RENEWABLES 2005

GLOBAL STATUS REPORT

REN21 Renewable Energy Policy Network for the 21st Century

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the REN21 Network by
The Worldwatch Institute

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Renewable Energy Policy Network for the 21st Century

REN21 is a global policy network aimed at providing a forum for international leadership on renewable energy. Its goal is to allow the rapid expansion of renewable energies in developing and industrial countries by bolstering policy development and decision making on sub-national, national, and international levels.

Open to all relevant and dedicated stakeholders, REN21 is a network of the capable and the committed which creates an environment in which ideas and information are shared and cooperation and action are encouraged to promote renewable energy worldwide. REN21 connects governments; international institutions and organizations; partnerships and initiatives; and other stakeholders on the political level with those "on the ground." REN21 is not an actor itself but a set of evolving relationships oriented around a commitment to renewable energy.

The establishment of a global policy network was embraced in the Political Declaration of the International Conference for Renewable Energies, Bonn 2004 (Renewables 2004), and formally launched in Copenhagen in June 2005.

REN21 Steering Committee

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(*) Full notes and references are available on the REN21 Web site, www.ren21.net.

EXECUTIVE SUMMARY

This report provides an overview of the status of renewable energy worldwide in 2005. It covers markets, investments, industries, policies, and rural (off-grid) renewable energy in developing countries. By design, the report does not provide analysis, recommendations, or conclusions. An extensive research and review process over several months involving more than 100 researchers and contributors has kept inaccuracies to a minimum. REN21 sees this report as the beginning of an active exchange of views and information.

This report reveals some surprising facts about renewable energy, many reflecting strong growth trends and increasing significance relative to conventional energy.

- About $30 billion was invested in renewable energy worldwide in 2004 (excluding large hydropower), a figure that compares to conventional power sector investment of roughly $150 billion. Investment in large hydropower was an additional $20–25 billion, mostly in developing countries.
- Renewable power capacity totals 160 gigawatts (GW) worldwide (excluding large hydropower), about 4 percent of global power sector capacity. Developing countries have 44 percent of this capacity, or 70 GW.
- Renewable energy generated as much electric power worldwide in 2004 as one-fifth of the world's nuclear power plants, not counting large hydropower (which itself was 16 percent of the world's electricity).
- The fastest growing energy technology in the world is grid-connected solar photovoltaic (PV), which grew in existing capacity by 60 percent *per year* from 2000–2004, to cover more than 400,000 rooftops in Japan, Germany, and the United States. Second is wind power capacity, which grew by 28 percent per year, led by Germany, with almost 17 GW installed as of 2004.
- Rooftop solar collectors provide hot water to nearly 40 million households worldwide, most of these in China, and more than 2 million geothermal heat pumps are used in 30 countries for building heating and cooling. Even so, biomass-fueled heating provides five times more heat worldwide than solar and geothermal combined.
- Production of biofuels (ethanol and biodiesel) exceeded 33 billion liters in 2004, about 3 percent of the 1,200 billion liters of gasoline consumed globally. Ethanol provided 44 percent of all (non-diesel) motor vehicle fuel consumed in Brazil in 2004 and was being blended with 30 percent of all gasoline sold in the United States.
- There were more than 4.5 million green power consumers in Europe, the United States, Canada, Australia, and Japan in 2004, purchasing power voluntarily at the retail level or via certificates.
- Direct jobs worldwide from renewable energy manufacturing, operations, and maintenance exceeded 1.7 million in 2004, including some 0.9 million for biofuels production.
- Renewable energy, especially small hydropower, biomass, and solar PV, provides electric power, heat, motive power, and water pumping for tens of millions of people in rural areas of developing countries, serving agriculture, small industry, homes, schools, and other community needs. Sixteen million households cook and light their homes with biogas, and two million households use solar lighting systems.

Policies to promote renewables have mushroomed over the past few years. At least 48 countries worldwide now have some type of renewable energy promotion policy, including 14 developing countries. By 2005, at least 32 countries and 5 states/provinces had adopted feed-in policies, more than half of which have been enacted since 2002. At least 32 states or provinces have enacted renewable portfolio standards (RPS), half of these since 2003, and six countries have enacted

national renewable portfolio standards since 2001. Some type of direct capital investment subsidy, grant, or rebate is offered in at least 30 countries. Most U.S. states and at least 32 other countries offer a variety of tax incentives and credits for renewable energy. The U.S. federal production tax credit has applied to more than 5.4 GW of wind power installed since 1995.

Policy targets for renewable energy exist in at least 45 countries worldwide, including 10 developing countries, all 25 European Union (EU) countries, and many states/provinces in the United States and Canada. Most targets are for shares of electricity production, typically 5–30 percent, by the 2010–2012 timeframe. There is an EU-wide target of 21 percent of electricity production by 2010. China's target of 10 percent of total power capacity by 2010 (excluding large hydropower) implies 60 GW of renewables capacity by 2010, up from today's 37 GW.

Municipalities around the world are also setting targets for future shares of renewable energy for government consumption or total city consumption, typically in the 10–20 percent range. Some cities have established CO_2-reduction targets. Many cities are enacting a variety of policies for promoting solar hot water and solar PV, and conducting urban planning that incorporates renewable energy.

Brazil has been the world leader in promoting biofuels for the past 25 years. All gasoline sold must be blended with ethanol, and all gas stations sell both pure ethanol and ethanol blends. In addition to Brazil, mandates for blending biofuels into vehicle fuels have been enacted in at least 20 states/provinces worldwide and two countries (China and India).

Renewable energy has become big business. Large commercial banks are starting to take notice, and several are "mainstreaming" renewable energy investments in their lending portfolios. Other large investors are entering the renewable energy market, including venture capital investors and leading investment banks like Morgan Stanley and Goldman Sachs. Major investments and acquisitions have been made in recent years by leading global companies, such as GE, Siemens, Shell, BP, Sanyo, and Sharp. Five of the largest electrical equipment and aerospace companies in China have decided to enter the wind power business. Combined, 60 leading publicly-traded renewable energy companies, or renewable energy divisions of major companies, have a market capitalization of at least $25 billion.

Half a billion dollars goes to developing countries each year as development assistance for renewable energy projects, training, and market support, with the German Development Finance Group (KfW), the World Bank Group, and the Global Environment Facility (GEF) providing the majority of these funds, and dozens of other donors and programs providing the rest.

Government support for renewable energy was on the order of $10 billion in 2004 for the United States and Europe combined, including direct support ("on-budget") and support from market-based policy mechanisms ("off-budget"). This includes more than $700 million per year in research and development spending.

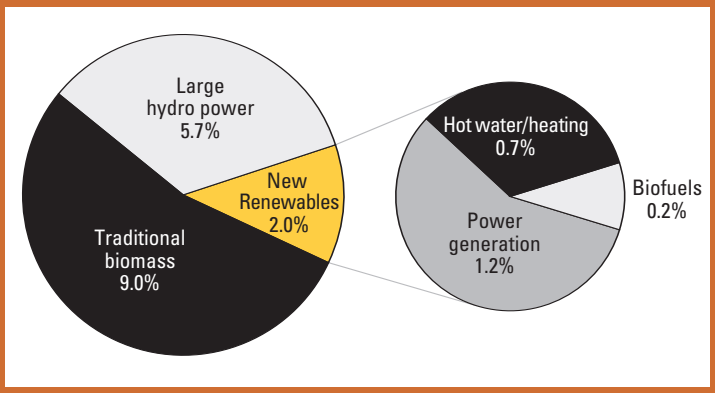
The costs of many renewable energy technologies are declining with technology improvements and economies of scale in production. Solar and wind power costs are now half what they were 10–15 years ago. Many renewable technologies can compete with retail and even wholesale prices of conventional energy under good conditions, even as conventional technology costs also decline (offset by increased fuel prices).

Market facilitation organizations (MFOs) are supporting the growth of renewable energy markets, investments, industries, and policies through some combination of networking, information exchange, market research, training, partnering, project facilitation, consulting, financing, policy advice, and other technical assistance. A preliminary list shows at least 150 such organizations around the world, including industry associations, non-governmental organizations, multilateral and bilateral development agencies, international partnerships and networks, and government agencies.

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

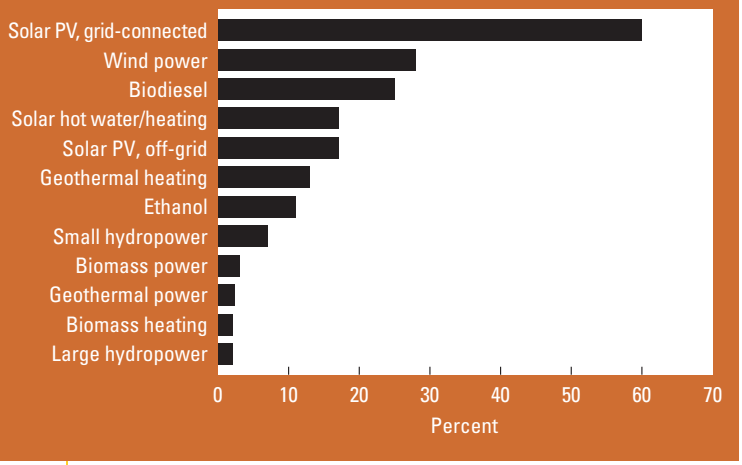
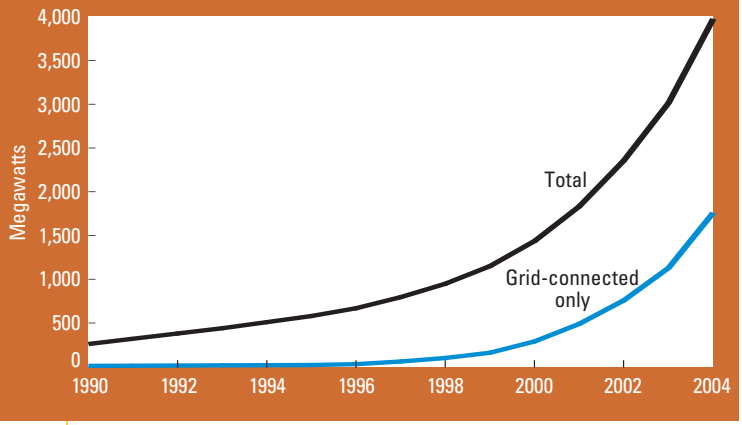


