2 billion per year. U.S. state-level policies and programs, including public benefit funds providing an estimated $300 million per year (off-budget), might add another $1 billion dollars or more. In comparison with these figures, total energy subsidies/support for fossil fuels on a global basis are suggested by the United Nations and the International Energy Agency in the range of $150–250 billion per year, and for nuclear about $16 billion per year.[N16]

* Export credits have rarely applied to renewables in the past, but this situation appears to be changing. The OECD recently decided to give special treatment to renewable energy within the OECD Arrangement on Officially Supported Export Credits, including extending repayment terms from 12 to 15 years. This special status may help bring export credit agency terms in line with other financing going to developing country renewable energy projects, potentially increasing export credit agency investment in renewables.

3. INDUSTRY TRENDS

These investment flows mean that renewable energy has become big business. Worldwide, at least 60 publicly traded renewable energy companies, or renewable energy divisions of major companies, had a market capitalization greater than $40 million in 2005. The estimated total market capitalization of these companies and divisions was more than $25 billion. The next largest 100 renewable energy companies or divisions would add several billion dollars more of market capitalization to this figure. Solar PV is becoming one of the world's fastest growing, most profitable industries. Capacity expansion plans for 2005–2008 total several hundred megawatts, and an estimated $5–7 billion of capital investment will be made in 2005.[N17]

Perhaps the best illustration of how renewable energy has become big business is the entrance of the largest industry players into the wind power market, historically dominated by dedicated wind-turbine manufacturing companies. GE and Siemens are prominent examples of large electrical-equipment companies that have entered the wind market in recent years, both through acquisition (GE bought Enron Wind in 2003 and Siemens bought Bonus in 2004). In China, five of the largest electrical, aerospace, and power generation equipment companies began to develop wind turbine technology in 2004. Four signed technology-transfer contracts with foreign companies and were planning to produce their first prototype turbines in 2005. Such big players are bringing new competencies to the market, including finance, marketing, and production scale, and are adding additional credibility to the technology.

The wind power industry produced more than 6,000 wind turbines in 2004, at an average size of 1.25 MW each. The top six manufacturers are Vestas (Denmark, merged with NEG Micon in 2004), Gamesa (Spain), Enercon (Germany), GE Energy (USA), Siemens (Denmark, merged with Bonus in 2004), and Suzlon (India). In China, there are two primary turbine manufacturers, Goldwind and Xi'an Nordex, with market shares of 20 percent and 5 percent respectively (75 percent of the market being imports). Global industry progress has been closely related to turbine size, with the average installed turbine increasing from 500 kW in 1995 to 1,300 kW in 2004. The U.S. and European wind industries now produce turbines in the 1,000–3,000 kW range, but production of 600–1,000 kW sizes is still common in India and China. European manufacturers have introduced prototype wind turbines in the 5,000 kW range. Making larger turbines is still the number-one technological issue in the turbine industry. The industry has continued to make innovations in materials, electronics, blade and generator design, and site optimization, and these innovations offer further potential for cost reduction.[N18]

The solar PV industry celebrated its first gigawatt of global cumulative production in 1999. Five years later, by the end of 2004, cumulative production had quadrupled to more than 4 gigawatts. Production expansion continued aggressively around the world in 2004, and annual production exceeded 1,100 MW. Announced plans by major manufacturers for 2005 included at least a 400 MW increase in production capacity and several hundred megawatts further capacity in the 2006–2008 period. The top three global manufacturers in 2004 were Sharp, Kyocera, and BP Solar (though rapid capacity expansions by many players lead to changes in the top positions year to year).[N19]

China and other developing countries have emerged as solar PV manufacturers. Chinese module production capacity doubled during 2004, from 50 MW to 100 MW, and cell production capacity increased to 70 MW. Production capacity could double again in 2005 due to announced industry plans. India has 8 cell manufacturers and 14 module manufacturers. India's primary solar PV producer, Tata BP Solar, expanded production capacity from 8 MW in 2001 to 38 MW in 2004. In the Philippines, Sun Power planned in 2004 to double its cell production capacity to 50 MW. Solartron in Thailand announced plans for 20 MW cell production capacity by 2007. Across the whole industry, economies from larger production scales, as well as design and process improvements, promise further cost reductions.

Industries for biomass power and heat and small hydro are much more mature, localized, and diverse than those for wind and solar PV. Biomass heat and power investments tend to be made by the same companies generating waste biomass resources, such as timber and paper companies and sugar mills. European industry has maintained a leading position in the field of small hydropower manufacturing, with particular concern in recent years for upgrading and refurbishing existing plants. Small hydro technology improvements are focused on exploiting low heads (less than 15 meters) and small capacities (less than 250 kW). China's small hydro industry numbers at least 500 enterprises producing hydro generators. In contrast, five large firms dominate the international geothermal power industry (Ansaldo, Fuji, Mitsubishi, Ormat, and Toshiba).[N20, N21]

The global ethanol industry is centered in Brazil and the United States. There were more than 300 sugar mills/distilleries producing ethanol in Brazil in 2004, and 39 new distillers were licensed in early 2005. In the United States, construction of 12 new ethanol plants was completed in 2004, bringing the total to more than 80. Also in 2004, construction of 16 new plants was started. Several large ethanol plants will begin production in 2005 in Germany and the United States. Brazil's ethanol industry has also become a major ethanol exporter, accounting for about half of international shipments of ethanol during 2004. There was also considerable biofuels trade (of both ethanol and biodiesel) within the EU, and several other countries planned to expand their ethanol industries.[N22]

The sophistication of many segments of the renewable-energy industry increases year by year. For example, small wind turbine manufacturers are offering easier set-up and hybridization options with solar and other technologies. The off-grid solar PV industry is beginning to develop standardized "plug and play" packages for lanterns and full-scale household systems. Some companies are innovating with packaging hybrid systems; for example, one U.S. company is blending PV and small wind turbines on shipping containers with advanced batteries and controls to offer complete pre-packaged systems. More sophisticated controls, performance monitoring, and communications are being integrated into systems, allowing better energy accounting and more sophisticated billing and payment schemes.

The renewable energy industry continues to grow rapidly. Direct jobs worldwide from renewable energy manufacturing, operations, and maintenance exceeded 1.7 million in 2004, including some 0.9 million for biofuels production. Indirect jobs are likely several times larger. These estimates are preliminary, as published job estimates exist for only a few specific industries and countries. Examples of country-specific estimates include: 400,000 jobs in the Brazil ethanol industry; 250,000 jobs in the China solar hot water industry; 130,000 jobs in Germany from all renewables; 75,000 jobs in the European wind industry; 15,000 jobs in the European solar PV industry; 12,000 jobs in the U.S. solar PV industry; 11,000 jobs in the Nepal biogas industry; 3,400 jobs in Japan from renewables; and 2,200 jobs in the EU for small hydro.*[N24]

* No estimates exist in the literature for total jobs from renewable energy worldwide. See Note 24 for details of the analysis used for this report, which includes small hydro, biomass power, wind power, geothermal power, solar PV, solar hot water, ethanol, and biodiesel, but does not include geothermal and biomass heating.