United States International Trade Commission

Renewable Energy Services: An Examination of U.S. and Foreign Markets

Investigation No. 332-462
USITC Publication 3805
October 2005

U.S. International Trade Commission

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Washington, DC 20436

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Publication 3805 **October 2005**

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ABSTRACT

As requested by the United States Trade Representative (USTR), this report examines global markets for renewable energy services as well as issues related to the international trade of these services, for the purpose of providing information that would be useful in conducting trade negotiations and environmental reviews. The report finds that demand for renewable energy services is driven largely by government policies including those that stem from national obligations under international environmental agreements. To a lesser extent, demand for renewable energy services is also derived from technological advances that have improved the cost-competitiveness of renewable energy technologies, concerns regarding the environment and energy security, and other factors. While the wind energy industry is the largest in terms of installed capacity among the five renewable energy sectors (which are: wind, solar, biomass, geothermal, and ocean energy) discussed in this report, the biomass energy industry is the largest in terms of electricity generation. The United States is the world's largest market for biomass and geothermal power, while Germany, Japan, and France are the largest markets for wind power, solar power, and ocean power, respectively. There are few barriers that specifically target trade and investment in the renewable energy services sector, although regulatory barriers that apply separately to related sectors, or horizontally to all industry sectors, may affect trade and investment in the renewable energy industry.

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EXECUTIVE SUMMARY

This is the second of two reports prepared at the request of the U.S. Trade Representative to examine discrete segments of the environmental and energy services industries. The first report, *Air and Noise Pollution Abatement Services: An Examination of U.S. and Foreign Markets* (Inv. No. 332-461), was transmitted to the U.S. Trade Representative on April 1, 2005. This second report focuses on renewable energy services which, for the purpose of this report, include the generation, transmission, distribution, and sale of heat and electricity produced through the use of wind, solar, biomass, geothermal, or ocean (including tidal) energy, as well as incidental services such as construction, operation and maintenance, and research and development.

The renewable energy sectors that are the focus of this report accounted for less than 2 percent of global electricity production in 2002. Although the market for renewable energy remains small, worldwide electricity production from renewable energy sources increased at an average annual rate of 8.6 percent during 1995-2002, while total world electricity production grew by 3.3 percent annually. Environment-friendly government incentive measures and other policies, including those that stem from national obligations under international environmental agreements (such as the Kyoto Protocol), have played a leading role in the development of certain renewable energy sectors, but other factors such as technological advances that have improved the cost-competitiveness of renewable energy technologies, and concerns regarding the environment and energy security have also contributed to the growth of certain segments of this industry. More specifically, wind and solar capacity have expanded rapidly as a result of these market factors. Biomass and geothermal power capacity have also increased in recent years, but at a significantly slower rate than wind and solar capacity. The ocean energy industry remains in the developmental stage, with only a small number of commercial facilities in existence.

In terms of installed capacity, the wind energy industry is the largest of the renewable energy sectors discussed in this report, with approximately 47,900 megawatts (MW) in 2004 (table ES-1). However, biomass is largest in terms of electricity generation, in part due to the intermittence of wind resources, and in part due to longstanding economic incentives to incinerate biomass in industrial facilities. The United States is the world's largest market for biomass and geothermal power. Other market segments are led by Germany (wind power), Japan (solar power), and France (ocean power).

Services incidental to the production of renewable energy include consulting, construction, installation and design, maintenance and operation, and research and development services. Industry sources estimate that the global markets for services incidental to wind, solar, and biomass power production totaled approximately $3.8 billion, $2.8 billion, and $1.7 billion, respectively, in 2004.[1] Germany was the largest market for wind power services having accounted for about $1.6 billion, or 41 percent, of such services in 2004. The United States and Spain were the second and third

[1] McIlvaine Co., estimate provided to USITC staff via e-mail, June 21, 2005.

Table ES-1
Worldwide electricity capacity and generation from renewable energy sources, 2002

	Capacity	Electricity generation	Share of total generation	Largest market
	Megawatts	*Gigawatts*	*Percent*	
Wind[1]	47,912	96,500	0.4	Germany
Solar	[2]2,400	[3]930	<0.01	Japan
Biomass	[4]35,000	[3]194,935	1.2	United States
Geothermal	[5]8,246	[3]52,235	0.3	United States
Tidal/ocean[6]	[7]261	[8]<1	[8]<0.01	France

[1] 2004 data. BTM Consult ApS, *World Market Update 2004, Forcast 2005-2009*, Mar. 2005, pp. 3, 53-55.
[2] 2003 data. European Photovoltaic Industry Association and Greenpeace, *Solar Generation: Solar Electricity for Over 1 Billion People and 2 Million Jobs by 2020*, Oct. 2004, p. 5, found at *http://www.epia.org/05Publications/EPIAPublications.htm*, retrieved Feb 24, 2005.
[3] International Energy Agency, *Energy Statistics of OECD Countries, 2001-2002* (Paris: OECD, 2004).
[4] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Frequently Asked Questions, p. 1, found at *http://www.eere.energy.gov/biomass/electricalpower.html*, retrieved Aug. 1, 2005.
[5] 1999 data. Geothermal Energy - Markets, found at *http://www.worldbank.org/html/fpd/energy/geothermal/markets.htm*, retrieived Mar. 27, 2005.
[6] Largely experimental.
[7] 1996 data. *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, p. 14; and China New Energy, “Table 1: List of Main Tidal Power Stations,” found at *http://www.newenergy.org/english/ocean/casestudy/tide/*, retrieved June 21, 2005.
[8] Reflects generation by worlds largest tidal energy facility, which accounts for 240 MW of total world capacity for tidal/ocean power.

Source: Compiled by USITC staff.

largest markets for wind energy services, respectively, accounting for 16 percent and 10 percent of the world market for such services.[2] Leading country markets for solar power services included Japan (43 percent), Germany (26 percent), and the United States (5 percent). In the biomass segment, Finland accounted for about $480 million, or 28 percent, of the worldwide services market in 2004, followed by the United States (23 percent), Romania (7 percent), Japan (7 percent), and France (6 percent).[3] Comparable estimates reflecting the value of country markets for geothermal and tidal energy are not available.

Although government sources do not publish discrete data on trade and investment in renewable energy and related services, one industry source estimates that cross-border trade in engineering and construction services related to wind power, solar PV and concentrating solar power, and biomass facilities was valued at $828 million, $150 million, and $178 million, respectively, in 2004.[4] No data on trade and investment in the

[2] Ibid.
[3] Ibid.
[4] McIlvaine Co., estimates provided to USITC staff via e-mail, June 23, 2005.

geothermal power generation sector are available. However, over the next 20 years, countries outside the United States are expected to spend a combined $25 to $40 billion developing and constructing geothermal power plants, creating a significant opportunity for suppliers of geothermal equipment and services. Anecdotal evidence also suggests that there currently is significant international activity in the renewable energy sector. For example, numerous wind power companies such as Vestas (Denmark), GE Wind (U.S.), and EHN (Spain) provide services in overseas markets, and certain solar energy firms also provide services globally. Investment activity frequently includes the development of renewable energy facilities in overseas markets.

There are few barriers that specifically affect trade and investment in the wind, solar, biomass, geothermal, or ocean energy production or services sectors. Existing provisions affecting trade in renewable energy services include, for example, provisions in China and Spain requiring a certain amount of local content in wind power development projects. However, regulatory barriers that apply to incidental sectors, such as professional licensing provisions that apply in the consulting and engineering industries, as well as investment measures, land use provisions, and limitations on movement of persons that apply to trade and investment in all sectors, may affect trade and investment in the renewable energy industry. Equipment used in the renewable energy industry is subject to a wide range of tariffs in different countries. For example, while Canada and Japan do not impose tariffs on imports of wind-powered generating sets, such generating sets are subject to 15 and 30 percent duties in India and China, respectively. However, tariffs in those countries and elsewhere reportedly are not a significant impediment to trade in such equipment.

GLOSSARY

Acid rain: Acid rain (sometime acid deposition) refers to precipitation that has become more acidic than normal due to adsorption oxidants, particularly sulfur dioxide (SO_2) and nitrogen oxides (NO_X). In the United States, about 2/3 of all SO_2 and 1/4 of all NOx comes from electric power generation that relies on burning fossil fuels like coal.

Baseload power: The power supply that electric utility companies deliver/or have available for delivery, on a continuous basis, requiring a stable, continuous source of fuel.

Binary cycle: Geothermal electricity generating system used where reservoir temperatures fall below 350 degrees. The system works by passing geothermal fluid through a heat exchanger, which produces steam to drive a turbine.

Biogas: A methane rich gaseous fuel generated by fermenting biomass materials in an oxygen-starved environment. Biogas can be used to fuel combustion turbine single combined cycle power generation plants.

Biomass energy: Energy derived from any plant-derived organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal wastes, and other waste materials.

Capacity: The amount of electricity that a generation plant is capable of producing at peak operation. The combined capacity of the generation plants located in a certain country is frequently referred to as that country's total capacity.

Captive consumption: Consumption of electricity from a local power plant not attached to the grid.

Carbon/ Greenhouse gas emissions: Emissions of gasses generally considered as contributing to the natural greenhouse effect. Largely generated by the burning of fossil fuels.

Cogeneration: The simultaneous production of heat and electricity, also referred to as combined heat and power (CHP).

Distribution: The movement of electrical energy over low-voltage power lines. Typically, this involves the transportation of power from a transmission grid to a consumer.

Dry steam: Geothermal electricity generating system utilizing pressurized steam pumped directly from a vapor reservoir into a turbine.

Feed-in tariff system: Government-determined prices paid by electric utilities to renewable energy producers which are above average wholesale electricity prices, and thus serve as a subsidy for renewable energy.

Flash steam: Geothermal electricity generating system utilizing hot water, with natural temperature of 350 degrees or above, piped through a separator which creates steam, which is then drives a turbine.

Flat plate module: An arrangement of photovoltaic cells or material mounted on a rigid flat surface with the cells exposed freely to incoming sunlight.

Fossil fuel: Fuels formed in the ground from the remains of dead plants and animals over millions of years. Oil, natural gas, and coal are fossil fuels.

Futures market: A market in which traders buy and sell contracts for the delivery of a commodity at a specified date and price in the future. A futures market for electricity is one in which electricity is the subject commodity.

General Agreement on Trade in Services (GATS): The GATS, which entered into force on January 1, 1995 as part of the Agreement Establishing the World Trade Organization, is the first multilateral, legally enforceable agreement covering trade and investment in services.

Generation: The act of producing electrical energy.

Geothermal energy: Energy available as heat emitted from the earth's crust, usually in the form of hot water or steam.

Global warming: An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is most often used to refer to the warming predicted to occur as a result of increased emissions of greenhouse gases. Scientists generally agree that the Earth's surface has warmed by about 1 degree Fahrenheit in the past 140 years. The Intergovernmental Panel on Climate Change (IPCC) recently concluded that increased concentrations of greenhouse gases are causing an increase in the Earth's surface temperature and that increased concentrations of sulfate aerosols have led to relative cooling in some regions, generally over and downwind of heavily industrialized areas.

Green certificates: Renewable energy certificates (RECs), also known as green certificates, green tags, or tradable renewable certificates, represent the environmental attributes of the power produced from renewable energy projects and are sold separate from commodity electricity. Customers can buy green certificates whether or not they have access to green power through their local utility or a competitive electricity marketer. And they can purchase green certificates without having to switch electricity suppliers. Currently, more than 30 organizations market green energy certificates at the wholesale or retail level nationally.

Grid: A network of power lines and substations. Both transmission and distribution networks are referred to as grids.

Hydropower: Kinetic energy of water converted into electricity in hydroelectric plants.

Joule: The International System unit of electrical, mechanical, and thermal energy which stands for a unit of electrical energy equal to the work done when a current of one ampere is passed through a resistance of one ohm for one second.

Kinetic energy: Energy available as a result of motion that varies directly in proportion to an object's mass and the square of its velocity.

Kyoto Protocol to the United Nations Framework Convention on Climate Change: An international agreement that introduces binding emissions reduction targets for countries that ratify the treaty, which entered into force in 2005. The United States has signed the Kyoto Protocol, but has not ratified it.

Nuclear power: Electricity generated by an electric power plant whose turbines are driven by steam produced by the heat from the fission of nuclear fuel in a reactor.

Photovoltaic array: An interconnected system of PV modules that function as a single electricity-producing unit. The modules are assembled as a discrete structure, with common support or mounting. In smaller systems, an array can consist of a single module.

Photovoltaic cells: The smallest semiconductor element within a PV module to perform the immediate conversion of light into electrical energy. Also called a solar cell.

Photovoltaic (PV) module: The smallest environmentally protected, essentially planar assembly of solar cells and ancillary parts, such as interconnections, terminals, and protective devices such as diodes intended to generate direct current power under unconcentrated sunlight. The structural (load carrying) member of a module can either be the top layer (superstrate) or the back layer (substrate).

Photovoltaic solar power: Solar energy derived from photovoltaic solar cells, which produce small flows of electricity when in contact with sunlight.

Solar energy: Solar radiation used for hot water production and electricity generation, collected through flat plate heat collectors, photovoltaic cells, or solar thermal-electric plants.

Solar thermal electric system: Solar energy conversion technologies that convert solar energy to electricity, by heating a working fluid to power a turbine that drives a generator. Examples of these systems include central receiver systems, parabolic dish, and solar trough.

Solar thermal heating system: Heating systems that are powered by radiation energy from the sun.

Tariff: A price or fee. For example, a transmission tariff is a fee charged for the use of a transmission grid.

Thermal: A term used to describe any generation plant that uses heat to produce electricity.

Tidal/ocean energy: Mechanical energy derived from ocean currents, tidal movement, or wave motion.

Transmission: The movement of electrical energy over high-voltage power lines. Typically, this involves the transportation of power from an electricity generation plant to a local distribution network of low-voltage power lines.

Watt: A unit of electrical power equaling the amount of power produced from the expense of one joule of energy in one second. Wattage is expressed as follows:

1,000 watts (W)	=	1 kilowatt (kW)
1,000 kilowatts (kW)	=	1 megawatt (MW)
1,000 megawatts (MW)	=	1 gigawatt (GW)
1,000 gigawatts (GW)	=	1 terawatt (TW)

Watt-hour: A measure of electricity consumption. One watt-hour (Wh) is equal to the steady expense of one watt of power over one hour. Electricity consumption is expressed as follows:

1,000 watt-hours (Wh)	=	1 kilowatt-hour (kWh)
1,000 kilowatt-hours (kWh)	=	1 megawatt-hour (MWh)
1,000 megawatt-hours (MWh)	=	1 gigawatt-hour (GWh)
1,000 gigawatt-hours (GWh)	=	1 terawatt-hour (TWh)

Wind energy: Kinetic energy of wind, collected through wind turbines for electricity generation.

Wind turbine: A wind turbine is a mechanical assembly that converts the energy of wind into electricity. The three key elements of any wind turbine are the rotor, (turbine blades and hub) the nacelle (which contains the rotor shaft, gearbox, generator and control and monitoring equipment) and the tower.

ACRONYMS AND CHEMICAL SYMBOLS

CHP	Combined heat and power
CO_2	Carbon dioxide
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EU	European Union
EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom
EU-25	EU-15 and Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia
EUFORES	European Forum for Renewable Energy Sources
GATS	General Agreement on Trade in Services
GW	Gigawatts
GWh	Gigawatt-hour
HS	Harmonized system
IEA	International Energy Agency
kW	Kilowatts
kWh	Kilowatt-hour
MFN	Most-favored-nation treatment
MW	Megawatts
MWh	Megawatts-hour
Mtoe	Million Tons Oil Equivalent
NO_x	Nitrogen oxides
OECD	Organization for Economic Cooperation and Development
PV	Photovoltaic
R&D	Research and development
SO_2	Sulfur dioxide
TJ (terajoule)	10^{12} joules
TW	Terawatts
TWh	Terawatt-hour
UN	United Nations
USITC	United States International Trade Commission
USTR	United States Trade Representative
WITS	World International Trade Statistics
WTO	World Trade Organization

CHAPTER 1
INTRODUCTION

Purpose

On July 12, 2004, the U.S. International Trade Commission (Commission or USITC), received a request from the United States Trade Representative (USTR) to conduct two investigations[1] and provide individual reports that examine discrete segments of the environmental and energy services industries. The first investigation, completed in April 2005, focused on air and noise pollution abatement services and equipment,[2] and this second investigation focuses on renewable energy services and equipment. As requested by USTR, this report provides an overview of U.S. and foreign markets for renewable energy services, focusing specifically on solar, wind, biomass, geothermal, and tidal or ocean energy (hereafter, ocean energy); corresponding trade and investment, including barriers; and where possible, existing regulatory practices that influence demand for renewable energy services and equipment.[3] The report provides information on both developed and developing country markets for renewable energy services, and includes examples from those countries with which the United States has established, or is negotiating, a free trade agreement.[4]

As requested, the report also includes information on trade and market conditions for those goods related to the subject energy services. Renewable energy services and goods are frequently economic complements, as specific types of renewable energy require specific types of equipment. For example, wind power generation requires the installation and use of wind generating sets, and solar power generation requires the use of solar panels.

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[1] As identified under section 332(g) of the Tariff Act of 1930.

[2] The findings of the previous investigation, *Air and Noise Pollution Abatement Services: An Examination of U.S. and Foreign Markets*, Pub. No. 3761, were provided to the USTR on April 1, 2005. The report is available on the Commission website, *http://www.usitc.gov*. For a copy of the request letter, see appendix A. For a copy of the Federal Register notice for this investigation, see appendix B.

[3] Such regulatory practices may include national and subnational environmental regulations, as well as multinational conventions or agreements on environmental issues that may have an effect on the renewable energy services market.

[4] Country markets examined in this report were selected based on several factors including, in many cases, overall size of renewable energy markets. For the purposes of this report, "developed" countries include those considered by the World Bank to be high-income economies. "Developing" countries include those considered by the World Bank to be low- and middle-income economies. World Bank website, found at *http://www.worldbank.org/data/countryclass/classgroups.htm,* retrieved June 7, 2005. Developed countries highlighted throughout this report include Australia, Canada, Denmark, Germany, Italy, Japan, the Republic of Korea, Spain, and the United States. Developing countries highlighted throughout this report include Brazil, Chile, China, Costa Rica, India, Mexico, and Thailand. Discussion of additional developed and developing countries may be included in chapters 4-8, as appropriate. Of the countries highlighted in this report, the United States has concluded FTA negotiations with Australia, Canada, Chile, Costa Rica, and Mexico, and is currently in the process of negotiating an FTA with Thailand.

Scope

For this study, renewable energy derives from five sources.[5] *Solar* energy comprises solar radiation used for hot water production and electricity generation, collected through flat plate heat collectors, photovoltaic cells, or solar thermal-electric plants. *Wind* power collects the kinetic energy of wind through wind turbines for electricity generation *Geothermal* energy uses heat from the earth's crust, usually in the form of hot water and steam, to generate electricity or to be used as a heating source. *Ocean* energy generates electricity by capturing the mechanical energy derived from ocean currents, tidal movement, or wave motion. Finally, a wide variety of *biomass* fuels, including charcoal, wood, and municipal wastes, can also be used to generate heat and electricity by incineration. For this report, biomass means any plant-derived organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal wastes, and other waste materials.[6] In his request letter, the USTR specified the renewable energy services industries to be examined in this report. Other studies may be based upon different, but equally valid, definitions of renewable energy services.[7]

Renewable Energy Services

For the purpose of this report, renewable energy services include the generation, transmission, distribution, and sale of heat and electricity produced through the use of wind, solar, biomass, geothermal, or ocean energy. Related services include geological analysis, resource assessment, and other services incidental to the evaluation, planning, or siting of a renewable energy project or facility; design, construction, and installation services for renewable energy equipment and facilities; the operation, management, and monitoring of renewable energy projects or facilities; decommissioning services; services incidental to the issuance of renewable energy certificates; research and development (R&D) services related to renewable energy; and other services incidental to the development and use of renewable power sources.

Nations trade services, including renewable energy services, through two principal channels. The first channel, cross-border trade, entails sending individuals, information, or money across national borders.[8] The second channel, affiliate transactions, entails selling services through affiliated firms established or acquired by multinational companies in foreign markets.[9] Such affiliates are funded through foreign direct investment.

[5] The definitions for solar, wind, geothermal, and ocean energy used in the report are based on definitions found in International Energy Agency (IEA), *Renewable Energy: Market and Policy Trends in IEA Countries* (Paris: IEA/OECD, 2004), pp. 100-101.

[6] U.S. Department of Energy, Energy Efficiency and Renewable Energy website, found at *http://www.eere.energy.gov/RE/biomass.html,* retrieved May 12, 2005.

[7] The USTR did not request information on hydropower energy or biofuels and, consequently, these market segments are not addressed in this report.

[8] Employing terminology found in the General Agreement on Trade in Services (GATS), this channel encompasses modes of supply one (cross-border supply), two (consumption abroad), and four (movement of natural persons).

[9] Employing terminology found in the GATS, this channel encompasses mode of supply three (commercial presence).

Energy services, including renewable energy services, do not occupy a separate section of the World Trade Organization's (WTO) Services Sectoral Classification List (W/120), which is used by most signatories to the General Agreement on Trade in Services (GATS) to organize and define the scope of specific commitments in their national schedules.[10] As a way to apply the GATS agreement to energy services, and to other services that are not separately delineated in the W/120, WTO members have devised a "checklist" approach to making GATS commitments. Under this approach, members create a list that identifies those services listed in the W/120 considered relevant to the subject sector, and which together are agreed to represent the scope of that sector for scheduling purposes.[11] The checklist approach facilitates the scheduling of commitments without requiring significant changes to the W/120, assists WTO members in developing a common agreement about the full range of applicable services, and serves as a mechanism to assess the value of market access and national treatment offers.[12]

In its 2003 GATS offer, the United States proposed such a checklist as a way for GATS members to make commitments in energy services.[13] In the energy services checklist, the services listed in table 1-1, when grouped together, were deemed to constitute the scope of energy services. Commitments on energy services apply to renewable energy services, as long as they are not specifically exempted from a country's commitments. Details regarding specific country commitments on energy services included in the checklist are presented in appendix C.

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[10] The terms and conditions under which WTO signatories accord market access and national treatment to foreign firms are provided within each country's schedule of specific commitments. Under the GATS, countries are required to accord such treatment to foreign firms only for industries which are included in their GATS schedules. WTO, MTN.GNS/W/120, July 10, 1991.

[11] In addition to energy services, the checklist approach has been applied to WTO negotiations in express delivery and logistic services. For additional discussion of the checklist approach, see the following USITC publications: *Express Delivery Services: Competitive Conditions Facing U.S.-based Firms in Foreign Markets*, Publication No. 3678, Apr. 2004, and *Logistic Services: Competitive Conditions Facing U.S.-based Firms in Foreign Markets*, Publication No. 3770, May 2005.

[12] See OECD, "Assessing Barriers to Trade in Services, Using 'Cluster' Approaches to Specific Commitments for Interdependent Services," Working Party of the Trade Committee, Doc. No. TD/TC/WP(2000)9/FINAL, Nov. 7, 2000.

[13] WTO, "Council for Trade in Services - Special Session - Communication from the United States - Initial Offer," TN/S/O/USA, Sept. 4, 2003.

Table 1-1
Checklist of energy-related services included in the U.S. GATS offer, 2003

Central product classification code	Description
5115, 883	Services incidental to mining
8675	Certain related scientific and technical consulting services
887	Services incidental to energy distribution
861, 862, 863, 8672, 8673, 9312, 93191, 932	Certain professional services, including engineering and integrated engineering services
6111, 6113, 6121, 621, 622, 631, 632	Distribution services, including commission agents, wholesale trade, and retail trade services that apply to fuels, related products, and brokerage of electricity
633, 8861-8866	Maintenance and repair of equipment, except transport-related equipment
865	Management consulting and related services
511-518	Construction and related engineering services
7131	Pipeline transportation of fuels
7422	Storage and warehouse services, particularly bulk storage services of liquids and gases
8676	Technical testing and analysis services

Source: WTO, "Council for Trade in Services - Special Session - Communication from the United States - Initial Offer," TN/S/O/USA, Sept. 4, 2003.

Aside from specific market access and national treatment commitments, there are several general obligations that apply to virtually all service sectors,[14] and can aid in promoting trade in services, even when the services are not identified in a country's schedule of specific commitments (table 1-2). The GATS framework principles that apply to nearly all services sectors comprise, for example, most favored nation treatment, contained in Article II, and transparency, contained in Article III. In addition, where commitments have been scheduled, the framework contains disciplines on domestic regulation in Article VI, and limits on the actions of monopolies and exclusive suppliers in Article VIII.[15]

Renewable Energy Goods

Though this report principally focuses on renewable energy services, two types of goods are essential to the provision of such services. The first type are specific to the provision of renewable energy services and they have no other application. Among these are wind

[14] The exception is air transport services, which were largely excluded from the GATS, and services supplied in the exercise of government authority, such as postal services.
[15] WTO, General Agreement on Trade in Services.

Table 1-2
General obligations of the GATS

Nondiscrimination	Article II provides for most-favored-nation treatment (MFN), through which WTO members commit to accord treatment to services and service suppliers of any other member treatment no less favorable than that accorded to like services and service suppliers of any other country. Members must adhere to MFN principles except in those areas in which they have listed exemptions.
Transparency	GATS transparency obligations are listed in Article III, which requires: • prompt publication of relevant measures of general application; • notification to the WTO of significant changes in laws, regulations, or administrative guidelines with significant bearing on services trade; • establishment of enquiry points for use by other WTO members; and • prompt responses to information requests from other WTO members.
Domestic[1] Regulation	GATS domestic regulation obligations, as contained in Article VI, require WTO members to: • avoid using regulatory powers in such a way as to create services trade barriers; • ensure that measures of general application are administered in a reasonable, objective, and impartial manner; and • for sectors in which specific commitments are undertaken regarding market access or national treatment, ensure that licensing and qualification requirements or technical standards (1) are based on objective and transparent criteria, (2) are not more burdensome than necessary, and (3) in the case of licensing procedures, are not in themselves a restriction on the supply of the service.
Monopolies and Exclusive Suppliers[1]	Article VIII of the GATS states that WTO members should ensure that, in cases where a monopoly supplier competes in supplying a service outside the scope of its monopoly rights, it does not abuse its monopoly position in a manner that limits market access or national treatment.

[1] Note: Articles VI and VIII apply only to industries for which countries have made specific commitments.

Source: World Trade Organization, *General Agreement on Trade in Services.*

generating sets (found in Harmonized Schedule (HS) subheading 8502.31), photovoltaic cells (found in HS subheading 8541.40), and solar water heating systems (found in HS subheading 8419.19). The other types of goods are dual use goods, so called because they have both renewable energy and non-renewable energy applications, or they have additional applications altogether outside the energy sector.[16]

A composite list of renewable energy goods is presented in table 1-3. The goods appear side-by-side with their applicable 6-digit harmonized system (HS) subheadings. It should be noted that goods outside the scope of this study are found under the same HS numbers as dedicated and dual use renewable energy goods. Light emitting diodes (LEDs), for example, are found under the same HS number as photovoltaic cells, and anemometers, used for measuring wind force and velocity, are found alongside various other instruments and apparatus under the same HS number. One consequence of this is that trade data referenced in this report by HS subheading, using the World

[16] For further discussion of dual use goods, see OECD, "Liberalization of Trade in Renewable Energy and Associated Technologies," Joint Working Party on Trade and Environment, Doc. No. COM/ENV/TD(2005)23, May 26, 2005.

Table 1-3
Environmental goods

HTS no.	HTS 6 digit description	Renewable energy application
7308.20	Towers and lattice masts	For wind turbines
8402.11	Watertube boilers exceeding 45 tons of steam per hour	For biomass plants
8402.12	Watertube boilers not exceeding 45 tons of steam per hour	For biomass plants
8402.19	Other vapor generating boilers, incl. hybrid boilers	For biomass plants
8402.20	Super-heated water boilers	For biomass plants
8402.90	Parts of steam or other vapor generating boilers (including heat exchangers)	For biomass, geothermal, or solar concentrator systems
8404.10	Auxiliary plant for use with boilers of heading No. 8402 or 8403 (for example, economizers, super-heaters, soot removers, gas recoverers)	For biomass, geothermal, or solar concentrator systems
8404.20	Condensers for steam or other vapor power units	For biomass, geothermal, or solar concentrator systems
8404.90	Parts of auxiliary plant for use with boilers	For biomass, geothermal, or solar concentrator systems
8406.81	Steam turbines over 40 MW	For geothermal or biomass plants
8406.82	Steam turbines and other vapour turbines of an output not exceeding 40 MW	For geothermal or biomass plants
8406.90	Parts of steam turbines	For geothermal or biomass plants
8411.81	Other gas turbines, not exceeding 5,000 kW	For biomass plants
8411.82	Other gas turbines exceeding 5,000 kW	For biomass plants
8411.91	Parts of other gas turbines	For biomass plants
8413.50	Other reciprocating positive displacement pumps	Circulating pumps for geothermal, biomass, passive solar, and ocean energy plants
8413.60	Pumps for liquids, whether or not fitted with a measuring device; other rotary positive displacement pumps	For geothermal and thermal solar
8419.19	Other instantaneous or storage water heaters, non-electric	Solar water heaters
8419.40	Distilling or rectifying plant	For alcohol distillation from biomass
8419.50	Heat exchange units	For geothermal, biomass, solar, and ocean energy plants
8483.40	Gears and gearing, other than tooth	For wind turbines

Table 1-3—*Continued*
Environmental goods

HTS no.	HS 6 digit description	Renewable energy application
8483.60	Clutches and universal joints	For wind turbines
8501.61	AC generators not exceeding 75 kVA	For all electricity generating renewable energy plants
8501.62	AC generators exceeding 75 kVA but not 375 kVA	For all electricity generating renewable energy plants
8501.63	AC generators exceeding 375 kVA but not 750 kVA	For all electricity generating renewable energy plants
8501.64	AC generators exceeding 750 kVA	For all electricity generating renewable energy plants
8502.31	Generating sets, electric, wind-powered	For wind energy plants
8502.39	Other generating sets	Gas turbine sets for biomass plants
8503.00	Parts for equipment classified under 8501 and 8502	Parts of gas and wind powered turbines
8504.40	Other static converters	Inverters for photovoltaic solar equipment
8541.40	Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes	Solar cells
9001.90	Mirrors of other than glass	For solar concentrator systems
9002.90	Mirrors of glass	For solar concentrator systems
9026.80	Heat meters incorporating liquid supply meters, and anemometers	Wind speed (anemometers) indicators for wind turbines

Source: Compiled by Commission staff.

International Trade Statistics (WITS) database, reflect trade patterns in multiple goods, not only the subject renewable energy and dual use goods. Trade balances and trends suggested by these data may therefore be somewhat misleading. There is no sound method for separating trade data for items classified under the same HS number.

Approach

To gather information for this report, the Commission elicited the views of interested parties through a public hearing on April 19, 2005 (see appendices D and E);[17]

[17] Hearing participants included Richard Sellers, International Energy Agency; Alexander Karsner, Enercorp, LLC; Richard E. Morgan, District of Columbia Public Service Commission; Scott Miller, III, PJM Interconnection, LLC; Leslie Parker, Renewable Energy and International Law Project; George Sterzinger, Renewable Energy Policy Project; Peter W. Ullman, Tidal Electric Limited; and Christopher O'Brien, Sharp Solar.

conducted in-person and telephone interviews with knowledgeable sources; and consulted a wide range of secondary sources in search of both quantitative and qualitative information. During the course of the study, staff conducted interviews with representatives of renewable energy service providers and goods suppliers, government officials, industry and trade associations, educational facilities, non-governmental organizations, and international organizations in numerous locations. Fieldwork was conducted in several U.S. cities, and in Belgium, Brazil, Chile, Costa Rica, Germany, Italy, Japan, Korea, Poland, Spain, Thailand, and the United Kingdom. The Commission interviewed representatives of large, multinational firms, smaller firms, and U.S. and foreign government agencies. In total, 159 interviews were conducted. Secondary sources consulted by Commission staff included industry journals and websites, U.S. and foreign government publications, and other publications available from international organizations such as the World Bank, the WTO, the OECD, and the European Bank for Reconstruction and Development (EBRD).

The Commission also reviewed and incorporated, as appropriate, data from the International Energy Agency (IEA) and the Energy Information Administration (EIA) of the U.S. Department of Energy. Data on total electricity production and electricity production from renewable energy, based on annual questionnaires completed by national statistical agencies, were obtained from IEA. IEA data on renewable energy are the most comprehensive data available, but there are significant information gaps. Statistical agencies have less experience compiling data regarding newer forms of renewable energy, such as wind and solar power, compared to older technologies, particularly geothermal. Data reflecting off-grid renewable energy facilities generally are not included in the IEA statistics, resulting in underestimates of the totals for wind, solar, and biomass power. In addition, the IEA questionnaires sent to national statistical agencies were revised in 2000, markedly improving the statistics beginning in the 1998 data year, but making comparisons to previous data difficult.[18] IEA does not collect data on renewable energy from ocean sources.

Data on total installed electricity generation capacity and electricity production from renewable energy were obtained from EIA, which collects the data from individual country statistical agencies, international organizations, and non-governmental organizations.[19] EIA data are released on both an annual and a monthly basis, and include capacity of both utility and non-utility electricity producers.[20]

Additional data were obtained from the McIlvaine Company[21] and country-specific sources. McIlvaine data reflect both the global and country-specific wind, solar, and biomass energy markets for 1994-2008. Data include electric power generation, based on megawatts (MW) of installed capacity; capital investment, reflecting equipment costs associated with developing renewable energy capacity; estimated revenues, based on

[18] IEA, *Renewable Energy: Market and Policy Trends in IEA Countries,* Annex 2: Renewable Energy Statistics – Definitions and Issues, pp. 99-103.

[19] For further detail, see "International Energy Annual 2002: Electricity Data Sources," found at *http://www.eia.doe.gov/emeu/iea/6source.html,* retrieved June 14, 2005.

[20] USDOE, EIA, "International Energy Annual 2002: Notes and Sources for Table 6.4," found at *http://www.eia.doe.gov/emeu/iea/Notes%20for%20Table%206_4.html,* retrieved June 14, 2004.

[21] The Commission specifically contracted for the data supplied by the McIlvaine Company.

capital investment, and taking into account energy prices plus incentives provided to renewable energy suppliers; and estimated export and import data, also based on capital investment data. Data for capital investment, exports, and imports are available for both goods and services. McIlvaine compiles U.S. and foreign data by interviewing industry sources, and by tracking orders for renewable energy products.

Organization

This chapter presents the background and scope of the report. Chapter 2 provides a review of literature pertaining to renewable energy services and related goods. Chapter 3 presents an overview of the global market and examines factors that affect supply and demand for renewable energy services in the global marketplace. Chapters 4 through 8 present a more focused discussion of markets for wind, solar, biomass, geothermal, and ocean energy, respectively. These chapters largely follow a similar format, beginning with principal findings, followed by technologies and methods used to provide renewable energy in each segment, an overview of the services and related goods markets, and the trade and investment in each area. The report concludes with a summary of current trends within the global market for renewable energy services, including a discussion of overall trade and investment trends. This conclusion is followed by seven appendices. Appendix A reproduces the letter from the USTR requesting this study and appendix B reproduces the Federal Register notice that announced institution of this investigation. Appendix C provides information on GATS commitments related to renewable energy services. Appendices D and E present the hearing schedule and the views of interested parties, respectively. Appendix F lists selected renewable energy policies or programs, by selected countries, covered in this report. The final appendix G discusses the role of project-based mechanisms.