Figure 3. Solar PV, Existing World Capacity, 1990–2004



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

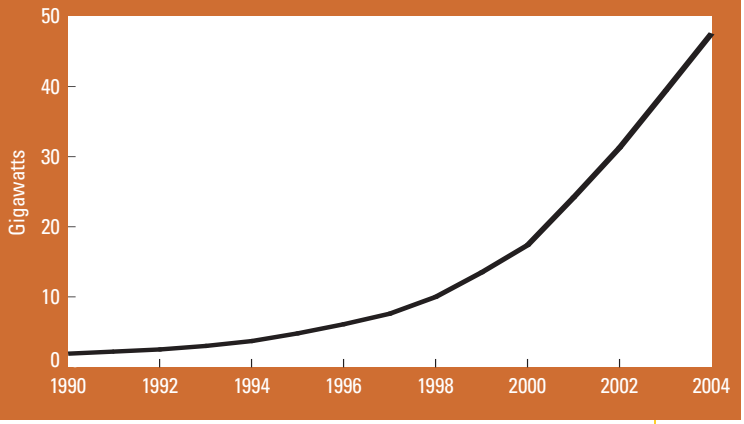
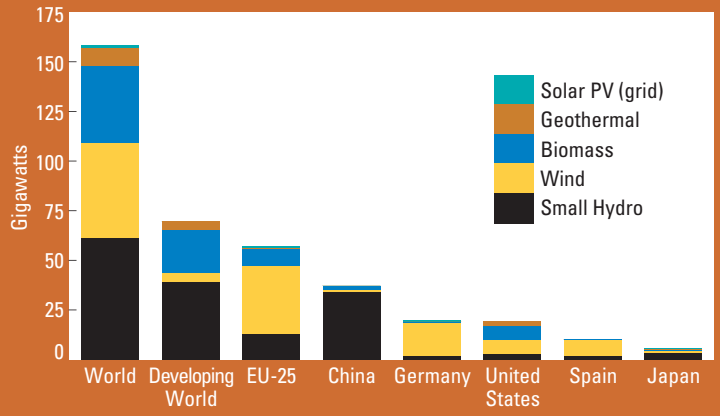


Figure 5. Renewable Power Capacities, EU,Top 5 Countries, and Developing World, 2004



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]

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

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

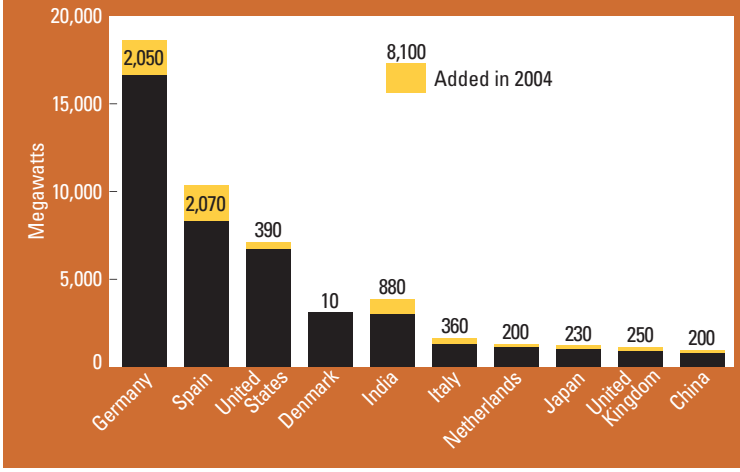
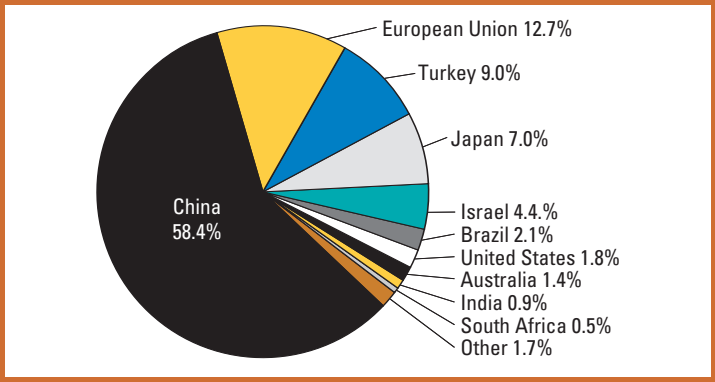


Figure 7. Share of Existing Solar Hot Water/Heating Capacity, Selected Countries, 2004



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

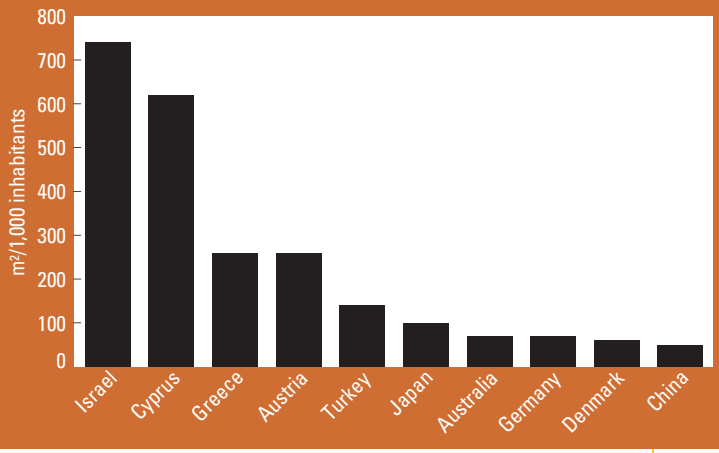
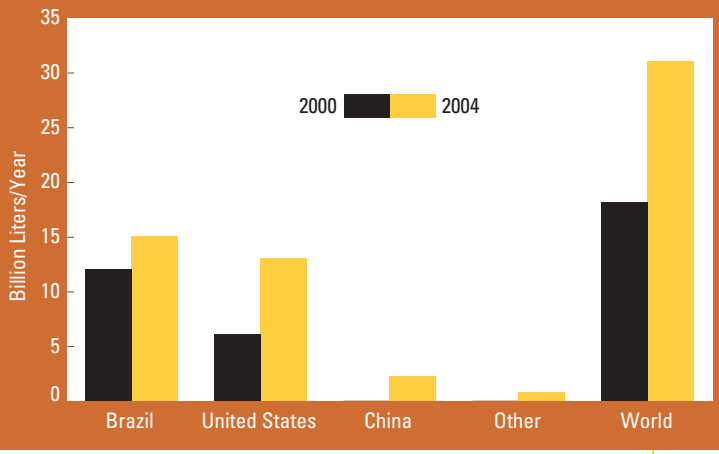


Figure 9. Fuel Ethanol Production, 2000 and 2004



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 m^2 *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*

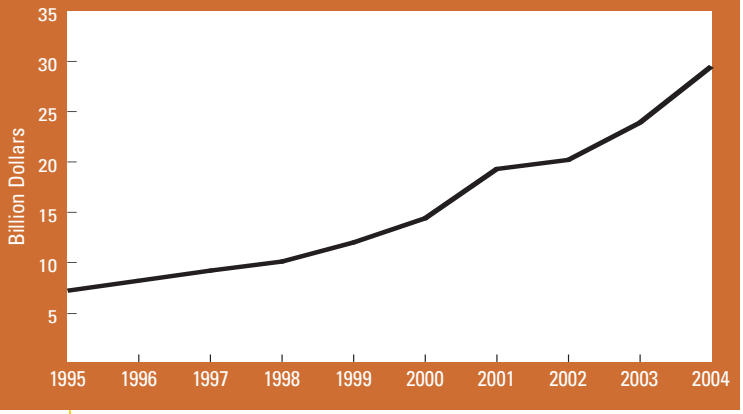
Technology	Typical Characteristics	Typical Energy Costs (cents/kWh)	Cost Trends and Potential for Cost Reduction
Rural (off-grid) Energy			
Mini-hydro	*Plant capacity:* 100–1,000 kW	5–10	Stable.
Micro-hydro	*Plant capacity:* 1–100 kW	7–20	Stable to moderately declining with efficiency improvements.
Pico-hydro	*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]

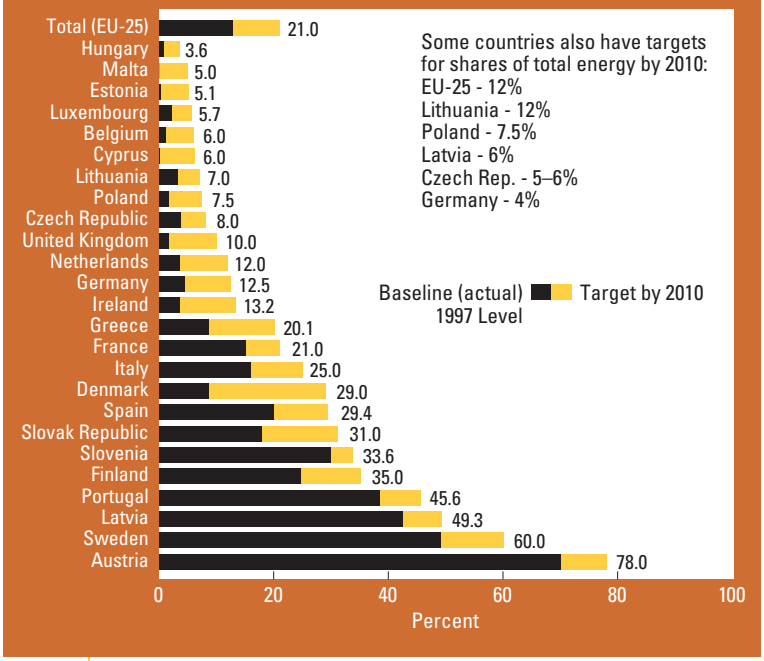
* No estimates exist in the literature for total jobs from renewable energy worldwide. See Note 24 for details of the analysis used for this report, which includes small hydro, biomass power, wind power, geothermal power, solar PV, solar hot water, ethanol, and biodiesel, but does not include geothermal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

4. POLICY LANDSCAPE

Policies to promote renewable energy existed in a few countries in the 1980s and early 1990s, but renewable energy policy began to emerge in many more countries, states, provinces, and cities during the late 1990s and early 2000s. Many of these policies have exerted substantial influence on the market development reviewed in the previous section. This section discusses existing targets and policies to promote renewable power generation, solar hot water/heating, and biofuels. It also discusses municipal-level policies and voluntary green power/pricing.*

It is beyond the scope of this report to provide detailed analysis of policy impacts and lessons. Nevertheless, the policy literature clearly shows that policies have had a major impact on the speed and extent of renewable energy development, despite a myriad of design and implementation problems. The International Energy Agency observed in 2004, in its milestone book on market and policy trends in IEA countries, that significant market growth has always resulted from combinations of policies, rather than single policies, that longevity and predictability of policy support is important, that local and state/provincial authority and involvement are important, and that individual policy mechanisms are evolving as countries gain more experience. Although a wealth of experience exists for older policies, the IEA suggests that it is still too soon to assess the impacts of many policies because most have been established since 2000.