CHAPTER 2
LITERATURE REVIEW

Introduction

While there is vast literature on the technological dimensions of renewable energy, this chapter briefly summarizes some of the recent work on economic literature pertaining to this area. For the most part, economists have not analyzed renewable energy services separately from goods, but rather have focused on systems comprised of both goods and services. This research examines (1) determinants of growth in the use of renewable technologies; (2) variations in growth trends between countries; (3) responsiveness of demand for renewable technologies to economic incentives; and (4) the effect of various government policy interventions on the renewable energy sector. Whether occurring through market forces or through government interventions, the literature indicates that costs are an important determinant in the progress, or lack of progress, toward increased adoption of renewable energy. Chapter 3 of this report provides more detail both on market influences on renewable energy products, services, and systems and on the role of government policies in specific countries.

Different authors often classify different groups of technologies as renewable energy technologies. For example, Martinot et al. state that "[r]enewable energy commonly refers to both traditional biomass (i.e., fuelwood, animal wastes, and crop residues burned in stoves) and modern technologies based on solar, wind, biomass, geothermal, and small hydropower."[1] They focus on the latter, which they refer to as "new renewables," and also exclude large hydropower projects.[2] They note that while traditional biomass provides about 7 to 11 percent of global energy supply, the modern forms of renewable energy provide only about 2 percent, though such figures may be considerably higher in some developing economies.

Renewable Energy in Developing Countries

Martinot points out that the World Bank provided sizable funding for renewable energy development through the 1990s, with total Bank loans and credits of $700 million, and more proposed projects - at the time of writing - under consideration at the Bank.[3] Major recipient countries were China for photovoltaic home systems; India for photovoltaic home systems, as well as wind applications; and the Philippines for geothermal energy. Martinot finds that developing countries are often reluctant to

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[1] Eric Martinot, Akanksha Chaurey, Debra Lew, Jose Roberto Moreira, and Njeri Wamukonya, "Renewable Energy Markets in Developing Countries," *Annual Review of Energy and the Environment,* Vol. 27, Nov. 2002, p. 310.

[2] The definition of renewable energy services employed in this study excludes all hydropower facilities, as noted in the USTR's request. See appendix A.

[3] Eric Martinot, "Renewable Energy Investment by the World Bank," *Energy Policy*, Vol. 29, 2001.

borrow from the World Bank for renewable energy projects, while internal barriers within the Bank to promoting renewable energy projects have also limited lending.

Examples of internal World Bank factors limiting such lending include: (1) the complexity of renewable energy projects, implying long preparation time relative to conventional energy projects of the same dollar amount; (2) concern over nontraditional project risks such as new institutional development and concern with technology acceptance; (3) lack of appropriate skills by project managers; and (4) the initial perception that renewable energy is strictly an energy issue rather than a development issue. Despite these barriers, World Bank lending for renewable energy has been growing, with Martinot noting that "the role of renewables within the Bank [has] started to become less driven by an energy-sector agenda and more driven by a rural-development agenda."[4]

Martinot et al. discuss growth in developing country utilization of renewable energy, and in particular the development of markets in rural areas for electricity provided by solar home systems, biogas, and small wind turbines. On the developing country side, Martinot finds that insufficient understanding of renewable energy technologies, risk avoidance, entrenched political interests, or corruption often bias policy makers toward conventional energy sources. They point to China and Kenya as having the strongest growth in solar home systems, registering 10 to 20 percent growth annually in recent years. While aid programs and incentives from industrialized countries and multilateral organizations were the initial impetus to installation of a variety of renewable energy technologies, the authors stress the increasing role of commercial markets and private firms.[5]

Renewable Energy in Developed Countries

Turning to developed economies, Joskow finds only modest movements in the United States during the 1990s toward renewable energy sources, with only wind energy supplies growing substantially, though from a very low base.[6] McVeigh et al. examine the factors behind the limited growth of many renewable energy technologies in the United States, finding that this has been due more to greater-than-expected cost reductions for conventional energy sources than to the failure of renewables to meet their own projected cost patterns.[7] They do find, however, that wind and biomass applications have exceeded earlier U.S. market penetration expectations.[8]

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[4] Ibid., p. 691.

[5] Martinot, Chaurey, Lew, Moreira, and Wamukonya, "Renewable Energy Markets in Developing countries," p. 310.

[6] Paul L, Joskow. "U.S. Energy Policy During the 1990s," National Bureau of Economic Research Working Paper 8454, 2001.

[7] James McVeigh, Dallas Burtraw, Joel Darmstadter, and Karen Palmer, "Winner, Loser, or Innocent Victim? Has Renewable Energy Performed As Expected?" Resources for the Future Discussion Paper 99-28, June 1999.

[8] The post-hearing submission of the National Association of Regulatory Utility Commissioners discusses various state-level incentive programs in the United States which serve to promote renewable energy. These include tax incentives, grant programs, "renewable portfolio standards" which specify a minimum renewable energy content in retail electricity sales, and facilitation of interconnection of renewable sources to the electric power grid.

A recent International Energy Agency (IEA) report examines the pattern of penetration of renewables in developed economy energy markets.[9] Overall, for 2001 - taking the broad definition of renewable energy[10] - their market share in total primary energy supply for IEA countries was 5.5 percent, increasing slowly from 4.6 percent in 1970. Of this, almost all was what might be called traditional renewables - combustible renewables and waste, and hydropower - representing 5 percent of the total primary energy supply, or more than 90 percent of all renewable energy in developed economies.

The IEA study further examines country policies towards technological innovation and market deployment of renewable energy services, as well as the market frameworks in which they compete with traditional sources of energy. Not surprisingly, patterns of renewables research and development (R&D) investment by country, much of which is government funded, tend to follow resource endowments. This suggests that price and cost considerations matter in the choice of energy - both within the category of renewables, and between renewables and traditional sources. For example, countries such as Turkey and New Zealand, with substantial geothermal resources, devoted the bulk of their renewable energy R&D funds in that direction, while Denmark and the United Kingdom, with great potential for wind energy, devoted between one-third and one-half of their renewable energy R&D budgets to developing wind projects.

Private sector R&D in renewable energy reportedly is generally focused on solar photovoltaic and wind technology. Its relative importance compared to public funding varies by country. Private spending in Denmark was five times higher than public spending in 1998. In contrast, Austrian private sector spending was only about one-third of public sector spending during 1993-98, and Spanish private spending was about one-tenth of government efforts during 1995-2004.

The Cost of Renewable Energy Equipment

Isoard and Soria examine evidence on the patterns of cost reductions for renewable energy equipment manufacturers, focusing on the relative contributions of economies of scale, or cost reductions related to the rate of output within a given time period, and cost reductions related to the cumulative production volume.[11] They analyze manufacturers' annual cost and installed capacity data on solar photovoltaic and wind power, technologies for which capital costs represent on average 90 percent of the cost of electricity produced. Isoard and Soria conclude that the primary force driving cost reductions is cumulative production, though scale effects are also present.

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[9] International Energy Agency (IEA), *Renewable Energy: Market and Policy Trends in IEA Countries* (Paris: IEA/OECD, 2004).

[10] This broad definition of renewable energy includes hydro and geothermal power, combustible renewables and waste (most of which is often referred to as 'biomass"), solar radiation exploited for hot water production and electricity generation (though not passive solar energy for direct heating or lighting of buildings), ocean/tidal (mechanical) energy exploited for electricity generation, and wind power for electricity generation (though not kinetic wind energy used for applications such as water pumps).

[11] Stephane Isoard and Antonio Soria, "Technical Change Dynamics: Evidence from the Emerging Renewable Energy Technologies," *Energy Economics*, Vol. 23 (6), Nov. 2001.

The previously discussed IEA report notes that the equipment cost of solar photovoltaic installations in new buildings has fallen by about 75 percent over the past two decades while the quantity of photovoltaic module shipments has increased 20 times over that period. Whether the correlation observed between cost and shipments is an example of how market acceptance and development of renewables responds to price and cost signals, or how government programs can reduce costs by stimulating demand, the result for the United States was that the installed capacity of photovoltaic energy increased by roughly 20 percent per year during 1990-2001.

External Costs of Fossil Fuel Energy

The issue of price incentives for adoption of renewables is closely tied to the question of whether external costs of conventional energy generation are considered. Owen presents estimates of these external costs, along with discussion of the impact that internalization of these costs would have on electricity prices for the major technologies.[12] Estimates of these external costs for electricity production in the European Union range from about 0.1-0.3 cents per kilowatt-hour for wind power to between 3 and 19 cents per kilowatt-hour for coal and oil (table 2-1). Owen indicates a preference for such "full-cost" pricing approaches over subsidies for renewables. While either would make newer technologies more cost competitive relative to traditional fossil fuel technologies, the full pricing approach has the advantage of encouraging increased efficiency in the use of existing technology, with the result being reduced emissions.[13]

Similarly, Finon and Menanteau discuss the two static disadvantages faced by renewables in competing with fossil fuels in the electricity market: the lack of internalization of external costs of the latter and the inability to observe in the current period the costs of the former if allowed to expand sufficiently to realize economies of scale and/or learning curve savings.[14] They discuss, from a theoretical perspective, the relative benefits and costs of differing policy mechanisms for promoting the use of renewables.[15] Based on the European experience, they find that "feed-in tariffs" –

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[12] Anthony D. Owen, "Environmental Externalities, Market Distortions and the Economics of Renewable Energy Technologies," *The Energy Journal*, Vol. 25 (3), 2004. Owen breaks these external costs into two types: "costs of the damage caused to health and the environment by emissions of pollutants other than those associated with climate change;" and "costs resulting from the impact of climate change attributable to emissions of greenhouse gases" (p. 142).

[13] Owen does note, however, that it is important to analyze full costs of both renewables and non-renewables from a "life-cycle" perspective that includes environmental external costs associated with production of equipment used in both renewable and non-renewable applications (or in the case of fuel cells, the environmental costs if the requisite hydrogen is produced from fossil fuels).

[14] Dominique Finon and Philippe Menanteau, "The Static and Dynamic Efficiency of Instruments of Promotion of Renewables," *Energy Studies Review*, Vol. 12 (1), Fall 2004.

[15] Not discussed by Finon and Menanteau, but detailed in a post-hearing brief provided by General Electric are examples of how some foreign government incentive and development assistance programs in support of renewables can disadvantage U.S. providers of related equipment and services. General Electric Company, written submission to the Commission, May 5, 2005, p. 6.

Table 2-1
External and direct costs for electricity production in the European Union

Country	Coal & lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	Solar PV	Wind
	U.S. cents/kWh								
External cost:									
Austria	—	—	—	1-3	—	3	0.1	—	—
Belgium	5-19	—	—	1-3	0.6	—	—	—	—
Germany	4-7	—	6-10	2-3	0.6-1	4	—	0.2-0.4	0.1
Denmark	4-8	—	—	2-4	—	2	—	—	0.2
Spain	6-10	—	—	1-3	—	4-7	—	—	0.2
Finland	3-6	3-6	—	—	—	1	—	—	—
France	9-12	—	11-14	3-4	0.3	1	1	—	—
Greece	6-11	—	3-6	1-2	—	0.13-1	1	—	0.3
Ireland	7-11	4-5	—	—	—	—	—	—	—
Italy	—	—	4-7	2-3	—	—	0.4	—	—
Netherlands	4-5	—	—	1-2	1	0.5	—	—	—
Norway	—	—	—	1-2	—	0.3	0.3	—	0.1-0.3
Portugal	5-8	—	—	1-3	—	2-2.3	0.04	—	—
Sweden	2-5	—	—	—	—	0.4	0-0.9	—	—
United Kingdom	5-8	—	4-6	1-3	0.3	1	1.3	—	0.2
EU range	2-19	3-6	3-14	1-4	0.3-1	0.13-7	0-1.3	0.2-0.4	0.1-0.3
Direct cost	4-6	—	6-7	3-4	4-7	4-5	—	64-107	8-9

Source: Adapted from the European Commission (2003) as presented in Owen (2004, p. 147).

above-average wholesale electricity prices paid by electric utilities to renewable energy producers – will effectively promote technical progress in this area. Renewable energy quotas combined with tradeable "green" certificates have some advantages for efficiency, but their impact on the diffusion of technical innovation is less clear.

Diffusion of Renewable Energy Technologies

Jacobsson and Bergek analyze the diffusion of renewable technologies in Germany, Sweden, and the Netherlands, identifying the challenges faced by policy makers attempting to influence this process.[16] As noted by others, they identify the difficulty of inducing competition to traditional fossil fuels, which have associated external costs not internalized in pricing. As an example, they refer to a European Commission study suggesting the full cost of coal or oil based electricity would be roughly double the

[16] Staffan Jacobsson and Anna Bergek, "Transforming the Energy Sector: The Evolution of Technological Systems in Renewable Energy Technology," *Industrial & Corporate Change*, Vol. 13 (5), Oct. 2004.

current level. Jacobsson and Bergek point out that government policy can both induce and stunt technological innovation, and that the most successful policies have promoted the legitimacy of renewables in the eyes of users and investors and have encouraged markets for these technologies.

What they call the "promotion of legitimacy" can be viewed as establishing institutions (e.g., zoning regulations and building codes that allow or encourage the use of solar collectors or wind turbines), providing information on potential benefits and costs of renewables to relevant decision-makers, and aiding policy coordination among local and central governments. In a sense, Jacobsson and Bergek are implying that an appropriate policy framework needs to be in place before the more traditional economic policy approaches suggested by Finon and Menanteau (e.g., feed-in tariffs) can be effective.

The Choice of Renewable Energy Technology

While the choice among renewable energy technologies is influenced by local climate and availability of natural resources, a dynamic perspective focuses on differing potential among them for technological and cost efficiencies. Macauley et al. perform simulations of the expected consumer welfare gains over the 2000 to 2020 period from innovation in each of five renewable electricity technologies relative to continual improvement in conventional technology, relying on DOE and IEA generation demand forecasts.[17] Basing their estimates on two regions of the United States, California and the North Central States, their simulations favor wind and geothermal investment over the other renewable technologies, though they emphasize that uncertainties about future costs, demand growth, and externalities limit the strength of their conclusions. Solar photovoltaic energy fares particularly poorly, with negative benefits relative to the conventional, non-renewable technology. This result suggests that perhaps market forces alone have not been responsible for the rapid growth in photovoltaic capacity indicated earlier in the IEA report.

The renewable/non-renewable choice also seems dependent both on explicit incentives to develop renewable energy and the implicit incentive to continue using non-renewable energy when external costs are not internalized. Tahvonen and Salo develop a model consistent with the historical observation of a U-shaped relationship between development and the prominence of renewables.[18] Under this model, resource constraints and small market size initially lead to use of biomass and hydropower, while as development increases, growth in energy demand leads to greater use of non-renewable sources. Later, when the highest levels of development are achieved, countries increase the use of various renewable technologies. The model suggests increased movement towards renewables, at both very low and very high stages of development, even in the absence of government policy.

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[17] Molly K. Macauley, Jhih-Shyang Shih, Emily Aronow, David Austin, Tom Bath, and Joel Darmstadter; "Measuring the Contribution to the Economy of Investments in Renewable Energy: Estimates of Future Consumer Gains," Resources for the Future Discussion Paper 02-05, Feb. 2002. The five renewable energy technologies are solar photovoltaic, solar thermal, geothermal, wind, and biomass. The conventional technology chosen is a combined-cycle gas turbine.

[18] Olli Tahvonen and Seppo Salo, "Economic Growth and Transitions between Renewable and Non-renewable Energy Resources," *European Economic Review*, Vol. 45 (8), Aug. 2001.

However, government policy will continue to influence market deployment of renewables, just as policy has influenced the use of non-renewable sources of energy. The IEA study presents a listing of the various types of market deployment policies that are available to governments to encourage demand and supply of renewables, both in terms of building capacity and utilizing that capacity to generate energy. For the most part, IEA countries established government-funded R&D for renewable technologies and demonstration projects by the mid-1970s, and moved to greater use of tax-based incentives for investment or use of capacity and guaranteed prices through the 1980s to the present (see chapter 3). These were supplemented in the 1990s by both voluntary and binding targets for renewables, and most recently – in what can be viewed as a more market-based approach to obligations – a movement toward the use of tradeable certificates promoting greater flexibility in the use of renewables.

It is ultimately the cost of renewables versus non-renewables – as perceived by market participants – that will drive market acceptance and the share of energy provided by renewable sources. Government policy can be viewed as presenting to market players, on both the supply and demand sides of the energy market, the true costs of their choices and providing the institutional framework within which they can interact.

CHAPTER 3
MARKET OVERVIEW

Introduction

This chapter begins with an overview of the global market for renewable energy power focusing on the size and growth of renewable energy markets in developed and developing countries. The chapter then examines the effect of deployment policies on market participants, and how policies directed at one participant reverberate throughout the entire supply chain. The chapter also looks at other policies, mostly at the national level, and their effects on the renewable energy market or the energy sector more broadly.

Global Market

Global electricity production from renewable energy sources measured 292.2 thousand gigawatt hours (GWh) in 2002, slightly less than 2 percent of total world electricity production, with total installed renewable energy capacity of 55.5 million kilowatts (table 3-1). Renewables-based electricity production in the United States and the European Union was approximately equal, with 92.6 thousand GWh and 94.5 thousand GWh, respectively, in 2002. However, renewables accounted for 3.7 percent of total electricity production in the EU, compared with 2.4 percent in the United States. Germany, Italy, and Spain together accounted for 52.8 percent of total EU electricity production from renewables. Denmark reports a particularly high rate of renewables-based electricity production, at 19.2 percent of total electricity production. Non-OECD countries as a group recorded 55.4 thousand GWh of electricity production from renewable energy in 2002. Among these countries, Costa Rica reports the highest rate of renewables-based electricity production, at 18.9 percent of total electricity production. Worldwide, biomass accounts for the largest share of non-hydroelectric renewable energy production, although wind power is the largest segment of the global non-hydoelectric renewable energy industry in terms of installed capacity. The United States led the world in power generation from geothermal, solar, and biomass resources in 2002 (table 3-2), while Germany was the world leader in the wind, tidal, and other renewable resources segment.[1] However, more recent data indicate that Japan has become the world's largest market for solar power generation.[2]

Worldwide electricity production from renewable energy sources increased by 7.4 percent per annum during 1995-2002 (table 3-3). The combined market for electricty production from solar, wind, tide, and other renewable sources grew at a particularly rapid rate, increasing by 27.2 percent per annum during 1995-2002. This rapid growth was likely due to technological developments which led to decreasing production costs,

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[1] International Energy Agency (IEA), *Energy Statistics of OECD Countries, 2001-2002* (Paris: OECD, 2004); various tables.

[2] For more information, see chapter 5.

Table 3-1
Renewable net electricity production and installed capacity, selected countries, 2002

Country	Total electricity production[1]	Electricity production from renewable sources	Renewables' share of production	Total installed capacity	Installed renewable energy capacity	Renewables' share of installed capacity
	Thousand Gigawatt hours		*Percent*	*Gigawatts*		*Percent*
European Union (15)[2]	2,523.0	94.5	3.7	561.0	23.8	4.2
United States	3,867.2	92.6	2.4	884.9	17.4	2.0
Japan	1,036.2	27.9	2.7	237.0	0.7	0.3
Germany	548.6	27.5	5.0	115.6	10.9	9.4
Spain	230.1	12.6	5.5	50.6	4.0	7.9
Brazil	340.1	14.6	4.3	76.2	3.5	4.6
Italy	261.1	9.8	3.8	69.1	2.0	2.9
Canada	582.2	8.5	1.5	112.5	1.4	1.2
Denmark	36.4	7.0	19.2	12.8	2.7	21.1
United Kingdom	360.1	6.3	1.7	77.0	1.3	1.7
Mexico	203.7	5.6	2.7	43.5	0.9	2.1
Netherlands	91.1	5.0	5.5	20.4	0.5	2.5
India	563.5	4.1	0.7	122.1	1.5	1.2
Australia	209.6	2.7	1.3	45.3	1.2	2.6
China	1,570.4	2.3	0.1	338.2	([3])	0.0
Thailand	102.9	1.9	1.8	20.9	([3])	0.0
Chile	43.9	1.6	3.6	10.3	([3])	0.0
Costa Rica	7.4	1.4	18.9	1.7	0.2	11.8
Korea	288.0	0.8	0.3	54.5	0.6	1.1
OECD Countries	9,343.1	236.8	2.5	2,081.4	44.4	2.1
Non-OECD Countries	6,020.0	55.4	0.9	1,544.3	11.1	0.7
World Total	15,363.1	292.2	1.9	3,625.7	55.5	1.5

[1] Production data reported are net of electricity consumed by generating units.

[2] Members of the EU-15 include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

[3] Not available.

Sources: USDOE, EIA, *International Energy Annual 2002,* "Table 6.3 - World Net Electricity Generation by Type," and "Table 6.4 - World Electricity Installed Capacity by Type," found at *http://www.eia.doe.gov/emeu/international,* retrieved Mar. 18, 2005.

Table 3-2
Renewable electricity production,[1] total and type, 2002

Country	Total	Type: Geothermal	Solar	Wind, tide, and other electricity production[2]	Combustible renewables and waste (biomass)
	Gigawatt hours				
Australia	2,800	0	5	361	2,434
Brazil	11,444	([3])	([3])	40	11,404
Canada	8,910	0	22	719	8,169
Chile	1,664	([3])	([3])	([3])	1,664
China	2,438	([3])	([3])	([3])	2,438
Costa Rica	1,433	1,121	([3])	259	53
Denmark	7,386	0	0	4,890	2,496
Germany	28,992	0	188	15,856	12,948
India	4,312	([3])	([3])	2,463	1,849
Italy	10,368	4,662	21	2,173	3,512
Japan	29,325	3,374	0	415	25,536
Korea	813	0	6	15	[4]792
Mexico	5,916	5,398	32	16	470
Spain	13,238	0	35	8,704	4,499
Thailand	2,042	([3])	([3])	([3])	2,042
United States	96,387	14,939	572	10,459	70,417
European Union	98,449	4,761	279	37,180	56,229
OECD total	252,328	32,889	930	50,143	168,366
Non-OECD total	49,298	19,346	([3])	3,383	26,569
World Total	301,626	52,235	930	53,526	194,935

[1] Total renewable electricity production, as reported in this table, may differ from total renewable electricity production, as reported in table 3-1, as the data included in these tables were obtained from two different sources.
[2] For non-OECD countries, solar is included. For all countries, other renewable energy technologies not separately reported, such as ocean energy, are included.
[3] No or negligible production.
[4] Biomass data for Korea are estimates.

Source: International Energy Agency (IEA), *Energy Statistics of OECD Countries, 2001-2002* (Paris: OECD, 2004).

Table 3-3
Growth rates of renewable electricity production,[1] by sector, 1995-2002

Market/sector	1995	2002	Average annual growth
	Gigawatt hours		*Percent*
OECD:			
Geothermal	28,909	32,889	1.9
Solar	880	930	0.8
Wind, tide, and other	8,733	50,143	28.4
Combustible renewables and waste (biomass)	120,636	168,366	4.9
Total OECD	159,158	252,328	6.8
Non-OECD:			
Geothermal	9,986	19,346	9.9
Solar, wind, tide, and other	497	3,383	31.5
Combustible renewables and waste (biomass)	13,322	26,569	10.4
Total Non-OECD	23,805	49,298	11.0
World:			
Geothermal	38,895	52,235	4.3
Solar, wind, tide, and other	10,110	54,456	27.2
Combustible renewables and waste (biomass)	133,958	194,935	5.5
Total World	152,963	301,626	7.4

[1] Total renewable electricity production, as reported in this table, may differ from total renewable electricity production, as reported in table 3-1, as the data included in these tables were obtained from two different sources.

Source: International Energy Agency (IEA), *Energy Statistics of OECD Countries, 2001-2002* (Paris: OECD, 2004).

particularly in the wind sector, as well as government incentive measures that were particularly favorable to power produced from wind and solar resources. Production of electricity from biomass and geothermal resources grew at much slower rates of 5.5 percent and 4.3 percent, respectively, reflecting the relative maturity of these industry segments. Further, renewable energy production in OECD countries increased at a slower rate (6.8 percent) than renewable energy production in non-OECD countries (11.0 percent) during 1995-2002, relecting the fact that production in non-OECD countries was growing from a relatively small base of 23,805 GWh.[3]

International Energy Agency (IEA) data suggest that, among developing countries, India and Thailand are notable with renewable energy posting average annual growth rates of 43.4 percent and 41.4 percent, respectively, during 1995-2002. In India, the reported growth rate was most likely a result of increased wind power. In addition, Indian electricity production based on biomass fuel reached 1,849 GWh, or 43 percent of all renewables, in 2002.[4] In Thailand, the reported electricity production from renewable sources is almost entirely dependent on biomass fuels. Though rapidly growing, total electricity production from renewable energy in these countries was relatively small, with 2002 production at 4,312 GWh in India and 2,042 GWh in Thailand, representing 0.72 and 1.87 percent of total electricity production, respectively. By contrast, renewables-based electricity production in China declined at an average annual rate of 2.8 percent during 1995-2002, to 2,438 GWh. Data for China as reported to the IEA reflect biomass fuel only. However, other evidence points to growth in Chinese renewable energy outside of the biomass segment.[5]

In addition to their application in power generation facilities, certain renewable resources - particularly solar, biomass, and geothermal energy - are used as a direct source of heat. For example, energy from sunlight can be used to heat water, while wood pellets and other biomass resources can be used to fuel household stoves. Anecdotal evidence suggests that there is a substantial market for heat generated through the use of renewable resources, particularly in developing economies where wood-fueled cookstoves are common. However, due to the small-scale nature of many of these activities, data and other information on the global market for heat from renewable resources are largely unavailable.

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[3] Total renewable electricity production may differ from total renewable electricity production as reported in table 3-1, as the data points were obtained from two different sources.

[4] Since the reported 1995 figure is zero, it is not possible to calculate the average annual growth rate for India's electricity production based on biomass fuel.

[5] For example, industry representatives and government officials in Europe cite China as a current or expected growth market for exports of both wind and solar power services and equipment. Industry representatives and government officials, interviews with USITC staff, Bonn and Berlin, Germany, Apr. 12-14, 2005, and Madrid, Spain, Apr. 15 and 18, 2005.

Market Factors

Ultimately, perceived prices (i.e., explicit prices paid by consumers) will determine the quantity of renewable energy demanded and supplied.[6] At present, however, many governments have implemented policies and programs that modify market mechanisms, altering relative prices and consumer latitude in the interest of promoting renewable energy (see appendix F). The following discussion first examines some of these policies and programs, beginning with market deployment policies designed to increase the commercial supply of renewable energy. The discussion then examines other factors with bearing on supply and demand, such as electric power reform, technological advances, energy security interests, and environmental obligations under international agreements.

Market Deployment Policies

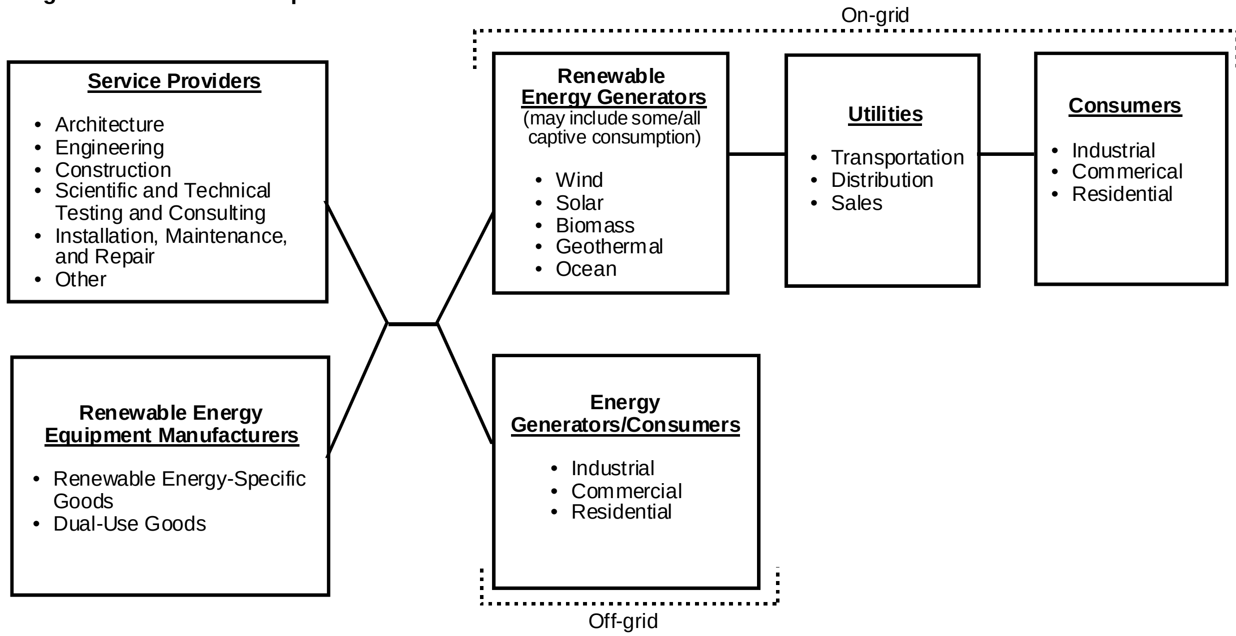
The renewable energy market comprises four principal players: renewable energy consumers, electric power utilities, renewable energy generators, and equipment and service suppliers. Figure 3-1 illustrates a typical supply chain for the renewable energy market. As depicted in the figure, renewable energy service providers and equipment manufacturers supply goods and services to generators. Generators supply power to the electric utilities. The utilities, in turn, distribute and sell renewable power to commercial, industrial, and residential consumers. However, variations of this general framework exist. For example, although utilities typically purchase renewable power from generators, in some cases, utilities may have their own renewable energy operations. In addition, utilities may buy back unused electric power from consumers or, alternatively, generators may consume a portion of their own electricity output, potentially bypassing the electric utility altogether. Bypass, or virtual bypass, of the electric utility is most commonly seen in biomass applications. In some markets there may actually be no utility (bottom, or off-grid, portion of figure 3-1), which is most commonly seen in remote areas of developing countries and rural areas of developed countries. Off-grid consumers who generate their own electricity do so using biomass, solar, and, to a far lesser extent, wind technologies. Finally, while renewable energy service providers and equipment manufacturers are often distinct entities, in some instances, equipment and services are supplied by the same firm.

Broadly, market deployment policies are divided into the following categories: investment incentives (e.g., capital grants and third-party financing); tax measures (e.g., tax credits and tax exemptions); incentive tariffs (e.g., guaranteed prices, feed-in tariffs, and bidding systems); legislative obligations (e.g., portfolio standards and targets); and voluntary programs (e.g., green pricing and net metering programs) (table 3-4).[7] These policies typically target one participant in the renewable energy market (be it generators, electric utilities, or consumers) but commonly produce upstream or downstream effects that affect other, sometimes all, market participants. Of the policies examined in chapters 4 through 8, three types appear to be particularly prevalent in this report's

[6] See chapter 2 for a more in-depth discussion of issues regarding renewable energy pricing.

[7] OECD, *IEA, Energy Policies of IEA Countries: 2004 Review*, pp. 86-90.

Figure 3-1
On-grid and off-grid market relationships



Source: Compiled by USITC staff.

Table 3-4
Market deployment policies, by country

Country	Investment incentives	Tax measures	Incentive tariffs[1]	Legislative obligations	Voluntary programs
Australia	●			●	●
Brazil	●		●	●	
Canada	●	●	●	●	●
Chile	●				
China	●	●	●		
Costa Rica	●	●			
European Union	●	●	●	●	●
India	●	●		●	
Japan	●			●	●
Korea	●	●	●		
Mexico	●	●			
Thailand	●		●		
United States	●	●	●	●	●

[1] An incentive tariff is a relief from normal tariff rates offered by the government to attract investment to a specific economic sector; these often take the form of price guarantees or feed-in tariffs.

Source: Organization for Economic Cooperation and Development, IEA, *Renewable Energy: Market Policy Trends in IEA Countries*; Australian Government, Department of Industry, Tourism and Resources, found at *http://www.industry.gov.au*; Johannesburg Renewable Energy Coalition, “Policies by Technology;” *Viewpoint*, “Promoting Private Investment in Rural Electrification—The Case of Chile;” “Costa Rica: National Off-Grid Electrification Programme Based on Renewable Energy Sources,” found at *http://www.gefweb.org;* Official Journal of the European Communities, *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001*, found at *http://europa.eu.int/;* Ministry of Non-Conventional Energy Sources, Government of India, found at *http://mnes.nic.in/*; Global Issue Papers, “Transitioning to Renewable Energy An Analytical Framework for Creating an Enabling Environment,” June 2004, found at *http://www.boell.de/*; General Directorate for Research into Urban, Regional, and Global Pollution, “Mexico's Advances With Regard to Climate Change, 2001-2002;" Renewable Energy Policy Project, “U.S. Federal Policies: Tax Credits;” Union of Concerned Scientists USA, “Table C-1: State Minimum Renewable Electricity Requirements (as of December 2004);” EIA Country Analysis Briefs, “Japan: Environmental Issue;” Ministry of Energy, Mexico, “Policy Framework for the Development of Renewable Energy in Mexico;” and “Energy and Resources: Japan Fact Sheet,” Web Japan, found at *http://web-japan.org/factsheet/energy/profile.html*.

subject countries: consumer tax exemptions; electricity feed-in-tariffs; and renewable energy obligations.

Tax exemptions are established to stimulate consumer demand for renewable energy by exempting sales taxes on purchases of renewable energy or by reducing income taxes on households that purchase renewable energy equipment. For example, consumers are exempted from paying sales taxes on purchases of wind energy in Estonia, while in Austria and Greece, consumers are permitted to deduct the money that they spend on renewable-related household equipment (e.g., solar water heaters) from their income taxes.[8] Tax exemptions effectively reduce the renewable energy price to consumers, thereby increasing the quantity demanded. Increases in consumer demand for renewable energy reverberate throughout the on-grid supply chain. For example, utilities' attempts to meet rising demand motivates them, in turn, to demand more power from renewable energy generators. Generators' efforts to meet greater demand may entail augmenting existing capacity, thereby increasing demand for renewable energy design and installations services and equipment. Similarly, tax exemptions for renewable equipment expenditures by off-grid consumers would likely increase the quantity of services and equipment demanded.

Feed-in-tariffs, often in combination with purchase quotas, provide subsidies to utilities allowing them to pay premium prices for renewable energy, thereby motivating generators to increase their supply of such energy.[9] Many countries have enacted feed-in-tariff programs, including Austria, Brazil, France, Germany, and Spain.[10] The effects of feed-in tariffs are also experienced by other market participants. Providers of renewable energy services and equipment may experience greater demand if renewable energy generators are motivated by the feed-in tariffs to augment capacity. Consumers, too, may experience effects if their electricity rates increase to cover the new tariffs.[11]

Renewable energy obligations, which require that utilities source a specified proportion of electricity from renewable energy generators, have been introduced by several countries. The obligations are established through legislation, and are often administered and enforced through policy mechanisms such as portfolio standards

[8] IEA, "IEA Renewable Energy Database: Policies and Measures," found at *http://www.iea.org*, retrieved Apr. 12, 2005; OECD, *IEA, Energy Policies of IEA Countries: 2004 Review*, p. 336; and Organizations for the Promotion of Renewable Energy Technologies, "Sustainable Energy Technologies in the Baltic Sea Region: Estonia Country Overview," found at *http://www.opet.dk/baltic*, retrieved Apr. 15, 2005. For more information on country specific policy measures, see appendix F.

[9] Feed-in-tariffs are government-mandated prices paid by electric utilities to private generators for electricity produced from renewable energy. Feed-in tariffs are set above average wholesale electricity prices.

[10] IEA*, Energy Policies of IEA Countries: 2004 Review*, pp. 146, 312, 316, and 555; and Johannesburg Renewable Energy Coalition (JREC), "Policies by Technology," found at *http://www.iea.org*, retrieved Apr. 8, 2005.

[11] Consumers may not experience direct effects if governments provide subsidies to utilities to offset the premium prices offered to renewable energy firms, though as taxpayers they may be indirectly affected.

(table 3-5), targets, and tradable certificates.[12] Like tax exemptions and feed-in tariffs, renewable energy obligations exert both supply- and demand-side effects. Generators increase their renewable energy supply in response to greater demand from utilities. Renewable energy service providers and equipment manufacturers experience greater demand if generation capacity is augmented. Consumers and/or taxpayers may see rates increase as higher-cost renewable energy displaces lower-cost fossil fuel energy. Under both feed-in tariffs and obligations, higher rates may induce consumers to practice greater conservation, thereby reducing demand.

Both the European Union and Japan have recently enacted laws that require electricity producers to use renewable energy sources. In September 2001, the European Commission passed the EU Directive for Electricity Produced from Renewable Energy Sources. The Directive requests that all EU members adopt specific targets for the provision of electricity from renewable sources, and to document with renewable energy guarantees of origin (REGO) certificates that such targets are being met.[13] Under the Directive, targets vary by member state, but all members must meet their targets by 2010.[14] Similarly, in April 2003, Japan adopted the Special Measures Law Concerning the Use of New Energy by Electric Utilities, which requires electric power utilities to supply a collective minimum of 12.2 billion kilowatt-hours of electricity, or 7 percent of total electricity generation, from renewable energy sources by 2010.[15] Other subject countries that have introduced renewable energy obligations include Australia, Brazil, China, and the United States (on a state-by-state basis).[16] As noted in table 3-5, countries with the highest renewable portfolio standards generally appear to have relatively larger

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[12] Portfolio standards, also referred to as quota systems, require countries to supply a minimum amount of their electric power from renewable energy sources, irrespective of the type of renewable energy source that is used. Targets establish benchmarks for the amount of electric power to be generated by each renewable energy source. Separately, tradable certificates are used by countries to certify that government-mandated renewable energy targets with respect to electric power output have been met. These certificates can be exchanged or "traded" with other countries separately from the electric power generated from renewable sources. IEA, *Renewable Energy: Market Policy Trends in IEA Countries*, pp. 85-88.

[13] Reportedly, renewable energy targets outlined in the EU Directive are only indicative targets and are therefore not binding. Government and industry representatives, interviews with USITC staff, Berlin, Germany, Apr. 13, 2005.

[14] Under the Directive, the percentage of electric power output to be generated from renewable energy varies according to the electricity a country produces from renewable energy sources, and the total amount of electric power from both renewable and non-renewable sources that the country consumes. *Official Journal of the European Communities*, "Directive 2001/77/EC of the European Parliament and the Council of 27 September 2001 on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market," Oct. 10, 2001; and DTI, "Guarantees of Origin for Renewable Energy: Implementing Article 5 of the EU Renewables Directive (2001/77/EC)," found at *http://www.dti.gov.uk/*, retrieved Feb. 22, 2005.

[15] Shinichi Nakakuki and Hiroki Kudo, "Discussion Points in Japan's Renewable Energy Promotion Policy," 382nd Regular Researchers' Meeting of the Institute of Electrical Engineers of Japan, Abstract of the Report, Sept. 2003, p. 8, found at *http://eneken.ieej.or.jp/en/data/pdf/205.pdf*, retrieved July 29, 2005; and government and industry representatives, interviews with USITC staff, Tokyo, Japan, Nov. 5-8, 2004.

[16] Fred Beck and Eric Martinot, "Renewable Energy Policies and Barriers, 2004," found at *http://www.martinot.info/Beck_Martinot_AP.pdf/*, retrieved May 26, 2005, pp. 7 and 9.

Table 3-5
Proportion of electricity derived from renewable energy and renewable portfolio standards as a share of total electricity production, by country

Country	Electricity production from renewable energy	Renewable portfolio standards
	Percent	
Denmark	18.82	[1]29
Spain	5.38	[1]29.4
Netherlands	5.22	[1]9
Germany	5.07	[1]12.5
European Union	3.67	[2]22
Italy	3.63	[1]25
Japan	2.67	[1]7
United States	2.4	[3]1.1-30
United Kingdom	1.71	[1]10
Canada	1.48	[4]10
Australia	1.26	[1]11
China	0.15	[5]10

[1] By 2010.
[2] For EU-15.
[3] Renewable portfolio standards are adopted on a state-by-state basis. Such standards have not been adopted by every state.
[4] Ontario only.
[5] By 2020.

Sources: Official Journal of the European Communities, "Directive 2001/77/EC of the European Parliament and the Council of 27 September 2001 on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market," Oct. 10, 2001, found at *http://www.europa.int/*, retrieved Mar. 11, 2005; Center for American Progress, "China's Energy Strategy: A Lesson for the United States?" July 20, 2005, found at *http://www.americanprogress.org*, retrieved Aug. 2, 2005; Interstate Renewable Energy Council, Database of State Incentives for Renewable Energy, found at *http://www.dsireusa.org/dsire/aboutus.cfm*, retrieved Aug. 3, 2005; James Shevlin, Australian Greenhouse Office, Department of the Environment, "MRET and Greenhouse Friendly Programmes that Work," found at *http://www.climateandbusiness.com/papers/Day%201/1445JamesShevlin%20nn.ppt*, retrieved Aug. 2, 2005; Ontario Ministry of Energy, "Renewable Energy Sources: Renewable Portfolio Standard," found at *http://www.energy.gov.on.ca*, retrieved Aug. 15, 2004; and José Goldemberg, "The Brazilian Energy Initiative–Perspectives after Johannesburg," found at *http://www.gfse.at/papers/final_jg_graz_nov_021.doc*, retrieved Aug. 2, 2005.

shares of electric power production derived from renewable energy.[17] Nonetheless, according to industry sources, the overall success of renewable energy obligations has been mixed, with Germany and, in the United States, Texas cited as examples of markets where such obligations have been implemented with favorable results.[18]

[17] Countries with distant target dates for implementation of renewable portfolio standards will likely see increased growth in renewables as those dates draw closer.

[18] Richard Sellers, Renewable Energy Unit, International Energy Agency (IEA), Commission hearing testimony, Apr. 19, 2005 p. 32; Alexander Karsner, Enercorp, LLC, Commission hearing testimony, Apr. 19, 2005, pp. 144-148; and Richard E. Morgan, National Association of Regulatory Utility Commissioners (NARUC), Commission hearing testimony, Apr. 15, 2005, p. 75.

Research and Development Policies

Countries have also employed a wide range of programs to promote R&D in renewable energy, potentially expanding its supply. In 2002, the share of total energy R&D budgets allocated to renewables ranged from 1.6 percent (Portugal) to 26.8 percent (Japan) among the subject countries (table 3-6). Most programs are broad-based, and are designed to promote energy research in general, and research on renewable sources in particular. For example, Australia initially provided R&D funding for renewable energy through the National Energy Research, Development, and Demonstration Council (NERDDC), and Canada provided R&D funding through the Program of Energy Research and Development (PERD). Under the umbrella of PERD, the Canadian Government established the Renewable Energies Technologies Program (RETP) to support renewable energy development by private industry.[19] Similarly, the Australian Government established the National Greenhouse Response Strategy program, two components of which were the Renewable Energy Promotion Programme and the Australian Cooperative Research Centre for Renewable Energy (ACRE).[20] In certain countries, governments designed policies to encourage the development of specific types of renewable energy technology. For instance, Japan's Program for Development and Dissemination of Photovoltaic Systems, begun in 2000, promotes the development of solar PV technologies.[21] Separately, Denmark, Germany, and Finland have each established programs to promote the development of wind energy technology, as have developing countries, such as Brazil, China, and India.[22]

Electric Power Reform

Apart from the policy measures discussed above, the supply of renewable energy has also been influenced by reforms in the electric power industry. In the 1990s, many countries, including most of the targeted countries, undertook reform of their electric power sectors by privatizing government-owned monopoly utilities and unbundling power generation, transmission, distribution, and supply so that these functions could be performed by separate entities.[23] In countries such as Denmark and the United Kingdom, this restructuring was undertaken with the objective of increasing energy

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[19] Established in 1978, the NERDDC was later reorganized as the Energy Research & Development Corporation (ERDC). The ERDC remained in operation until 1997. The PERD was established in 1974. OECD, IEA, *Renewable Energy: Market Policy Trends in IEA Countries*, 2004, pp. 111, 121, and 193.

[20] The Australian Cooperative Research Centre for Renewable Energy currently functions as the Research Institute for Sustainable Energy Development. Research Institute for Sustainable Energy Development, found at *http://www.rise.org.au/*, retrieved Mar. 9, 2005.

[21] IEA, *Renewable Energy: Market Policy Trends in IEA Countries*, p. 420.

[22] Ibid., pp. 232, 258, and 308; Louise Guey-Lee, "Wind Energy Developments: Incentives in Selected Countries," USDOE, Energy Information Administration, *Renewable Energy Annual 1998*, pp. 5-7; USDOE, National Renewable Energy Laboratory, "Renewable Energy in China: An Overview," found at *http://www.nrel.gov/international*, retrieved Mar. 10, 2005; and Richard Sellers, Renewable Energy Unit, IEA, Commission hearing testimony, Apr. 19, 2005, pp. 39-40, 48-49, 54, 56-57.

[23] Chile was one of the first countries to restructure its electric power industry, beginning the process in the late 1970s. In other countries, reform of the electric power sector is ongoing. For further discussion of electric power sector reform, see USITC Investigation No. 332-411, *Electric Power Services: Recent Reforms in Selected Foreign Markets*, Publication No. 3370, Nov. 2000, available at *http://www.usitc.gov/*.

Table 3-6
Government budgets for energy research and development and share allocated to renewable energy, 2002

Country	Total energy R&D[1]	Total energy R&D allocated to renewables	Share of total energy R&D budget allocated to renewables
	Millions U.S. dollars		*Percent*
EU-15[2]	1,704.9	334.5	19.6
Austria	33.6	11.2	33.3
Denmark	26.0	11.2	43.1
Finland	80.2	11.2	14.0
France	462.6	27.2	5.9
Germany	301.7	86.1	28.5
Greece	10.3	3.8	36.9
Italy	349.1	60.5	17.3
Ireland	4.2	1.0	23.8
Netherlands	162.9	51.1	31.4
Portugal	2.2	1.4	63.6
Spain	53.8	18.8	34.9
Sweden	108.4	28.9	26.7
United Kingdom	251.4	[3]53.0	21.1
Japan[3]	3,602.1	134.6	3.7
United States	2,893.8	251.4	8.7
Canada	220.3	19.7	8.9
Korea	94.6	10.4	11.0

[1] 2003 prices and exchange rates.
[2] EU-15 countries do not include Belgium or Luxembourg because this information is not available.
[3] 2001.

Source: IEA, Beyond 20/20 Web Data Server, found at *http://www.iea.org/rdd/eng/ReportFolders/Rfview/Explorerp.asp?cs_referer=*, retrieved Aug. 12, 2005.

efficiency and expanding renewable energy usage. One key outcome of electricity reform was that third-party power producers were permitted access to transmission and distribution networks operated by the monopoly utilities.[24] This meant that third-party firms using renewable sources could supply power on a wholesale basis to the electric utilities or on a retail basis to end users without incurring the costs of building transmission and distribution facilities.[25] In addition to creating competitive wholesale and retail markets for electric power, reform also encouraged self-generation by consumers who could now choose their own energy source.[26] Further, electric power restructuring has often included long-term plans to augment the capacity of transmission

[24] Hearing testimony, USITC Inv. No. 332-462, *Renewable Energy Services: An Examination of U.S. and Foreign Markets*, Apr. 19, 2005.
[25] EIA, "Transmission Pricing Issues for Electricity Generation from Renewable Sources," *Renewable Energy Annual 1998: Issues and Trends*, p. 3, found at *http://tonto.eia.doe.gov/FTPROOT/features/transpc.pdf*, retrieved June 3, 2005.
[26] Beck and Martinot, "Renewable Energy Policies and Barriers," 2004, pp. 16-17.

and distribution facilities to accommodate electricity generators that use renewable technologies.[27]

Technological Advances

Technological development is another factor that has enhanced the supply of renewable energy. The production costs of developing certain types of renewable technologies, such as geothermal, solar, and wind energy, have declined in recent years, which may have led to more widespread use of these technologies. For example, because of declining capital costs associated with U.S. geothermal generation, it is estimated that U.S. electric power generated from geothermal energy will more than double in the next 20 years.[28] Similarly, the cost of deploying solar photovoltaic (PV) technology has decreased, particularly in countries such as Germany and Japan, which have devoted significant resources to the development of solar PV systems. In both countries, power-generating capacity from solar PV technology has increased more than two-fold during the 1992-2001 period.[29] Advances in wind turbine engines have also made wind energy more efficient and cost-effective. Such advances include the development of larger turbines that can generate higher electrical output, the adaptation of onshore wind technology to offshore locations, and the ability to use wind turbine technology to generate power in geographic areas with low wind speeds.[30] Among the developing countries, India is at the forefront of wind energy production, and ranks fifth in installed capacity behind Denmark, Germany, Spain, and the United States.[31]

Energy Security and Economic Development

Demand for renewable energy is also influenced by government concerns over energy security as well as countries' economic development. Energy security is an issue for countries whose demand for fossil fuels are not met by domestic resources. This issue has been highlighted recently by escalating world demand, driven in part by the efforts of certain countries and to secure adequate energy supplies. To address energy security, many countries have slowly diversified their energy portfolios. One strategy has been to increase the proportion of renewable sources that contribute to overall energy supplies.[32] As noted in chapter 2, the share of renewable energy in the total energy supply of OECD countries increased from 4.6 percent to 5.5 percent during 1970-

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[27] IEA, *Energy Policies of IEA Countries*: *2004 Review*, pp. 315 and 349.

[28] Renewable Energy Policy Project, "Geothermal Resources," found at *http://www.repp.org/*, retrieved Mar. 16, 2005.

[29] IEA, *Renewable Energy: Market Policy Trends in IEA Countries*, 2004, p. 76.

[30] Ibid., pp. 81-82; and Louise Guey-Lee, "Wind Energy Developments: Incentives in Selected Countries," EIA, *Renewable Energy Annual 1998*, p. 7.

[31] Ari Reeves, "Wind Energy for Electric Power," Renewable Energy Policy Project Issue Brief, July 2003, found at *http://www.repp.org/*, retrieved Mar. 16, 2005.

[32] Richard Sellers, Renewable Energy Unit, IEA, Commission hearing testimony, Apr. 19, 2005, pp. 30-31, 46-47; Richard E. Morgan, NARUC, Commission hearing testimony, Apr. 19, 2005, pp. 73, 77; George Sterzinger, Renewable Energy Policy Project (REPP), Commission hearing testimony, Apr. 19, 2005, pp. 96, 181; and Christopher O'Brien, Sharp Solar, Commission hearing testimony, Apr. 19, 2005, p. 109.

2001.[33] Further depletion of the world's oil and gas reserves will likely increase demand for renewable energy sources, as technological advances allow renewables to become a viable substitute for traditional fossil fuels.[34]

As noted in chapter 2, demand for renewable energy has also arisen in the context of economic development. Renewable energy contributes to economic development in a variety of ways. According to a World Bank estimate, only one-third of homes in developing countries were connected to a power grid in 1990. Renewable energy offers electricity to areas not served by the national grid, greatly reduces the overall investment costs of providing power to such areas, and likely increases local employment compared to fossil-fuel based electric power generation.[35] The arrival of electricity in a village may free women and children from the significant burden of gathering wood for fuel, allowing women to focus on more economically productive areas, and children to increase their time spent in school.[36] Photovoltaic solar applications in particular have been used to provide off-grid power for residences, water pumping systems, lights and computers in schools, vaccine refrigerators and sterilization equipment in medical facilities, and telecommunications relay stations and terminals.[37]

The World Bank's Global Environment Facility (GEF) has served as an important catalyst for the development of renewable energy projects in developing countries through its climate change program.[38] The GEF helps countries stimulate markets for renewable energy by aiding in the establishment of pro-renewable energy policies, and providing technical assistance in implementing and financing renewable energy projects.[39] The World Bank has contributed more than $2 billion since 1994 to renewable energy projects in 58 developing countries under the aegis of the GEF.

[33] This percentage includes hydropower, combustible renewables and waste as well as geothermal, solar, wind, and tidal energy. In 2001, renewables accounted for 15.1 percent of total electricity production by OECD countries. Of this share, 86.3 percent of electricity generated from renewables came from hydropower, with the remainder derived from combustible renewables and waste (biomass), geothermal, solar, tidal, and wind energies. IEA, *Renewable Energy: Market Policy Trends in IEA Countries*, pp. 43 and 48.

[34] IEA, *Energy Policies of IEA Countries: 2004 Review*, p. 40; and "Policy Recommendations for Renewable Energies," paper from the International Conference for Renewable Energies, Bonn, Germany, June 2004, p. 7.

[35] However, data regarding increased employment are not available. Richard Sellers, Renewable Energy Unit, IEA, Commission hearing testimony, Apr. 19, 2005, p. 48; Richard E. Morgan, NARUC, Commission hearing testimony, Apr. 19, 2005, p. 75; government officials, interviews with USITC staff, Berlin, Germany, Apr. 13, 2005 and Madrid, Spain, Apr. 15, 2005; and industry representatives, interview with USITC staff, Bonn, Germany, Apr. 11, 2005.

[36] IEA, Renewable Energy Working Party, "Renewable Energy...Into the Mainstream," Oct. 2002, pp. 45-46.

[37] World Bank, found at *http://www.worldbank.org/html/fpd/energy/subenergy/solar/solar_pv.htm,* retrieved May 11, 2005; and Isofoton, *http://www.isofoton.com/html//flash/ing/proyectos.htm,* retrieved May 11, 2005.

[38] The GEF was originally established within the World Bank as a pilot program to assist in funding environmentally sustainable development. In 2003, the GEF was formally restructured under three implementing agencies: The UN Development Program, the UN Environment Program, and the World Bank, to serve as the funding arm of the 1992 United Nations Framework Convention on Climate Change and the Convention on Biological Diversity. "Instrument for the Establishment of the Restructured Global Environment Facility," May 2004, found at *http://thegef.org/GEF_Instrument3.pdf,* retrieved May 13, 2005.

[39] GEF website, found at *http://www.gefweb.org/Projects/Focal_Areas/climate/CCProject_types.html,* retrieved May 13, 2005.

Those projects have involved additional financing of more than $3.2 billion from non-World Bank sources.[40]

Environmental Obligations

Finally, obligations undertaken by countries to reduce greenhouse gas emissions have also increased demand for renewable energy. For example, the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCC), implemented on February 16, 2005, requires ratifying countries to limit greenhouse gas emissions by a collective amount of 61.6 percent, relative to 1990 levels, during the 2008-2012 period.[41] The Kyoto agreement requests that countries implement specific measures to meet commitments for reducing carbon dioxide emissions, including the research, development, and promotion of renewable energy technologies. As of March 2005, 145 countries had ratified the agreement,[42] including the EU, China, Russia, and Japan, four of the five countries with the largest emissions of carbon dioxide (CO_2).[43] Certain countries have established autonomous measures to reduce carbon dioxide and other greenhouse gas emissions. For example, the Clean Air Act requires U.S. states to meet federally-mandated air quality standards by established deadlines.[44] The Act contains an emissions allowance for electric power generated from renewable energy.[45] Further, nine U.S. states have agreed to a 10-percent reduction in air pollution emissions from power plants by 2020.[46] Elsewhere, countries such as Australia, Canada, Korea, Japan, and Mexico have implemented legislation pertaining to air quality and emissions

[40] World Bank financing includes funds from the GEF, the International Development Agency, and the World Bank (International Bank for Reconstruction and Development). World Bank Global Environment Facility, Renewable Energy Projects Database, found at *http://www.gefonline.org/home.cfm*, retrieved May 11, 2005.

[41] Greenhouse gases include, for example, carbon dioxide (CO_2), methane (CH_4), and manmade compounds such as aerosols. The emission of these gases accelerates a natural process in which the earth's atmosphere retains heat from the sun, thereby creating a "greenhouse effect." EIA, "What Are Greenhouse Gases?" found at *http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html*, retrieved July 27, 2005. United Nations, "Kyoto Protocol to Enter into Force 16 February 2005," Press Release, found at *http://unfccc.int/*, retrieved Mar. 21, 2005; and "Kyoto Protocol: Status of Ratification," last updated Mar. 21, 2005.

[42] The United States is not among those countries that have ratified the Kyoto Protocol.

[43] In 2002, the EU accounted for 14 percent of worldwide CO_2 emissions, followed by China (13.5 percent), Russia (6.2 percent), and Japan (4.8 percent). Although China has ratified the Kyoto Protocol, it is considered a developing or Annex II country and therefore is not bound to a specific emissions reduction target at this time. The United States, which accounts for 24.3 percent of worldwide CO_2 emissions, is a signatory to the Kyoto Protocol, but has not ratified the agreement. EIA, *International Energy Annual 2002*, "Table H.1: CO_2 World Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels," last updated June 9, 2004, found at *http://www.eia.doe.gov/*, retrieved Mar. 21, 2005; and "Kyoto Protocol: Status of Ratification," found at *http://unfccc.int*, last updated Mar. 21, 2005.

[44] Clean Air Act, 42 U.S.C. §7401 et seq. (1970).

[45] U.S. Environmental Protection Agency, "Clean Air Act," found at *http://www.epa.gov/*, retrieved Mar. 23, 2005; and EPA, "Emissions Trading Under the Clean Air Act," found at *http://www.repp.org/repp_pubs/articles/issuebr15/03emTrad.htm*, retrieved Mar. 24, 2005.

[46] "Northeast States to Reduce Emissions," *BusinessWeek Online*, Aug. 24, 2005, found at *http://www.businessweek.com/*, retrieved Sept. 20, 2005.

standards.[47] Due to the recent development of these measures, the extent and nature of their impact on the renewable energy industry is presently unclear. However, it is likely that such measures will have a positive effect on the demand for renewable energy.

[47] For further discussion on country-specific air pollution laws, see USITC Investigation No. 332-461, *Air and Noise Pollution Abatement Services: An Examination of U.S. and Foreign Markets*, Publication No. 3761, Apr. 2005, available on the Commission website at *http://www.usitc.gov/*.

CHAPTER 4
WIND ENERGY

This chapter provides information on both developed- and developing-country markets for wind power services and equipment, with special emphasis on wind power markets in Australia, Brazil, Canada, Chile, China, Costa Rica, Denmark, Egypt, Germany, India, Japan, Mexico, Morocco, New Zealand, Spain, and the United States. These countries were chosen for special emphasis based on the size of their wind power markets, and based on the USTR's request for information on developed- and developing-country markets, as well as information on markets with which the United States has established, or is in the process of negotiating, a free trade agreement.[1]

Overview

In recent years, several factors including favorable government programs, international environmental obligations, technological improvements, and the increasing cost-competitiveness of wind power relative to other conventional and renewable energy sources, among others, have led to significant growth in the global wind power industry, making wind power the fastest-growing segment of the entire global energy market.[2] The global market for wind energy is presently dominated by developed countries. In 2004, Germany was the world's largest single-country market for wind energy in terms of installed capacity, followed by Spain and the United States.[3] However, certain developing countries, particularly India and China, have significant wind resources and are becoming important markets for the wind power industry. Data and anecdotal evidence suggest that there is significant cross-border trade and investment activity in the wind power industry,[4] and there are few barriers that specifically affect such trade and investment. Factors such as government support for renewable energy, technological advances, rapid increases in offshore wind power capacity, siting issues, and market consolidation will likely have an impact on prospects for the global wind power market during the next five to ten years.

Technologies and Methods

The development of the modern wind power industry began in the 1970s, in response to the high oil prices of that time.[5] Modern wind turbines produce mechanical power from the wind's kinetic energy. This power is applied to specific activities– including

[1] For more information on the USTR's request, see appendix A of this report.
[2] Windustry, "Why Wind Energy?" Feb. 3, 2005, found at *http://www.windustry.com/*, retrieved May 23, 2005.
[3] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 20.
[4] For more information on trade and foreign investment in the wind power industry, see the Trade and Investment section of this chapter.
[5] Organization for Economic Cooperation and Development, *Renewable Energy: Market Policy & Trends in IEA Countries*, (Paris: OECD/IEA, 2004), p. 80.

the pumping of water or the milling of grain– or is used to generate electricity.[6] Such turbines are employed in both small- and large-scale applications. A single turbine, or a small number of turbines, may be used to generate electricity for a single household or a remote village, while wind farms comprising a large number of high-capacity turbines may be used to generate electricity that is supplied to the grid.[7]

Most wind turbines are installed at onshore locations; however, due to the diminishing number of potential locations for onshore wind facilities in certain markets, such as Denmark and Germany, and the precedent established by the successful installation of several offshore wind parks, the development of offshore wind facilities has increased.[8] Space limitations have also led to an increase in repowering, which involves replacing relatively old turbines with larger, higher-capacity models.[9]

Although several different types of turbines have been developed for use in the modern wind energy industry, most wind power operations use horizontal axis turbines with two or three blades (figure 4-1).[10] In recent years, the size of utility-scale wind turbines has been increasing in terms of both rotor diameter and capacity.[11] The wind turbines currently being marketed for on-grid applications typically have a rotor diameter of between 50 and 90 meters and an electricity production capacity of between 700 kW and 1.8 MW.[12] However, wind turbines with a capacity of 3 to 3.5 MW have become commercially available, and even larger turbines – such as REpower's 5 MW turbine in Germany– are operating on an experimental basis. Larger turbines are particularly useful in the offshore wind energy industry, as building a facility with a small number of large turbines can reduce high construction costs.[13] For example, GE Wind (United States) markets a 3.6 MW turbine for use by the offshore wind power industry, and Vestas (Denmark) has designed a 4.5 MW offshore wind turbine that it will market by

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[6] U.S. Department of Energy, Energy Efficiency and Renewable Energy, "How Wind Turbines Work," Mar. 2, 2004, found at *http://www.eere.energy.gov/*, retrieved May 18, 2005.

[7] U.S. Department of Energy, Energy Efficiency and Renewable Energy, "Wind Turbine Use," found at *http://www.eere.energy.gov/*, retrieved June 7, 2005; and Department of Energy, Energy Efficiency and Renewable Energy, "How Wind Turbines Work," Mar. 2, 2004, found at *http://www.eere.energy.gov/*, retrieved May 18, 2005.

[8] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005; and Renewable Energy Trust, "Offshore Wind Energy Collaborative," 2004, found at *http://www.mtpc.or/*, retrieved June 10, 2005.

[9] European Wind Energy Association, "The Current Status of the Wind Energy," found at *http://www.ewea.org/*, retrieved May 18, 2005.

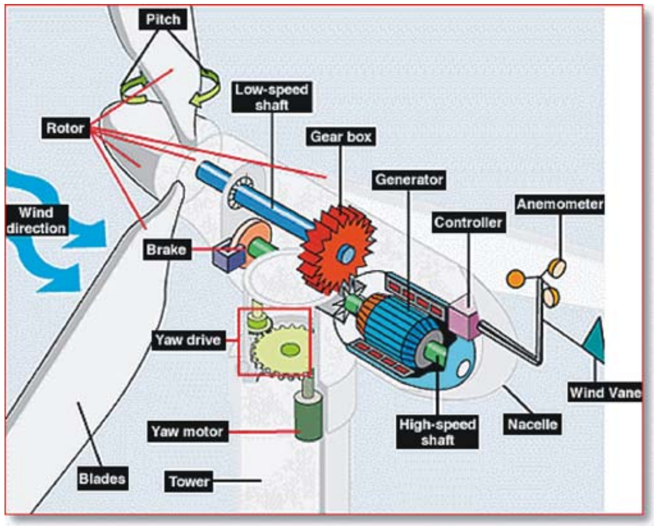
[10] U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy, "Wind Energy Technologies," May 16, 2005, found at *http://www.eere.energy.gov/*, retrieved June 7, 2005; and U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy, Wind and Hydropower Technologies Program, "How Wind Turbines Work," Apr. 8, 2004, found at *http://www.eere.energy.gov/*, retrieved May 18, 2005.

[11] For example, in Germany and Denmark, the average capacity of grid-connected turbines increased from about 200 kW to approximately 1.5 MW during 1990-2002. European Wind Energy Association (EWEA), "Wind Power Economics," found at *http://www.ewea.org/*, retrieved May 18, 2005.

[12] American Wind Energy Association (AWEA), "Wind Energy Basics," 2004, found at *http://www.awea.org/*, retrieved June 6, 2005.

[13] "Wind Turbines: How Big Can They Get?," *Refocus*, Mar./Apr. 2005, p. 22.

Figure 4-1
Inside the wind turbine



Source: U.S. Department of Energy, Energy Effigency and Renewable Energy, Wind and Hydro Technologies Program, found at *http://www.eere.energy.gov/*, retrieved, Aug. 16, 2005.

year-end 2006.[14] Small turbines with a capacity of less than 50 kW are typically used for off-grid applications such as power generation for households in remote locations, water pumping, and other small-scale applications.[15]

Wind turbines are the principal piece of equipment used in the wind energy industry, but other equipment and infrastructure are also necessary to the development and operation of wind power facilities. These include turbine platforms, power cables and other equipment needed to connect the wind farm to the transmission grid, and access roads.[16]

Market Size and Characteristics

Market for wind power services

For the purpose of this discussion, wind power services include the generation of electricity through the application of wind energy; the transmission, distribution, and sale of wind power; and those services related to the establishment and operation of a

[14] GE Wind Energy, "3.6s Offshore Wind Turbine," pamphlet, 2004; Vestas, "Vestas Product Overview," and "V120 - the Offshore Leader," found at *http://www.vestas.com/*, retrieved June 13, 2005.

[15] U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy, Wind and Hydropower Technologies Program, "How Wind Turbines Work," Apr. 8, 2004, found at *http://www.eere.energy.gov/*, retrieved May 18, 2005.

[16] The European Wind Energy Association (EWEA), "Wind Power Technology," found at *http://www.ewea.org/*, retrieved May 23, 2005.

wind power facility. Related services include a wide variety of activities, such as the assessment of wind resources, site analysis, retail sale of turbines, project management, wind project financing, project engineering and design, construction and operation of wind power facilities, installation of equipment, and maintenance of equipment, among others.[17]

The wind power industry is one of the largest segments of the global market for non-hydro renewable energy,[18] and the fastest-growing segment of the world energy market.[19] Recent data published by BTM Consult ApS indicate that total electricity generation through the use of wind energy increased at an average annual rate of 29 percent during 1996-2004, reaching 96.50 TWh by the end of the period. The global market for wind power is largely concentrated in a small number of countries.[20] Germany is, by far, the world's top producer of wind power, accounting for 29.87 TWh, or 31 percent, of global wind power generation in 2004 (see table 4-1 at end of chapter). Other top wind power generators included Spain (18 percent), the United States (16 percent), Denmark (7 percent), and India (6 percent). In 2004, wind power accounted for less than 1 percent of global electricity generation. However, industry sources estimate that worldwide wind power generation will continue to grow rapidly during the next 10 years, potentially reaching 535.1 TWh and accounting for over 2 percent of global electricity generation by 2014.[21]

Data on wind power capacity are available from a number of different sources such as the World Wind Energy Association (WWEA), the American Wind Energy Association

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[17] The types of services provided by participants in the wind energy industry are frequently itemized on company internet sites. For example, see GE Energy, "Services for Wind Turbines," found at *http://www.gepower.com/*, retrieved May 23, 2005; Airtricity, "About Us," found at *http://ww.airtricity.com/*, retrieved June 13, 2005; Clipper Windpower, "Clipper Windpower Project Development: Capabilities," found at *http://www.clipperwind.com/*, retrieved June 13, 2005; GHD, "Wind Energy Services," found at *http://www.ghd.com.au/*, retrieved June 13, 2005; and Vestas, "The Stages of Wind Project Planning," found at *http://www.vestas.com/*, retrieved June 13, 2005.

[18] The wind power market is the largest segment of the non-hydro renewable energy industry in terms of installed capacity, while the biomass power market is the largest segment of the non-hydro renewable energy industry in terms of electricity generation. McIlvaine Co., estimates provided to USITC staff via e-mail, June 21, 2005 and June 23, 2005; and BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, pp. 3, 54-55.

[19] World Wind Energy Association, "Worldwide Wind Energy Capacity at 39,151 MW - 7,981 MW added in 2003," press release, Mar. 5, 2005, found at *http://www.wwindea.org/*, retrieved May 26, 2005; and Windustry, "Introduction to Wind Energy," Feb. 3, 2005, found at *http://www.windustry.com/*, retrieved May 18, 2005.

[20] World Wind Energy Association, "World Wind Energy Capacity at 39,151 MW - 7,981 MW added in 2003," press release, Mar. 5, 2004, found at *http://www.wwindea.org/*, retrieved May 20, 2005.

[21] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, pp. 53-55.

(AWEA), and the global Wind Energy council (GWEC).[22] BTM Consult ApS' *World Market Update 2004*, indicates that worldwide wind power capacity increased by 8,154 MW, or 19 percent, in 2004, reaching a year-end total of 47,912 MW.[23] Europe and North America led the world in installed wind power capacity,[24] having accounted for 73 percent and 15 percent of such capacity, respectively, in 2004.[25] As with wind power generation, Germany is the world's leading single-country market for wind energy capacity, having accounted for 16,649 MW, or 35 percent, of global installed wind energy capacity in 2004. Other markets that accounted for a substantial share of global wind energy capacity in 2004 included Spain (17 percent), the United States (14 percent), Denmark (6 percent), and India (6 percent).[26] However, markets for wind power exist in many parts of the world, with more than 50 countries having some quantity of wind power capacity.[27] Many of the countries selected for special emphasis in this chapter have both grid-connected wind power capacity, as well as off-grid capacity which is used to generate power for households, water pumping facilities, and other small-scale operations (see table 4-1 at end of chapter). The shares of grid-connected and off-grid wind power capacity in these markets are unknown.