Figure 11. EU Renewable Energy Targets—Share of Electricity by 2010



Policy Targets for Renewable Energy

Policy targets for renewable energy exist in at least 45 countries worldwide. By mid-2005, at least 43 countries had a national target for renewable energy supply, including all 25 EU countries. (See Figure 11 and Table 3, page 20.) The EU has Europe-wide targets as well: 21 percent of electricity and 12 percent of total energy by 2010. In addition to these 43 countries, 18 U.S. states (and the District of Columbia) and 3 Canadian provinces have targets based on renewables portfolio standards (although neither the United States nor Canada has a national target). An additional 7 Canadian provinces have planning targets. Most national targets are for shares of electricity production, typically 5–30 percent. Electricity shares range from 1 percent to 78 percent. Other targets are for shares of total primary energy supply, specific installed capacity figures, or total amounts of energy production from renewables, including heat. Most targets aim for the 2010–2012 timeframe.[N25]

The 43 countries with national targets include 10 developing countries: Brazil, China, the Dominican Republic, Egypt, India, Malaysia, Mali, the Philippines, South Africa, and Thailand. A few other developing countries are likely to announce targets in the near future. China's target of 10 percent of total power capacity by 2010 (excluding large hydropower) implies 60 GW of renewables capacity given projected electric-power growth. China also has targets for 2020, including 10 percent of primary energy and 12.5 percent of power capacity, 270 million square meters of solar hot water, and 20 GW each of wind and biomass power.†

* This section is intended to be indicative of the overall landscape of policy activity. Policies listed are generally those that have been enacted by legislative bodies. Some of the policies listed may not yet be implemented, or are awaiting detailed implementing regulations. It is obviously difficult to capture every policy, so some policies may be unintentionally omitted or incorrectly listed. Some policies may also be discontinued or very recently enacted. Updates will be posted to the Web-based notes for this section, which contain more policy details.

† China's targets are present in a draft renewable energy development plan that is pending approval by the government, but were announced publicly at the Renewables 2004 conference in Bonn, Germany, in June 2004. The Chinese renewable energy law of February 2005 requires the government to publish the renewable energy development plan, including targets, by January 2006.

Table 3. Non-EU Countries with Renewable Energy Targets

Country	Target(s)
Australia	9.5 TWh of electricity annually by 2010.
Brazil	3.3 GW added by 2006 from wind, biomass, small hydro.
Canada	3.5% to 15% of electricity in 4 provinces; other types of targets in 6 provinces.
China	10% of electric power capacity by 2010 (expected 60 GW); 5% of primary energy by 2010 and 10% of primary energy by 2020.
Dominican Republic	500 MW wind power capacity by 2015.
Egypt	3% of electricity by 2010 and 14% by 2020.
India	10% of added electric power capacity during 2003–2012 (expected 10 GW).
Israel	2% of electricity by 2007; 5% of electricity by 2016.
Japan	1.35% of electricity by 2010, excluding geothermal and large hydro (RPS).
Korea	7% of electricity by 2010, including large hydro, and 1.3 GW of grid-connected solar PV by 2011, including 100,000 homes (0.3 GW).
Malaysia	5% of electricity by 2005.
Mali	15% of energy by 2020.
New Zealand	30 PJ of added capacity (including heat and transport fuels) by 2012.
Norway	7 TWh from heat and wind by 2010.
Philippines	4.7 GW total existing capacity by 2013.
Singapore	50,000 m^2 (~35 MWth) of solar thermal systems by 2012.
South Africa	10 TWh added final energy by 2013.
Switzerland	3.5 TWh from electricity and heat by 2010.
Thailand	8% of total primary energy by 2011 (excluding traditional rural biomass).
United States	5% to 30% of electricity in 20 states (including DC).

Thailand is targeting 8 percent of primary energy by 2011 (excluding traditional biomass). India is expecting 10 percent of added electric power capacity, or at least 10 GW of renewables, by 2012.* The Philippines is targeting nearly 5 GW total by 2013, or a doubling of existing capacity. South Africa in 2003 set a target of 10 TWh of additional final energy from renewables by 2013, which would represent about 4 percent of power capacity. The Mexican legislature was considering in 2005 a new law on renewable energy that would include a national target.

Power Generation Promotion Policies

At least 48 countries—34 developed and transition countries and 14 developing countries—have some type of policy to promote renewable power generation. (See Table 4.) The most common existing policy is the feed-in law, which has been enacted in many new countries and regions in recent years. The United States was the first country to enact a national feed-in law (PURPA), in 1978. (Several states actively implemented PURPA but most implementation was discontinued in the 1990s.) Feed-in policies were next adopted in Denmark, Germany, Greece, India, Italy, Spain, and Switzerland in the early 1990s. By 2005, at least 32 countries and 5 states/provinces had adopted such policies, more than half of which have been enacted since 2002. (See Table 5, page 23.)

Among developing countries, India was the first to establish feed-in tariffs, followed by Sri Lanka and Thailand (for small power producers only), Brazil, Indonesia, and Nicaragua. Three states in India adopted new feed-in policies in 2004, driven by a 2003 national law requiring new state-level policies (the old feed-in laws during the 1990s were gradually discontinued). In the first half of 2005, feed-in policies were enacted in China, Ireland, Turkey, and the U.S. state of Washington. China's feed-in policy was part of a comprehensive renewable energy promotion law enacted in February 2005.[N26, N27]

Feed-in tariffs have clearly spurred innovation and increased interest and investment, notably in Germany, Spain, and Denmark over the past several years. For example, power from eligible forms of renewable generation under Germany's feed-in law more than doubled between 2000 and 2004, from 14 TWh to 37 TWh. In several coun-

* India's national target is a planning or indicative target but is not backed by specific legislation.

Table 4. Renewable Energy Promotion Policies

Country	Feed-in tariff	Renewable portfolio standard	Capital subsidies, grants, or rebates	Investment excise, or other tax credits	Sales tax, energy tax, or VAT reduction	Tradable renewable energy certificates	Energy production payments or tax credits	Net metering	Public investment, loans, or financing	Public competitive bidding
Developed and transition countries										
Australia		✓	✓			✓			✓	
Austria	✓		✓	✓		✓				
Belgium		✓	✓	✓		✓		✓		
Canada	(*)	(*)	✓	✓	✓			(*)	✓	(*)
Cyprus	✓		✓							
Czech Republic	✓		✓	✓	✓	✓		✓		
Denmark	✓			✓		✓		✓		
Estonia	✓				✓					
Finland			✓		✓	✓	✓			
France	✓		✓	✓	✓	✓			✓	✓
Germany	✓		✓	✓	✓				✓	
Greece	✓		✓	✓						
Hungary	✓				✓	✓			✓	
Ireland	✓		✓	✓		✓				✓
Italy		✓	✓	✓		✓		✓		
Israel	✓									
Japan	(*)	✓	✓			✓		✓	✓	
Korea	✓		✓		✓					
Latvia	✓								✓	
Lithuania	✓		✓	✓					✓	
Luxembourg	✓		✓	✓						
Malta					✓					
Netherlands	✓		✓	✓		✓	✓			
New Zealand			✓						✓	
Norway			✓	✓		✓				✓
Poland		✓	✓		✓				✓	✓
Portugal	✓		✓	✓	✓					
Slovak Republic	✓			✓					✓	
Slovenia	✓									
Spain	✓		✓	✓					✓	
Sweden	✓	✓	✓	✓	✓	✓	✓			
Switzerland	✓									
United Kingdom		✓	✓		✓	✓				
United States	(*)	(*)	✓	✓	(*)	(*)	✓	(*)	(*)	(*)
Developing countries										
Argentina			✓				✓			
Brazil	✓								✓	
Cambodia			✓							
China	✓		✓	✓	✓				✓	✓
Costa Rica	✓									
Guatemala				✓	✓					

Table 4. *continued*

Country	Feed-in tariff	Renewable portfolio standard	Capital subsidies, grants, or rebates	Investment excise, or other tax credits	Sales tax, energy tax, or VAT reduction	Tradable renewable energy certificates	Energy production payments or tax credits	Net metering	Public investment, loans, or financing	Public competitive bidding
India	(*)	(*)	✓	✓	✓				✓	✓
Indonesia	✓									
Mexico				✓				✓		
Nicaragua	✓			✓						
Philippines				✓	✓				✓	
Sri Lanka	✓									
Thailand	✓	✓	✓					✓		
Turkey	✓		✓							

Notes: (a) Only enacted policies are included. However, for some policies shown, implementing regulations may not yet be developed or effective, leading to lack of implementation or impacts. (b) Entries with an asterisk (*) mean that some states/provinces within these countries have state/province-level policies but there is no national level policy. (c) Some policies shown may apply to other markets beside power generation. (d) The table omits policies known to be discontinued; for example Norway's feed-in policy for wind discontinued in 2003, Denmark's capital grants discontinued in 2002, and Belgium's feed-in tariffs (Green Frank system) discontinued in 2003. (e) Several African countries have subsidy policies supporting modest amounts of rural solar PV, including Mali, Senegal, Tanzania, and Uganda (also micro-hydro). South Africa had a policy for subsidies to rural energy service concessions for solar PV that now appears dormant. (f) Several developing countries are planning renewable energy strategies and/or are expected to enact new or additional policies in the future, including Algeria, Armenia, Colombia, Egypt, Guatemala, Jordan, Macedonia, Mexico, Peru, South Africa, Vietnam, and Yemen.

tries, feed-in policies have had the largest effect on wind power, but have also influenced biomass and small hydro development. (Most laws set a limit on maximum size of eligible hydro, for example 5 MW in Germany.) Most recently, Spain's feed-in tariff has helped new investment plans for solar thermal power generation (decisions for two 50 MW plants were expected in 2005).

Feed-in tariffs vary in design from country to country. Some policies apply only to certain technologies or maximum capacity. Most policies establish different tariffs for different technologies, usually related to the cost of generation, for example distinguishing between off-shore and on-shore wind power. Some policies also differentiate tariffs by location/region, year of plant operation, and operational season of the year. Tariffs for a given plant may decline over time, but typically last for 15–20 years. Some policies provide a fixed tariff while others provide fixed premiums added to market- or cost-related tariffs (or both, as in the case of Spain).

Renewables portfolio standard (RPS) policies are expanding at the state/provincial level in the United States, Canada, and India. (See Table 6.) At least 32 states or provinces have enacted RPS policies, half of these since 2003. Eight new U.S. states (and the District of Columbia) enacted RPS policies in 2004–2005, bringing to 20 the number of U.S. states with RPS. Likewise in India, five new states enacted RPS policies in 2004–2005, bringing the total number of states to six (the Indian 2003 Electricity Act allows states to set minimum shares from renewables). Canada has three provinces with RPS policies (and several more with planning targets). Most of the above RPS policies require renewable power shares in the range of 5–20 percent, typically by 2010 or 2012. Most RPS targets translate into large expected future investments. One study estimates that state RPS laws currently existing in the United States would require an additional 52 GW of renewable energy by 2020, which would more than double existing U.S. renewables capacity.*[N28]

There are also six countries with national RPS policies, all enacted since 2001. Australia's RPS (2001) requires utility companies to submit a certain number of renewable energy certificates each year (1.25 percent of generation was required for 2004, or about 2,600 GWh total); this requirement will be adjusted each year to eventually lead

* RPS percentages don't necessarily correspond to ambitiousness or level of effort required, as some states/provinces already have capacity close to their targets, while others are far below their targets. Further, some RPS policies set upper limits on the size of hydro eligible to fulfill the requirement. See Note 25 for a list of mandated percentages or capacity targets for individual countries.

Table 5. Cumulative Number of Countries/States/Provinces Enacting Feed-in Policies

Year	Cumulative Number	Countries/States/Provinces Added That Year
1978	1	United States
1990	2	Germany
1991	3	Switzerland
1992	4	Italy
1993	6	Denmark, India
1994	8	Spain, Greece
1995	8	
1996	8	
1997	9	Sri Lanka
1998	10	Sweden
1999	13	Portugal, Norway, Slovenia
2000	14	Thailand
2001	16	France, Latvia
2002	20	Austria, Brazil, Czech Republic, Indonesia, Lithuania
2003	27	Cyprus, Estonia, Hungary, Korea, Slovak Republic, Maharashtra (India)
2004	33	Italy, Israel, Nicaragua, Prince Edward Island (Canada), Andhra Pradesh and Madhya Pradesh (India)
2005	37	Turkey, Washington (USA), Ireland, China

Note: Figure for 2005 is for first half of the year only.

Table 6. Cumulative Number of Countries/States/Provinces Enacting RPS Policies

Year	Cumulative Number	Countries/States/Provinces Added
1997	1	Massachusetts (USA)
1998	3	Connecticut, Wisconsin (USA)
1999	7	Maine, New Jersey, Texas (USA); Italy
2001	12	Arizona, Hawaii, Nevada (USA); Flanders (Belgium); Australia
2002	16	California, New Mexico (USA); Wallonia (Belgium); United Kingdom
2003	20	Minnesota (USA); Japan; Sweden; Maharashtra (India)
2004	34	Colorado, Maryland, New York, Pennsylvania, Rhode Island (USA); Nova Scotia, Ontario, Prince Edward Island (Canada); Madhya Pradesh, Karnataka, Andhra Pradesh, Orissa (India); Poland; Thailand
2005	38	District of Columbia, Montana, Delaware (USA); Gujarat (India)

to Australia's national target of 9,500 GWh by 2010. The United Kingdom's RPS (2002) will lead to 10 percent by 2010 and then to 15 percent by 2015, continuing to 2027. Japan's RPS (2003) also requires a certain percentage from utilities, which increases over time to reach 1.35 percent by 2010. Sweden's RPS (2003) requires consumers, or electricity suppliers on their behalf, to purchase a given annual percentage, which increases yearly, through either electricity purchases or renewable certificate purchases. (Sweden sets penalties for non-compliance at 150 percent of the average certificate price of the prior period.) Poland's RPS (2004) will reach 7.5 percent by 2010. Thailand's RPS (2004) requires that 5 percent of all additional future generation capacity be renewables.*

There are many other forms of policy support for renewable power generation, including direct capital investment subsidies or rebates, tax incentives and credits, sales tax and VAT exemptions, direct production payments or tax credits (i.e., per kWh), green certificate trading, net metering, direct public investment or financing, and public competitive bidding for specified quantities of power generation. (See Table 4, p. 21.) Some type of direct capital investment subsidy, grant, or rebate is offered in at least 30 countries. Tax incentives and credits are also common ways of providing financial support. Most U.S. states and at least 32 other countries offer a variety of tax incentives and credits for renewable energy.

Energy production payments or tax credits exist in several countries, with the U.S. federal production tax credit most significant in this category. That credit has applied to more than 5,400 MW of wind power installed from 1995 to 2004. Indexed to inflation, that credit started at 1.5 cents/kWh in 1994 and increased over time, through several expirations and renewals, to 1.9 cents/kWh by 2005, with expiration extended to 2007. The production tax credit has helped to make wind power a "mainstream"

* National targets from Table 3 and Figure 11 may be considered "binding," "planning," or "indicative" targets, but do not imply national RPS policies, which are legal mandates on specific classes of utility companies or consumers.

investment in the U.S. in recent years, capturing financier interest in the sector. Other countries with production incentives include Finland, the Netherlands, and Sweden.*

Policies to promote rooftop grid-connected solar PV exist in a few countries and utilize either capital subsidies or feed-in tariffs, or both (along with net metering). These policies have been clearly responsible for the rapid growth of the grid-connected market in recent years. Japan's rooftop solar PV policies, which were to end in 2005, provided capital subsidies which started at 50 percent in 1994 but declined to around 10 percent by 2003 and 4 percent by 2005. Those policies resulted in over 800 MW—more than 200,000 homes. Germany, with more than 160,000 rooftop solar homes and almost 700 MW installed, provides a guaranteed feed-in tariff, and until 2003 also provided low-interest consumer loans. Continuing policies in California, other U.S. states, and several other countries (including France, Greece, Italy, Korea, Luxembourg, the Netherlands, Portugal, and Spain) provide capital subsidies (typically 30–50 percent) and/or favorable power purchase tariffs. Korea expects 300 MW by 2011 through its 100,000-rooftop program, which initially provides 70-percent capital subsidies that will decline over time. New solar PV rooftop programs have been announced in several countries, including Hungary and Thailand.[N29]

Some countries or states/provinces have established renewable energy funds used to directly finance investments, provide low-interest loans, or facilitate markets in other ways, for example through research, education, standards, and investments in public facilities. The largest such funds are the so-called "public benefit funds" in 14 U.S. states. These funds, often applied to energy efficiency as well as renewable energy, are collected from a variety of sources, with the most common being a surcharge on electricity sales. These 14 funds, all initiated between 1997 and 2001, are collecting and spending more than $300 million per year on renewable energy. It is expected that they will collect upwards of $4 billion for renewable energy through 2012. The India Renewable Energy Development Agency (IREDA) similarly provides loans and other project financing. China's 2005 renewable energy law calls for establishing a fund, and Mexico was considering a "green fund" in 2005 to finance renewable energy projects.[N30]

Net metering laws exist in at least 7 countries, 35 U.S. states, and several Canadian provinces. Four additional U.S. states had one or more electric utilities offering net metering. A form of net metering is also occurring in Japan on a voluntary basis. Net metering laws are being enacted regularly, with six new U.S. states passing such laws in 2004. Most recently, a 2005 U.S. federal law requires all U.S. electric utilities to provide net metering within three years. Net metering has been particularly instrumental in facilitating grid-connected solar PV markets in the United States and Japan.[N30]

Policies for competitive bidding of specified quantities of renewable generation, originally used in the United Kingdom in the 1990s, now exist in at least seven other countries: Canada, China, France, India, Ireland, Poland, and the United States. China bid and awarded 850 MW of wind power in 2003–2004 and planned another 450 MW of bidding in 2005. The province of Ontario in Canada bid 1,000 MW of wind power in 2004, and other Canadian provinces were following suit. Utilities in many countries use competitive bidding to meet RPS requirements.[N31]

Other policies include tradable renewable energy certificates, typically used in conjunction with voluntary green power purchases or obligations under renewables portfolio standards. At least 18 countries had schemes and/or markets for tradable certificates. Many other regulatory measures, such as building codes, administrative rules and procedures, and transmission access and pricing, also serve important roles in promoting renewable power generation. Such regulatory measures can be steps towards future renewable energy markets, particularly in developing countries (Mexico and Turkey are examples of countries taking such regulatory measures). Policies for power-sector restructuring, carbon taxes, fossil fuel taxes, and many others can also affect the economic competitiveness of renewable energy.

Solar Hot Water/Heating Promotion Policies

The world's largest market for solar hot water collectors is China, with 80 percent of the global additions in 2004. China's national goal is 65 million square meters by 2005 (which was almost met in 2004) and 230 million square meters by 2015. With its origins in small towns and villages in the 1980s, the market has been driven mainly by unmet demand for hot water, economics, and systems that sell for a small fraction of prices found in developed countries. Although there are no explicit policies for promoting solar hot water in multi-storey urban buildings, building design and construction by developers has begun to incorporate solar hot water as energy costs rise and public demand increases, particularly during the current construction boom. There are also government programs for technology standards, building codes, and testing and certification centers to help the industry mature.[N32]

* Energy production incentives, which offer producers a payment per unit of energy produced (i.e., kWh), may appear similar to, and even be called, feed-in tariffs. The distinction is not simple, as the financing for production incentives may come from explicit utility surcharges or foregone tax revenues. The U.S. production tax credit could be considered a feed-in law under some definitions. The definition used here is that feed-in tariffs should be revenue neutral to the government, with the difference paid implicitly by utility customers (as in the case of Germany and Spain), rather than explicitly through a special levy (as in the case of the Netherlands) or foregone tax revenue (as in the case of Finland).