Although the same countries rank among the world's top wind power markets in terms of both generation and installed capacity, a certain country may account for a larger or smaller share of global wind power generation or capacity based on the natural wind resources in that country. For example, Germany has relatively few natural wind resources, explaining why Germany accounts for 35 percent of global wind power capacity but only 31 percent of global wind power generation. By contrast, Spain and the United States, which both have substantial natural wind resources, account for a greater share of worldwide wind power generation than capacity.

Industry data indicate that the economic value of the global market for wind power is significant, having generated an estimated \$6.4 billion in revenues during 2004.[28] These data suggest that those countries with the largest shares of wind power generation and installed wind power capacity also accounted for the largest percentage of wind power revenues. Specifically, Germany was the largest market for wind power generation in 2004, having accounted for about \$2.6 billion, or 40 percent, of global revenues in this industry sector. Other markets that reportedly accounted for a significant share of global wind power revenues included Spain (20 percent), the United States (8 percent),

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[22] For example, the World Wind Energy Association reports that worldwide wind power capacity increased by 7,981 MW, or 26 percent, in 2003, reaching a year-end total of 39,151 MW. World Wind Energy Association, "World Wind Energy Capacity at 39,151 MW - 7,981 MW added in 2003," press release, Mar. 5, 2004, found at *http://www.wwindea.org/*, retrieved May 20, 2005.

[23] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 3.

[24] American Wind Energy Association, "Global Wind Energy Market Report," Mar. 2004, found at *http://www.awea.org/*, retrieved May 18, 2005.

[25] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, pp. 5-6.

[26] Ibid., p. 20.

[27] European Wind Energy Association (EWEA), "The Current Status of the Wind Industry," found at *http://www.ewea.org/*, retrieved May 18, 2005.

[28] An explanation of the data estimation methodology employed by McIlvaine Co. is included in chapter 1. McIlvaine Co., estimate provided to USITC staff via e-mail, June 21, 2005.

Denmark (8 percent), and India (4 percent).[29] Industry data also suggest that engineering, construction, and transportation services related to the development of wind power facilities worldwide totaled approximately $3.8 billion in 2004.[30] Germany accounted for about $1.6 billion, or 41 percent, of such services, while the United States and Spain were the second and third largest markets for wind energy services, respectively, accounting for 16 percent and 10 percent of such services.[31]

Although the vast majority of global wind power is generated at onshore facilities, offshore wind power capacity has increased rapidly in recent years.[32] BTM Consult reports that global offshore wind capacity reached 589 MW by year-end 2004, following increases of 250 MW during 2003 and 60 MW during 2004. The vast majority of this capacity is located in Denmark and the United Kingdom, which accounted for 68 percent and 21 percent of global offshore wind power capacity, respectively, in 2004.[33] However, despite rapid growth in this market segment, offshore wind power has not yet become an economically viable alternative to onshore wind power.[34] The investment costs associated with offshore wind facilities are particularly high because of the significant costs of building, maintaining, and establishing grid connections to these facilities.[35] Although estimates regarding the relative cost of onshore and offshore wind power facilities vary– with different sources suggesting that the costs associated with offshore wind power facilities may be anywhere between 30-70 percent higher than the costs associated with onshore facilities– all of these estimates indicate that the establishment and operation of offshore wind power facilities is relatively expensive.[36] Industry sources indicate that it is difficult to secure financing for such projects because of the nascency of this industry segment.[37] In addition, not all offshore locations are suitable for the generation of wind power. For example, the depth of Spain's continental shelf is an obstacle to the installation of offshore wind power capacity in that country.[38]

The rapid growth in the global market for wind energy is a product of several factors. Numerous industry representatives have indicated that favorable government legislation,

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[29] McIlvaine Co., estimate provided to USITC staff via e-mail, June 21, 2005.

[30] Ibid.

[31] Ibid.

[32] As discussed, the rapid increase in off-shore wind power capacity is reportedly a product of the decreasing number of suitable onshore wind sites in some countries and the successful installation of offshore capacity in certain markets. Industry representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005; and Renewable Energy Trust, "Offshore Wind Energy Collaborative," 2004, found at *http://www.mtpc.or/*, retrieved June 10, 2005.

[33] The balance of the world's offshore wind power capacity is located in 3 countries: Ireland (4 percent), Sweden (4 percent), and the Netherlands (3 percent). BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 20.

[34] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[35] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005; industry representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005; and the Irish Wind Energy Association, "Offshore," found at *http://www.iwea.com/offshore/*, retrieved July 26, 2005.

[36] Industry representatives, interviews by USITC staff, Madrid, Spain, Apr. 18, 2005; and U.S. Army Corps of engineers, New England District, "Cape Wind Energy Project Draft Environmental Impact Statement," Nov. 9, 2004, found at *http://www.nae.usace.army.mil/*, retrieved July 26, 2005.

[37] Industry representative, interview by USITC staff, Dortmund, Germany, Apr. 12, 2005; and industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.

[38] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 15, 2005.

including long-term incentive programs, is a key driver of demand in the wind power industry.[39] Such incentives reportedly create market stability and facilitate project financing, which is important[40] in the particularly capital-intensive wind power industry.[41] Germany and Spain's feed-in tariff programs, under which wind power producers are guaranteed a premium price for their electricity for a period of time, have reportedly contributed to the tremendous growth in these countries' wind power markets.[42] By contrast, several sources indicate that the installation of new wind power capacity in the United States declined sharply during 2004, as the federal production tax credit[43] for wind energy was not renewed until the end of 2004.[44] Similarly, the installation of new wind power capacity decreased significantly in Denmark after the country's feed-in tariff was abolished in 2001.[45]

International agreements, particularly the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), may affect demand in the wind power market. Although some industry and government representatives indicate that it is too early to assess the impact of the Kyoto Protocol[46]– under which member countries have agreed to reduce air emissions– other industry and government representatives argue that the Kyoto Protocol has boosted demand for wind power as a non-emitting source of electricity.[47] In addition, some firms are reportedly establishing renewable

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[39] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005; government representative, interview by USITC staff, Madrid, Spain, Apr. 15, 2005; and industry representatives, interviews by USITC staff, Madrid, Spain, Apr. 18, 2005.

[40] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005; and industry representatives, interviews by USITC staff, Madrid, Spain, Apr. 18, 2005.

[41] The European Wind Energy Association reports that up-front capital costs account for approximately 75 percent of overall wind power costs. In comparison, up-front capital costs account for 40-60 percent of the overall costs of a natural gas fired generation facility. European Wind Energy Association, "Wind Power Economics," found at *http://www.ewea.org/*, retrieved May 18, 2005.

[42] Government representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005; and government representatives, interviews by USITC staff, Madrid, Spain, Apr. 15, 2005.

[43] In the United States, commercial wind facilities that initiate electricity generation under the production tax credit (PTC) are eligible for a 10-year, inflation-adjusted tax credit (currently 1.9 cents) for each kWH of wind power that they produce. Since 1999, the PTC has been subject to short-term extensions and has expired three times, creating market instability for investors. American Wind Energy Association , "Wind Power: Outlook 2005," found at *http://www.awea.org/*, retrieved June 10, 2005, and American Wind Energy Association, "Wind Energy & Energy Policy," Oct. 15, 2004, found at *http://www.awea.org/*, retrieved June 27, 2005.

[44] Industry representatives, interviews by USITC staff, Madrid, Spain, Apr. 18, 2005; American Wind Energy Association (AWEA), "Wind Power: Outlook 2004," found at *http://www.awea.org/*, retrieved June 10, 2005; and American Wind Energy Association, "Wind Power: Outlook 2005," found at *http://www.awea.org/*, retrieved June 10, 2005.

[45] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005; and Niels I. Myer, "Renewable Energy Policy in Denmark," *Energy for Sustainable Development*, Vol. 8, No. 1, Mar. 2004, found at *http://www.ieiglobal.org/ESDVol8No1/05denmark.pdf*, retrieved July 27, 2005.

[46] Government representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005; industry representative, interview by USITC staff, Dusseldorf, Germany, Apr. 12, 2005; industry representative, interview by USITC staff, Dortmund, Germany, Apr. 12, 2005; and industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[47] Government representatives, interviews by USITC staff, Madrid, Spain, Apr. 15, 2005; and industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

energy projects in developing countries to earn emissions credits under the Kyoto Protocol's Clean Development Mechanism (CDM), which is described in further detail in appendix G of this report.[48]

Demand for wind power services has also grown as a result of the increasing cost-competitiveness of wind power. Two decades ago, the cost of generating 1 kilowatt hour of wind power was approximately 40 cents.[49] By comparison, one source has suggested that such wind power generation costs have declined to 4-6 cents, while a 2003 EWEA estimate suggested that such costs have declined to about 5-10 cents, depending on the average wind speeds at a certain location.[50] The increasing cost-competitiveness of wind power generation is largely a product of the growth in production volume and improvements in technology that have occurred during the last 20 years.[51] For example, during 1989-2001, the cost of wind turbines– as measured by kWh/m^2, or swept rotor area– experienced an overall decrease of 30 percent.[52] In addition, it has been argued that wind power has a significantly smaller environmental impact than many conventional sources of electricity, making wind power more competitive than conventional power on the basis of social cost (defined as the cost of generation plus environmental externalities). For example, EWEA estimates that the external costs of producing 1 kilowatt hour of wind power are approximately 0.06-0.3 cents, while the external costs of coal-fired generation range from 6-22 cents per kilowatt hour.[53]

The viability of a wind power establishment may be a product of several factors. The natural wind conditions at a site are an important element in determining cost competitiveness, as the cost of generating wind power decreases significantly as wind speed increases.[54] The success of a wind power facility also depends on whether the facility has access to the transmission grid.[55] In certain countries, including Germany and Spain, renewable energy is given priority dispatch into the grid.[56] Grid access reportedly may be more difficult in developing countries that lack legislation on this issue.[57] More

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[48] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[49] "Reaping the Wind," *The Financial Express*, Apr. 24, 2005, found at *http://www.financialexpress.com/*, retrieved May 17, 2005.

[50] "Reaping the Wind," *The Financial Express*, Apr. 24, 2005, found at *http://www.financialexpress.com/*, retrieved May 17, 2005; and European Wind Energy Association, "Wind Power Economics," found at *http://www.ewea.org/*, retrieved May 18, 2005.

[51] The European Wind Energy Association , "Wind Energy The Facts: An Analysis of Wind Energy in the EU-25," (Brussels: Corin Millais, Feb. 2004), pp. 7-8.

[52] European Wind Energy Association , "Wind Power Economics," found at *http://www.ewea.org/*, retrieved May 18, 2005.

[53] These data were chosen for the purpose of presenting a consistent comparison based on information from a single source and may differ slightly from information presented elsewhere in this report. The European Wind Energy Association , "Wind Energy The Facts: An Analysis of Wind Energy in the EU-25," (Brussels: Corin Millais, Feb. 2004), pp. 154-156.

[54] American Wind Energy Association, "The Economics of Wind Energy," Feb. 2005, found at *http://www.awea.org/*, retrieved Apr. 4, 2005.

[55] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005; and industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[56] RWE, "REA, Renewable Energy Act (Resolution of the German Parliament)," PowerPoint presentation, Apr. 12, 2005; and government representative, interview by USITC staff, Madrid, Spain, Apr. 15, 2005.

[57] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

specifically, one industry representative reports that Mexico gives priority dispatch to least expensive sources of electricity, putting renewable energy sources at a disadvantage.[58] Further, complicated licensing requirements reportedly may affect the development of wind power projects.[59]

There are several non-institutional factors, however, that may discourage the development of wind power facilities in certain markets. Wind energy does not produce a steady supply of electricity, as wind speeds are variable. Some industry representatives argue that this inconsistency may affect the overall stability of the grid,[60] especially as the share of electricity generated from wind energy increases.[61] In response to this issue, some entities are developing improved methods of wind prediction[62] which will enhance grid operators' ability to balance intermittent wind power with electricity produced from other sources.[63] There are also concerns that the rotating blades of wind turbines kill birds and bats,[64] particularly when wind facilities are located along migratory paths. Although wind energy enjoys public support in certain markets,[65] there are also concerns regarding the visual impact of turbines, especially in popular tourist destinations.[66] The Spanish region of Navarra has placed a moratorium on wind power development because of the large number of turbines currently installed in that area.[67] One industry representative indicated that Australia maintains particularly stringent regulations regarding visual impact, shadows, and noise.[68] Repowering projects also may raise public concern, as this process involves the installation of larger, taller turbines that may require warning lights for aircraft.[69]

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[58] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[59] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.

[60] This has been a particularly contentious issue in Germany, where the German Energy Agency (DENA) has produced a report on the impact of renewable energy on the grid. For more information on the DENA grid study, see *http://www.deutsche-energie-agentur.de/page/index.php?id=2836&type=5&L=4.*

[61] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005; and industry representative, interview by USITC staff, Dortmund, Germany, Apr. 12, 2005.

[62] Government representative, interview by USITC staff, Madrid, Spain, Apr. 15, 2005; and industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[63] The European Wind Energy Association, "Wind Power Technology," found at *http://www.ewea.org/*, retrieved May 23, 2005.

[64] U.S. Department of Agriculture, Natural Resources Conservation Service, "Wind Turbine Impacts on Birds and Bats," found at *http://www.nrcs.usda.gov/*, retrieved June 12, 2005.

[65] Government representative, interview by USITC staff, Madrid, Spain, Apr. 15, 2005.

[66] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005; and industry representative, interview by USITC staff, Florence, Italy, Apr. 7, 2005.

[67] Government representative, interview by USITC staff, Madrid, Spain, Apr. 15, 2005.

[68] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[69] Industry representative, interview by USITC staff, Dortmund, Germany, Apr. 12, 2005.

Entities that generate electricity through the use of wind power are varied, and can include large utilities, small firms, and individual landowners. Spanish firms Iberdrola and EHN Acciona Group, and U.S. utility Florida Power & Light are the world's largest operators of wind power facilities. In 2004, Iberdrola, Florida Power & Light, and EHN Acciona Group each operated 2,400 MW, or 5 percent, of the world's wind power generation capacity. Other key operators of wind power facilities include UK-firm PPM Scottish Power and Japanese-firm Eurus that operate 1,200 MW and 1,140 MW of wind power, respectively.[70] In some countries, electric utilities are the principal operators of wind power facilities, while in other countries, utilities are minimally involved in this market segment. In Germany, for example, utilities are not key players in the wind power generation industry. This is because, until recently, German utilities were state-owned enterprises, and thus ineligible for Germany's feed-in tariff prior to the establishment of the 2003 German Renewable Energy Act.[71] By contrast, electric utilities such as Iberdrola and Endesa are among Spain's largest generators of wind power.[72]

Providers of services incidental to wind energy include large energy and engineering companies that supply a wide range of vertically-integrated products and services, wind farm developers, and small firms that may specialize in the provision of certain niche wind energy services. Turbine manufacturers frequently participate in the wind power services market by providing services related to the sale of their turbines, or by developing wind power facilities at which their turbines are installed. For example, German-firm Siemens provides services such as training, repair, and monitoring services in conjunction with the sale of its turbines,[73] while the Japanese-firm Mitsubishi supplies services such as design, construction, and installation to its customers.[74]

There are a significant number of firms that focus on the development of wind power projects in the world's leading wind power markets. These include BlueSkyWind, Evergreen Wind Power, Windland Inc., and Atlantic Renewable Energy Corp. in the United States; Sea Breeze Power and Western Wind in Canada; and Airtricity, Energia Hidroelectrice de Navarra (EHN), National Wind Power, Renewable Energy Systems, and WindKraft Nord AG in the European Union, among others.[75] There are also a number of small firms providing niche services related to the installation and operation of wind power capacity, such as U.S. firm Hamer Environmental which supplies environmental monitoring and permitting services for wind power projects,[76] and Canadian firm Rowan Williams Davies & Irwin, Inc. (RWDI) which supplies wind

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[70] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 34.

[71] Government and industry representatives, interviews by USITC staff, Berlin, Germany, Apr. 13-14, 2005.

[72] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 34.

[73] Siemens Westinghouse, "Wind Power Services," found at *http:/www.siemenswestinghouse.com/*, retrieved June 13, 2005.

[74] Mitsubishi Power Systems, "Total Project Resources for Expansion, Modernization, and New Plant Construction," found at *http://www.mpshq.com/*, retrieved June 13, 2005.

[75] EcoBusinessLinks, "Wind Farm Development," found at *http://www.ecobusinesslinks.com/*, retrieved June 9, 2005; and The European Wind Energy Association, "Wind Energy The Facts: An Analysis of Wind Energy in the EU-25," (Brussels: Corin Millais, Feb. 2004), p. 126.

[76] Hamer Environmental, "Wind Energy Services," found at *http://www.HamerEnvironmental.com/*, retrieved June 9, 2005.

modeling, mapping, and resource assessment services.[77] Casandra, a subsidiary of Spanish wind turbine manufacturer Gamesa Energia, supplies wind prediction services to both its parent company and outside firms.[78]

Market for equipment and technologies

The global market for wind energy equipment is large and growing. Global sales of wind power equipment increased from about $7 billion in 2002 to $9 billion in 2003,[79] and one industry representative has suggested that such sales could reach $20 billion within 10 years.[80] The market for wind power equipment is dominated by a small number of large, private firms. These firms are largely based in those countries that rank as the world's largest markets for wind power capacity. In 2004, Danish firm Vestas Wind Systems solidified its position as the world's top manufacturer of wind energy equipment by merging with Danish firm NEG Micon, the third largest manufacturer of wind turbines in the world.[81] The newly-merged Vestas Wind Systems accounted for 2,783 MW, or 33 percent, of the 8,513 MW global market for wind power equipment in 2004. Other key suppliers included Gamesa (Spain), Enercon (Germany), GE Wind (United States), Siemens (Denmark), Suzlon (India), REpower (Germany), Mitsubishi (Japan), Ecotécnia (Spain), and Nordex (Germany). Together, these 10 firms accounted for 96 percent of the global market for wind power equipment in 2004.[82] All of these firms manufacture large turbines that are used in utility-scale applications. A number of firms manufacture small turbines that are intended for use at commercial and industrial establishments, farms, and residences. Manufacturers of small turbines are located in a number of markets, and include Bergey Windpower Company, Southwest Windpower, and Wind Turbine Industries Corporation in the United States; Atlantic Orient Corporation in Canada; Windsave in the United Kingdom; and Vaigunth EnerTek (P) Ltd. in India.[83]

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[77] Rowan Williams Davies & Irwin, Inc., "Wind Energy Services," found at *http://www.rwdi.com/*, retrieved June 9, 2005.

[78] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[79] American Wind Energy Association, "Wind Energy Industry Grows at Steady Pace, Adds Over 8,000 MW in 2003," Mar. 2004, found at *http://www.awea.org/*, retrieved June 9, 2005.

[80] "GE Has High Expectations for Wind Turbine Unit Likely to Generate $1 Billion in Revenue for 2003," *Associated Press*, May 15, 2003, found at *http://www.climateark.org/*, retrieved June 9, 2005.

[81] Danish Trade Council, Royal Danish Ministry of Foreign Affairs, "Merger Makes the World's Largest Wind Turbine Manufacturer Even Larger," *Focus Denmark*, Apr. 14, 2004, found at *http://www.um.dk/*, retrieved May 23, 2005.

[82] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, pp. 29-30.

[83] "Manufacturers of Small Wind Generators," found at *http://www.ecobusinesslinks.com/*, retrieved June 10, 2005; American Wind Energy Association, "Manufacturers of Small Wind Turbines," 2004, found at *http://www.awea.org/*, retrieved June 10, 2005; and Windustry, "Small Wind Turbine Resources," Mar. 30, 2005, found at *http://www.windustry.com/*, retrieved June 10, 2005.

Trade and Investment

Wind power services

Official data that specifically reflect cross-border trade and investment in the wind power and wind energy services industries are not available. However, one industry source estimates that cross-border trade in wind power services totaled $828 million in 2004 (see table 4-2 at end of chapter).[84] In general, those countries with large domestic wind power markets also rank among the top exporters and importers of wind power services. Denmark, Germany, and the United States were reportedly the top exporters of wind power services in 2004, accounting for approximately 55 percent, 20 percent, and 13 percent of such exports, respectively. In that same year, Germany, the United States, and Spain were reportedly the world's top importers of wind energy services, respectively accounting for an estimated 42 percent, 11 percent, and 7 percent of such services.[85]

An analysis of wind power services trade estimates suggests that there is a positive correlation (approximately 0.74) between services imports and goods imports.[86] This may suggest that wind power services and equipment are often provided as a single package. This relationship also may suggest that countries that are not globally competitive in the wind power services industry are similarly not competitive in the wind power equipment industry. Additionally, this analysis yields a positive albeit weak correlation[87] between exports of services and GDP per capita perhaps suggesting that there may be a connection between financial resources and the ability to market wind power services abroad. A similar positive relationship[88] is observed between wind power equipment imports and GDP per capita, possibly demonstrating that wealthier countries have a greater ability or desire to purchase costly wind power equipment.

Although some wind power firms have chosen to focus on domestic[89] or regional markets,[90] anecdotal evidence suggests that there is a significant amount of international activity in the market for wind power services. Like cross-border trade, foreign investment activities seem to be dominated by firms that are based in the world's top wind power markets. For example, Spanish firm EHN developed, operates, and owns

[84] The wind energy services estimates produced by McIlvaine Co. reflect engineering, construction, and transportation services provided in conjunction with the establishment of a wind facility. McIlvaine Co., e-mail to USITC staff, June 29, 2005. McIlvaine Co., estimate provided to USITC staff via e-mail, June 25, 2005.

[85] McIlvaine Co., estimate provided to USITC staff via e-mail, June 25, 2005.

[86] Correlation coefficients span values of one to negative one. A coefficient of negative one suggests a perfect inverse relationship; a value of one suggests a perfect positive relationship. USITC calculations based on data obtained from the U.S. Census Bureau and McIlvaine Co.

[87] The correlation coefficient is measured at approximately 0.54.

[88] USITC calculations based on data obtained from the U.S. Census Bureau and McIlvaine Co. The correlation coefficient is measured at approximately 0.56.

[89] For example, one German government representative indicated that German firms are focusing their attention on the domestic market, because of the strength of that country's wind power market. Government representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005.

[90] Industry representatives, interviews by USITC staff, Madrid, Spain, Apr. 18, 2005; and industry representative, interview by USITC staff, Dortmund, Germany, Apr. 12, 2005.

wind power facilities in several foreign markets, including France, Germany, Ireland, and the United States.[91] German-based WindKraft Nord AG has established subsidiaries in France, Italy, and the United States for the purpose of developing wind power projects in those markets.[92] In addition, wind turbine manufacturers often provide services to foreign customers in conjunction with the sale or use of their turbines. For example, Gamesa Energía developed and owns an Illinois facility which generates electricity using 63 Gamesa turbines,[93] and GE Wind provides operation, maintenance, and installation services in conjunction with the sale of its turbines in Germany and Spain.[94]

There are few barriers that specifically apply to trade and foreign investment in the wind power and wind energy services segments in the countries examined in this chapter.[95] Industry representatives indicate that both foreign and domestic electricity suppliers are generally eligible to participate in government incentive programs such as the feed-in tariff programs in both Germany and Spain.[96] However, a number of countries maintain measures that may affect a foreign firm's ability to operate or invest in the wind power industry. One industry representative suggested that there may be some implicit favoritism for domestic electricity producers under Spain's feed-in tariff program.[97] Moreover, a government representative indicated that Germany does not allow foreign entities to derive double benefits from the same electricity sale (for example, benefits under both the German feed-in tariff program and an incentive program in the entity's home market).[98] One industry representative noted that establishments must maintain at least 50-percent local ownership to qualify for the feed-in tariff in Brazil, but indicated that this provision is not a significant obstacle to entering Brazil's renewable energy market because the industry favors joint venture arrangements.[99] Additionally, a certain amount of local content must be employed in wind power development projects in China and Spain.[100] These measures have led certain firms to establish manufacturing facilities in these markets.[101]

As noted in chapter 1, the General Agreement on Trade in Services (GATS) contains no provisions that specifically pertain to the supply of wind power services. However, there are measures that apply separately to incidental services sectors, such as engineering and construction, or horizontally to all services sectors, such as investment measures, which may affect a firms' ability to supply wind power services abroad. These measures are addressed in appendix C of this report. Moreover, one industry representative noted

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[91] EHN, "Projects Implemented," found at *http://www.ehn.es/*, retrieved June 22, 2005.

[92] WindKraft Nord AG, Internet site, found at *http://www.windkraftnord.com/*, retrieved June 13, 2005.

[93] Industry representative, interview by USITC staff, Madrid, Spain, April 18, 2005; and Environmental Law & Policy Center, "Illinois First Wind Farm Opens!," found at *http://www.elpc.org/*, retrieved June 13, 2005.

[94] GE Energy, "Worldwide Capabilities," found at *http://www.gepower.com/businesses/ge_wind_energy/en/worldwide.htm*, retrieved June 10, 2005.

[95] Government representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005.

[96] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 11, 2005; and industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[97] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[98] Government representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005.

[99] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[100] Organization for Economic Cooperation and Development, "Liberalisation of Trade in Renewable Energy and Associated Technologies," May 26, 2005, p. 21.

[101] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.

concern that trade provisions, such as those established under the WTO, may interfere with a country's ability to maintain feed-in tariffs, subsidies, and other preferences for renewable energy.[102]

Equipment and technologies

As noted in chapter 1, equipment incidental to wind power generation is varied, and includes products that are classified in a number of different HS categories. Many of these categories include dual-use products such as gears, switches, and AC adaptors that are used in multiple industries. As such, export and import data on these product categories do not necessarily reflect the nature or extent of merchandise trade in the wind power industry. Only one six-digit HS subheading– HS 8502.31, wind-powered electric generating sets– includes products that are unique to the wind power industry. Data reflecting trade in this HS category indicate that in general, those countries with large domestic wind power markets also rank among the top exporters of wind power equipment. Denmark is the leading global exporter of wind-powered electric generating sets, having accounted for $965 million, or 86 percent, of world exports of such products in 2003 (see table 4-3 at end of chapter).[103] This likely reflects the location of the world's largest manufacturer of wind turbines, Vestas Wind Systems, in Denmark.[104] Other top exporters of these products included Germany, Spain, and the United Kingdom, which respectively accounted for 7 percent, 4 percent, and 2 percent of world exports in this product category in 2003. The United States is the world's largest importer of wind-powered electric generating sets, having accounted for $380 million, or 35 percent, of world imports in 2003. Other top importers of these products included Germany, Japan, and the Netherlands, which respectively accounted for 30 percent, 9 percent, and 6 percent of world imports of such products.[105]

U.S. domestic exports of wind-powered electric generating sets totaled $4.4 million in 2004. Data reflecting such exports indicate that Germany was the only export destination for U.S.-produced wind-powered electric generating sets in 2004. However, an examination of U.S. trade data for the years 1996-2004 reveals that top export markets for these products varied significantly from year to year. Denmark and Japan are major sources of U.S. imports of wind-powered generating sets. Other countries that supplied a significant share of U.S. imports in this product category in 2004 included the United Kingdom and Spain. Overall, U.S. imports of wind-powered generating sets totaled $60.0 million, a significant decrease from 2003 import levels, which was likely due to the decrease in wind farm development resulting from the delay in the renewal of the production tax credit. The strong competitive position of European wind turbine manufacturers and the overseas manufacturing activities of the United States' top wind turbine producer– GE Wind– may explain why U.S. imports of wind-powered generating sets exceed U.S. exports of such products.[106]

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[102] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[103] UN Commodity Trade Statistics Database (UN Comtrade), data retrieved on May 25, 2005.

[104] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, pp. 29-30.

[105] UN Comtrade, found at *http://unstats.un.org/unsd/comtrade/*, data retrieved May 25, 2005.

[106] USITC, Interactive Tariff and Trade DataWeb, found at *http://dataweb.usitc.gov/*, data retrieved July 26, 2005.

Most of the world's top manufacturers of wind turbines export a substantial share of their output to foreign markets. In fact, two top wind turbine manufacturers– Vestas Wind Systems and Siemens– exported more than 98 percent of their total output in 2004, in terms of installed capacity.[107] Several large producers of wind turbines also maintain manufacturing facilities in foreign markets. For example, in addition to the production facilities located in their respective home markets, Vestas maintains manufacturing facilities in Australia, Germany, India, Italy, Norway, Spain, Sweden, and the United Kingdom;[108] GE Wind maintains manufacturing facilities in Germany and Spain;[109] and Enercon maintains production facilities in Brazil, India, Sweden, and Turkey.[110] Firms may choose to establish manufacturing facilities abroad for a number of reasons. Turbines are often built locally because of the high cost of transporting wind energy equipment.[111] Further, a European industry representative indicated that, partially because of the high value of the euro, his firm is planning to establish a manufacturing facility in the United States to improve the firm's competitiveness in that market.[112] The countries chosen for special emphasis in this chapter generally maintain low tariffs on imports of wind-powered generating sets. Among these countries, only China and India maintain tariffs above 5 percent on the subject products (see table 4-3 at end of chapter).

Future Prospects

Industry sources expect that the global market for wind energy will continue to grow rapidly during the next 5-10 years. EWEA predicts that global wind power capacity may grow from 31,400 MW in 2002 to 80,050 MW in 2007 and 160,900 MW in 2012 if government support in the subject countries for wind power continues to increase.[113] BTM Consult also anticipates rapid market growth, predicting that total installed capacity in the global wind power market may increase from 47,912 MW to 117,142 MW during 2004-09.[114] Other trends that may influence the global wind power industry in the future include technological advances, such as the development of larger turbines; rapid increases in offshore wind power capacity; and market consolidation.[115]

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[107] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 31.

[108] Vestas, "Where are the Turbines Manufactured?," found at *http://www.vestas.com/*, retrieved June 2, 2005; and industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.

[109] GE Energy, "Company Snapshot," found at *http://www.gepower.com/*, retrieved June 2, 2005.

[110] Enercon, "Enercon at a Glance," found at *http://www.enercon.de/*, retrieved June 2, 2005.

[111] Organization for Economic Cooperation and Development, *Renewable Energy: Market Policy & Trends in IEA Countries*, (Paris: OECD/IEA, 2004), p. 84; and industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[112] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[113] The European Wind Energy Association, "Wind Energy The Facts: An Analysis of Wind Energy in the EU-25" (Brussels: Corin Millais, Feb. 2004), pp. 230-231.

[114] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 40.

[115] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005; industry representative, interview by USITC staff, Dusseldorf, Germany, Apr. 12, 2005; "Wind Turbines: How Big Can They Get?," *Refocus*, Mar./Apr. 2005, p. 22; and BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 48.

EWEA projects that Europe and North America will continue to dominate the global market for wind power.[116] Several industry observers speculate that Germany and Spain will remain leaders in this industry sector, although market saturation in Germany may slow market growth until offshore wind farms become a more practical option.[117] Other European markets that are expected to develop substantial wind power capacity during the next 5-10 years include Denmark, France, Italy, the Netherlands, Sweden, and the United Kingdom.[118] The U.S. market for wind power could also grow rapidly during the next decade.[119]

There is significant potential for the development of wind power in low- and middle-income economies, and such countries could realize reduced dependence on foreign oil and other economic benefits from the installation of renewable energy capacity.[120] For example, Morocco– a country with abundant wind resources– is interested in expanding its wind power capacity because of the country's high dependence on imported fuel.[121] Based on Morocco's relatively high wind speeds, the Centre de Développement des Energies Renouvelables (CDER) estimates that the country could accommodate 6,000 MW of wind power capacity.[122] Other developing countries that are interested in expanding their wind power capacity include India, which is already the world's fifth-largest wind energy market in terms of installed capacity, as well as Brazil, China, Egypt, and Turkey.[123] In addition, certain countries such as China and Brazil reportedly could become manufacturers of renewable energy products, including those products used in the wind energy industry.[124] Such trends may lead to increases in both supply and demand for wind energy in developing-country markets.

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[116] European Wind Energy Association , "Future Prospects for Wind Power Markets," found at *http://www.ewea.org/*, retrieved May 18, 2005.

[117] Ibid.; industry representative, interview by USITC staff, Dortmund, Germany, Apr. 12, 2005; and "European Wind: Offering Growth Amidst Diverse Market Conditions," *Repower*, Mar./Apr. 2005, pp. 31, 35.

[118] European Wind Energy Association, "Future Prospects for Wind Power Markets," found at *http://www.ewea.org/*, retrieved May 18, 2005.

[119] Ibid. and industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[120] Timothy Gardner, "Developing Nations Ripe for Wind, Solar Energy, U.N. Says," *Reuters*, Apr. 15, 2005, found at *http://enn.com*, retrieved May 23, 2005.

[121] European Wind Energy Association, "Future Prospects for Wind Power Markets," found at *http://www.ewea.org/*, retrieved May 18, 2005; and "ADB Should Fund Surveys to Assess Wind Energy Potentials in Morocco, CDER," *ArabicNews.com*, Oct. 30, 2004, found at *http://www.arabicnews.com/*, retrieved June 7, 2005.

[122] Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, "Energy-policy Framework Conditions for Electricity Markets and Renewable Energies: 21 Country Analyses," June 2004, p. 143, found at *http://www2.gtz.de/wind/english/*, retrieved June 7, 2005.

[123] BTM Consult ApS, *World Market Update 2004, Forecast 2005-2009*, Mar. 2005, p. 20; and European Wind Energy Association, "Future Prospects for Wind Power Markets," found at *http://www.ewea.org/*, retrieved May 18, 2005.

[124] Timothy Gardner, "Developing Nations Ripe for Wind, Solar Energy, U.N. Says," *Reuters*, Apr. 15, 2005, found at *http://www.enn.com*, retrieved May 23, 2005.

Table 4-1
Characteristics of selected markets for wind power and wind energy services

Country	Market size & characteristics	On-grid and off-grid wind power applications	Key market participants
Australia	- Australia has substantial wind resources, and the country's market for wind power is growing rapidly. A significant amount of wind power capacity is currently in the planning or construction phase. However, the future of this market is unclear because of policy uncertainty at the federal level.[1] - In 2004, wind power accounted for approximately 780 GWh, or less than 1 percent, of total electricity generation in Australia.[1] - Australia had 421 MW of installed capacity in 2004.[2]	-Australia has at least seven large wind facilities that provide power to the grid,[3] and some owners of smaller systems provide excess power to the grid.[4] Small turbines are also used in off-grid applications, such as to supply power in remote areas.[3]	- There are 17 different entities that own and operate commercial wind power facilities in Australia. Entities that own and/or develop wind farms in Australia include utilities, government-owned electricity generators, public firms, and private investors. A variety of public and private firms supply related services.[1]
Brazil	-Brazil has substantial wind resources,[5] and the country's government is promoting wind power development. As of 2003, nine wind facilities were operating in Brazil and an additional 88 projects had received approval.[6] - As of Feb. 2004, wind power accounted for about 0.03 percent of Brazil's energy capacity.[5] - Brazil had 31 MW of installed capacity in 2004.[2]	- Brazil has a small number of grid-connected wind farms.[7] Wind power is also used in some off-grid applications, such as water pumping and battery charging.[8]	- An Enercon (Germany) subsidiary– Wobben Windpower– developed and operates two of Brazil's wind power facilities. Together, these facilities account for about half of Brazil's wind power capacity.[7] Coelce– a Brazilian electricity supply firm– has been involved in a wind measurement project and in the development of two 30 MW wind power facilities.[7]

See footnotes at end of table.

Table 4-1—*Continued*
Characteristics of selected markets for wind power and wind energy services

Country	Market size & characteristics	On-grid and off-grid wind power applications	Key market participants
Canada	-Canada has substantial wind resources. There are programs in place at the federal and provincial levels that support wind power development, and the country's wind power market has experienced rapid but uneven growth in recent years.[1] - Canada generates about 850 million GWh of wind power annually.[9] - Canada had 444 MW of installed capacity in 2004[2] and approximately 570 MW of installed capacity by July 2005.[9]	- Canada has a number of wind power facilities that provide power to the grid.[10] In addition, Canada also has a market for off-grid wind power capacity that is used to generate power for remote communities, individual households, navigational beacons, and other purposes.[11]	-Vision Quest Windelectric generates electricity at five wind power facilities with a combined capacity of about 114 MW. Vision Quest also generates power through joint ventures with Vestas (3 MW) and ENMAX (75 MW) Together, these seven facilities account for about 34 percent of Canada's wind power capacity. Other companies that account for significant shares of Canada's wind power capacity include Axor (17 percent), 3Ci and Creststreet Asset Management Ltd. (9 percent), Northland Power Income Fund (9 percent),and Canadian Hydro Developers, Inc. (9 percent).[12] - A number of firms provide wind energy services in Canada, including Atlantic Orient Canada Inc., Renewable Energy Services Ltd., Sea Breeze Power Corp., and Wind Dynamics Incorporated, among many others.[13]
China	- China has substantial wind resources.[14] Since 1990, wind power capacity in China has increased rapidly,[15] and a significant amount of wind power capacity is currently under development.[14] - Wind power accounted for less than 0.2 percent of China's electricity generation capacity in 2005.[14] - China had 769 MW of installed capacity in 2004.[2]	- There were 40 grid-connected wind facilities in China by year-end 2003.[15]	-Vestas (Denmark), Gamesa (Spain), and Goldwind (China) were the top three wind turbine manufacturers active in the Chinese market during 2004.[2] Each of these firms provides services related to the development and/or operation of wind power facilities, such as construction and project planning.[16]
Costa Rica	- Costa Rica is the largest wind power market in Latin America in terms of installed capacity.[2] -In 2001, wind power accounted for approximately 4 percent of total power generation in Costa Rica.[17] - Costa Rica had 79 MW of installed capacity in 2004.[2]	-As of 2001, Costa Rica had three wind farms that supplied electricity to the grid.[17]	-Enel Latin America (a subsidiary of Enel GreenPower, Italy) operates a wind power facility in Costa Rica. Zilkha Renewable Energy (United States) and EnXco (Denmark) have also provided wind power services in Costa Rica.[18]

See footnotes at end of table.

Table 4-1—*Continued*
Characteristics of selected markets for wind power and wind energy services

Country	Market size & characteristics	On-grid and off-grid wind power applications	Key market participants
Egypt	- Egypt's market for wind power is small. However, Egypt has significant wind resources, particularly in the area near the Red Sea. The Egyptian government aims to increase non-hydro renewable power generation with the goal that these renewable energy sources will account for 3 percent of Egyptian electricity generation by 2010.[19] - Egypt had 46 MW of installed capacity in 2004.[2]	-Egypt has a least one large wind facility (Zafarana Wind Park) that provides electricity to the grid.[19]	-Egypt's Zafarana wind facility is operated by the New and Renewable Energy Authority (NREA).[19] -Danish firm Riso Wind Consult has provided wind energy services in Egypt.[20] Other firms that have developed, or have won contracts to develop wind power capacity in Egypt include, Gamesa (Spain), Nordex (Germany), Vestas (Denmark), and local engineering firms.[21]
European Union:			
- Denmark	- Denmark has had a commercial wind power market for about 25 years, and during that time, the country's wind power industry has experienced substantial technological development and growth in generation capacity. In some areas, onshore sites for wind power capacity have become limited; thus, repowering may be a principal source of market growth in the future.[1] -Wind energy accounted for 6,580 GWh, or approximately 18.5 percent, of Denmark's total power generation in 2004.[1] - Denmark had 3,083 MW of installed capacity in 2004.[2]	- Denmark has a substantial amount of commercial wind-power capacity, and recently, smaller household systems have been installed in this country.[22]	- Firms that own, operate, and develop wind power facilities in Denmark include DONG, Elsam, and Energi E2.[1] - Wind turbine maintenance and repair is provided by wind turbine manufacturers, such as Vestas and Siemens, as well as by independent firms, such as DanService A/S and DWP Mølleservice A/S. There are also a number of firms that provide other services related to wind energy, such as construction, insurance, and transportation. Consultancies such as BTM Consult ApS, Elsam Engineering, E&M data, Tripod ApS, and WEA ApS, are active in the Denmark's wind power market.[1]

See footnotes at end of table.

Table 4-1—*Continued*
Characteristics of selected markets for wind power and wind energy services

Country	Market size & characteristics	On-grid and off-grid wind power applications	Key market participants
- Germany	- Germany is the world's largest market for wind power in terms of generation capacity.[2] Growth in the German onshore wind power sector has slowed, due to market saturation. However, the repowering and offshore wind power sectors will likely increase in the future.[23] -In 2004, wind power accounted for 25 TWh, or about 4 percent, of German electricity consumption.[24] - Germany had 16,649 MW of installed capacity in 2004.[2]	- Germany has a substantial amount of commercial wind power capacity.[1] - Private investors are the key buyers of wind farms. These entities purchase wind facilities for use as tax shelters.[25]	- Wind development firms are responsible for the development and operation of approximately 90 percent of German wind farms, which are typically sold to private investors. Over 100 developers are active in the German wind power market. Each of these developers accounts for 4 percent or less of the German wind power market, and none of these firms ranks among the 10 largest wind power developers in the world. Key wind power developers in Germany include Energiekontor, Enertrag/Prokon Nord, Ostwind, Plambeck, P&T Technology, Umweltkontor, WKN, and WPD.[25] - Utilities are not key participants in the German wind power industry.[25] -Enercon (Germany), Vestas (Denmark), and REpower (Germany) were the top three wind turbine manufacturers active in the German market during 2004.[2] Each of these firms provides services related to the development and/or operation of wind power facilities, such as maintenance, construction, and project planning.[26]
- Spain	-Spain has a large and rapidly growing wind power industry largely due to regulatory stability with regard to wind power prices and grid stability.[1] -Wind energy accounted for 14,178 GWh, or about 5.7 percent, of total power generation in Spain during 2004.[1] - Spain had 8,263 MW of installed capacity in 2004.[2]	- The Spanish wind power market is dominated by large-scale utility projects.[25] However, there seems to be some potential for, and use of, wind turbines in off-grid applications.[27]	- Wind farms are principally developed by wind farm owners. Utilities– such as EHN and Iberdrola, among others– are the key participants in this market segment.[25] -Gamesa (Spain), Vestas (Denmark), and GE Wind (U.S.) were the top three wind turbine manufacturers active in the Spanish market during 2004.[2] Each of these firms provides services related to the development and/or operation of wind power facilities, such as maintenance, installation, and project planning.[28]

See footnotes at end of table.

Table 4-1—*Continued*
Characteristics of selected markets for wind power and wind energy services

Country	Market size & characteristics	On-grid and off-grid wind power applications	Key market participants
India	- India's wind power capacity has increased rapidly in recent years, making this country the largest developing-country market for wind energy, and the fifth-largest market for such energy in the world.[29] Wind power incentives and grid improvements have contributed to the rapid growth of India's wind energy market.[30] - Only a small share of India's energy needs are supplied through the use of wind power.[31] - India had 3,000 MW of installed capacity in 2004.[2]	- Commercial wind power projects accounted for approximately 1,869 MW of the wind power capacity installed in India by March 2003.[32]	-Suzlon (India), Vestas (Denmark), and Enercon (Germany) were the top three wind turbine manufacturers active in the Indian market during 2004.[2] Each of these firms provides services related to the development and/or operation of wind power facilities, such as maintenance, installation, and project planning.[16]
Japan	-During Apr. 2003-Mar. 2004, wind power accounted for approximately 987.8 GWh, or 0.1 percent, of total power generation on Japan.[1] - Japan had 991 MW of installed capacity in 2004.[2]	- Japan has a substantial amount of commercial wind power capacity.[1] Wind power is also used in at least one battery charging operation in Japan.[33]	- Vestas (Denmark), Mitsubishi (Japan), and GE Wind (U.S.) were the top three wind turbine manufacturers active in the Japanese market during 2004.[2] Each of these firms provides services related to the development and/or operation of wind power facilities, such as maintenance, installation, and project planning.[34]
Mexico	- Mexico's market for wind power is very small, despite the presence of substantial wind resources.[35] -Wind power accounts for a negligible share of total electricity generation in Mexico.[1] - Mexico had 3 MW of installed capacity in 2004.[2]	-Mexico has both grid-connected wind power capacity, such as the La Venta facility in Oaxaca,[36] and off-grid wind power capacity, such as the system in San Juanico, Baja California Sur which consists of 10 Bergey Windpower Co. (United States) turbines.[37]	- The state-owned Comisión Federal de Electricidad (CFE) owns both of Mexico's wind power installations.[38]
Morocco	-The Moroccan market for wind energy is small, with only 2 large wind power facilities. However, there is significant potential for market growth, and it is expected that two additional wind farms will begin operations during 2006-2007.[39] - In 2003, wind power accounted for 203 GWh, or 1 percent, of total electricity generation in Morocco.[40] - Morocco had 54 MW of installed capacity in 2004.[1]	- Morocco has 2 large wind farms that contribute to the country's overall electricity supply. In addition, Morocco has a large number of off-grid power generation facilities and pumps that are fueled by wind energy.[47]	Office National de l'Electricite (ONE)– Morocco's national electricity company– operates a 3.5 MW wind farm using Enercon (Germany) turbines, and plans to develop two additional wind farms with capacities of 140 MW and 60 MW. Compagnie Eolienne de Détroit (CED) operates a 50 MW wind farm using Vestas (Denmark) turbines.[41]

See footnotes at end of table.

Table 4-1—*Continued*
Characteristics of selected markets for wind power and wind energy services

Country	Market size & characteristics	On-grid and off-grid wind power applications	Key market participants
New Zealand	- New Zealand has substantial wind resources.[42] However, as of 2001, wind energy accounted for only about 0.5 percent of total power generation in New Zealand.[43] - As of May 2005, New Zealand had five wind facilities with capacities ranging from 0.23 MW to 90 MW.[44] New Zealand had 167 MW of installed capacity in 2004.[2]	-New Zealand has 5 grid-connected wind facilities, as well as numerous off-grid turbines that provide electricity to households, small boats, and at least 1 small business.[45]	- Domestic wind farm developers that are active in the New Zealand market include state owned firms such as Genesis Energy[46] and Meridian Energy,[47] and publically-listed firms such as TrustPower,[48] and Windflow Technology,[49] among others.[44]
United States	- The United States is the world's third-largest wind power market in terms of installed capacity.[2] Interest in the U.S. wind power industry is growing among utilities and other electricity firms. However, growth in this U.S. industry reportedly is constrained by insufficient grid capacity, problematic transmission rules, and inconsistent tax incentives at the federal level.[50] - In 2004, wind power accounted for 19.6 TWh, or approximately 0.5 percent, of total U.S. electricity generation.[1] - The United States had 6,750 MW of installed capacity in 2004.[2]	-The United States has a substantial number of grid-connected wind power facilities, many of which sell electricity to the local/regional utility. Wind power is also used in off-grid applications in the United States.[51]	- In 2004, American Electric Power, Florida Power and Light, Pacific Power Marketing, and Shell were among the top investors in the U.S. wind power industry. Communities and passive investors are increasingly involved in the U.S. wind energy market.[1] - Firms that developed wind power capacity in the United States during 2004 included Cielo Wind Power, Clipper Wind, enXco, Florida Power & Light, and Invenergy.[1] - GE Wind (United States), Mitsubishi (Japan), and Vestas (Denmark), were the top three wind turbine manufacturers active in the U.S. market during 2004.[2] Each of these firms provides services related to the development and/or operation of wind power facilities, such as maintenance, installation, and project planning.[52]

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Table 4-2
Extent of wind power and wind energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Measures affecting trade
Australia	Industry estimates suggest that Australian imports of wind power services totaled $29 million in 2004. It is estimated that Australia recorded no exports of wind power services in 2004.[1]	Australian firm GHD– which provides a number of services integral to the development of a wind power facility– has established a presence in several foreign markets, including Chile, China, Indonesia, Malaysia, New Zealand, the Philippines, Qatar, Thailand, Vietnam, the United Arab Emirates, and the United States.[2] Suzlon– an Indian manufacturer of wind turbines– maintains an office in Australia through which the company provides a number of wind energy services such as project implementation and marketing.[3] Danish Wind Turbine manufacturer Vestas[4] has established an office in Australia.[5] German wind turbine manufacturer REpower has established an office in Australia through which it provides wind power services.[6] Spanish wind turbine manufacturer Gamesa provides services through several of the offices it has established in overseas markets, including Australia.[7]	No measures that specifically affect trade and foreign investment in the wind power or wind energy services sectors have been identified.
Brazil	Industry estimates suggest that Brazilian imports of wind power services totaled $1 million in 2004. It is estimated that Brazil recorded no exports of wind power services in 2004.[8]	No evidence that Brazilian firms participate in foreign wind power generation or services markets has been identified. Spanish utility Iberdrola is pursuing wind power development in Brazil.[9] Danish Wind Turbine manufacturer Vestas[10] has established an office in Brazil.[11] Spanish wind turbine manufacturer Gamesa provides services through several of the offices it has established in overseas markets, including Brazil.[12]	Establishments reportedly must maintain at least 50-percent local ownership in order to qualify for the feed-in tariff in Brazil.[13]
Canada	Industry estimates suggest that Canadian imports of wind power services totaled $31 million in 2004. It is estimated that Canada recorded no exports of wind power services in 2004.[14]	No evidence that Canadian firms participate in foreign wind power generation or services markets has been identified. Danish Wind Turbine manufacturer Vestas[15] has established an office in Canada.[16] German wind turbine manufacturer REpower has established an office in Canada, but it is not clear if the firm provides wind power services through this office.[17]	Quebec reportedly requires the use of a certain share of local content in wind power development projects.[18]

See footnotes at end of table.

Table 4-2—*Continued*
Extent of wind power and wind energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Measures affecting trade
China	Industry estimates suggest that Chinese imports of wind power services totaled $30 million in 2004. It is estimated that China recorded no exports of wind power services in 2004.[19]	Although Chinese wind turbine manufacturer Goldwind has established relationships with foreign firms, it does not seem to be a supplier of turbines and related services in foreign markets.[20] China is interested in working with European firms to develop public-private partnerships for the purpose of building wind farms.[21] Australian firm GHD– which provides a number of services integral to the development of a wind power facility– has established a presence in China.[22] Suzlon– an Indian manufacturer of wind turbines– maintains an office in China through which the company provides a number of wind energy services such as project implementation and marketing.[23] German wind turbine manufacturer REpower has established an office in China through which it provides wind power services.[24] Danish wind turbine manufacturer Vestas[25] has established an office in China.[26]	Locally manufactured products must account for a substantial share of the equipment used in the development of wind power facilities. Beginning in 2005, this local content requirement stood at 70 percent.[27]
Costa Rica	Official and industry sources do not report discreet data on Costa Rican trade in wind power services.	No evidence that Costa Rican firms participate in foreign wind power generation or services markets has been identified. Several foreign firms have provided services related to the development and operation of wind power facilities in Costa Rica, such as Global Energy Concepts (United States),[28] Sterling Energy (United States),[29] enXco (Denmark),[30] Zilkha Renewable Energy (United States),[31] and Energía Global International (acquired by Italian-firm Enel in 2001).[32]	No measures that specifically affect trade and foreign investment in the wind power or wind energy services sectors have been identified.
Egypt	Industry estimates suggest that Egyptian imports of wind power services totaled $2 million in 2004. It is estimated that Egypt recorded no exports of wind power services in 2004.[33]	No evidence that Egyptian firms participate in foreign wind power generation or services markets has been identified. In 2004, Gamesa (Spain) won a contract under which it will provide and install 100 turbines.[34] Other foreign firms that have provided wind energy services in Egypt include Global Energy Concepts (United States).[35]	No measures that specifically affect trade and foreign investment in the wind power or wind energy services sectors have been identified.

See footnotes at end of table.

Table 4-2—*Continued*
Extent of wind power and wind energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Measures affecting trade
European Union:			
Denmark	It is estimated that Denmark recorded no imports of wind power services in 2004. Industry estimates suggest that Danish exports of wind power services totaled $452 million in 2004.[36]	Danish Wind Turbine manufacturer Vestas[37] has established offices in a number of different foreign markets including Argentina, Australia, Brazil, Canada, China, France, Germany, Greece, Italy, Japan, the Netherlands, New Zealand, Poland, Portugal, Spain, Sweden, the United Kingdom, and the United States.[38] Siemens, a German turbine manufacturer, maintains a service department in Denmark.[39] Suzlon– an Indian manufacturer of wind turbines– has established its international headquarters in Denmark. Suzlon provides a number of wind energy services such as marketing, operations, project implementation, and maintenance, among others.[40]	Foreign participation in Denmark's wind power market reportedly may be affected by complicated legislation and the availability of certain key documents in Danish only.[41]
Germany	Industry estimates suggest that German imports of wind power services totaled $347 million in 2004, while German exports of such services totaled $168 million.[42]	Siemens, a German turbine manufacturer, maintains service departments in Denmark, the United Kingdom, and the United States.[43] German wind turbine manufacturer REpower has established offices in Australia, China, France, Greece, Spain, and the United Kingdom through which it provides wind power services.[44] German wind turbine manufacturer Enercon maintains sales and services facilities in a large number of overseas markets.[45] As of December 2003, Spanish firm EHN owned two wind power facilities in Germany.[46] Suzlon– an Indian manufacturer of wind turbines– maintains a research and development facility in Germany.[47] U.S. firm GE Energy has provided services such as operation, installation and maintenance of wind turbines in Germany.[48] Danish wind turbine manufacturer Vestas[49] has established an office in Germany.[50] Wind turbines produced by Japanese manufacturer Mitsubishi[51] are installed in Germany.[52]	The German Renewable Energy Act of 2004 does not permit renewable energy providers to benefit from Germany's feed-in tariff if they have already received benefits under another country's incentive program for the same sale.[53]

See footnotes at end of table.

Table 4-2—*Continued*
Extent of wind power and wind energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Measures affecting trade
Spain	Industry estimates suggest that Spanish imports of wind power services totaled $61 million in 2004, while Spanish exports of such services totaled $70 million.[54]	There is evidence that Spanish firms are active in foreign wind power and related services markets. For example, Spanish firm EHN has developed, operates, and owns wind power facilities in several foreign markets, including France, Germany, Ireland, and the United States.[55] Spanish utility Iberdrola has developed a strategic partnership with Rokas Group, Greece's principal operator of wind power facilities; is pursuing project development in Brazil, France, Mexico, Portugal, and the United Kingdom; and has agreed to purchase four French wind farms.[56] Spanish wind turbine manufacturer Gamesa provides services through several of the offices it has established in overseas markets, including Australia, Brazil, and the United States.[57] There are several foreign firms that are active in the Spanish wind power industry. For example, Japanese firm Eurus Energy has developed wind projects in Asturias and Galacia.[58] Danish wind turbine manufacturer Vestas[59] has established an office in Spain.[60] U.S. firm GE Energy has provided services such as operation, installation and maintenance of wind turbines in Spain.[61] German wind turbine manufacturer REpower has established an office in Spain through which it provides wind power services.[62]	Local and regional governments reportedly require that wind power development projects use a certain share of locally produced wind turbines.[63] There reportedly may be some implicit favoritism for domestic electricity producers under Spain's feed-in tariff program.[64] The Spanish region of Navarra has placed a moratorium on wind power development.[65]
India	Industry estimates suggest that Indian imports of wind power services totaled $29 million in 2004, while Indian exports of such services totaled $5 million.[66]	U.S. development firms including Cannon, Optimum Power, Sea-West, and Zond are currently making an effort to enter the Indian wind power market.[67] Wind turbines produced by Japanese manufacturer Mitsubishi[68] are installed in India.[69] Suzlon– an Indian manufacturer of wind turbines– maintains offices in Australia, China, Denmark, and the United States through which the company provides a number of wind energy services such as marketing, operations, project implementation, and maintenance, among others. Suzlon also maintains a research and development facility in Germany.[70]	No measures that specifically affect trade and foreign investment in the wind power or wind energy services sectors have been identified. Joint ventures with Indian firms are required in order for foreign firms to participate in the provision of construction, architecture, and engineering services in India.[71]

See footnotes at end of table.

Table 4-2—*Continued*
Extent of wind power and wind energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Measures affecting trade
Japan	Industry estimates suggest that Japanese imports of wind power services totaled $1 million in 2004, while Japanese exports of such services totaled $20 million.[72]	Japanese firm Eurus Energy has developed wind projects in several foreign markets, including Italy, Spain, the United Kingdom, and the United States.[73] Wind turbines produced by Japanese manufacturer Mitsubishi[74] are installed in several foreign markets, including Germany, India, Mexico, Peru, Portugal, the United Kingdom, and the United States.[75] Danish wind turbine manufacturer Vestas[76] has established an office in Japan.[77]	No measures that specifically affect trade and foreign investment in the wind power or wind energy services sectors have been identified.
Mexico	Industry estimates suggest that Mexican imports of wind power services totaled $8 million in 2004. It is estimated that Mexico recorded no exports of wind power services in 2004.[78]	Evidence that Mexican firms participate in foreign wind power generation or services markets has not been identified. Vestas (Denmark) and Gamesa (Spain) turbines are installed at Mexico's two commercial wind power facilities,[79] and one Mitsubishi (Japan) wind turbine is installed in Mexico,[80] but evidence that these firms maintain an ongoing presence in the Mexican market for the purpose of providing wind power services has not been identified. Spanish-firm Iberdrola has indicated that it plans to participate in the Mexican wind power market.[81]	No measures that specifically affect trade and foreign investment in the wind power or wind energy services sectors have been identified.
Morocco	Industry estimates suggest that Moroccan imports of wind power services totaled $1 million in 2004. It is estimated that Morocco recorded no exports of wind power services in 2004.[82]	Evidence that Moroccan firms participate in foreign wind power generation or services markets has not been identified. French firm La Compagnie du Vent developed a 50.4 MW wind facility in Morocco, and was chosen to construct a 10.2 MW facility which will supply electricity to a cement works.[83]	No measures that specifically affect trade and foreign investment in the wind power or wind energy services sectors have been identified.

See footnotes at end of table.

Table 4-2—*Continued*
Extent of wind power and wind energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Measures affecting trade
New Zealand	Industry estimates suggest that New Zealand's imports of wind power services totaled $4 million in 2004. It is estimated that New Zealand recorded no exports of wind power services in 2004.[84]	No evidence that New Zealand firms participate in foreign wind power generation or services markets has been identified. Danish wind turbine manufacturer Vestas [85] has established an office in New Zealand.[86]	No measures that specifically affect trade and foreign investment in the wind power or wind energy services sectors have been identified.
United States	Industry estimates suggest that U.S. imports of wind power services totaled $93 million in 2004, while U.S. exports of such services totaled $110 million.[87]	U.S. firm GE Energy has provided services such as operation, installation and maintenance of wind turbines in Germany and Spain, and has supplied development services through partnerships with customers in Sweden, France, and the United Kingdom.[88] There are several foreign firms that are active in the U.S. wind power industry. For example, Japanese firm Eurus Energy has developed wind projects in California and Oregon.[89] PPM Energy– which develops, maintains, and operates wind power facilities in the United States – is a subsidiary of UK-based Scottish Power.[90] As of December 2003, Spanish firm EHN owned one wind power facility in the United States.[91] Australian firm GHD– which provides a number of services integral to the development of a wind power facility– has established a presence in the United States.[92] Siemens, a German turbine manufacturer, maintains service department in the United States.[93] Suzlon– an Indian manufacturer of wind turbines– maintains an office in the United States through which the company provides a number of wind energy services such as marketing, maintenance and project support.[94] Spanish wind turbine manufacturer Gamesa provides services through several of the offices it has established in overseas markets, including the United States.[95] Wind turbines produced by Japanese manufacturer Mitsubishi [96] are installed in the United States.[97] Danish wind turbine manufacturer Vestas [98] has established an office in the United States.[99]	An industry representative reports that a U.S. firm has patented a technology that is in wide use in Europe, creating difficulties for foreign firms.[100]

[1] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.
[2] GHD, "Wind Energy Services," found at *http://www.ghd.com.au/*, retrieved June 13, 2005.
[3] Suzlon, "Locations, Global Footprint," Internet page, found at *http://www.suzlon.com/*, retrieved June 22, 2005.
[4] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas' services activities in particular foreign markets is unclear. Vestas, "Vestas Wind Project Planning," found at *http://www.vestas.com/*, retrieved June 13, 2005.

[5] Vestas, “Vestas World Wide,” found at *http://www.vestas.com/*, retrieved June 22, 2005.

[6] REpower, “REpower International,” found at *http://www.repower.de/*, retrieved June 22, 2005.

[7] Gamesa, “Gamesa on the World,” found at *http://www.gamesa.es/*, retrieved June 22, 2005.

[8] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[9] Iberdrola, “2004 Results,” found at *http://www.iberdrola.com/*, retrieved June 22, 2005; and Iberdrola, “Iberdrola reaches an agreement to buy wind farms from the German developer P&T/EECH Group,” press release, found at *http://www.iberdrola.com/*, retrieved June 24, 2005.

[10] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas’ services activities in particular foreign markets is unclear. Vestas, “Vestas Wind Project Planning,” found at *http://www.vestas.com/*, retrieved June 13, 2005.

[11] Vestas, “Vestas World Wide,” found at *http://www.vestas.com/*, retrieved June 22, 2005.

[12] Gamesa, “Gamesa on the World,” found at *http://www.gamesa.es/*, retrieved June 22, 2005.

[13] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[14] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[15] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas’ services activities in particular foreign markets is unclear. Vestas, “Vestas Wind Project Planning,” found at *http://www.vestas.com/*, retrieved June 13, 2005.

[16] Vestas, “Vestas World Wide,” found at *http://www.vestas.com/*, retrieved June 22, 2005.

[17] REpower, “REpower International,” found at *http://www.repower.de/*, retrieved June 22, 2005.

[18] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.

[19] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[20] Goldwind Science & Technology, “Technical Exchange” and “International Cooperation,” found at *http://www.goldwind.cn/*, retrieved June 23, 2005.

[21] Stephen Leahy, “Change in the Chinese Wind,” *Wired.com*, Oct. 4, 2004, found at *http://www.energybulletin.net/*, retrieved June 15, 2005.

[22] GHD, “Wind Energy Services,” found at *http://www.ghd.com.au/*, retrieved June 13, 2005.

[23] Suzlon, “Locations, Global Footprint,” Internet page, found at *http://www.suzlon.com/*, retrieved June 22, 2005.

[24] REpower, “REpower International,” found at *http://www.repower.de/*, retrieved June 22, 2005.

[25] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas’ services activities in particular foreign markets is unclear. Vestas, “Vestas Wind Project Planning,” found at *http://www.vestas.com/*, retrieved June 13, 2005.

[26] Vestas, “Vestas World Wide,” found at *http://www.vestas.com/*, retrieved June 22, 2005.

[27] Organization for Economic Cooperation and Development (OECD), Liberalisation of Trade in Renewable Energy and Associated Technologies,” May 26, 2005, p. 21.

[28] Global Energy Concepts, “International Project Experience,” 2005, found at *http://www.globalenergyconcepts.com/*, retrieved June 23, 2005.

[29] Sterling Energy,” Wind Power Management Services,” 1999-2000, found at *http://www.sterling-energy.com/*, retrieved June 22, 2005.

[30] EnXco, “Costa Rica,” found at *http://www.enxco.com/*, retrieved June 23, 2005.

[31] Zilkha Renewable Energy, “What We’ve Done: Costa Rica, Tierras Morenas,” 2002, found at *http://www.zilkha.com/*, retrieved June 23, 2005.

[32] U.S. Department of Energy (DOE), Office of Policy and International Affairs, *Energy and Water for Sustainable Living: A Compendium of Energy and Water Success Stories,* 2002, found at *http://www.pi.energy.gov/library/ewsl.html*, retrieved June 22, 2005; and Enel GreenPower, “Enel Latin America,” 2002-2003, found at *http://www.enelgreenpower.enel.it/*, retrieved June 23, 2005.

[33] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[34] “New Wind Farm Tender Issued,” *Middle East Economic Digest*, Mar. 4, 2005, found at *http://www.amcham.org.eg/BSAC/WatchBulletin/Issues/Mar1505.asp*, retrieved June 23, 2005.

[35] Global Energy Concepts, “International Project Experience,” 2005, found at *http://www.globalenergyconcepts.com/*, retrieved June 23, 2005.

[36] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[37] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas’ services activities in particular foreign markets is unclear. Vestas, “Vestas Wind Project Planning,” found at *http://www.vestas.com/*, retrieved June 13, 2005.

[38] Vestas, “Vestas World Wide,” found at *http://www.vestas.com/*, retrieved June 22, 2005.

[39] Siemens, “Wind Power Services,” found at *http://www.powergeneration.siemens.com/*, retrieved June 22, 2005.

[40] Suzlon, “Locations, Global Footprint,” Internet page, found at *http://www.suzlon.com/*, retrieved June 22, 2005.
[41] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.
[42] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.
[43] Siemens, “Wind Power Services,” found at *http://www.powergeneration.siemens.com/*, retrieved June 22, 2005.
[44] REpower, “REpower International,” found at *http://www.repower.de/*, retrieved June 22, 2005.
[45] Enercon, “Enercon at a Glance,” 2004, found at *http://www.enercon.de/*, retrieved June 20, 2005.
[46] EHN, “Projects Implemented,” found at *http://www.ehn.es/*, retrieved June 22, 2005.
[47] Suzlon, “Locations, Global Footprint,” Internet page, found at *http://www.suzlon.com/*, retrieved June 22, 2005.
[48] GE Energy, “Worldwide Capabilities,” 1997-2005, found at *http://www.gepower.com/*, retrieved June 20, 2005.
[49] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas’ services activities in particular foreign markets is unclear. Vestas, “Vestas Wind Project Planning,” found at *http://www.vestas.com/*, retrieved June 13, 2005.
[50] Vestas, “Vestas World Wide,” found at *http://www.vestas.com/*, retrieved June 22, 2005.
[51] In addition to its manufacturing activities, Mitsubishi provides services related to the development and/or operation of wind power facilities, such as installation, construction, and design. The extent of Mitsubishi’s services activities in the foreign markets listed in this section is unclear. Mitsubishi Power Systems, “Total Project Resources for Expansion, Modernization and New Plant Construction,” found at *http://www.mpshq.com/*, retrieved June 13, 2005.
[52] Mitsubishi Power Systems, “MHI Contributes to Global Environment,” found at *http://www.mpshq.com/*, retrieved June 22, 2005.
[53] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 13, 2005.
[54] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.
[55] EHN, “Projects Implemented,” found at *http://www.ehn.es/*, retrieved June 22, 2005.
[56] Iberdrola, “2004 Results,” found at *http://www.iberdrola.com/*, retrieved June 22, 2005; and Iberdrola, “Iberdrola reaches an agreement to buy wind farms from the German developer P&T/EECH Group,” press release, found at *http://www.iberdrola.com/*, retrieved June 24, 2005.
[57] Gamesa, “Gamesa on the World,” found at *http://www.gamesa.es/*, retrieved June 22, 2005.
[58] Eurus Energy, “Wind Power Projects,” 2004, found at *http://www.eurus-energy.com/*, retrieved June 22, 2005.
[59] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas’ services activities in particular foreign markets is unclear. Vestas, “Vestas Wind Project Planning,” found at *http://www.vestas.com/*, retrieved June 13, 2005.
[60] Vestas, “Vestas World Wide,” found at *http://www.vestas.com/*, retrieved June 22, 2005.
[61] GE Energy, “Worldwide Capabilities,” 1997-2005, found at *http://www.gepower.com/*, retrieved June 20, 2005.
[62] REpower, “REpower International,” found at *http://www.repower.de/*, retrieved June 22, 2005.
[63] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.
[64] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.
[65] Government representative, interview by USITC staff, Madrid, Spain, Apr. 15, 2005. This measure does not apply specifically to wind power development by foreign entities. However, it is included in this table as it may affect market access for service suppliers in this industry segment.
[66] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.
[67] Indian Renewable Energy Development Agency Ltd., “Windpower in India,” found at *http://solstice.crest.org/renewables/ireda/wind.html*, retrieved May 17, 2005.

[68] In addition to its manufacturing activities, Mitsubishi provides services related to the development and/or operation of wind power facilities, such as installation, construction, and design. The extent of Mitsubishi's services activities in particular foreign markets is unclear. Mitsubishi Power Systems, "Total Project Resources for Expansion, Modernization and New Plant Construction," found at *http://www.mpshq.com/*, retrieved June 13, 2005.

[69] Mitsubishi Power Systems, "MHI Contributes to Global Environment," found at *http://www.mpshq.com/*, retrieved June 22, 2005.

[70] Suzlon, "Locations, Global Footprint," Internet page, found at *http://www.suzlon.com/*, retrieved June 22, 2005.

[71] United States Trade Representative (USTR), *2004 National Trade Estimate Report on Foreign Trade Barriers*, 2004, p. 222.

[72] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[73] Eurus Energy, "Wind Power Projects," 2004, found at *http://www.eurus-energy.com/*, retrieved June 22, 2005.

[74] In addition to its manufacturing activities, Mitsubishi provides services related to the development and/or operation of wind power facilities, such as installation, construction, and design. The extent of Mitsubishi's services activities in the foreign markets listed in this section is unclear. Mitsubishi Power Systems, "Total Project Resources for Expansion, Modernization and New Plant Construction," found at *http://www.mpshq.com/*, retrieved June 13, 2005.

[75] Mitsubishi Power Systems, "MHI Contributes to Global Environment," found at *http://www.mpshq.com/*, retrieved June 22, 2005.

[76] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas' services activities in particular foreign markets is unclear. Vestas, "Vestas Wind Project Planning," found at *http://www.vestas.com/*, retrieved June 13, 2005.

[77] Vestas, "Vestas World Wide," found at *http://www.vestas.com/*, retrieved June 22, 2005.

[78] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[79] International Energy Agency (IEA), *IEA Wind Energy Annual Report*, 2004, p.158, found at *http://www.ieawind.org/*, retrieved June 21, 2005.

[80] Mitsubishi Power Systems, "MHI Contributes to Global Environment," found at *http://www.mpshq.com/*, retrieved June 22, 2005.

[81] "Spain's Iberdrola Buys Half of Greece's Rokas," *Reuters*, Dec. 2, 2004, found at *http://www.planetark.com/*, retrieved June 21, 2005.