Beyond China, at least 18 countries, and probably several more, provide capital grants, rebates, or investment tax credits for solar hot water/heating investments, including Australia, Austria, Belgium, some Canadian provinces, Cyprus, Finland, France, Germany, Greece, Hungary, Japan, the Netherlands, New Zealand, Portugal, Spain, Sweden, the United Kingdom, many U.S. states, and the U.S. federal government. Capital grants are typically 20–40 percent of system cost. Investment tax credits may allow deduction of all or part of the investment cost from tax liability. (Italy's renewable energy certificates also apply to solar hot water, so-called "white certificates.") Israel appears to be the only country with a national-level policy mandating solar hot water in new construction. Since 1980, most buildings in Israel have been required to have solar hot water collectors. The technical requirements vary by size and type of building. Certain industrial, medical, and high-rise buildings are exempt. The European Commission was to consider promotion policies for renewable heating, including solar, potentially leading to a new directive.

At the local level, a number of major cities around the world have enacted ordinances requiring solar hot water in new buildings or providing incentives or subsidies for solar hot water investment. Examples are Barcelona (Spain), Oxford (UK), and Portland, Oregon (USA). Barcelona in particular has enacted one of the most far-reaching of such policies. Starting in 2000, the Barcelona Solar Thermal Ordinance has represented a major milestone in urban energy policy. The ordinance requires all new buildings above a specific size category (292 MJ/day hot water energy consumption) to provide at least 60 percent of their domestic hot water energy demand from solar thermal collectors. Swimming pool heating must be 100-percent solar. Buildings undergoing major refurbishment are also subject to the ordinance. The size category means typically that all commercial buildings, and all residential buildings of 16 or more households, are subject to the ordinance. Due to the ordinance, 40 percent of all new buildings now include solar hot water, and per-capita installed capacity (m^2/1,000 people) has leaped 15-fold, from 1.1 in 2000 to 16.5 in 2004. The city's objective is about 100,000 square meters installed by 2010.

Following Barcelona's lead, other cities and towns in Spain adopted solar thermal ordinances as well, including Madrid, Valencia, Seville, Burgos, and Pamplona. The strong interest by municipalities prompted the Spanish Institute for Energy Diversification and Saving (IDAE) in 2003 to elaborate a solar ordinance template, largely based on Barcelona's solar ordinance, which could be used by cities and towns as a basis for their own such rules. By November 2004, 34 municipalities and one region had adopted solar ordinances, with additional ordinances in the pipeline for 10 more regions (out of a total of 17). Results have been significant. For example, Pamplona's solar ordinance, which entered into force in mid-2004, caused a 50-percent increase in solar thermal collectors in one year. A nationwide solar ordinance was under consideration and expected to be enacted in 2005.

Biofuels Promotion Policies

Brazil has been the world leader in promoting biofuels for 25 years under its "ProAlcool" program. Policies have included blending mandates, retail distribution requirements, production subsidies, and other measures. Since 1975, Brazil has mandated that ethanol be blended with all gasoline sold. Although the required blend level is adjusted frequently, it has been in the range of 20–25 percent. All gas stations are required to sell gasohol (E25) and pure ethanol (E100). Tax preferences have been given to vehicles that run on pure ethanol. The recent introduction and soaring sales of so-called "flex-fuel" vehicles by several automakers was not driven primarily by policy, but the government did extend the preferential vehicle licensing tax to cover flexible-fuel cars, beyond the original coverage of pure ethanol cars.* Brazil has more recently begun to target increased use of biodiesel fuels, derived primarily from domestically produced soybean oil. A recent law in Brazil allows blending of 2-percent biodiesel in diesel fuels since January 2005. This percentage may be increased to 5 percent or more by 2013.[N33]

In addition to Brazil, mandates for blending biofuels into vehicle fuels have been appearing in several other countries in recent years. In particular, at least 20 states/provinces and two countries now have mandates for blending ethanol and/or biodiesel with all vehicle fuels sold. In India, the government mandated 10-percent ethanol blending (E10) in 9 out of 28 states and 4 out 7 federal territories (all sugar cane producing areas), starting in 2003. In China, four provinces mandate E10 blending, and five additional provinces were slated for a similar mandate in 2005.† In the United States, three states also mandate E10 blending: Hawaii (most gasoline by 2006), Minnesota (increasing to 20 percent by 2013), and Montana. Minnesota also mandates 2-percent blending of biodiesel (B2), a policy that other states and countries are considering. In Canada, the province of Ontario mandates

* This turning point, in which half of all new cars sales by 2005 were flex-fuel vehicles, was driven by the voluntary initiative of national automotive manufacturers, lead by Volkswagen. Producing flex-fuel cars rather than separate pure-ethanol and gasohol models has allowed automakers to simplify supply and assembly chains.

† Due to poor cane crop yields during 2003–2004, India had to import ethanol in order to meet state blending targets, and has had to postpone broader targets until sufficient supplies of domestic ethanol reappear on the market. Chinese provinces have also had to suspend blending mandates due to ethanol shortages.

E5 (average) blending by 2007. National blending mandates have appeared in Columbia (E10) and the Dominican Republic (E15 and B2 by 2015). Thailand has a target for biofuels as a share of total energy by 2011, for which it is considering E10 and B2 blending mandates. Japan is considering an E5 blending mandate based on imports from Brazil.[N33]

Tax incentives for biofuels are most prominent in the United States, where a number of policies have been enacted at the state and federal levels over the past 25 years. The Energy Security Act of 1979 created a federal ethanol tax credit of up to 60 cents per gallon, proportional to the blend percentage of the fuel (e.g., 6 cents/gallon for E10). In 2004, this tax credit was extended through 2010. A tax credit for biodiesel was also added, of about 1 cent per percentage point of biodiesel blended (i.e., 2 cents per gallon for B2). Several U.S. states also offer tax and other incentives for ethanol production and sales. Canada provides a national fuel tax exemption of 10 cents per liter, and many provinces offer similar or higher exemptions (up to 25 cents/liter). A number of European countries provide fuel or VAT tax exemptions for biofuels, including Austria (95 percent exemption for biodiesel), France, Germany (100 percent exemption for biodiesel), Hungary, Italy (100 percent exemption for biodiesel), Spain, Sweden, and the United Kingdom.

Several other European countries have been considering biofuels policies as part of efforts to achieve the EU biofuels target of 5.75 percent of transport fuels by 2010. An EC Directive in 2003 provided targets for each country to meet by 2005 (2 percent) and 2010 (5.75 percent). Although the targets are voluntary, countries have had to submit plans for meeting targets, or justifications for why they won't. Some EU members have recently enacted biofuels promotion laws or binding targets, including Hungary, which mandates 2 percent of total energy from biofuels by 2010, and the Netherlands, with a target of 2 percent of transport fuels.

Green Power Purchasing and Utility Green Pricing

There were more than 4.5 million green power consumers in Europe, the United States, Canada, Australia, and Japan in 2004. Green power purchasing and utility green pricing programs are growing, aided by a combination of supporting policies, private initiatives, utility programs, and government purchases. The three main vehicles for green power purchases are utility green-pricing programs, competitive retail sales by third-party producers allowed through electricity deregulation (also called "green marketing"), and tradable renewable energy certificates. Community-organized green power programs also exist in Japan. As markets expand, the price premiums for green power over conventional power have continued to decline. In the United States, retail green power premiums are now typically 1–3 cents/kWh.[N34]

In Europe, green power purchasing and utility green pricing have existed in some countries since the late 1990s. By 2004, there were almost 3 million green power consumers in the Netherlands, supported by a tax exemption on green electricity purchases. Other countries in Europe with retail green power markets include Finland, Germany, Switzerland, and the United Kingdom. Germany's green power market has grown steadily since 1998, with more than 600,000 consumers purchasing 2,000 GWh in 2004. Eighteen European countries are members of RECS, a renewable energy certificates system founded in the late 1990s to standardize and certify renewable energy certificates and trading. By 2005, a cumulative total of 33,000 GWh of renewable energy certificates had been issued, with nearly 13,000 GWh of certificates used for consumer purchases of green electricity.*

The United States has an estimated half-million green power consumers purchasing 4,500 GWh of power annually. Green power purchasing began in earnest around 1999. By 2004, at least 2 GW of additional renewable energy capacity was built in the United States to accommodate this market.† The federal government is the largest single buyer of green power, with the U.S. Air Force purchasing 320 GWh annually. By 2004, more than 600 utilities in 34 states had begun to offer green-pricing programs. Most of these offerings were voluntary, but regulations were enacted in five states between 2001 and 2003 that require utilities to offer green power products to their customers. Utility green pricing accounted for almost half of green power sales in 2004.

Many large companies in the United States, from aerospace contractors to natural foods companies, are voluntarily buying green power products. Among these corporate buyers are IBM, Dow, Dupont, Alcoa, Intel, HP, Interface, Johnson & Johnson, Pitney Bowes, Staples, Baxter, FedEx Kinkos, General Motors, and Toyota. Public and non-governmental initiatives have facilitated these buyers. The U. S. Environmental Protection Agency's "Green Power Partnership" had 600 partners by 2005, purchasing 2,800 GWh of green power annually. And a voluntary "Green-e" certifica-

* In the United Kingdom, the distinction between voluntary green power purchases and renewable energy obligations by utilities has been questioned. There are claims that green power voluntary purchases in the United Kingdom are not always "additional" to existing utility obligations. In Germany, more than 50 percent of the green power market is served by hydropower plants, predominantly those put into operation well before the German electricity market was liberalized.

† Green power purchases in the United States are separate from and additional to any renewable energy mandates, for example renewables portfolio standards.

Table 7. Selected Major Cities with Renewable Energy Goals and/or Policies

City	Renewable Energy Goals	CO_2 Reduction Goals	Policies for for Solar Hot Water	Policies for Solar PV	Urban Planning, Pilots, and Other Policies
Adelaide, Australia	✓	✓			✓
Barcelona, Spain	✓	✓	✓	✓	✓
Cape Town, South Africa	✓	✓			✓
Chicago, United States	✓				
Daegu, Korea	✓	✓			✓
Freiburg, Germany	✓	✓		✓	✓
Göteborg, Sweden					✓
Gwangju, Korea	✓	✓			✓
The Hague, Netherlands		✓			
Honolulu, United States					✓
Linz, Austria					✓
Minneapolis, United States	✓				✓
Oxford, United Kingdom	✓	✓	✓	✓	✓
Portland, United States	✓	✓	✓	✓	✓
Qingdao, China					✓
San Francisco, United States					✓
Santa Monica, United States					✓
Sapporo, Japan		✓			✓
Toronto, Canada		✓			
Vancouver, Canada		✓			

tion program has helped build credibility in the market.

In Japan, there were an estimated 60,000 green power consumer-participants by early 2005. These are utility customers who voluntarily contribute to green power through cooperatives, community organizations, and utility programs. Green power in Japan initially developed through voluntary community organizations. The first green power program was initiated by a consumer's cooperative union, Seikatsu Club Hokkaido. Working with the regional utility, the union collects electricity bills, along with voluntary contributions from its members and the general public, and invests in renewable energy projects. Members can purchase shares in wind power projects, thus creating the first "citizen-owned" wind turbines. Similar green funds have been established elsewhere in Japan, and ten Japanese electric utilities now offer customers an option to contribute to a green power fund to support wind and solar systems. As of early 2005, there were 57,000 customers making monthly voluntary contributions to their electricity bills.

Renewable energy certificate markets have also emerged in Japan. The Japan Natural Energy Company (JNEC) now sells green power certificates to commercial and industrial customers, including more than 50 large Japanese companies like Sony, Asahi, Toyota, and Hitachi. JNEC will sell certificates to these companies representing a total of 60 GWh over 15 years, at premiums of 2.4–3.4 cents/kWh (3–4 Yen/kWh).

Australia has over 100,000 green power consumers purchasing from a variety of retailers. And green power purchasing is spreading to other countries. One example is China, where twelve enterprises in Shanghai began to voluntarily purchase green electricity from three local wind farms in 2005, the first such purchases in China. The price premium was high—6 cents/kWh (0.53 yuan) higher than conventional power.

Municipal-Level Policies

Many local governments around the world are enacting their own renewable energy policies. Cities are setting future renewable energy targets and CO_2 emissions-reductions goals, enacting policies to support solar hot water and/or rooftop solar PV, modifying their urban planning methods or processes to incorporate future energy consumption, constructing demonstrations or pilot installations, and enacting a variety of other policies and programs. (See Table 7.)[N35]

A number of cities have decided to purchase green power for municipal government buildings and operations. Examples are Portland, Oregon, and Santa Monica, California, in the United States, which purchase 100 percent of their power needs as green power. Other U.S. cities purchasing 10–20 percent of municipal government power are Chicago, Los Angeles, Minneapolis, and San Diego.

Many cities are adopting future targets of 10–20 percent

of electricity from renewables for all consumers in the city, not just the municipal government. Examples are Adelaide, Australia; Cape Town, South Africa; Freiberg, Germany; and Sacramento (California), United States. Targets typically aim for some year in the 2010–2020 timeframe. Some targets are for share of total energy consumption, such as Daegu, Korea, with a target of 5 percent by 2012. Other city targets address installed capacity. Both Oxford, United Kingdom, and Cape Town, South Africa, are targeting 10 percent of homes with solar hot water by 2010 (and solar PV as well in Oxford). Barcelona, Spain, is targeting 100,000 square meters of solar hot water by 2010. Some local governments in the UK are requiring on-site renewables for all new buildings over specific size thresholds.

Some cities have also proposed or adopted CO_2 emissions-reduction goals, typically a 10–20 percent reduction over a baseline level (usually 1990 levels), consistent with the form of Kyoto Protocol targets. (However, at the city level, such target setting is complicated by industrial production, as emissions associated with industry are not necessary attributable to residents of the city.) Examples are Freiburg, Germany (25 percent); Gwangju, Korea (20 percent); Sapporo, Japan (10 percent); Toronto, Canada (20 percent for municipal government energy); and Vancouver BC, Canada (6 percent). The Hague, Netherlands, plans for municipal government consumption to be "CO_2 neutral" by 2006 and for the whole city to be "CO_2 neutral" in the long term. Adelaide, Australia, plans "zero net emissions" by 2012 in buildings and by 2020 in transport.

Urban planning that incorporates future clean-energy visions is gaining hold in many cities, often with participation from a variety of stakeholders. Göteborg, Sweden, is an example of a city creating a long-term vision, through a project called Göteborg 2050. That project is a collaborative effort between universities, the city government, and the city's energy utility. It includes research, scenario development, strategic planning, dialogue with the public, and demonstration projects. In Japan, where renewable energy policy has been quite active at the local level, 800 local governments have laid out future urban visions over the past 10 years, with support from a national government program. These Japanese cities are creating advanced and unique visions taking into consideration their local characteristics, and incorporating renewable energy into their visions.

Cities worldwide are collectively organizing and participating in a variety of global initiatives that support renewable energy development at the local level, such as the Cities for Climate Protection campaign of ICLEI (Local Governments for Sustainability), the International Solar Cities Initiative, the European Solar Cities Initiative, the European Green Cities Network, and the European Climate Alliance.

5. RURAL (OFF-GRID) RENEWABLE ENERGY

The most common applications of renewable energy for rural (off-grid) energy services are cooking, lighting and other small electric needs, process motive power, water pumping, and heating and cooling. These applications are described in Table 8 (page 30), which blends "first-generation" or "traditional" applications and technologies (i.e., unprocessed biofuels and small-scale hydro) with "second-generation" applications and technologies (i.e., wind, solar PV, biomass gasification, and pico-scale hydro). Although much development attention has focused on second-generation technologies, rural development professionals are continually reminding the development and renewable energy communities about the continued importance of first-generation technologies, especially in the least-developed countries. This section discusses some of the rural energy applications from Table 8 and then discusses rural electrification policy.[N36]

"Traditional" applications mean primarily burning fuel wood, agricultural and forestry wastes (residues), dung, and other unprocessed biomass fuels for home cooking and heating and other process-heating needs. Some biomass is converted to charcoal and sold in commercial markets. Biomass accounts for a large share of total primary energy supply in many developing countries. In 2001, this share was 49 percent in Africa, 25 percent in Asia, and 18 percent in Latin America. In 2000, households in sub-Saharan Africa consumed nearly 470 million tons of wood fuels (0.72 tons per capita) in the form of wood and charcoal. In comparison, India and China together consumed 340 million tons. In sub-Saharan Africa, wood or crop residues are the primary source of household energy for 94 percent of rural households and 41 percent of urban households. Charcoal is the primary source of household energy for 4 percent of rural households and 34 percent of urban households. And kerosene is the primary source of household energy for 2 percent of rural households and 13 percent of urban households.[N37]

The costs and health impacts of traditional biomass use (and the corresponding benefits of improved biomass stoves and other technologies) are beyond the scope of this report but still highly significant. Much of the biomass fuel is collected outside of the commercial economy, with collection time being a large non-monetary expenditure, especially for women. Researchers Ezzati and Kammen, in a comprehensive literature review, state that "conservative estimates of global mortality as a result of exposure to indoor air pollution from solid fuels show that in 2000 between 1.5 million and 2 million deaths were attributed to this risk factor, accounting for 3–4 percent of total mortality worldwide."[N37]

Cooking: Improved Biomass Cook Stoves

Improved biomass stoves save from 10–50 percent of biomass consumption for the same cooking service provided and can dramatically improve indoor air quality. Improved stoves have been produced and commercialized to the largest extent in China and India, where governments have promoted their use, and in Kenya, where a large commercial market developed. There are 220 million improved stoves now in use around the world, due to a variety of public programs and successful private markets over the past two decades. This number compares with the roughly 570 million households worldwide that depend on traditional biomass as their primary cooking fuel. China's 180 million existing improved stoves now represent about 95 percent of such households. India's 34 million improved stoves represent about 25 percent of such households.*[N38]

In Africa, research, dissemination, and commercialization efforts over the past few decades have brought a range of improved charcoal—and now wood-burning—stoves into use. Many of these stove designs, as well as the programs and policies that have supported their commercialization, have been highly successful. There are now 5 million improved stoves in use. In Kenya, the Ceramic Jikko stove (KCJ) is found in more than half of all urban homes and roughly 16–20 percent of rural homes. About one-third of African countries have programs for improved biomass cook-stoves, although there are few specific policies in place. Non-governmental organizations and small enterprises continue to promote and market stoves as well.

Cooking and Lighting: Biogas Digesters

An estimated 16 million households worldwide receive energy for lighting and cooking from biogas produced in household-scale plants (called anaerobic digesters). This includes 12 million households in China, 3.7 million households in India, and 140,000 households in Nepal. In addition to providing energy for cooking and lighting, biogas

* Improved biomass cook stoves are more properly considered a fuel-efficiency technology rather than a renewable energy production technology. Nevertheless, they are clearly a form of rural renewable energy use, one with enormous scope and consequences of use. Policies and programs to promote efficient stoves are therefore not renewable energy "promotion" policies, as is typical with other renewables covered in this report, but rather are designed to improve the health, economic, and resource impacts of an existing renewable energy use (and thus closely linked to sustainable forestry and land management). The number of existing and operating improved stoves may be significantly less than reported figures given here; for example, in India some estimates say a majority of stoves have passed their useful lifetimes and no longer operate.

Table 8. Common Existing Applications of Renewable Energy in Rural (Off-Grid) Areas

Energy Services	Renewable Energy Applications	Conventional Alternatives
Cooking (homes, commercial stoves and ovens)	• biomass direct combustion (fuel wood, crop wastes, forest wastes, dung, charcoal, and other forms) • biogas from household-scale digester • solar cookers	LPG, kerosene
Lighting and other small electric needs (homes, schools, street lighting, telecom, hand tools, vaccine storage)	• hydropower (pico-scale, micro-scale, small-scale) • biogas from household-scale digester • small-scale biomass gasifier with gas engine • village-scale mini-grids and solar/wind hybrid systems • solar home systems	candles, kerosene, batteries, central battery recharging, diesel generators
Process motive power (small industry)	• small hydro with electric motor • biomass power generation and electric motor • biomass gasification with gas engine	diesel engines and generators
Water pumping (agriculture and drinking)	• mechanical wind pumps • solar PV pumps	diesel pumps
Heating and cooling (crop drying and other agricultural processing, hot water)	• biomass direct combustion • biogas from small- and medium-scale digesters • solar crop dryers • solar water heaters • ice making for food preservation	LPG, kerosene, diesel generators

has improved the livelihood of rural households in indirect ways. For example, analysis of the benefits of biogas in Nepal shows a reduction of workload for women and girls of 3 hours/day per household, annual savings of kerosene of 25 liters/household, and annual savings of fuel wood, agricultural waste, and dung of 3 tons/household.[N39]

In China, household-scale biogas for rural home lighting and cooking is a widespread application. A typical digester, sized 6–8 cubic meters, produces 300 cubic meters of biogas per year and costs 1,500–2,000 RMB ($200–250), depending on the province. Because digesters are a simple technology, there is no need for advanced expertise, and they can be supplied by local small companies. Farmers, after receiving proper training, can build and operate the digesters themselves. A new government program, started in 2002, provides 1 billion RMB annually as subsidies to farmers who build their own digester. The subsidy is 800 RMB per digester. Some estimate that more than 1 million biogas digesters are being produced each year. Beyond household scale, a few thousand medium and large-scale industrial biogas plants were operating in China, with a recent national biogas action plan expected to expand the numbers of such plants.