[82] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[83] "La Compagnie du Vent to build 10.2 MW Tetouan Wind Farm," *Windpower Monthly*, Sept. 2004, found at *http://www.windpower-monthly.com/*, retrieved May 26, 2005.

[84] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[85] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas' services activities in particular foreign markets is unclear. Vestas, "Vestas Wind Project Planning," found at *http://www.vestas.com/*, retrieved June 13, 2005.

[86] Vestas, "Vestas World Wide," found at *http://www.vestas.com/*, retrieved June 22, 2005.

[87] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005.

[88] GE Energy, "Worldwide Capabilities," 1997-2005, found at *http://www.gepower.com/*, retrieved June 20, 2005.

[89] Eurus Energy, "Wind Power Projects," 2004, found at *http://www.eurus-energy.com/*, retrieved June 22, 2005.

[90] PPM Energy, "What We Do," 2005, found at *http://www.ppmenergy.com/*, retrieved June 22, 2005.

[91] EHN, "Projects Implemented," found at *http://www.ehn.es/*, retrieved June 22, 2005.

[92] GHD, "Wind Energy Services," found at *http://www.ghd.com.au/*, retrieved June 13, 2005.

[93] Siemens, "Wind Power Services," found at *http://www.powergeneration.siemens.com/*, retrieved June 22, 2005.

[94] Suzlon, "Locations, Global Footprint," Internet page, found at *http://www.suzlon.com/*, retrieved June 22, 2005.

[95] Gamesa, "Gamesa on the World," found at *http://www.gamesa.es/*, retrieved June 22, 2005.

[96] In addition to its manufacturing activities, Mitsubishi provides services related to the development and/or operation of wind power facilities, such as installation, construction, and design. The extent of Mitsubishi's services activities in the foreign markets listed in this section is unclear. Mitsubishi Power Systems, "Total Project Resources for Expansion, Modernization and New Plant Construction," found at *http://www.mpshq.com/*, retrieved June 13, 2005.

[97] Mitsubishi Power Systems, "MHI Contributes to Global Environment," found at *http://www.mpshq.com/*, retrieved June 22, 2005.

[98] In addition to its manufacturing activities, Vestas provides services related to the development and/or operation of wind power facilities, such as maintenance and project management. The extent of Vestas' services activities in particular foreign markets is unclear. Vestas, "Vestas Wind Project Planning," found at *http://www.vestas.com/*, retrieved June 13, 2005.

[99] Vestas, "Vestas World Wide," found at *http://www.vestas.com/*, retrieved June 22, 2005.

[100] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.

Table 4-3
Trade in wind-powered electric generating sets (HS 8502.31)

Country	Imports, 2003[1]	Exports, 2003[1]	Import tariff rate
Australia	$9.7 million	$1.5 million	Wind-powered AC generating sets with an output of more than 500 Kva- free; other wind-powered generating sets - 5%.
Brazil	$2 million	None in 2003 (exports of such products totaled $1.8 million in 2002)	Not available
Canada	$31.3 million	$430,443	Free
China	$31.3 million	$15,879	General rate - 30%; MFN rate - 8 %. Such imports are also subject to a VAT of 17%.
Costa Rica	$11,180	None	Ad valorem rate - Free; such imports are subject to a sales tax of 13% and a 1% fee associated with Law 6946.
Egypt	None	None	Not available
European Union:			
Denmark	$25,889	$965 million	Wind-powered electric generating sets for use in civil aircraft - Free; Other wind-powered electric generating sets - 2.7%.
Germany	$319.1 million	$78.9 million	Wind-powered electric generating sets for use in civil aircraft - Free; other wind-powered electric generating sets - 2.7% .
Spain	$11 million	$44.8 million	Wind-powered electric generating sets for use in civil aircraft - Free; other wind-powered electric generating sets - 2.7%.
India	$1.2 million	$771,400	15%
Japan	$100.3 million	$1.3 million	Free
Mexico	$52,327	None (exports of such products totaled $7,110 in 2002)	Not available
Morocco	$54,055	None	Ad valorem rate of 2.5%.
New Zealand	$12.6 million	$935	Wind-powered electric generating sets of an output of at least 10 KW - Free; wind-powered electric generating sets with under 10 KW of output - 5%.
United States	$379.7 million	$745,682	2.5%

[1] UN Commodity Trade Statistics Database (UN Comtrade), data retrieved on May 25, 2005.

Source: Compiled by USITC staff.

CHAPTER 5
SOLAR ENERGY

This chapter provides information on developed- and developing-country markets for solar power and solar heating and cooling services and equipment. Countries examined include Australia, Brazil, Canada, China, France, Germany, India, Japan, Mexico, Morocco, Spain, and the United States for solar power – and concentrating solar power – (CSP) photovoltaic (PV) and solar heating and cooling; Costa Rica, Italy, the Netherlands, South Africa, South Korea, and Thailand for solar power; and Austria, Greece, Israel, and Turkey for solar heating and cooling. These countries were chosen for special emphasis based on the size of their solar energy markets, and based on the USTR's request for information on developed- and developing-country markets, as well as information on markets with which the United States has established, or is in the process of negotiating, a free-trade agreement.[1]

Overview

Solar PV is the fastest growing solar technology deployed, especially in the world's leading producing and consuming markets, Japan and Germany. The governments of these countries have instituted effective policies and incentive programs in recent years to stimulate and sustain demand for affordable installation of residential solar power systems, especially those tied to an electricity distribution network, while also substantially endowing research funding to advance solar cell technologies and strengthen national solar energy services and equipment industries. Improvements in solar cell efficiency and production cost reductions averaging 5 percent per year for at least a decade on solar modules have helped solar energy to begin to be more competitive with other forms of renewable energy and conventional sources of power supplied to the electricity grid, and to be the low-cost alternative energy source for off-grid rural electrification in certain developing country markets such as China. Trade in services usually is in conjunction with the purchase of solar PV equipment, and investments in solar PV firms and operations abroad have increased substantially in recent years.

Solar heating and cooling is an established, yet evolving, market that is highly dependent upon government incentives to create demand and that tends to receive a relatively lower level of such incentives compared to solar PV in many developed-country markets. China is the world leader in use and growth of solar heating.

Concentrating solar power (CSP) systems vary widely in power output, as the smallest supply households in developing countries with a few hours of electricity per day, while the largest systems linked to power plants operate commercially solely in southern California. Large scale CSP projects under development at additional sites in the United

[1] For more information on the USTR's request, see appendix A of this report.

States and abroad in developed and developing countries with plentiful radiant energy are likely to enable CSP systems to supply more power commercially within this decade.

Technologies and Methods[2]

Active solar technologies[3] using radiant energy from the sun may provide electricity to a grid, may be used locally without connection to a grid, or may heat or cool air or water. Two principal solar technologies are used in electricity production– solar PV and CSP. Radiant energy may be converted directly into solar PV electricity, or may be collected and concentrated by means of CSP technologies. Solar technologies other than those concerned with electricity production chiefly use the sun's thermal properties to heat water used in buildings or swimming pools.

Solar PV systems are based on small semiconductor devices known as PV or solar cells, which produce small flows of about 0.5 volts of electricity when in contact with sunlight.[4] PV cells made mostly of silicon[5] are grouped together in panels known as modules, which in turn are linked in larger panel groupings known as an array

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[2] Information on technologies and methods is derived from a variety of sources, as noted, especially U.S. Department of Energy, National Renewable Energy Laboratory (NREL), *Renewable Energy Summary 2003*, found at *http://www.nrel.gov/*, retrieved Feb. 17, 2005; and DOE, Energy Efficiency and Renewable Energy Clearinghouse, *Overview of Thermal Energy Technologies*, found at *http://www.eere.energy.gov/consumerinfo/tech_reports.html*, retrieved Mar. 22, 2005.

[3] Passive solar energy technology which incorporates building designs and construction materials to maximize the heating and cooling effects of radiant energy without the use of mechanical equipment are outside the scope of this report.

[4] For an explanation of the photovoltaic effect, see DOE, Energy Efficiency and Renewable Energy Clearinghouse, "Solar Glossary of Terms," found at *http://www.eere.energy.gov/solar/solar_glossary.html*.

[5] About four-fifths of PV cell production for land-based applications is based on silicon wafer technologies, while the remaining newer technologies are either based on thin silicon or thin-film semiconductor materials rather than silicon, such as copper indium selenide, copper indium sulfide, and cadmium telluride, in order to reduce manufacturing costs and ease the current worldwide under-supply of silicon wafers for solar PV use. On-going research explores the convergence of silicon-based and alternative-material cell technologies, such as cells made of plastics or organic materials. Sarasin, *Solar Energy - Sunny Days Ahead?*, report, Nov. 2004, pp. 9-11, provided to USITC staff via e-mail, Mar. 21, 2005; NREL, *Renewable Energy Summary 2003*; F. Roca and J. Carabe, "New R&D Trends in Europe on Thin-Silicon Photovoltaics," paper, undated; and industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

(figure 5-1).[6] A power-processing center or controller receives electricity from the PV cells and dispatches it along several pathways, such as to batteries that may store power for use when solar energy is absent or insufficient; to converters for operations requiring direct current (DC);[7] or to inverters that change DC into alternating current (AC) used in most household and office electrical devices.[8]

CSP technologies concentrate solar energy to temperatures 50 to 5,000 times higher than at the point of collection. A series of reflective mirrors concentrates the solar energy to reach such high temperatures, whereupon superheated fluid in a receiver located at the point of concentration produces steam that drives turbines or small engines and attached electrical generators at nearby power plants. Such technologies may generate several kilowatts in a remote system for a single household or hundreds of megawatts in a grid-linked system serving thousands of households and businesses. CSP technologies convert up to 30 percent of solar energy to electricity, making it nearly twice as efficient as other solar systems. The three main types of CSP technologies include parabolic trough, power tower, and dish/engine systems. Parabolic trough systems[9] (figure 5-2) have operated in California's Mojave Desert for more than a decade at the world's only commercial power plants[10] that use CSP technology in electricity generation.[11] Parabolic trough systems are perceived as the most mature CSP technology with demonstrated reliability, although they receive lower solar concentrations, resulting in lower peak

[6] Arrays may be stationary on the ground or configured on movable structures to track the sun's rays throughout the day and adjust for seasonal variations in the sun's position. NREL, *Renewable Energy Summary 2003*. In addition to the PV cells, module components typically include a top surface of coated glass or plastic to protect and convey light to the cells; an encapsulant such as ethyl vinyl acetate to hold together the top surface, PV cells, and rear surface and to further protect the cells; a rear layer commonly made of a thin polymer to protect the module from gases and water; electrical connections made of metal to connect the cells and move electrons from the cells and electricity from the modules; and a metal frame, usually of aluminum, which holds the module elements together and which is anchored to support the array. Renewable Energy Policy Project (REPP), *Solar PV Development: Location of Economic Activity*, technical report, Jan. 2005, found at *http://www.crest.org/*, retrieved Mar. 21, 2005.

[7] DC is the same current as that formed when sunlight reaches the PV cell.

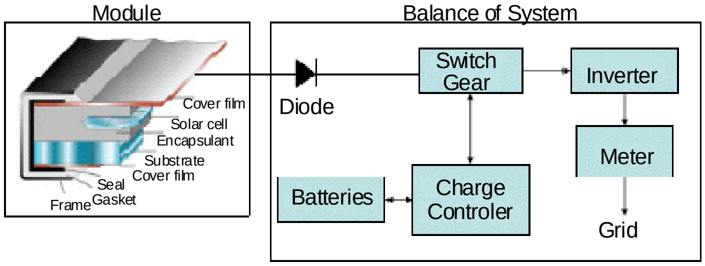
[8] The remainder of a PV system includes meters to measure the amount of energy generated, switch gears to direct the electricity flow, and copper wiring to connect the PV system to the utility grid or battery.

[9] An expanse of parabola-shaped mirrors concentrates sunlight onto an equally long metallic receiver tube filled with oil or other heat transfer fluids. Some parabolic trough systems adjust to the sun's movements throughout the day, maximizing the radiant effect. Pollution Probe, *Primer on the Technologies of Renewable Energy*, Sept. 2003, p. 60, found at *http://www.pollutionprobe.org/*, retrieved Feb. 17, 2005. Parabolic trough systems typically can use substitute fuel sources, such as natural gas, to produce electricity in the plant during periods without sunlight. Such plants, known collectively as hybrids for their capacity to utilize renewable and nonrenewable fuels depending on radiant energy conditions, are able to dispatch power as needed. NREL, *Renewable Energy Summary 2003*, and DOE, *Overview of Thermal Energy Technologies*.

[10] Nine such systems, ranging in size from 14 MW to 80 MW each, currently generate a total of 354 MW. John F. Myles, "An Overview of the Concentrating Solar Power Industry," conference presentation, Orlando, FL, Dec. 2, 2004, found at *http://www.solargenix.com/*, retrieved Mar. 2, 2005.

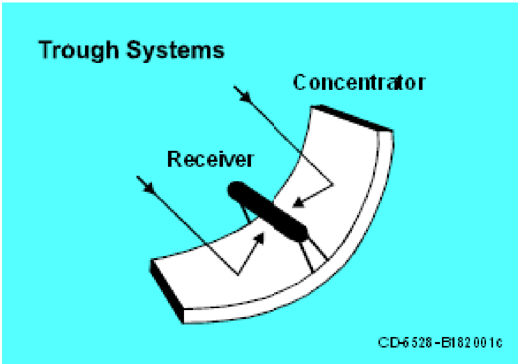
[11] DOE, *Overview of Thermal Energy Technologies*.

Figure 5-1
Photovoltaic system components



Source: Renewable Energy Policy Project, "Solar PV Development: Location of Economic Activity," *http://www.crest.org/*, retrieved Aug. 15, 2005.

Figure 5-2
Solar parabolic trough



Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy, "Overview of Solar Thermal Technologies," *http://www.eere.energy.gov/ consumerinfo.tech_reports.html*, retrieved Aug. 15, 2005.

efficiency and higher costs relative to other CSP technologies.[12] Significant improvements have been achieved in system performance, longevity, and cost reduction during the commercial operation of trough systems, such that additional similarly powered, commercially viable plants are scheduled to be operational in the near term.[13] Power towers are considered to be the CSP system most likely to become commercially available,[14] and are unique owing to their thermal storage capacity, which allows for the dispatch of power at any time.[15] Two experimental power towers have been built in California, one of which is considered a likely prototype for commercial deployment of power towers in the United States and Spain in the near future.[16] Moreover, a 500 MW solar power tower project is currently in the final financial-viability stage of development in Australia.[17] Dish/engine[18]– or parabolic dish – systems are modular and deemed the most efficient of all solar technologies.[19] As with the parabolic trough system, the dish/engine system can employ an alternative fuel source for electricity production during periods without sunlight. Prototypes of parabolic dish systems may be found in the United States and abroad, including in developing countries.

Solar water heater systems for residential and commercial buildings are primarily used in several European countries, China, and Israel, and have two primary

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[12] Ibid.

[13] For example, a 50-MW plant powered by parabolic trough systems currently is under construction in Boulder City, NV. Sandia National Laboratories, "Research and Development Advances in Concentrating Solar Power," found at *http://www.energylan.sandia.gov/sunlab/research.htm*, retrieved Mar. 23, 2005, and Solar Energy Industry Association (SEIA), found at *http://www.seia.org/learn/energytypes.asp#csp*, retrieved Mar. 23, 2005.

[14] This system includes a central receiver filled with molten salt or a synthetic oil and mounted atop a tower that is the focal point for a circular array of swiveling, flat-plane mirrors called heliostats. NREL, *Renewable Energy Summary 2003*, and DOE, *Overview of Thermal Energy Technologies*.

[15] The molten salt retains considerable heat even during periods without sunlight, so as to provide the plant with the ability to quickly raise the temperature of the stored salt to the level required to produce steam for electricity without resorting to other alternative fuel sources. Thermal energy storage capabilities also enable power plants, through more efficient load management, to operate with smaller, less expensive turbines than may otherwise be needed. Sandia National Laboratories, "Research and Development Advances in Concentrating Solar Power."

[16] Principal factors in determining the commercialization of power tower systems include the development of low-cost heliostats and the successful demonstration of the ability of molten-salt technology to remain operable over time. DOE, *Overview of Thermal Energy Technologies*.

[17] The technology, developed by Australian firm EnviroMission and partners, cleared the mainly technical pre-feasibility stages of development in 2004. EnviroMission Ltd., "Pre-Feasibility Success Signals Solar Tower Go Ahead," news release, Feb. 3, 2004, found at *http://www.enviromission.com.au,* retrieved June 22, 2005.

[18] This system uses parabolic dish-shaped glass mirrors to focus radial energy to heat fluid inside a thermal receiver positioned at the focal point of the dish. The heated fluid is used to power a small engine/generator, micro-turbine, or high-concentration PV module mounted to the receiver. Most often, a Stirling engine is used, in which heat drives pistons and rotates the engine's crankshaft to drive a generator that produces electric power. Such dish systems can be used individually or configured in groups for higher power generation requirements. Sandia National Laboratories, "CSP Technologies Overview," found at *http://www.energylan.sandia.gov/sunlab/overview.htm*, retrieved Mar. 23, 2005.

[19] DOE, *Overview of Thermal Energy Technologies*.

components–solar collectors[20] and water storage tanks (figure 5-3).[21] Heating of outdoor swimming pools is the most widely used application of solar water heating technologies in the United States, Australia, and a few other countries.[22] The pool is linked to the solar collector through the pool's own water filtration system and serves as the storage tank for such systems. Active solar systems used to heat air circulated in residential or commercial office buildings may resemble those used in water heaters. However, air temperature heating requirements in industrial applications vary widely, from constant, near-normal room temperatures used in crop drying, to high heat-intensity applications through the use of concentrating solar heating systems such as parabolic trough collectors.

Market Size and Characteristics

Market for Solar PV Services

Estimates of the generation of electricity from solar PV vary widely, although it is generally agreed that electricity generated from solar power is concentrated in a small number of countries. Solar power's contribution to total electricity production was believed to be negligible, at no more than 0.1 percent, in 2003.[23] Hence, certain countries report data on electricity generation from solar PV combined with that generated from certain other renewable energy sources. According to an industry source, revenues from solar power generation were estimated at $332 million, in 2004.[24] Japan was the global leader in revenues from solar power generation, accounting for 37 percent of the estimated world total, followed by Germany (21 percent), and the United States (15 percent). The same source estimated that engineering and construction management services revenues related to solar power implementation worldwide totaled $2.8 billion in 2004. The leading country markets for such services included Japan (43 percent), Germany (26 percent), and the United States (5 percent).

[20] DOE, Energy Efficiency and Renewable Energy Clearinghouse, "Solar Heating Basics," found at *http://www.eere.energy.gov/solar/sh_basics.html*, retrieved May 13, 2005. Solar collectors usually contain a reflective glass or plastic cover known as a glazing, through which sunlight passes to heat liquid circulating in flow tubes. Water or a heat-transfer fluid is heated to temperatures below 180 degrees Fahrenheit in solar collectors. The other components of a commonly used flat-plate solar heating collector include a dark-colored absorber plate, insulation, and a metal box to house the collector's components. Tubing connects the collector to the storage tank and usually electrical pumps, valves, and controllers that regulate the flow of heated liquid through the collector to the storage tank.

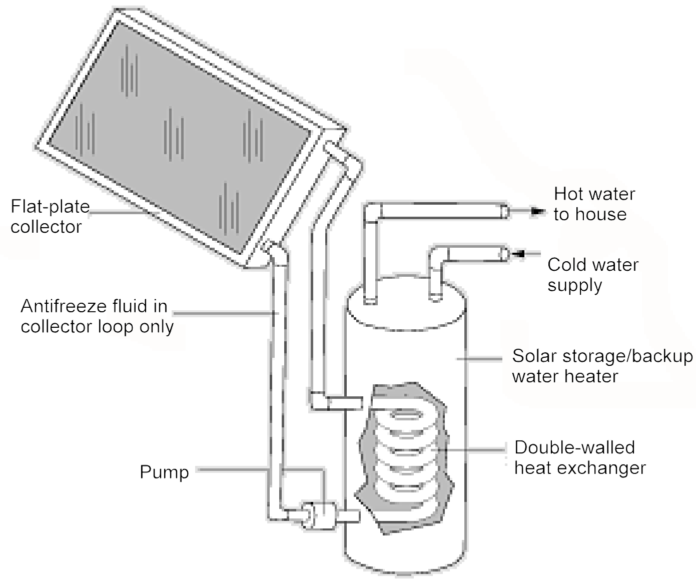
[21] Although conventional water heaters may be used in some solar systems, storage tanks typically used in solar water heating systems are larger and more insulated than conventional water heaters. In solar water systems that circulate liquids other than water through collectors, storage tanks contain coiled pipes, known as heat exchangers, that transfer heat to the potable water in the tank.

[22] Outdoor pool solar heating systems use unglazed collectors, while heating for indoor pools and hot tubs uses glazed collectors to attain higher water temperatures than outdoor pools. Solar collectors for pool systems may be installed on rooftops or on the ground.

[23] Robert Peltier, "Photovoltaics in a New Light," *Power*, Jan./Feb. 2004, p. 35.

[24] McIlvaine Co., estimates provided to USITC staff via e-mail, June 21, 2005. Estimates include electricity generated from solar PV and CSP systems, whether or not the systems are connected to grids.

Figure 5-3
Active, closed-loop solar water heater



Active, indirect systems are often used in climates with freezing temperatures.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy, found at *http://www.eere.energy.gov/*, retrieved, Aug. 15, 2005.

The principal indicator of progress in the world market for solar PV is installed capacity, expressed in megawatts (MW). Cumulative installed solar PV capacity in the world doubled to 2,400 MW during the 4 years ending in 2003.[25] During 1994-2003, world solar PV installed capacity increased 33 percent per year, on average. Solar PV market growth is evident in on- and off-grid applications. The proportion of grid-connected cumulative installed capacity increased from 29 percent in 1992 to 78 percent in 2003 among the 26 member countries of the International Energy Agency (IEA).[26] Even so, off-grid applications accounted for the majority of total cumulative and newly installed solar PV capacity in about one-half of reporting countries in 2003. Moreover, in most developing countries, solar PV is chiefly deployed in remote locations where connection to the grid is not technically or economically feasible. Table 5-1, at the end of this chapter, summarizes market and industry characteristics in selected developed and developing country markets for solar PV.

Japan, Germany, and the United States are the world's largest solar PV consuming markets, in terms of cumulative installed capacity. Japan's market is more than double that of Germany and more than three times larger than the U.S. market. During 1992-2003, cumulative solar PV installations in Germany and Japan, respectively, increased

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[25] European Photovoltaic Industry Association and Greenpeace, *Solar Generation: Solar Electricity for Over 1 Billion People and 2 Million Jobs by 2020*, Oct. 2004, p. 5, found at *http://www.epia.org/05Publications/EPIAPublications.htm*, retrieved Feb. 24, 2005.

[26] International Energy Agency, *PV Power*, Dec. 2004, found at *http://www.iea-pvps.org/*, retrieved Mar. 18, 2005.

by 48 percent and 41 percent annually, on average, while systems installed in the United States rose by 18 percent.[27]

Since 1997, when it surpassed the United States, Japan has been the world leader in cumulative solar PV installations. In 2003, Japan's capacity totaled 860 MW, about 48 percent of IEA countries' installed capacity. Japan has a goal of increasing installed capacity to 4,820 MW by 2010, representing a five-fold increase. Similarly, an industry source estimated that Japan led all countries in terms of expenditures on engineering and construction services related to solar power in 2004, accounting for 43 percent of the $2.8 billion world total.[28] Contributing to the success of solar PV in Japan,[29] the Japanese Government instituted net metering[30] favorable to small distributed PV systems connected to the national grid; provided subsidies to reduce PV installation costs;[31] and implemented high-profile programs resulting in 50,000 to 60,000 residential rooftop PV deployments per year.[32] The government also stimulated market development for more than a decade through sustained and extensive research funding, directly benefitting the Japanese solar PV industry.[33] Publicly funded research and development (R&D) continues work to improve efficiency of cells, modules, and production processes; reduce costs of advanced PV cells; and pursue innovation in next-generation PV cells by 2030. Increasing private-sector R&D is expected to focus mainly on reducing PV system design, manufacturing, and installation costs.[34] As of 2005, the Japanese market for small residential grid-connected solar PV power is believed to be sufficiently

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[27] IEA, *Trends in Photovoltaic Applications: Survey Report of Selected IEA Countries Between 1992 and 2003*, "Table 2: Cumulative Installed PV Power in IEA PVPS Countries: Historical Perspective," Sept. 2004, found at *http://www.oja-services.nl/iea-pvps/isr/index.htm*, retrieved Mar. 18, 2005. For more information, see IEA, *Renewable Energy: Market and Policy Trends in IEA Countries, 2004*, found at *http://www.iea.org/*, retrieved Feb. 24, 2005.

[28] McIlvaine Co., estimates provided to USITC staff via e-mail, June 21, 2005.

[29] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[30] Under net metering laws, a feed-in tariff guarantees that utilities will pay retail or premium prices for dispatched power made available to the grid through household solar PV systems.

[31] DOE, Energy Information Administration, "Policies to Promote Non-Hydro Renewable Energy in the United States and Selected Countries," Feb. 2005, found at *http://www.eia.doe.gov/fuelrenewable.html*, retrieved Mar. 18, 2005.

[32] Such deployments especially included those for building-integrated PV systems in modular newly constructed dwellings. Government of Japan, New Energy and Industrial Technology Development Organization (NEDO), *Overview of 'PV Roadmap Toward 2030' (PV2030)*, June 2004, found at *http://www.nedo.go.jp/engish/archives/161027/pv2030roadmap.pdf*, retrieved Mar. 30, 2005.

[33] IEA, *Trends in Photovoltaic Applications: Survey Report of Selected IEA Countries Between 1992 and 2003.*

[34] NEDO, *Overview of 'PV Roadmap Toward 2030' (PV2030);* and hearing testimony before the Commission, Apr. 19, 2005, p. 112.

established to withstand the expiration of subsidies[35] after fiscal year 2006.[36] Japanese Government and industry sources anticipate sustained PV market growth exceeding 30 percent annually as new subsidies begin in fiscal year 2007 on larger system installations such as in multi-family dwellings and for commercial and industrial consumers.

Germany's solar PV market development program has increased substantially in recent years. Solar PV installed capacity in Germany increased from less than 50 MW in 1997 to 416 MW in 2003.[37] One industry source estimates that Germany accounted for 26 percent, or $720 million, of total world expenditures on engineering and construction services in connection with solar power in 2004.[38] German Government legislation has stimulated such development, including the 100,000 Solar Roofs Program during 1999-2003 and the Renewable Energy Sources Act (EEG) of 2000, revised in 2004 upon conclusion of the solar roof program.[39] The incentives in these measures for residential and business consumers included a guaranteed 20-year buy-back rate[40] for solar-generated power provided to the grid, and a low-interest-rate on 10-year loans with repayments waived for the first two years to partially offset installation costs.[41] These incentives, coupled with exponential production increases, improved manufacturing methods and component efficiencies, and increased R&D funds and collaborations, enabled German PV system suppliers to reduce prices by 20 percent during the 100,000 Solar Roofs Program.[42]

In the United States, cumulative installed solar PV capacity totaled 275 MW in 2003, the majority of which was not connected to an electricity grid.[43] About 300,000 U.S. households have solar electricity, more than triple the total 5 years ago.[44] In 2004, it was estimated that the United States accounted for 5 percent of total world expenditures on engineering and construction services in connection with solar power.[45] Unlike in Japan

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[35] The cost of installing residential PV systems in Japan decreased from $26.54 per watt in the year ending in March 1995 to $6.50 per watt in the year ending in March 2004. Dave Algoso, Mary Braun, and Bernadette Del Chiaro, "Bringing Solar to Scale: California's Opportunity to Create a Thriving, Self-Sustaining Residential Solar Market," Apr. 2005, p. 19, found at *http://environmentcalifornia.org/*, retrieved May 6, 2005.

[36] The Japanese Government extended the incentive program three years beyond its original expiration date in 2003 in response to substantial consumer demand. Donald W. Aitken, "Transitioning to a Renewable Energy Future," paper prepared for International Solar Energy Society, 2003, p. 32, found at *http://whitepaper.ises.org/*, retrieved Mar. 21, 2005.

[37] EPIA and Greenpeace, *Solar Generation: Solar Electricity for Over 1 Billion People and 2 Million Jobs by 2020*, p. 22.

[38] McIlvaine Co., estimates provided to USITC staff via e-mail, June 21, 2005.

[39] Industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.

[40] The feed-in tariff is financed by a small electricity surcharge on all electricity consumers rather than by a subsidy. The buy-back rate decreases by 5 percent per year during 2001-2020, and is applicable to newly installed systems. The annual reductions in the buy-back rate are intended to approximate anticipated reductions in PV system prices resulting from increases in PV installations. EPIA and Greenpeace, *Solar Generation: Solar Electricity for Over 1 Billion People and 2 Million Jobs by 2020*, pp. 23 and 46.

[41] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[42] EPIA and Greenpeace, *Solar Generation: Solar Electricity for Over 1 Billion People and 2 Million Jobs by 2020*, p. 23.

[43] IEA, *Trends in Photovoltaic Applications: Survey Report of Selected IEA Countries Between 1992 and 2003*.

[44] "Solar Power Heats Up," *Wall Street Journal*, June 2, 2005, p. D1.

[45] McIlvaine Co., estimates provided to USITC staff via e-mail, June 21, 2005.

and Germany, no nationwide net metering incentive program exists in the United States.[46] Instead, individual U.S. states have various tax and rebate incentives to promote renewable energy.[47] Thirty-nine states mandate net metering, resulting in diverse solar PV market development among states. California alone– by far the most experienced and active state in implementing incentives to develop and deploy solar power– is the third largest world market for solar PV installations. To date, incentives in the United States for solar PV installations have applied chiefly to residential consumers retrofitting their homes, although legislation currently under consideration in California targets solar deployment in new construction. U.S. funding for R&D in solar PV technologies has lagged behind such funding in Japan since the early 1990s.[48] Recently enacted U.S. energy legislation is likely to increase demand for solar technologies in the United States, as the legislation provides for credits to businesses for the installation of solar power technologies.[49]

Significant recent increases in solar PV deployments have also occurred in certain developing countries, especially China, which added 60 percent of the country's current solar PV capacity during 2002-03. Various foreign aid programs have stimulated deployment of small, household-sized PV systems and have provided technical assistance and training in developing countries such as India, Kenya, and Morocco.[50]

Numerous services are related to the development and provision of solar PV electricity. Research is conducted by government and private laboratories, scientific institutes, universities, and private-sector companies.[51] Materials R&D involves all of these players and is especially dependent on government support. Industry sources state that although materials R&D is important, commercialization advances depend mostly on production process R&D.[52] Solar cell and module producers' ability to reduce prices and meet substantially higher demand is dependent partly on equipment manufacturers' ability to increase production of cells and modules and to facilitate reductions in services costs, such as those for PV system installation. Once PV modules are produced, services from private-sector distributors, system integrators, electrical designers and engineers, and

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[46] Sarasin, *Solar Energy - Sunny Days Ahead?*, p. 22.

[47] Foreign representatives of the solar PV industry cited several U.S. States, such as California, New Jersey, Oregon, and Texas, as having adopted regulations and incentives favorable to solar PV development. Nevertheless, several foreign representatives stated that incentives for electricity production from solar PV systems as provided in Germany and Spain are simpler and more effective than subsidies in U.S. states, which defray system installation costs but have no relation to electricity production. Industry representatives, interviews by USITC staff, Bonn, Germany, Apr. 11, 2005, and Madrid, Spain, Apr. 18, 2005.

[48] NREL, National Center for Photovoltaics, "Photovoltaics: New Energy for the New Millennium," found at *http://www.nrel.gov/ncpv/*, retrieved Apr. 18, 2005.

[49] "Tax Writers Unveil Details of $14.6 Billion Package of Credits," E&E Publishing LLC, found at *http://www.eenews.net/*, retrieved July 30, 2005.

[50] IEA, *16 Case Studies on the Deployment of Photovoltaic Technologies in Developing Countries*, IEA-PVPS T9-07:2003, Sept. 2003, found at *http://www.oja-services/iea-pvps/*, retrieved May 19, 2005; and industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[51] Firms conducting research include production-line equipment manufacturers; silicon feedstock, wafer/ingot, solar cell, and module producers; systems integrators; and electrical design and engineering companies, among others.

[52] Michael Rogol, Shintaro Doi, and Anthony Wilkinson, *Sun Screen: Investment Opportunities in Solar Power*, CLSA Asia-Pacific Markets, July 2004, p. 8, found at *http://www.photon-magazine.com/*, retrieved Mar. 26, 2005.

installers link modules and the other PV system components such as inverters to end-users. Post-installation services may include maintenance and repair, loan servicing, and financial incentive program administration. In systems for industrial customers, operations and management services and other additional services may be provided. Most frequently, many thousands of mainly small services firms not engaged in manufacturing provide one or more of the services stated above.[53] However, some major producers of PV modules or of goods in other industries such as prefabricated housing also provide services such as solar PV system installation, which is reported to be the most profitable service in the PV supply chain. In certain developing country markets such as South Africa where the customer is the government entity that awards concession contracts for the supply of solar PV systems to public or private end users, the provision of services may be an additional contractual requirement.[54] Although international standards exist for PV cell and module technology, no internationally recognized standards are in place for PV system design or installation services, which may result in widely varied system performance and installation norms between countries.[55]

Growth of the solar PV market continues despite generation costs of 25-40 cents per kWh, which are 3 to 10 times more expensive than generation costs of other renewable energy sources and fossil fuels.[56] The gap in generation costs between solar PV and other sources of renewable energy and conventional fossil fuels has narrowed considerably in recent years. For example, generation costs for solar PV power were nearly 10 times higher than for wind and more than 15 times that for biomass and coal in the late 1990s. Improvements in the energy efficiency of solar cells continue, which contributes, along with greater economies of scale, to reductions in generation costs. Moreover, external costs of producing 1 kilowatt hour of solar power– estimated at 0.2 to 0.4 cents in the European Union in the late 1990s and a negligible part of solar power costs– remain among the lowest of all renewable energy sources. In a residential market such as Japan, the average retail price of 25 cents per kWh for energy from conventional sources is high enough for solar power prices to be competitive. In markets where the retail price for conventional power is lower than in Japan, government or utility financial incentives remain essential to stimulate demand for solar PV systems, as effectively demonstrated in several European countries.[57] In developing country markets, solar PV can also be the low-cost alternative energy source for rural electrification.[58]

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[53] EPIA, *EPIA Roadmap*, 2005, p. 41, found at *http://www.epia.org/05Publications/EPIAPublications.htm*, retrieved Feb. 24, 2005, and industry representative, interview by USITC staff, Berlin, Germany, Apr. 14, 2005.

[54] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

[55] Despite the absence of international standards in design and installation, a few countries' national standards, such as those in Japan related to design and those in Australia concerning installation, are under review by other countries considering adoption of such standards. IEA, *The Role of Quality Management, Hardware Certification and Accredited Training in PV Programs in Developing Countries*, IEA-PVPS T9-04:2003, Sept. 2003, p. 13, found at *http://www.oja-services.nl/iea-pvps/*, retrieved May 19, 2005.