In India, the Ministry of Non-conventional Energy Sources has been promoting household-scale biogas plants since the early 1980s. The ministry provides subsidies and financing for constructing and maintaining biogas plants, training, public awareness, technical centers, and support to local implementing agencies. The well-known Khadi and Village Industries commission also supports biogas plants.

In Nepal, the SNV/Biogas Support Programme has provided technological innovation, financing, engineering, and market development for household-scale biogas plants (sized 4–20 cubic meters, with the most popular being 6 cubic meters). During the program, 60 private biogas companies increased their technical and market capabilities, 100 micro-credit organizations provided loans, quality standards were adopted, and a permanent market facilitation organization, Biogas Sector Partnership/Nepal, has been created.

Electricity, Heat, and Motive Power: Biomass Gasification

Small-scale thermal biomass gasification is a growing commercial technology in some developing countries, notably China and India. Gas from a gasifier can be burned directly for heat or used in gas turbines or gas engines for electricity and/or motive power. In a few Chinese provinces, biogas from thermal gasifiers also provides cooking fuel through piped distribution networks. The total installed capacity of gasifiers in India was estimated at 35 MW in 2002, and ten manufacturers are selling small-scale gasifiers together with engines up to 300 kW. In the Philippines, gasifiers have been coupled to dual-fuel diesel engines and used for rice-milling and irrigation since the 1980s. Gasifiers have also been demonstrated in Indonesia, Thailand, and Sri Lanka.[N40]

In India, projects involving biomass gasification in silk and other textile production and processing have been demonstrated on a commercial basis, involving local entrepreneurs and short payback periods. Spice (cardamom) drying, also with gasifiers and no reliance on electricity, yields a higher-quality product in a shorter drying period. In this application, the investments pay for themselves in one season. More than 85 percent of the beneficiaries are small producers who own less than two hectares. The drying of rubber, again with gasifiers, also demonstrates the capability to displace conventional energy and deliver a payback of less than one year. Gasifiers are also used to dry bricks before firing in a kiln. The use of a gasifier reduces fuel consumption and associated smoke and decreases the drying time (increasing productivity) while improving working conditions.

Electricity: Village-Scale Mini-Grids/Hybrid Systems

Village-scale mini-grids can serve tens or hundreds of households. Traditionally, mini-grids in remote areas and on islands have been powered by diesel generators or small hydro. Generation from solar PV, wind, or biomass, often in hybrid combinations including batteries and/or a supplementary diesel generator, is slowly providing alternatives to the traditional model, mostly in Asia. Tens of thousands of mini-grids exist in China, primarily based on small hydro, while hundreds or thousands exist in India, Nepal, Vietnam, and Sri Lanka. The use of wind and solar PV technologies in mini-grids and hybrid systems is still on the order of a thousand systems worldwide, mostly installed in China since 2000. China's "Township Electrification Program" from 2002–2004 electrified one million rural people in one thousand townships, about 250,000 households, with electricity from solar PV, wind-solar PV hybrid systems, and small hydropower systems. During 2002–2004, almost 700 townships received village-scale solar PV stations of approximately 30–150 kW (about 20 MW total). A few of these were hybrid systems with wind power (about 800 kW of wind total). India, the other main location for village-scale power systems, has 550 kW of solar/wind hybrid systems installed, which serve on the order of a few thousand households in several dozen villages.[N41]

Water Pumping: Wind and Solar PV

Solar PV and wind power for water pumping, both irrigation and drinking water, are gaining widespread acceptance, and many more projects and investments are occurring. On the order of one million mechanical wind pumps are in use for water pumping, primarily in Argentina, following decades of development. Large numbers of wind pumps are also used in Africa, including in South Africa (300,000), Namibia (30,000), Cape Verde (800), Zimbabwe (650), and several other countries (another 2,000). There are now more than 50,000 solar-PV pumps worldwide, many of these in India. Over 4,000 solar pumps (ranging from 200–2,000 W) were recently installed in rural areas as part of the Indian Solar PV Water Pumping Programme. There are an estimated 1,000 solar water pumps in use in West Africa. Donor programs for PV-powered drinking water have appeared in Argentina, Brazil, Indonesia, Jordan, Namibia, Niger, the Philippines, Tunisia, and Zimbabwe, among others.[N42]

A growing cohort of commercial projects for solar PV-powered drinking water, including both pumping and purification, has appeared in recent years, notably in India, the Maldives, and the Philippines. In the Maldives, a commercial pilot project anticipates sales of 1,000 liters/day, with a long-term delivered price of water to households expected to reach 0.2–0.5 cents per liter. Another recent example is on the Philippine island of Cebu. A 3-kW solar PV water pump distributes filtered and chlorinated surface water to 10 village locations. The 1,200 residents use prepaid debit cards to purchase potable water at a cost of about 3 PHP (5.5 cents) for 20 liters, or 0.3 cents/liter, a tenth of the cost of bottled water supplies. Fees collected from water sales are used to pay back an unsubsidized 10-year bank loan. The scheme could be duplicated on 10 more Philippine islands, providing potable water to 200,000 people in 40 municipalities.

Electricity: Solar Home Systems

By 2005, more than 2 million households in developing countries were receiving electricity from solar home systems. Most of these systems, and most of the global growth in recent years, is occurring in a few specific Asian countries (India, Sri Lanka, Nepal, Bangladesh, Thailand, and China), where the affordability problem has been overcome either with micro-credit or by selling small systems for cash, and where government and international donor programs have supported markets.* In each of these countries, hundreds or thousands of new household installations are now occurring monthly (10,000 per month reported in China in 2005). Total installations were more than 200,000 in 2004 alone. Indonesia has about 40,000 solar home systems installed through several donor programs, but macroeconomic difficulties of past years have dampened continued growth. Outside Asia, other large markets include Kenya, Morocco, and

* Projects by the GEF, the World Bank, and UNDP supported about 410,000 solar home systems installed worldwide by 2004, including 230,000 in China, 75,000 in Sri Lanka, 45,000 in India, 40,000 in Bangladesh, 10,000 in Zimbabwe, and perhaps another 10,000 through other projects combined. This has been the largest single donor-support program for solar home systems. Projects by these agencies and other government programs have also employed a rural energy-service concession approach, or "fee-for-service" business model, for example in South Africa, Cape Verde, Argentina, Senegal, and Botswana, but such business models are still in the early stages of demonstrating their viability.

Mexico. The plans of a number of Latin American countries may shift solar home system growth towards that region if promising approaches to affordability, including government subsidies and/or fee-for-service models, continue to be followed.* [N43]

Africa, with its very low rural-electrification rates and low per-capita income, has not seen significant growth in solar home systems, with the exception of a few countries. Kenya has 150,000 solar home systems, almost half of the installed base in Africa, and continuing market growth. Growth has been driven by cash sales of small modules to households in rural and peri-urban areas. Morocco is targeting 150,000 solar home systems by 2010. Uganda has a major 10-year program that targets solar home systems and other productive uses in education and health care. South Africa has been planning for several years to provide solar home systems to 200,000 rural households through "fee-for-service" concessions operated by private firms. Other countries like Mali, Tanzania, and Senegal are providing limited subsidies for rural renewables like solar home systems. In general, however, earlier expectations that millions of homes would obtain solar home systems in Africa have failed to materialize. Affordability is still a critical issue, as the cost of a typical low-end solar home system is high relative to average incomes in most African countries.

Solar home systems sales by private dealers have been the cornerstone of markets in five countries: China, Sri Lanka, India, Bangladesh, and Kenya. In China and Kenya, systems are almost exclusively sold for cash. In India, Sri Lanka, and Bangladesh, credit sales have improved affordability and fostered markets. Significant innovation is occurring with NGO-based microfinance, dealer-supplied credit, and consumer credit through commercial banks. In India, along with many cash purchases, credit for solar home systems purchases is now offered through more than 2,000 rural bank branches as part of a commercial solar loan program. Indeed, the estimated 120,000 solar home systems sold on credit in India, Sri Lanka, and Bangladesh during the past five years represents virtually the entire stock of credit-based installations worldwide. Kenya also has a very active private market, with more than 20 major PV import and manufacturing companies, and hundreds of rural vendors and urban distributors, many of which sell a range of brands.

Other Productive Uses of Heat and Electricity

Productive uses of heat and electricity for small-scale industry, agriculture, telecommunications, health, and education in rural areas are a growing area of attention for applying modern renewable energy technologies. Examples of industrial applications include silk production, brick making, rubber drying, handicraft production, sewing, welding, and wood working. Examples of agricultural and food processing applications include irrigation, food drying, grain mills, stoves and ovens, ice making, livestock fences, and milk chilling. Health applications include vaccine refrigeration and lighting. Communication applications include village cinema, telephone, computers, and broadcast radio. Other community applications include school and street lighting, and drinking water purification. Despite this diversity of potential applications, existing projects are still small demonstrations. For the most part, large-scale development of these applications on sustainable or commercially replicable terms has yet to occur.

Even as applications of renewable electricity for lighting, water pumping, medical refrigeration, and motive power are beginning to receive greater attention, application of modern renewables to heating needs is still much less discussed or practiced. Traditional biomass fuels are used to produce heat and heat-related services such as cooking, space heating, crop drying, roasting, agricultural processing, kilns, ovens, and commercial food-processing. Applications of solar heating and advanced biomass technologies are just beginning to attract the attention of the development community. Developing-country governments are focusing more on these areas as well. For example, the Indian government has launched comprehensive programs promoting biomass for electricity, heat, and motive power in rural areas, including combustion, co-generation, and gasification. These rural energy programs target all forms of household, community, and productive needs in hundreds of rural districts.

A good example of applications in health and education is the World Bank/GEF Uganda Energy for Rural Transformation project. The project is providing energy for medical equipment, staff quarters, lighting, cold chain, sterilizing, and telecom, and demonstrating to the Ministry of Health the viability of such applications. For education, solar PV will power equipment for vocational training, lighting for night classes, and staff housing. Other applications include water pumping and small enterprises. Mexico's "telesecundaria" program is another good example. This program is designed to enhance rural schools through distance education programs, and many remote schools rely on solar PV to power communications and other equipment for distance learning. In Guatemala, Honduras, and Bolivia, a new model for "telecenters" is emerging, combining public-service centers with for-profit telephone services.

Approaches to financing small and medium-scale enter-

* Solar home system totals include more than half a million households in India and other countries with "solar lanterns" in addition to fixed household-scale systems. Compact fluorescent lights are commonly used with solar home systems, but there is growing interest in low-wattage LEDs and cold-cathode fluorescent lamps for low-cost solar lanterns and solar home systems requiring less solar-PV capacity.

prises engaged in renewable energy-related productive business have gained considerable attention in recent years through programs like the UNEP/UN Foundation "rural energy enterprise development" (REED) program in Africa, Brazil, and China and other finance initiatives. These enterprises are providing a variety of services and products, including solar home systems, water pumping, solar crop drying, biofuels-powered engines for grinding and milling, solar bakeries, biomass briquettes and pellets, and other income-generating uses. The number of such enterprises is growing in rural areas, led by both donor programs and greater access to commercial bank credit.

Rural Electrification Policies and Programs

National rural electrification policies and programs, together with international donor programs, have employed renewable energy as an adjunct to "access" strategies. That is, serving increasing percentages of rural populations who don't have access to central electric power networks. An estimated 360 million households worldwide still lack such access. The main electrification options include power grid extension, diesel generators connected in mini-grids, renewable energy connected in mini-grids (solar, wind, and/or biomass gasification, sometimes combined with diesel), and household-scale renewable energy (solar home systems and small wind turbines). Often the cost of traditional grid extension is prohibitive; in Kenya, for example, the average cost of a new connection for a rural home is seven times the national per-capita income.[N44]

Interest in using renewable energy technologies to provide electricity to rural and remote areas as a cost-effective alternative to grid extension is gathering momentum in many developing countries. At the same time, there is a growing recognition that private investment alone is insufficient, and that public subsidies and policies play a key role, justified by development goals and public mandates for universal electricity access. "All our client countries in Latin America have told us that they have realized that they need subsidies and regulatory measures for reaching the 'last 20 percent' of their rural unelectrified populations, including with renewable energy," said a World Bank project manager.

Rural electrification programs in several countries, particularly in Latin America, are explicitly incorporating large-scale investment in solar home systems for some of the homes to be electrified. Governments are recognizing geographic rural areas that are non-viable for grid-extension, and enacting explicit policies and subsidies for renewables in these areas to supplement line-extension electrification programs. For example, Brazil plans to electrify 2.5 million households by 2008 under the "Luz para Todos" program (about 700,000 have already been electrified), and has targeted 200,000, or about 10 percent of these households for renewable energy. As mentioned before, China's "Township Electrification Program," which was substantially completed during 2004, provided power to 1 million people in rural areas with renewable energy. The Indian government's "Remote Village Electrification Programme" has identified 18,000 villages for electrification, partly with renewable energy technologies like biomass gasifiers.

Several other Latin American countries have recently launched or revamped new rural electrification programs, including Bolivia, Chile, Guatemala, Mexico, Nicaragua, and Peru. Most of these countries have launched efforts to "mainstream" renewable energy as a standard option of new rural electrification efforts. For example, Chile has recently recognized renewables as a key technology as it enters a second phase of a national rural electrification program. Given this planned scale-up of renewables for rural electrification, regulators and utilities have realized that legal and regulatory frameworks need to be adopted quickly. Indeed, new laws or regulations appeared during 2004 and 2005 in Argentina, Bolivia, Brazil, Chile, Guatemala, and Nicaragua.

Asian examples of countries with explicit mandates for renewable energy for rural electrification include Bangladesh, China, India, Nepal, the Philippines, Sri Lanka, Thailand, and Vietnam. Some of these countries are financing programs with multilateral assistance, as well as conducting other technical assistance and support measures. The Philippines launched a strategy in 1999 to achieve full rural village electrification by 2007, including renewable energy explicitly in that strategy. Sri Lanka is targeting 85 percent of the population with access to electricity and has started to directly subsidize rural solar home systems. Thailand decided in 2003 to electrify the remaining 300,000 off-grid households in the country with solar home systems by the end of 2005, and accomplished almost half of that goal in 2004.

GLOSSARY

Biodiesel. A vehicle fuel for diesel-powered cars, trucks, buses, and other vehicles. Biodiesel is produced from oilseed crops such as soy, rapeseed (canola), and mustard, or from other vegetable oil sources such as waste cooking oil.

Biogas digester. Converts animal and plant wastes into gas usable for lighting, cooking, heating, and electricity generation.

Biomass power and heat. Power and/or heat generation from solid biomass, which includes forest product wastes, agricultural residues and waste, energy crops, and the organic component of municipal solid waste and industrial waste. Also includes power and process heat from biogas.

Capital subsidies or consumer grants. One-time payments by the government or utility to cover a percentage of the capital cost of an investment, such as a solar hot water system or rooftop solar PV system.

Ethanol. A vehicle fuel made from biomass (typically corn, sugar cane, or wheat) that can replace ordinary gasoline in modest percentages (see "gasohol") or be used in pure form in specially modified vehicles.

Feed-in tariff. A policy that sets a fixed price at which power producers can sell renewable power into the electric power network. Some policies provide a fixed tariff while others provide fixed premiums added to market- or cost-related tariffs. Some provide both.

Gasohol. A blend of gasoline and ethanol, typically 10–25 percent ethanol (called E10, E25, etc.).

Geothermal power and heat. Heat energy emitted from within the Earth, usually in the form of hot water or steam, which can be used to produce electricity or direct heat for buildings, industry, and agriculture.

Gigawatt (GW)/Gigawatt-hour (GWh)/Gigawatt-thermal (GWth). See megawatt, kilowatt-hour, megawatt-thermal.

Green power purchasing. Voluntary purchases of green power by residential, commercial, government, or industrial customers, from utility companies (see "utility green pricing"), from a third-party renewable energy generator (also called "green marketing"), or with "renewable energy certificates." With utility green pricing or competitive sales, a customer's electricity demand is matched by an equivalent amount of renewable energy generation feeding into the power grid. Green certificates allow the renewable energy production to be located anywhere.

Investment tax credit. Allows investments in renewable energy to be fully or partially deducted from tax obligations or income.

Kilowatt-hour (kWh). A unit of produced or consumed electricity. Also the most common unit for the retail price of electricity, as in cents/kWh.

Large hydropower. Electricity from water flowing downhill, typically from behind a dam. No international consensus exists on the threshold that separates large from small hydro power, but the upper limit varies from 2.5–50 MW, with 10 MW becoming more standard.

Megawatt (MW). A unit of power-generating capacity. Represents an instantaneous power flow and should not be confused with units of produced energy (i.e., MWh, or megawatt-hours).

Megawatt-thermal (MWth). A unit of heat-supply capacity used to measure the potential output from a heating plant, such as might supply a building or neighborhood. More recently used to measure the capacity of solar hot water/heating installations. Represents an instantaneous heat flow and should not be confused with units of produced heat (i.e., MWh(th), or megawatt-hours-thermal).

Modern biomass. Biomass-utilization technologies other than those defined for traditional biomass, such as biomass co-generation for power and heat, biomass gasification, biogas anaerobic digesters, and production of liquid biofuels for use in vehicles.

Multilateral agency. Commonly refers to public agencies that work internationally to provide development, environmental, or financial assistance to developing countries, such as the World Bank, or to broker international agreements and treaties, such as the United Nations.

Net metering. Allows a two-way flow of electricity between the electricity distribution grid and customers with their own generation. When instantaneous consumption exceeds self-generation, the meter runs forward. When instantaneous self-generation exceeds consumption, the meter runs backward and power flows to the grid. The customer pays for the net electricity used in each billing period and may be allowed to carry over net generation from month to month.

Production tax credit. Provides the investor or owner of qualifying property with an annual tax credit based on the amount of electricity generated by that facility.

Renewable energy target. A commitment, plan, or goal by a country to achieve a certain level of renewable energy by a future date. Some targets are legislated while others are set by regulatory agencies or ministries. Can take many forms with varying degrees of enforcement leverage. Also called "planning targets," "development plans," and "obligations."

Renewables portfolio standard (RPS). A standard requiring that a minimum percentage of generation sold or capacity installed be provided by renewable energy. Obligated utilities are required to ensure that the target is met, either through their generation, power purchase from other producers, or direct sales from third parties to the utility's customers.

Small/mini/micro/pico hydropower. (See "large hydropower.") Small hydropower is commonly defined as below 10 MW, mini below 1 MW, micro below 100 kW, and pico below 1 kW. Pico hydro will typically not involve a dam but just captures the power of flowing water.

Solar home system. A rooftop solar panel, battery, and charge controller that can provide modest amounts of power to rural homes not connected to the electric grid. Typically provides an evening's lighting (using efficient lights) and TV viewing from one day's battery charging.

Solar hot water/heating. Rooftop solar collectors that heat water and store it in a tank for use as domestic hot water or for space heating.

Solar photovoltaic (PV) panel/module/cell. Converts sunlight into electricity. Cells are the basic building block, which is then manufactured into modules and panels.

Tradable renewable energy certificates. Each certificate represents the certified generation of one unit of renewable energy (typically one MWh). These certificates allow trading of renewable energy obligations among consumers and/or producers, and in some markets like the United States allow anyone to purchase separately the green power "attributes" of renewable energy.

Traditional biomass. Unprocessed biomass, including agricultural waste, forest products waste, collected fuel wood, and animal dung, that is burned in stoves or furnaces to provide heat energy for cooking, heating, and agricultural and industrial processing, typically in rural areas.

Utility green pricing. A utility offers its customers a choice of power products, usually at differing prices, offering varying degrees of renewable energy content. The utility guarantees to generate or purchase enough renewable energy to meet the needs of all green power customers.