[56] Michael Rogol and others, *Sun Screen: Investment Opportunities in Solar Power*, p. 5. Solar industry representatives state that only in certain limited instances is solar technology price-competitive with other grid-connected electricity sources. General Electric Co., post-hearing brief, May 5, 2005.

[57] Industry and government representatives, interviews by USITC staff, Berlin, Germany, Apr. 14, 2005, and Madrid, Spain, Apr. 15 and 18, 2005.

[58] Hearing testimony before the Commission, Apr. 19, 2005, p. 110.

Market for Solar PV Equipment and Technologies

Solar manufacturers have reduced production costs of modules by 5 percent per year for at least a decade and state that each doubling of production results in module cost reductions of 18 to 20 percent.[59] Incremental production cost savings– not withstanding recent silicon price increases– have resulted from numerous strategies, such as techniques to reduce the amount of silicon used per watt while increasing module efficiency, substituting lower cost materials where possible, and moving production to lower-wage developing countries. Attracting private-sector investment in solar PV markets has been easier in recent years, owing to government policies aimed at broadening demand and expanding industry size and capabilities, including export capabilities. Moreover, solar PV growth has been supported in Japan and Germany by utilities and government policymakers because solar power output is highest and can be dispatched to the grid during peak demand periods.[60] However, the average annual rate of growth in PV deployment in recent years is likely to have been adversely affected by under-supplies of cell and module manufacturing capacity and of silicon feedstock for solar cells.[61] Worsening shortages of silicon, at least in the short term, compel solar cell manufacturers to seek longer term supply contracts for feedstock.[62]

Japan, Germany, and the United States are the world's leading producers of solar PV cells and modules. In 2003, Japan held a 49-percent share of the world market for solar PV cell and module production, while Europe (primarily Germany) and the United States supplied 26 percent and 14 percent, respectively.[63] Despite generating most revenues from lines of business other than solar PV, the major Japanese solar PV cell and module manufacturers have become world leaders under Japan's favorable PV market incentives. For example, in 2003, Sharp and Kyocera were the world's two leading producers of solar cells and modules, while other Japanese firms Mitsubishi, Sanyo, and MSK were among the world's top eight producers of cells and/or modules.[64] German firms RWE Schott Solar, Q-Cells, and SolarWorld's subsidiary Deutsche Cell were the first, third, and fourth largest European solar PV cell producers in 2003.[65] These and other German PV firms and suppliers to the PV industry, such as for feedstock, production equipment, components, system integrators, and installers, have thrived in recent years, as Germany's Renewable Energy Sources Act has positively impacted investment and enabled solar PV technology to evolve beyond niche markets. Until

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[59] Michael Rogol and others, *Sun Screen: Investment Opportunities in Solar Power*, p. 7.

[60] Hearing testimony before the Commission, Apr. 19, 2005, p. 110.

[61] Hearing testimony before the Commission, Apr. 19, 2005, p. 114; Sarasin, *Solar Energy - Sunny Days Ahead?*, p. 6; and industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[62] Industry representatives, interviews by USITC staff, Bonn, Germany, Apr. 11, 2005, and Washington, DC, Apr. 19, 2005.

[63] Paul Maycock, "World PV Cell/Module Production, Consumer and Commercial (MW)," table, *PV News*, Mar., Apr. 2005, found at *http://www.nrel.gov/ncpv/*, retrieved Apr. 18, 2005.

[64] IEA, *Trends in Photovoltaic Applications: Survey Report of Selected IEA Countries Between 1992 and 2003*. MSK also provides PV module design and installation services, according to solar energy company information found at *http://www.solarbuzz.com/*, retrieved Mar. 30, 2005.

[65] IEA, *Trends in Photovoltaic Applications: Survey Report of Selected IEA Countries Between 1992 and 2003*.

1999, the United States was the world leader in solar cell and module production.[66] Currently, most of the largest solar PV cell and module producers in the United States are subsidiaries of multinational or foreign-owned firms, including oil firms Royal Dutch Shell and British Petroleum, electronics equipment manufacturer Sharp, and German utility firm RWE.

The production of solar cells and modules is also increasing in developing countries, especially in the area of balance-of-system components. For example, in India in 2003,at least 9 firms manufactured PV cells and 21 produced modules;[67] the Sudanese Government has formed a joint venture with China to assemble PV modules in Sudan; and Mexican PV module assembly operations of Japanese-owned firms export to the U.S. market. Proximity to local and regional markets is driving these developments, as establishing local production and distribution operations close to end users is more cost-effective than shipping completed modules.[68] Solar PV modules are usually sold to distributors, system integrators, or installers, although modules may also be sold to government entities or electric utilities. In Japan, where building integrated PV installations are common, building developers and construction companies may purchase solar PV products much the same as other building materials.

Market for Solar Heating and Cooling Services and Equipment

An estimated 118 million square meters of solar thermal collectors were in operation throughout the world in 2001.[69] Relative to solar PV, deployment of solar heating and cooling was concentrated among a smaller number of countries, despite being an older technology. Twenty-six countries accounted for about 101 million square meters, or 85 to 90 percent, of the world total, led by China (32 percent), the United States (25 percent), Japan (12 percent), Turkey (8 percent), and Germany and Israel (4 percent each) (see table 5-2 at end of chapter). The most dynamic growth in recent years in solar hot water heating deployment occurred in China, and secondly in several European countries. China led all country markets in newly installed collector area in 2003, capturing 74 percent of 13 million square meters installed.[70] Research and development incentives to Chinese solar water heater and system manufacturers intended to expand the industry in China reportedly stimulated market growth.[71] Most of the solar water heating systems are provided as part of the sharp increase in the number of new homes

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[66] Paul Maycock, "World PV Cell/Module Production, Consumer and Commercial (MW)," table, *PV News*, Mar. and Apr. 2004, found at *http://www.nrel.gov/ncpv/*, retrieved Apr. 18, 2005.

[67] U.S. Department of Commerce and U.S. Department of State, "India: Renewable Energy," Industry Sector Analysis Report 119847, Aug. 29, 2003, found at *http://www.stat-usa.gov/*, retrieved May 20, 2005.

[68] Organization for Economic Co-operation and Development, *Liberalization of Trade in Renewable Energy and Associated Technologies*, COM/ENV/TD (2005) 23, May 26, 2005, pp. 15-16.

[69] Werner Weiss, Irene Bergmann, and Gerhard Faninger, *Solar Heating Worldwide: Markets and Contribution to the Energy Supply 2001*, Feb. 2004, p. 6, found at *http://www.iea-shc.org/outputs/activities/iea_shc_solar_heating_worldwide_2001.pdf*, retrieved Mar. 3, 2005.

[70] Sarasin, *Solar Energy - Sunny Days Ahead?*, p. 32.

[71] Ibid, p. 34.

being built in China.[72] The Chinese Government has set a goal for 65 million square meters of such systems to be installed by 2005.

Solar heating market development is highly dependent on government support because alternatively powered electric hot water systems are substantially less expensive to purchase than solar thermal systems. The most effective government actions to stimulate this market have been regulations requiring the use of solar heating, such as those in existence for more than 20 years in Israel that have resulted in solar thermal systems supplying 80 percent of the hot water heater market in that country. Other examples include Spain, in which about 40 municipalities require minimum proportions of water in new and renovated buildings to be heated by solar energy, and Australia, in which the state of Victoria cited solar energy as one of two options to supply hot water to residents.[73] Various combinations of subsidies, tax breaks, or low-interest loans to end-users have been effective in stimulating deployment while the incentives were in effect, although when financed by general revenues, the incentives– and thus demand–have tended to vary over time. Moreover, rebates, tax incentives, and favorable loan terms did not appear to create sufficient incentives for system producers based on the performance of the heating system, unlike with grid-tied solar PV systems under net metering. Accordingly, even in most European countries, the deployment of solar heating systems is generally considered to be low and industry sources identify a shortage of installation service providers.[74] Common standards for solar water heating collector systems and installation have been established in Europe, although standards with regard to solar air heating systems and statements on best practices for installation of such systems for residences have not been developed.

China reportedly had more than 1,000 manufacturers of solar water heaters, components, and systems in 2001.[75] Eight such firms each reportedly surpassed approximately $12 million in sales in 2002.[76] Other major producers of solar water heating systems for buildings include Germany, Austria, and Greece, and for swimming pool heating include the United States, Australia, and Mexico.[77]

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[72] Donald W. Aitken, "Transitioning to a Renewable Energy Future," paper prepared for ISES, 2003, found at *http://whitepaper.ises.org/*, retrieved Mar. 21, 2005.

[73] IEA, Solar Heating and Cooling Program, *Solar Update*, Vol. 42, Oct. 2004, found at *http://www.iea-she.org/*, retrieved Mar. 3, 2005.

[74] European Solar Thermal Industry Federation, *Sun Action II: A Solar Thermal Strategy for Europe*, 2003, found at *http://www.estif.org/139.0.html*, retrieved Feb. 27, 2005.

[75] Donald W. Aitken, "Transitioning to a Renewable Energy Future," p. 28.

[76] "From Quality to Quantity," Magicalia Ltd., Feb. 21, 2005, found at *http://www.earthscan.co.uk*/, retrieved Mar. 18, 2005.

[77] IEA, *Solar Energy Activities in IEA Countries, 2002*, found at *http://www.iea-shc.org/outputs/activities/solar-energy_activities_2002.pdf*, retrieved Mar. 3, 2005.

Trade and Investment

Solar Power Services

Traded services are believed to principally include solar product and system wholesaling and retailing; research and development; design, engineering, and construction; management consulting; systems integration; training; and installation, maintenance, and repair of solar products and systems. Official trade data on solar power generation and services are not available. No evidence of trade in solar power generation and distribution across borders has been identified in this investigation. Nevertheless, certain firms providing solar energy related services have participated significantly in selected solar power plant development, engineering, and operations abroad, as in the large-scale CSP power plants in California originally designed and operated by the Luz Group of Israel.[78] Companies from certain foreign countries have begun to provide services in conjunction with the establishment of mini-grid solar PV power systems in villages in developing countries such as China and India under concession contracts, joint ventures, or multilateral and bilateral aid programs (see table 5-3 at the end of chapter).

One industry source estimated cross-border engineering and construction management services trade in connection with solar PV and concentrating solar power totaled $150 million in 2004.[79] Such services trade accounted for 5 percent of the total estimated revenues generated for these services in all countries. An analysis of solar power services yields a positive correlation between exports of services and GDP per capita,[80] suggesting that higher-income countries tended to be the largest exporters of solar energy services, principally reflecting the activities based in Germany and Japan. In 2004, these two countries led all export markets supplying such services, with 44 percent and 38 percent shares, respectively. Even in Japan and Germany, noted previously as the world's leading markets for solar power and related services, cross-border trade in engineering and construction management services on solar power projects is low in relation to domestic consumption of such services. In 2004, Germany exported 10 percent of such services in relation to its consumption, while Japan exported 5 percent. The proximity of other EU member states to Germany likely accounted for that country's higher proportion of exports of such services relative to Japan. Anecdotal evidence suggests that, in general, German services suppliers connected with solar power have begun to focus only recently on export market opportunities. Imports accounted for only 3 to 4 percent of consumption of these services in Germany and Japan, respectively, in 2004, further accentuating domestic services firms' preeminence in both countries. As a partial explanation of the relatively low incidence of trade in engineering and construction management services, sources note that multilateral aid projects in developing countries are increasingly likely to be awarded in part to support

[78] Solel Solar Systems Inc. of Israel acquired and continues to develop and market the CSP technologies pioneered by Luz. Company profile found at *http://solel.com/company/profile,* retrieved Apr. 22, 2005.

[79] McIlvaine Co., estimates provided to USITC staff via e-mail, June 27, 2005.

[80] The correlation coefficient is approximately 0.52 and is based on data obtained from the U.S. Census Bureau and McIlvaine Co. Correlation coefficients span values of one to negative one. A coefficient of negative one suggests a perfect inverse relationship; a value of one suggests a perfect positive relationship.

the development of commercially viable local solar PV energy services rather than the provision of turn-key projects by foreign suppliers.[81]

Equipment and Technologies

As with services, a positive relationship is observed between GDP and exports indicating that higher income countries were likely the largest exporters of goods related to solar energy,[82] especially firms based in Germany and Japan. The preeminence of Germany and Japan also demonstrate the follow-on effects of government policies that promote solar energy. Firms in these markets had clear incentives to manufacture increasingly high-quality goods while simultaneously working down the cost curve, either by achieving scale economies or by learning by doing, as discussed in chapter 2. Most of the largest PV cell and module producers in developed countries have manufacturing operations in both developing and developed countries.[83] Several major European solar cell manufacturers, such as RWE Schott Solar, have acquired foreign cell producers to augment cell production in their home countries. In certain developed country markets such as the United States, such acquisitions by foreign firms have been numerous in recent years.[84]

Entry into the Japanese market, however, has been difficult for foreign firms, as major Japanese companies involved in solar energy often supply multiple layers in the product and services chain.[85] However, European solar cell producers have established a presence in the Japanese solar energy products market by forming partnerships with Japanese firms to serve niche applications. Unlike the leading European firms, until recently Japanese solar cell manufacturers reportedly produced cells only locally, preferring to keep solar PV manufacturing in Japan as a "high potential new market" and a "key industry."[86] Nevertheless, most leading Japanese and European solar cell manufacturers have established operations in other countries to assemble solar PV modules, and some foreign operations of these firms provide services abroad that are

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[81] OECD, *Liberalization of Trade in Renewable Energy and Associated Technologies*, p. 17.

[82] The correlation coefficient is approximately 0.52 and is based on data obtained from the U.S. Census Bureau and McIlvaine Co.

[83] European Commission, Joint Research Center, *PV Status Report 2004: Research, Solar Cell Production and Market Implementation of Photovoltaics*, No. EUR 21390, Oct. 2004, found at *http://fotovoltaica.com/pvstatus2004.pdf*, retrieved June 21, 2005.

[84] Examples include BP Solar's acquisition of Solarex and RWE Schott Solar's purchase of firms that included solar energy operations of Mobil Corporation.

[85] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.

[86] The Japanese prime minister's advisory committee on competitiveness designated solar PV's high potential, and the Japanese industry has determined that PV manufacturing should not be performed by Japanese companies elsewhere in Asia. Amult Jäger-Waldau, *PV Status Report 2004: Research, Solar Cell Production and Market Implementation of Photovoltaics*, European Commission Joint Research Center report EUR 21390 EN, Oct. 2004, p. 27, found at *http://fotovoltaica.com/pvstatus2004.pdf*, retrieved June 21, 2005.

downstream of module production.[87] The number of major solar cell manufacturers with module production facilities in developing countries appears to be increasing. Examples include operations of Japanese firms Kyocera and Sanyo in Mexico, largely for export to the U.S. market at present, and Spanish firm Isofotón in South Africa. In large developing countries such as India and China, leading solar PV cell manufacturers such as BP Solar (United Kingdom), Kyocera, and SolarWorld (Germany) have established joint ventures to produce PV modules locally in the developing country in order to limit transportation costs.[88] Additional activity by solar energy firms in developing countries comes in response to aid programs by multilateral agencies or development banks, which may often be awarded to firms from the donor country for the provision of solar systems, components, or technologies.[89] To an increasing degree, however, especially as regards solar heating system components, balance-of-system components are available from local producers in developing markets.

As noted in chapter 1, equipment incidental to solar power production varies and includes products that are classified in a number of different HS subheadings. Many such subheadings include dual-use products such as controllers, converters, inverters, and batteries that are used in multiple industries. Accordingly, trade data on these product categories do not necessarily reflect the nature or extent of merchandise trade associated with the solar power industry. Trade data on the six-digit HS subheading 8541.40, photosensitive semiconductor devices, which includes photovoltaic cells whether or not assembled in modules or made up into panels, also includes additional products such as light emitting diodes. In 2003, for all products of HS subheading 8541.40, the leading exporting countries were Japan ($3.5 billion), the United States ($1.1 billion), Germany ($0.8 billion), and Malaysia ($0.7 billion), although the latter country is not believed to be a significant producer of solar cells or modules. The principal importing countries for products of HS subheading 8541.40 included China ($1.4 billion), the United States ($1.1 billion), Germany ($1.0 billion), Japan ($0.8 billion), and Korea ($0.7 billion).[90]

The countries chosen for special emphasis in this chapter generally maintain low applied tariff rates on imports of PV cells and modules. Nevertheless, Mexico and Morocco maintain high bound tariff rates of at least 30 percent on such products although applied tariff rates are below 3 percent; Brazil maintains bound tariff rates ranging from zero to 35 percent and applied rates ranging from zero to 16 percent. Tariffs amounting to 15 to 20 percent ad valorem on solar cells in certain developing countries in Asia, Africa, and the Middle East may add 7 to 10 percent to overall residential solar PV system

[87] Shell Solar's service activities in India illustrate such operations. "Shell Solar's Rural Operation Installs 100,000th Solar Home System," press release, June 6, 2005, found at *http://www.shell.com*, retrieved June 21, 2005.

[88] BP Solar operates joint ventures in at least six developing countries. Amult Jäger-Waldau, *PV Status Report 2004: Research, Solar Cell Production and Market Implementation of Photovoltaics*, p. 63.

[89] OECD, *Liberalization of Trade in Renewable Energy and Associated Technologies*, p. 15.

[90] World Integrated Trade Solution Database, The World Bank and the United Nation Conference on Trade and Development, retrieved June 29, 2005.

costs.[91] Additional tariffs on other PV system components such as charge controllers and inverters may also be levied in these and other countries, although certain countries such as Sudan may exempt solar PV system components from import duties and various taxes in order to encourage deployment of renewable energy technologies.

Future Prospects

Industry sources anticipate continued annual growth exceeding 30 percent in solar PV deployment in Japan and Germany, and also strong growth in other countries such as Spain and France that have recently adopted stronger PV market development incentive programs.[92] Technological improvements are expected to be incremental for the next decade, although production-process improvements and integration of PV systems into new buildings are likely to continue. Production of PV systems is likely to move more proportionately toward developing countries where potential consumer demand growth and production cost reductions are expected to be greatest over the long term.[93] Foreign investment in services related to solar PV may be expected to increase as the market for solar PV systems grows and as developing countries such as China export a larger share of world solar PV system production and begin exporting related services. The principal difficulties foreseen are the supply shortages of silicon feedstock, the challenge of recruiting and training large numbers of employees especially in system installation to meet expanded demand, and the likelihood that higher interest rates in some major markets such as the United States could dampen consumer demand.[94]

Demand for solar heating and cooling systems and services is expected to increase, although more slowly than that for solar PV in many markets.[95] As a mature technology, solar heating and cooling deployment will likely increase in developed country markets subject to the continuity, improvement, or initiation of favorable government programs such as subsidies, and the establishment of deployment targets and public awareness campaigns aimed at service providers and potential consumers. Deployment will likely be concentrated in new home construction as one of a number of optional features that may also include solar power systems. In developing country markets, the proliferation of solar heating systems in China in recent years will likely continue to benefit the industry, as China's vast population is considered by industry sources to be substantially under-served by solar heating technologies.[96]

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[91] MFN applied tariffs are 20 percent in Cambodia, the Solomon Islands, Djibouti, Libya, Maldives, Vanuatu, and Ethiopia, and 15 percent in India, Nepal, Nigeria, Oman, Rwanda, Seychelles, Syria, and Yemen. OECD, *Liberalization of Trade in Renewable Energy and Associated Technologies*, p. 15.

[92] Michael Rogol et al., *Sun Screen: Investment Opportunities in Solar Power*.

[93] Industry representatives, interviews by USITC staff, Germany, Spain, and Italy, Apr. 2005.

[94] Michael Rogol et al., *Sun Screen: Investment Opportunities in Solar Power,* pp. 14 and 23; and IEA, *the Role of Quality Management, Hardware Certification and Accredited Training in PV Programs in Developing Countries,* pp. 17-20.

[95] ESTIF, *Sun Action II: A Solar Thermal Strategy for Europe*.

[96] Sarasin, *Solar energy-Sunny Days Ahead?*, p. 32.

Table 5-1
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Australia	Gross generation in 2002: - Solar PV: 5 GWh.[1] Total electricity generation in 2002: 222 TWh.[1] Cumulative installed PV capacity in 2002: 39.1 MW; in 2003: 45.6 MW.[2] In 2004, the Australian Government announced a 9-year trial program to subsidize solar technology introduction (solar heat and solar electricity) in new and existing residential and commercial buildings in several Australian cities.[3] The program will test various pricing and other market mechanisms to maximize opportunities for grid-connected solar power. The Photovoltaic Rebate Program targeted initially to home owners and community groups to partially defray installation costs was expanded in 2004 to housing developers of new homes and was extended through 2006.[4] Remote off-grid solar PV power is less competitive than diesel upon the removal of the excise tax on stationary diesel applications.[5]	Off-grid applications (87 percent) predominate, with industrial applications accounting for about two times the capacity of residential applications.[2] PV systems are also deployed in applications such as water desalination.[6]	Solar PV: - Employment: 695 in 2003.[2] - R&D: The public budget for research, demonstration and field trials, and especially market stimulation totaled nearly $20 million for solar PV in 2003, or about one-tenth the amount budgeted for PV by the major government research funding source in Japan.[2] Priority programs include developing high efficiency applications to reduce production costs.[7] At least one electric utility participates in research into thin-film cell technologies.[2] - Manufacturing: BP Solar (cells and modules), Australia's largest cell producer, has operated in Australia for more than 20 years and recently announced plans to expand production capacity in Australia by 25 percent because of increased demand for exports.[8] Other producers include Solar Systems (modules), STI (cells and modules), and Pacific Solar (developing silicon thin-film cell technology).[9] - Services: Firms include Going Solar (energy consulting, management, and installation) and Sustainable Energy Enterprises (planning, installation, and manufacturing), both of which also recently became licensees for the sale of RWE Schott Solar products.[10] A few electricity firms install PV systems. System retailers reportedly also own and operate PV systems. Some utilities participate in the market for grid and off-grid solar PV power.[2] CSP: Services: EnviroMission Ltd. has developed a 500 MW solar power tower project currently in the final feasibility stage of development.[11]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Brazil	Total electricity generation in 2002 (net): 339.1 billion kWh.[12] Estimated cumulative installed solar PV capacity is at least 12 MW.[13] The Solar PV market has been slow to develop in Brazil. Since 1994, the PRODEEM program of the federal government has been most responsible for enabling the installation of solar PV systems in remote areas, especially the electrification of schools.[13] Although more than 9,000 systems have been purchased by the government under PRODEEM, maintenance and operational difficulties and resulting costs on systems installed to date have delayed the rate of new installations in recent years. Additional programs to accelerate solar PV deployment, especially to promote economic development, have been implemented by federal and state governments, nongovernmental organizations, and an electric utility, and by numerous non-Brazilian public and private entities.[14] Grid-tied solar PV systems are considered prohibitively expensive for small-scale consumers in the absence of significant government-mandated financial incentives.	Principal consumers are remotely located, widely dispersed, off-grid residents, public service entities, water-pumping consumers, and telecommunications entities.[13] A grid-connected solar PV system, the largest in Brazil, was established in Recife by the electric utility CHESF in 1995. Three additional grid-connected systems are exclusively used for research.	Solar PV: - Employment: No information available. - R&D: The Laboratory of Photovoltaic Research, established at the State University of Campinas, pioneered solar power research on cells and modules in Latin America and is regarded as among the developing world's leading sources of solar PV scientific output and related training of research scientists in the field.[15] - Manufacturing: The one Brazilian manufacturer of solar PV modules, Heliodinamica, has sold units totaling 2 MW since its founding in 1983.[13] Components of PV systems, usually manufactured locally, are often not designed specifically for PV applications but are adapted from other more widely used applications. - Services: Major foreign producers of PV modules have established distribution and installation networks in Brazil. CEMIG, the major electric utility in the State of Minas Gerais, established a program to train electricians in PV system installation, monitoring, and maintenance.

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Canada	Gross generation in 2002: - Solar PV: 22 GWh.[1] Total electricity generation in 2002: 601.4 TWh.[1] Cumulative installed PV capacity in 2002: 10 MW; in 2003: 11.8 MW.[2] The Canadian PV market is considered in an early developmental stage, with more than 95 percent of installed capacity not connected to a grid, and no significant financial incentives in place to mitigate installation costs.[16] Natural Resources Canada is addressing issues and barriers to integrating solar PV with the electricity grid. Currently, approval and installation of grid-connected PV systems is perceived to be costly and lengthy for residential consumers.[2] Canadian PV systems integrators have formed distribution and dealer networks in Canada to supply principally foreign-manufactured PV modules.	Almost three-fifths of solar PV capacity serves nonresidential and public-sector consumers, mainly in remote areas. Examples of applications include remote sensing and monitoring; telecommunications; and navigational aids.[2]	Solar PV: - Employment: 615 in 2003.[2] - R&D: National Resources Canada's CANMET Energy Technology Center - Varennes is the principal solar research center.[2] Adaptation of PV technologies in cold climates and building-integrated PV system applications are major emphases. - Manufacturing: Approximately 12 to 14 firms participate, including ARISE Technologies (component manufacturing; engineering, consulting, monitoring, and research services); Conserval Engineering (solar panels); ICP Solar Technologies (modules); Solar Converters Inc. (controllers); Soltek Solar Energy (components); StatPower (inverters); Surrette Battery Co. (inverters); Spheral Solar Power, a division of ATS Automation Tooling Systems Inc. (cells and modules); and Xantrex Technology Inc. (inverters, other components).[17] A majority of production is believed to be exported. - Services: A large majority of the 150 mainly small firms promoting solar PV in Canada are distributors, resellers, or installers operating solely in Canada.[18] By contrast, Canadian Solar Inc. (consulting, research, solar PV capacity building and market development services, with module manufacturing operations in China) participates mainly in developing country markets such as China in conjunction with the Canadian International Development Agency.[11]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
China	Cumulative installed PV capacity in 2003: 58 MW.[2] Approximately 60 percent of China's capacity was installed during 2002-03.[5] China's target for cumulative installed solar PV power by 2010 is 450 MW and by 2020 is 1 GW[5] – 100 MW of which may come from a large power plant currently being planned in Gansu Province.[19] Investments by industry firms, including firms based outside of China involved in joint ventures, have improved the quality, production methods, and output of Chinese PV module production in recent years.[5] These steps have helped to reduce solar PV market development impediments in China, such as above average costs to end users and poor system quality, while aiding the creation of significant export opportunities for producers in China.	Nearly three-fourths of installed capacity by year-end 2002 was off-grid for electrification in rural areas, where 80 percent of the population resides.[20] About 12 percent of capacity was for use in telecommunication systems.	Solar PV: - Employment: No information available. - R&D: The Beijing Solar Energy Research Institute (BSERI) leads solar energy technology R&D in China, aimed toward achieving advances in commercial production and applying PV technology. The National Engineering Research Center for Renewable Energy supports BSERI.[21] - Manufacturing: Baoding Yingli was China's largest producer of cells and modules in 2003. Other significant producers include Wuxi Snitch Solar Power (cells); Xi'an Jiayang (module encapsulation); Kyocera (modules); and Ningjin (monocrystalline ingots; wafers).[2] - Services: A system for training in PV engineering and technologies is under development, national standards for home solar PV systems have been drafted, and entities have been created to provide quality control and to rectify past PV product and maintenance service difficulties.[21]
Costa Rica	Cumulative installed PV capacity in 2003: No estimate is available, but capacity is believed to be small. Total electricity generation in 2002 (net): 6.61 billion kWh.[22] System maintenance is reported to be insufficient and there appears to be very limited ability to provide repairs.[23] There is no known grid-connected solar PV operating in Costa Rica, as deploying the technology is perceived to be beyond that country's economic capability.[24] Nevertheless, largely foreign financing has enabled solar PV to be deployed on a limited scale in rural and remote areas.[25]	Consumers are believed to be households, farms, businesses, and public-sector entities in remote mountainous, rural, or island areas not tied to an existing electricity grid.[26]	Solar PV: - Employment: No information available. - R&D: The National University of Costa Rica has established a model home equipped with solar PV products donated by the Indian Government for research and demonstration purposes.[27] - Manufacturing: No information available. - Services: Costa Rican firms supplying services in that country in relation to the consumption of solar PV systems include Interdinamica Energia, which provides consulting, design, sales, installation, and maintenance services; Intitech, which provides sales, installation, and maintenance services; and several distributors of solar PV systems and products from leading foreign manufacturers.[28]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
European Union[29]	Cumulative installed PV capacity in 2002: 392 MW; in 2003: 562 MW[30] In 2003, Germany accounted for about 70 percent of PV system capacity installed in the European Union.[30] The Netherlands (9 percent), Italy and Spain (5 percent each), and France (4 percent) accounted for most of the remainder. Information pertaining to these five EU member states is included beginning on the next page of this table.	In 2003, grid-connected customers accounted for about 85 percent of cumulative installed PV capacity in the European Union.[30]	Solar PV: - Employment: About 15,000 in 2003, most of whom were employed in Germany (60 percent) and Spain (27 percent).[30] - R&D: In 1998-2002, the European Commission spent more than 110 million euros conducting more than 100 R&D projects supporting solar PV,[31] including mid- to long-term programs centered on improving feedstock quality, costs and efficiency of silicon wafers, thin-film mass production, and new materials and systems. Short-term projects supported building-integrated PV and large grid-connected demonstration projects, among others. During 2003-06, the long-term emphasis is on next-generation materials development and building integration, while short-term programs are even more focused on cost reductions, high-efficiency PV cells and modules, silicon feedstock supply, and large-scale applications. - Manufacturing: In 2003, the manufacture of solar cells and modules chiefly occurred in Germany, with most of the remainder in Spain.[32] - Services: Services are not believed to be concentrated and, with the exception of large-scale and highly technical deployment and collaborative R&D, involve mostly local firms in each EU member state.
France	Gross generation in 2002: - Solar PV: 6 GWh.[1] Total electricity generation in 2002: 554.8 TWh.[1] Cumulative installed PV capacity in 2002: 17 MW; in 2003: 21 MW.[2] In 2003, 82 percent of cumulative installed PV capacity was not connected to an electricity grid.[2] Nevertheless, the market for grid-tied PV systems increased in 2003, although from a low base, as assistance from the national and regional governments and the European Commission covered up to 80 percent of system costs. However, multi-year delays in system installations have been numerous.[30]	Off-grid PV systems for residents accounted for 57 percent of cumulative installed capacity in 2003.[2] However, the relative share of off-grid residential installations is declining, as financial incentives shift to on-grid consumers.[33]	Solar PV: - Employment: 750 in 2003.[2] - R&D: Multiple entities are supported by funds from ADEME on priorities such as building-integrated PV systems, storage, conditioners, and innovative manufacturing of silicon and thin-film cells.[2] - Manufacturing: Photowatt International is the leading French firm (cells and modules).[2] - Services: The French Government-owned electricity firm EDF and Total Energie are active participants. EDF helped developed standards for PV, manages more than 5,000 off-grid PV installations, and developed off-grid, publicly funded systems.[2]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Germany	Gross generation in 2002: -Solar PV: 188 GWh.[1] Total electricity generation in 2002: 566.9 TWh.[1] Cumulative installed PV capacity in 2002: 277.3 MW;[30] in 2003: 416 MW.[20] In 2003, Germany was the world's second largest country market for solar PV installed capacity.[2] The Hundred Thousand Roof program propelled solar PV demand in Germany, beginning in 1999 and surging in the program's final year in 2003. The amended Renewable Energy Sources Act (EEG) further improved incentives to install PV systems, beginning in 2004. In 2003, 95 percent of cumulative installed PV capacity was connected to an electricity grid.[2] In 2003, Germany produced cells and modules nearly to the same extent as did the United States although production in both countries totaled considerably less than in Japan.[2] Nevertheless, Germany has shifted from a market supplied almost exclusively by foreign PV goods in 1999 to one in which German goods predominated in 2004.[34]	Residential consumers of grid-connected distributed PV power led the increase in PV system deployment in Germany in recent years. Business and industrial consumers are adopting PV power as well, evidenced by increases in the average size of systems approved for installation under government incentive programs.[20]	Solar PV: - Employment: Estimated at 10,000 to 12,000 in 2003.[2] - R&D: Solar PV received 49 percent of R&D funds allocated to renewable energy technologies during 1974-2002.[35] Even so, the German Government announced a four-fold increase in its annual solar PV R&D budget, to 100 million euros, in January 2004.[36] In 2003, Germany's R&D budget for PV ranked third largest in the world after Japan and the United States. German R&D projects focused on reducing production costs and increasing efficiencies of cells and modules, and improving conditions for building-integrated and off-grid applications.[2] - Manufacturing: RWE Schott Solar (mostly cells), Europe's largest cell producer in 2003; Q-Cells (cells), Europe's third largest cell producer in 2003; Solarworld's subsidiary Deutsche Cell (cells and modules), fourth largest producer in Europe in 2003; SMD (modules); SOLON (modules); Shell Solar (cells and modules); Ersol Solar Energy (cells), and Sunways (cells) are the leading firms. - Services: The installation of PV systems in Germany typically requires certified electricians.[34] Many utilities participate in the PV market in Germany.[2]
Italy	Gross generation in 2002: - Solar PV: 21 GWh.[1] Total electricity generation in 2002: 277.5 TWh.[1] Cumulative installed PV capacity in 2002: 22 MW; in 2003: 26 MW.[2] In 2003, 55 percent of cumulative installed PV capacity was connected to an electricity grid.[2] Although Italy initiated a solar roof program in 2001 and demand for PV has been significant, installations of grid-tied systems have reportedly been slowed by administrative problems.[20] Newly instituted feed-in tariffs and other recent incentives are considered likely to increase PV deployment.[2]	Newly installed, distributed, on-grid customers are the fastest growing segment of the Italian PV market.[2] Cumulative installed PV capacity for off-grid nonresidential consumers was 55 percent, compared to 45 percent capacity for residential consumers, in 2003.[2]	Solar PV: - Employment: 560 in 2003.[2] - R&D: The Italian Agency for New Technology, Energy, and Environment leads Italian PV research activity. - Manufacturing: Helios Technology and Enitechnologie (cells and modules) are the principal, although small, producers.[2] - Services: Several mid-sized firms provide design and power-plant construction services.[2] ConPhoebus, owned by ENEL, the largest Italian electric utility, provides engineering, consulting, and research services.[37] ENEL is believed to have significantly increased its experience and involvement with PV systems in recent years through grant-funded programs.[2]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Netherlands	Gross generation in 2002: - Solar PV: 18 GWh.[1] Total electricity generation in 2002: 96 TWh. [1] Cumulative installed PV capacity in 2002: 26.3 MW; in 2003: 45.9 MW.[2] In 2003, 90 percent of cumulative installed PV capacity was grid-connected.[2] Although a combination of subsidy programs stimulated installations in 2003, it is unclear such growth is sustainable without additional incentives, especially to encourage establishment of large PV electricity generation plants.	In recent years, residential apartment building owners and cooperatives of private houses have been the primary consumers of solar PV systems, as feed-in tariff rate increases have been most beneficial on systems at least mid-sized.[2]	Solar PV: - Employment: 430 in 2003.[2] - R&D: Netherlands Energy Research Foundation (ECN) (independent research institute) and Ecofys (consulting, management, and research firm) are the principal participants.[37] - Manufacturing: AKZO Nobel (cells) and Mastervolt and Philips (inverters) are leading firms.[9] - Services: Ecofys (consulting, management, and research) is a leading firm.[37] Utilities are active participants in incorporating PV with other renewable energy sources deployed on the grid.[2]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Spain	Gross generation in 2002: - Solar PV: 35 GWh.[1] Total electricity generation in 2002: 242.7 TWh.[1] Cumulative installed PV capacity in 2002: 20 MW; in 2003: 28 MW.[2] Growth to 135 MW by 2010 is the current government target.[38] In 2003, two-thirds of cumulative installed PV capacity was not connected to an electricity grid.[2] Grants from autonomous regions and the revised national feed-in tariff,[39] among other incentives, recently have stimulated the market.[2] The Spanish market increasingly consists of separately owned systems grouped together on large plantations for ease of management and maintenance.[38] Nevertheless, silicon product shortages and an underdeveloped installation services segment keep PV system prices high.[40]	In recent years, chief new consumers have been grid-connected residents of Barcelona and other towns and cities that initiated incentives to offset system costs.[30]	Solar PV: - Employment: 2,680 in 2003.[2] - R&D: The largest entity is the Department of Renewable Energies (DER-CIEMAT) in the Spanish Government. Other entities focusing on solar PV include the Institute of Solar Energy of the Polytechnic University of Madrid (focuses nearly exclusively on solar PV research, including applications in Africa, South America, and Spain); the Tehnological Institute of Renewable Energy in the Canary Islands; and the Polytechnic University of Cataluma.[37] - Manufacturing: Isofoton (cells and modules), Europe's second largest cell producer in 2003; BP Solar (cells and modules), Europe's sixth largest cell producer in 2003; and Elecnor subsidiary Atersa (cells and modules) are leading firms.[9] Production is primarily exported. - Services: More than 500 companies provide PV installation services in Spain.[38] CSP: - Spain allocated relatively more R&D funds to CSP technologies than to any other renewable energy technology during 1990-2002, although annual expenditures on CSP R&D totaled less than $10 million annually.[35] - Although applications of CSP technologies are not yet commercialized in Spain, two 50 MW plants using thermal storage properties of molten salt in power tower systems in southern Spain are in the latter stages of development, drawing on expertise in the United States, Germany, Israel, and other countries. Moreover, other CSP technologies such as dish/engine systems are under development in Spain.[41]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
India	Cumulative installed PV capacity in 2003: 83 MW.[2] India's target for cumulative installed solar, including solar thermal, power capacity by 2012 is 280 MW. System integration and installation standards are perceived as deficient in India, which has experienced frequent systems performance issues.[42] The World Bank has earmarked $15 million for solar PV projects in India by 2008, intended to improve the quality of PV system design and installation, technical training, and customer service and marketing infrastructures. Suppliers of solar PV systems and services in India are generally small and based in various industries. During 1996-2002, PV cell and module production increased from 13 to 40 MW.[43]	The Government is considered the leading consumer of solar PV power in India.[44] About 3,600 remote villages have stand-alone solar PV power. PV systems are deployed in agricultural applications including irrigation, egg incubation, and poultry farming, and in lighting applications in all segments of the Indian economy.[6] While off-grid applications predominate in India, 2.5 MW of grid-connected solar PV power have been installed at about 31 projects, and an additional 800 kW are awaiting completion at 14 projects.[45]	Solar PV: - Employment: No information available. - R&D: The Ministry of Non-Conventional Energy Sources (MNES) established the Solar Energy Center as the lead entity responsible for product standardization, certification, and testing; specialized training in solar energy, including system repair and maintenance; and collaboration with other entities on solar research.[45] - Manufacturing: In 2003, 9 firms manufactured solar cells and 21 firms produced modules in India.[44] Firms included TATA BP Solar (modules), which accounts for about half of national production, WEBEL (modules), and Maharishi Solar Technology (modules, cells, wafers).[2] Titan Energy Systems (modules producer and exporter) recently formed a partnership with ICP Solar (Canada) to provide lamination and finishing on modules made in Australia.[46] - Services: At least 50 small firms are engaged in PV system integration and installation in India.[42] Major world producers such as BP Solar and Xantrex have established distribution and services networks in India.[44]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Japan	Gross generation in 2002: - Solar PV: No information reported.[1] (Net generating capacity in 2002, solar PV: 637 MW)[1] Total electricity generation in 2002: 1087.7 TWh.[1] Cumulative installed PV capacity in 2002: 636.8 MW; in 2003: 859.6 MW.[2] Japan's target for installed PV capacity by 2010 is 4,820 MW. Japan is the world's largest market for solar PV installed capacity (total and per capita) and PV production. Japan accounted for 53 percent of world PV cell production and 60 percent of module production in 2003.[2] Japan's solar PV installations increased at more than 40 percent per year, on average, during 1992-2001.[35] Beginning in 1994, a subsidy program, available to homeowners and owner/developers of residential properties, partially defrayed costs of purchasing newly installed solar PV systems, peripheral equipment, installation, and certain other costs. The subsidy, which covered 50 percent of such costs in the program's first three years, was gradually reduced thereafter as the price of PV systems also decreased. The subsidy is scheduled for elimination as of fiscal year-end 2006, after surpassing government targets for stimulating solar PV system installations. In 2003, 91 percent of cumulative installed PV capacity was linked to an electricity grid.[2]	On-grid residential use, principally rooftop installations, accounted for 86 percent of solar PV applications installed in 2002.[35] Residential applications accounted for 70 percent of cumulative installed capacity through 2003. Off-grid capacity is virtually all for non-residential applications.[2]	Solar PV: - Employment: 11,300 in 2003.[2] - R&D: Japan's public budget for PV R&D was the world's largest in 2003,[2] and totaled $270 million in 2004.[20] Japan's multi-faceted programs include development of long-term, next-generation PV technologies and shorter-term programs to reduce PV costs, extend mass deployment of PV systems to new consumer segments,[20] and field-test advanced current-generation PV technologies.[2] - Manufacturing: Sharp (the world's largest manufacturer of cells and modules); Kyocera (the world's second largest manufacturer of cells and modules, and vertically integrated by providing services such as installation); MSK (modules); Mitsubishi (cells and modules); and Sanyo (cells and modules) are the leading firms.[2] - Services: Sekisui Chemical (installs solar systems integrated into or added to firm's prefabricated housing).[47]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Mexico	Gross generation in 2002: - Solar PV: 32 GWh.[1] Total electricity generation in 2002: 215.2 TWh.[1] Cumulative installed PV capacity in 2002: 16.2 MW; in 2003: 17.1 MW.[2] Only about 0.1 percent of solar PV power in Mexico was connected to an electricity grid in 2003.[2] The Mexican market for solar PV systems has grown at about 9 percent annually, chiefly in remote areas, since the mid 1990s.[48] The catalysts for growth in PV system deployment in Mexico include development bank programs such as the FIRCO Shared Risk Trust, the World Bank, and the Mexican Renewable Energy Program managed and supported by U.S. Government agencies. In Mexico, the provision of services and manufacture of solar PV components are principally by small Mexican firms.[48] Component manufacturers often integrate various parts of PV systems into packaged systems sold to Mexican installers. PV cells are not believed to be manufactured by Mexican-owned companies; cells are imported principally from the United States.	The supply of electricity to residents of rural areas not connected to a power grid accounts for about 60 percent of solar PV power generated in Mexico; the remainder principally supplies electric power to unmanned oil rigs and remote telecommunication repeating stations, and to water pumps used in agriculture.[48]	Solar PV: - Employment: 125 in 2003.[2] - R&D: Mexican national utility Comisión Federal de Electricidad (CFE). Grid-connected R&D activities are on-going on existing experimental solar PV systems. USAID-funded research programs are among the development programs helping to share expertise and build PV technology applications in Mexico.[2] - Manufacturing: Japanese firms Kyocera and Sanyo and U.S. firm ECD Ovonics operate PV module assembly plants in Mexico, chiefly for export to the U.S. market. Mexican-owned firms such as Dondumex, Grupe Alpe, Alternativa Solar, and Energia Alternativa de Mexico manufacture and integrate components.[48] - Services: Distributors and installers are principally small Mexican-owned firms.[48]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Morocco	Cumulative installed solar PV capacity in 2003: 7 MW.[2] The Government has projected 15 MW to be installed by 2010. The Moroccan solar PV market is considered small and with insufficient resources to provide adequate products and services, and thus was selected to receive $5 million in International Finance Corporation (IFC) support using GEF funds under the Photovoltaic Market Transformation Initiative.[42] Since 2000, the National Electricity Office has instituted competitive bidding on concessions to provide solar PV systems to 270,000 rural households. The concessionaires are also required to provide services such as collection of credit payments from such households, whose PV systems are partially subsidized and financed on credit.[49]	The principal consumers are rural residents without electricity supplied by a grid.[42] Deployment of solar PV power for water pumping and remote telecommunication facilities is also important in Morocco.[49]	Solar PV: - Employment: No information available. - R&D: No information available. - Manufacturing: One local firm is believed to produce PV modules - Services: About 30 organizations are believed to participate in systems integration, supply, and distribution, and about 6 firms supply modules from foreign producers.[42] For example, the Moroccan company Temasol, jointly owned by the Moroccan subsidiary of French firm Total Energie and by Electricité de France (EDF), has been awarded concessions to supply and maintain solar PV systems for 53,000 rural households, using PV systems produced by Total Energie.[50] SunLightPower Maroc (SPM) sells, installs, maintains, repairs, and finances solar PV systems for residential consumers.[51]
South Africa	Cumulative installed PV capacity in 2003: 11 MW.[2] Deployment of solar PV systems is limited. In 2003, a joint-venture project between Shell and South African utility company ESKOM to test economic viability of solar power in rural areas did not achieve goals established for affordable system costs and public acceptance.[52]	The South African Government is believed to be the main consumer on behalf of rural schools, telecommunication systems, and health clinics, but also rural residential ultimate consumers.[53]	Solar PV: - Employment: No information available. - R&D: Research at Rank Afrikaans University is in a latter stage of planning for commercial production of solar panels based on cells made from copper indium gallium diselenide (CIGS) as a lower-cost alternative to cells based on silicon.[54] - Manufacturing: Tenesa, a South African subsidiary of Total Energie, assembles and installs PV panels in the country, with an annual capacity of 8 MW.[53] - Services: Although little information is available on services related to solar PV power in South Africa, a joint subsidiary of French firms EDF and Total Energie is engaged in a project to install PV systems in 15,000 homes in South Africa by 2006, including a 20-year maintenance and customer service obligation.[53] Also, Solar Engineering Services, a small South African consulting and engineering firm, participates in the solar PV market.[55]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
South Korea	Gross generation in 2002: - Solar PV: 6 GWh.[1] Total electricity generation in 2002: 326.9 TWh.[1] Cumulative installed PV capacity in 2002: 5.4 MW; in 2003: 6.4 MW.[2] Korea's target for cumulative installed PV capacity by 2012 is 1.3 GW. The solar PV market has been slow to develop in Korea.[56] In order to stimulate deployment of grid-linked PV systems in Korea, the Solar Land 2010 program began in January 2004, aiming for new solar PV installations on 30,000 rooftops. Subsidies provide 70 percent of installed system costs, and buy-back of electricity is guaranteed at the full marginal electricity price for 15 years.[36] A 15-MW solar PV power station, reportedly the world's largest, is to be constructed in Korea by 2006.[57]	Off-grid applications accounted for 71 percent of the Korean market in 2003; non-residential applications accounted for about 90 percent of the off-grid capacity.[2]	Solar PV: - Employment: 223 in 2003.[2] - R&D: During 1988-2002, Korea invested $27 million ($16 million, public; $11 million, private) in solar PV R&D.[58] The Korean Government plans to allocate $2.4 billion to PV R&D during 2004-2011, naming PV one of three energy technologies targeted to receive priority government R&D funding. At least 15 private firms, 6 public research entities, and 16 universities participate in solar PV R&D.[58] - Manufacturing: Photon Semiconductor & Energy (cells); ATS Solar (modules); S-Energy (modules); and Solar Tech (modules) are leading, although small producers.[2] Hyundai Heavy Industries has announced plans to begin module manufacturing.[59] Inverter manufacturers include Hex Power Systems and Samwha Engineering for grid-connected systems and Dongmyung Electric and Solar Home Systems for stand-alone systems. Global High-tech Co. manufactures solar batteries. - Services: Utilities have exhibited limited interest in participating in solar PV system deployment to date.[2]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
Thailand	Cumulative installed PV capacity in 2003: 6 MW.[2] Thailand's target for installed PV capacity by 2011 is 250 MW. Following two decades of allocating limited funding to support development of solar power in remote areas not linked to a power grid, in 2003 the Thai Government began to significantly increase funds and tax incentives to develop a market for rooftop solar PV[36] and designated PV as a priority renewable energy technology. Such actions have led several Thailand-based firms to increase investments in PV cell or module production.[60] With the promulgation of net metering legislation in Thailand in 2002, expansion of grid-integrated solar PV is expected, up from more than 60 solar PV systems that were integrated prior to net metering requirements.[61] In 2003, a 5 MW solar power plant, the country's largest yet small relative to the preponderance of natural gas plants, began operation in Thailand.[62]	Solar PV primarily serves remote regions of the country. The primary customer is usually the national or local government, on behalf of ultimate consumers.[60] While residential applications predominate, additional applications include telecommunication, maritime, water supply, public lighting, and grid-connected power demonstration projects.[36]	Solar PV: - Employment: Although aggregated data for the solar PV industry are not available, the largest integrated producer and services firm– Solartron– reported 189 employees in November 2004.[60] - R&D: A subcommittee in the Office of National Research in the Ministry of Science, Technology, and Environment coordinates research and development of renewable energy technologies. Key entities involved in solar PV power include the Electricity Generating Authority of Thailand (EGAT) and several Thai universities.[63] - Manufacturing: Solartron Public Co., Ltd. is the largest producer of solar PV modules and also provides services including the survey, design, distribution, transportation, and installation of solar PV systems in Thailand, Cambodia, and Laos.[60] In 2005, the firm contracted to expand operations upstream to manufacture crystalline silicon solar cells, reportedly the first Thai producer of solar cells, from imported silicon ingots. Other solar module manufacturers in Thailand reportedly include Bangkok Solar, Thai Photovoltaics Ltd., and BP Thai Solar. Other PV system components, such as inverters, are produced locally by Thai firms.[61] - Services: In addition to services provided by Solartron, design and engineering services reportedly are provided by Sawasdee Sabaidee Co. and Thai Semcon Co.[64]

See footnotes at end of table.

Table 5-1—*Continued*
Characteristics of selected markets for solar power and solar energy services

Country	Market size & characteristics	Consumers of solar power	Key market participants
United States	Gross generation in 2002: - Solar PV: 3 GWh.[1] - Concentrating solar power (CSP): 569 GWh[65] Total electricity generation in 2002: 3,992.7 TWh.[1] Cumulative installed solar PV capacity in 2002: 212 MW; in 2003: 275 MW.[2] Solar PV: The United States was the third largest country market for cumulative installed solar PV capacity in 2003. System capacity increased at approximately 20 percent per year, on average, during 1990-2001, a slower rate than in the world's leading markets, Japan and Germany.[35] Three-fifths of cumulative U.S. PV capacity in 2003 was not linked to an electricity grid. Nevertheless, the majority of capacity growth in recent years, about 35 MW per year, has been in grid-connected applications[2] in states that have instituted feed-in tariffs among other incentives beneficial to PV development. U.S. solar cell producers' share of the world market decreased from 45 percent in 1995 to 14 percent in 2003.[35] CSP: Nine systems supply 354 MW at the world's only power plants generating electricity on a commercial basis from parabolic trough solar systems located in the Mojave Desert in California.[35]	Non-residential consumers accounted for almost three-fifths of off-grid PV system cumulative installed capacity in 2003.[2] The deployment of solar PV systems varies widely and is concentrated in certain states, most notably California, that provide legislative, regulatory, and economic incentives conducive to stimulating demand and supply.[66] The Department of Energy supports state and local initiatives with grants to promote deployment of solar PV and solar heating and cooling systems on 1 million rooftops of businesses and households. Grants totaling $1.6 million were made in 2003.[2]	Solar PV: - Employment: 1,950 in 2003.[2] - R&D: Federal Government PV R&D funding declined to under $100 million annually in constant 2002 dollars during 1996-2002, about one-third of peak levels in the early 1980s.[35] The Department of Energy (DOE) finances PV R&D chiefly through research by the National Renewable Energy Laboratory (NREL), with Sandia and Brookhaven labs, DOE Centers of Excellence at university institutes, regional experiment stations, and partnerships with universities, utilities, and industry entities.[67] The NREL's National Center for Photovoltaics (NCPV) and national labs collaborate with U.S. industry to improve component and system design, production, technology deployment, and training in many markets, including developing country markets. - Manufacturing: Shell Solar, General Electric, BP Solar, United Solar Systems, and RWE Schott Solar led U.S. cell production in 2003.[68] Although U.S. inverter manufacturing consolidated in recent years, new inverter producers entered the market in 2003. - Services: Major firms include Conservation Services Group (CSG), ETA Engineering, PowerLight, Solar Design Associates, Solargenix (also a manufacturer), and Sun Power and Geothermal Energy Co.[11] CSP: FPL Energy operates and partially owns the CSP systems in California, which were constructed and operated initially by an Israeli firm.[69] Bechtel, Boeing, Science Applications International (SAIC), and Stirling Energy Systems are among the partners with national labs to develop and test CSP systems for power generation.[70]

Note.—For each country tabled, these data include employment by firms primarily engaged in manufacturing, research and development, distribution, installation, maintenance, and energy services in connection with solar PV. The data do not include public-sector employment.

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Table 5-2
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
Australia	Australia, ranking seventh, had about 3 million m^2 (3 percent) of the world's solar thermal water and air collector operating area in 2001.[1] Annual installed solar collector area in 2003 more than doubled as the electricity act enacted in 2000 stimulated the replacement of fossil-fuel powered water heaters by solar heaters so that utility firms could accrue renewable energy certificates.[2] Solar thermal is among the distributed solar energy technologies which will be examined on a trial basis in three Australian cities under the Australian Government's Solar Cities Program announced in 2004.	In 2001, Australia was the world leader per capita and was second to the United States in total operating area of unglazed plastic collectors used to heat swimming pools.[1] About two-thirds of Australia's total solar thermal collector operating area was for swimming pool heating.	Manufacturing: - The supply of solar water heating systems in Australia is believed to be highly concentrated in a few firms and has partially become export oriented.[3] For example, Solar Edwards chiefly produces thermosyphon collector systems, which are exported to more than 55 countries.[6]
Brazil	Solar heating accounts for only a small portion of electric water heaters in use in Brazil. The high purchase price of solar heaters over alternative electric water heating systems limits the Brazilian solar water heating market to mostly upscale consumers.[4] Nevertheless, the market for solar heating in Brazil accelerated in recent years, but from a low base, following electricity shortages and rationing. About 150 million liters per day are estimated to be solar heated, equivalent to water consumed in 600,000 households.	Residences, hotels, hospitals, and swimming pools are the principal applications of solar water heaters.[5]	Manufacturing: - About 100 mostly small, regional firms manufacture solar water heaters in Brazil.[4] Services: - Research by the National Council on Scientific and Technological Development and the Research Support Foundation of Sao Paulo is attempting to develop solar water heaters made with less expensive materials so as to broaden the market.[4]
Canada	In 2001, Canada had almost 635,000 m^2, about 1 percent of the world's solar thermal collector area in operation.[1]	Nearly 90 percent of the solar thermal collector area in operation in Canada in 2001 was for swimming pool heating.[1]	Manufacturing: - Thermo Dynamics makes solar heaters for hot water and pool applications. Services: - Enersol Solar Products installs solar pool heating systems.[6]

See footnotes at end of table.

Table 5-2—*Continued*
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
China	China is the world's largest market for solar thermal heating, with more than 51 million m^2 in cumulative installed area in 2003. China held 74 percent of the world's 12.9 million m^2 newly installed collector area in operation in the same year. Moreover, China was the only country believed to have achieved higher growth in installations per capita each year during 2000-2003.[2] During 1998-2002, the solar water heating market in China increased by 27 percent per year, on average.[7] The substantial growth of China's solar thermal market is especially notable because the government provides subsidies only for research and development and none for installation.[2] The European Solar Thermal Industry Federation reported that China exported only about 1 percent of its solar thermal production in 2001, although the share exported is expected to increase, as Chinese product quality is well regarded.[3]	About three-quarters of solar thermal systems in China are in private homes to heat water, about 20 percent are systems used by multiple households, and 5 percent are in industrial applications.[2]	Manufacturing: - More than 1,000 firms reportedly manufacture and sell solar heating systems. One industry source reported that the largest 33 firms employed 50,000 workers.[3] The top eight firms in 2002, each with sales totaling more than $12 million, included Himin, Tsinghua Yang Guang, Linuo Paradigma, Tianpu, Hua Yang, Mei Da, Sunpu, and Five Star.[7]

See footnotes at end of table.

Table 5-2—*Continued*
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
European Union	An estimated 526.4 of energy production was attributed to solar thermal systems in 2003. Cumulative installed capacity of solar thermal collectors, net of capacity decommissioned, totaled 14 million m^2 in the EU-15 in 2003, 9 percent above the previous year. Glazed collectors represented 12 million m^2 of the total. Germany accounted for the largest share (39 percent) and together Germany, Greece, and Austria accounted for about 80 percent of the total.[8] Installed solar thermal surface area increased by 13 percent per year, on average, during 1990-2003, although large fluctuations in the rate of installation occurred in recent years and among individual member states, attributed largely to discontinuity in financial incentive programs and the absence to date of a directive in the EU specifically supporting solar heating and cooling systems.[9] Installations decreased by 24 percent in 2002 but increased 22 percent in 2003. The EU fell about 1 million m^2 short of its 15 million m^2 goal by 2003 and lags on its 100 million m^2 goal by 2010.[8] However, Directive 2002/91/EC requiring member states to formalize energy performance criteria for buildings must be transposed into national law by January 2006, which is expected to stimulate further growth in solar heating demand.[3] Trade in solar thermal components is widespread, while the market for complete systems is largely national.[9] While European-wide norms and standards for solar heating collectors and systems have been established, standards have not been established for installation, which results in widely varied system design and higher installation costs.[3]	The principal consumer segment is residential, accounting for about 90 percent of the solar thermal market.[3] Single-family houses, primarily existing homes, account for almost 90 percent of the residential consumer segment. For the remainder of the residential segment accounted for by multi-family dwellings, newly constructed buildings account for most solar thermal heating consumption. Additional segments including commercial and public consumers with high demand for domestic water heating, such as hotels, sports facilities, swimming pools, and prisons, account for 8 percent of the market, and other consumers such as district heating networks, industrial users of process heating technologies, and users of newly developing solar cooling technologies, collectively comprise about 2 percent of the market.	Manufacturing: - The solar thermal industry in Europe contains chiefly small and medium sized firms.[9] - The heating industry continues to absorb solar thermal manufacturers in order to broaden its scope of products. Services: - More than 1,000 suppliers and 14,600 installers participate in the solar thermal market in the European Union. - Engineers, whether or not they specialize in solar thermal systems, design a wide variety of such systems for the European market.[3] See information on selected EU member states, beginning on the following page.

See footnotes at end of table.

Table 5-2—*Continued*
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
Austria	On a per capita basis, Austria led all European countries in solar thermal installed surface area, amounting to 334 m^2 per thousand inhabitants in 2003. Austria accounted for 2.7 million m^2 (19 percent) of the cumulative installed solar thermal area in the EU in 2003, ranking second to Germany.[8] Austria has instituted support mechanisms, to improve quality standards for solar thermal heating systems and to help the industry to develop new market segments, including through support of training programs for planners and installers, and feasibility studies.[10] Consequently, the growth of solar thermal system penetration in Austria is more steady than in most EU Member States.[8] Salzburg has subsidized solar thermal collectors and other renewable energy technologies used for heat in newly constructed buildings since 1994. In 2004, 70 percent of newly constructed buildings in Salzburg incorporated solar thermal collectors.[11] Additional Austrian provinces also award subsidies with varied criteria for the incorporation of solar heating systems.	See EU summary.	Manufacturing: - GREENoneTEC, an Austrian firm, is Europe's largest producer of solar thermal collectors, although it does not make complete solar thermal systems. - Other Austrian firms include Gasokol and Kalkgruber Solar.[8] - Austria is considered a major exporter of solar heating collectors.[18]

See footnotes at end of table.

Table 5-2—*Continued*
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
France	In France, the cumulative installed solar thermal capacity totaled 0.7 million m^2 in 2003, ranking fourth in the EU in cumulative capacity and eighth in capacity per capita.[8] Solar heating was scarcely used in France until the government approved initiation of the "Plan Soleil" incentive program in 1999, which extends through 2006.[8] France's installed solar thermal capacity increased by 43 percent in 2003, evidence of growing demand since the incentive program began. The plan, embracing residential, commercial, and public consumers, includes investment subsidies; partnerships with regional councils, energy suppliers, and manufacturers; and public awareness. In the plan's first four years, investment costs have been reduced by 30 percent.[11]	See EU summary.	Manufacturing: - Giordano and Clipsol are the main French solar thermal system suppliers. Each firm employs about 50 workers.[8]

See footnotes at end of table.

Table 5-2—*Continued*
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
Germany	With 5.4 million m^2 of cumulative installed capacity as of 2003, Germany held 39 percent of the EU's solar thermal market, the most in the EU.[8] Nevertheless, Germany ranked a distant third in the EU in cumulative installed area per capita and is behind schedule in reaching its target of 10 million m^2 by 2010.[8] Solar thermal area installed in Germany increased by 34 percent in 2003, attributable in part to increased financial incentives in 2003 following the decrease in 2002 when incentive funds were reduced. Orders increased at an even faster rate, although backlogs in installations kept about half of the purchases from being installed until 2004.[8] Despite price reductions of 50 percent spanning a decade, solar thermal heat is not considered economically sustainable without support programs. About 90 percent of Germany's renewable market incentive program has been directed to solar thermal heat systems.[11] German manufacturers are reported to supply about two-thirds of the flat-panel collector market, while foreign manufacturers account for the remainder.[2]	See EU summary.	Manufacturing: - Wagner Solartechnik concentrates production on a wide spectrum of solar heating systems, including compact collectors for residences and large-scale systems integrated into facades and on roofs.[8] - Viessmann and Buderus are general heating equipment manufacturers with products that include solar water heaters and solar systems that combine heat and hot water.[8] - Plambeck develops and produces solar absorbers and collectors.[12] - Paradigma develops and markets solar heating systems, among other heating-application technologies.[12] - Additional manufacturing firms include Conegy, KBB Kollektorbau, Pro Solar, Ritter Solar, Shuco, and Solvis.[13] Services: -Lahmeyer provides project management and consulting services.[13] - Manufacturer Wagner Solartechnik also provides services such as training and technical consulting.[12]

See footnotes at end of table.

Table 5-2—*Continued*
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
Greece	On a per capita basis, Greece ranked second among European countries in solar thermal installed surface area, at 274 m^2 per thousand inhabitants in 2003. Greece also ranked second in the EU in cumulative installed solar thermal area, with 2.9 million m^2 in 2003.[8] About one-fourth of Greek households have a solar water heating system.[11] Newly installed capacity increased by 6 percent in 2003.[8] High growth rates especially during the 1990s were not sustainable, especially upon the elimination at the end of 2002 of tax-deduction incentives on solar water heaters purchased by private individuals, which had been in effect since the mid-1980s.[14] Other important characteristics of the market's development in Greece were the Public Power Corporation's support in the promotion of solar thermal heating, beginning in 1994; and manufacturers' provision of staff trained in installation and repair of solar water heaters supplied.[11]	See EU summary.	Manufacturing: - Foco SA is the largest Greek-owned solar thermal systems producer. The firm manufactures components and both produces and distributes complete systems. More than 90 percent of its revenues are generated from exports. - Other firms include Calpak-Kikeron, Dimas SA Solar, Helional, Maltezos, Sammler, and Sole SA.[8]
Spain	Cumulative installed solar thermal capacity in Spain totaled 0.3 million m^2 in 2003, ranking Spain seventh among EU-15 member states in cumulative capacity and ninth in capacity per capita.[8] Spain's goal of installing 4.8 million m^2 of solar thermal collector surface area by 2010 is behind schedule. Although the growth rate averaged about 10 percent per year for the last several years, the rate may increase in the near term, owing to recent legislation in about 40 Spanish towns and cities mandating that minimum proportions of water heated in new and renovated buildings be supplied by solar energy.[15]	See EU summary.	Manufacturing: - In addition to its main business producing solar PV systems, Isofoton produces and markets complete solar thermal systems.[8] The solar thermal industry in Spain formed an association in 2004.[15]

See footnotes at end of table.

Table 5-2—*Continued*
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
India	India had 600,000 m^2, about 1 percent of the global total, of cumulative solar thermal water and air collector operating area in 2001.[1] India's target for cumulative installed solar, including solar thermal, power capacity by 2012 is 280 MW. The target for solar thermal installation by 2012 is an additional 5 million m^2.[3]	In 2001, commercial and industrial consumers accounted for 80 percent of installed solar thermal collectors in India.[3]	Manufacturing: - TATA BP Solar designs, engineers, manufactures, supplies, and installs solar thermal and solar PV systems in India.[6] - Other firms include ATR Solar India and NRG Technologists Pvt. Ltd.
Israel	Israel, ranking sixth, had about 4 million m^2 (4 percent) of the world's solar thermal water and air collector operating area in 2001.[1] Israel is the world leader in solar thermal water collector operating area per capita.[16]	Solar water heaters comprise about 80 percent of Israel's hot water systems, owing to regulatory requirements in effect for more than two decades to install such heaters in buildings less than 27 meters high.[16]	Manufacturing: - Rand Solar Energy Systems is a division of American Israeli Gas Corporation Group. - Plastic Magen Group, an Israeli firm, is a major manufacturer and supplier of solar swimming pool heating equipment.[6] Services: - Solel Solar Systems
Japan	In 2003, Japan's solar thermal collector area in operation was 7.35 million m^2. Newly installed collector area decreased by 9 percent in 2003, casting doubt on Japan's ability to attain its target of 35 million m^2 by 2010. However, beginning in 2005, a new government incentive for solar collectors in Japan subsidizes up to 50 percent of installation costs for public buildings and up to 33 percent for private homes,[2] which marks the resumption of subsidies on solar collectors for residential use for the first time since 1997.[3]	Ninety percent of Japan's solar collector area is used for single-family hot water heating, which is installed in approximately 15 percent of Japanese households.[3]	Services: - Although non-mandatory solar water heating equipment standards exist in Japan, member firms of the Solar System Development Association submit such equipment to an official authorized testing facility for certification.[3]
Mexico	In 2001, Mexico had approximately 430,000 m^2, less than one-half of one percent of the world's solar thermal collector area in operation.[1] The USAID provided technical assistance to Mexico's National Energy Saving Commission (CONAE) to help assess after-sales services provided to consumers by solar water heater producers and distributors.[17]	By about a three-to-one margin as measured in collector area in 2001, the principal application of solar thermal collectors in Mexico was swimming pool heating.[1]	Manufacturing: - Forty firms manufactured solar thermal collectors in Mexico in 2001, up from 25 the previous year.[18] Services: - System suppliers include the Mexican subsidiary of Conergy (Germany).

See footnotes at end of table.

Table 5-2—*Continued*
Characteristics of selected markets for solar heating and cooling

Country	Market size & characteristics	Consumers of solar heating/cooling	Key market participants
Morocco	About 50,000 m ^{2} of solar water heaters were in place in Morocco in 2003.[19] Solar water heater use increased from 20,000 in 1998 to 110,000 systems in 2004, as the government's PROMASOL program initiated in 2003 to stimulate deployment of solar heating began to show results. Determination of quality standards for solar water heaters has been accomplished as one of the goals of the PROMASOL program.[19] On Dec. 29, 2004, Morocco signed an agreement with the Italian Government and United Nations agencies to further encourage solar water heater market development in Morocco through the financing of concessions.[20]	Households are believed to be the principal users of solar heating equipment and services in Morocco.[19]	Manufacturing: - Industry sources consulted have not identified firms that manufacture solar heating products in Morocco. Services: - Industry sources identify about 10 firms as importers, distributors, or installers of solar heating systems in Morocco. Examples include Getradis Energies Renouvelables and Phototherm Electronique.[21]
Turkey	Turkey, ranking fourth, had 8 million m ^{2} (8 percent) of the world's solar thermal water and air collector operating area in 2001. All installations reported were of glazed water collectors.[1]	Domestic hot water production is the predominant consumer segment for solar heating in Turkey.[22]	Manufacturing: - Auraset Solar Thermal Systems engineers and manufactures residential and industrial solar thermal systems.[6] - Additional firms include Eraslan Solar Energy System Co. Ltd.; Ezinc Metal Sanayi ve Tic. A.S.; and Solaren Ltd. Sti.[6]
United States	Solar heat generation capacity: 650 MW in 2001. Solar thermal production increased 34 percent per year, on average, during 1990-2001.[23] In 2001, the United States ranked second to China and held 25 percent of the world's solar thermal water and air collector operating area totaling 100.6 million m ^{2}. The United States ranked first in the world, with 83 percent of operating collector area totaling 27.7 million m ^{2} for solar thermal systems used for swimming pool heating. These systems use unglazed plastic collectors.[1] In 2001, the United States ranked seventh and held 3 percent of the world's collector area totaling 71.4 million m ^{2} for solar thermal systems used for hot water and space heating.[1]	Swimming pool heating is the dominant application for solar thermal systems in the U.S. market, accounting for 97 percent by area.[23] Solar water heaters for residences and businesses are a small fraction of the U.S. market except in Hawaii, which has had state and utility incentives for such solar-powered appliances since 1996.[23]	Manufacturing: - U.S. providers of solar heating systems include Solargenix and SunEarth (hot water solar heating),[24] Aquatherm Industries and FAFCO (swimming pool solar heating), and Sun Systems (solar heating systems for hot water and swimming pools).[25] Services: - Alternate Energy Technologies Inc. provides engineering, design, systems integration, and project management services in addition to solar water heating product manufacturing. - Industrial Solar Technology Corp. provides engineering, design, and installation of residential and commercial solar water heating systems.[6]

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Table 5-3
Extent of solar energy services trade, by certain countries; foreign operations or investments in such countries; and impediments to trade or market development

Country	Solar power services trade in 2004[1]	Foreign operations or investments[2]	Measures affecting trade
Australia	Estimated imports totaled $4 million, exceeding exports totaling $3 million.	Manufacturing: BP Solar (U.K.). Services: BP Solar (integrates and markets complete systems); Eurosolare (Italy) of ENI Group (raised its partial ownership stake in Pacific Solar, a major Australian firm, to 25 percent); Schlaich Bergermann & Partner (Germany) (design and engineering services for a large solar power tower in the final feasibility stage of development in Australia).	No measure specific to solar power and solar energy services trade has been identified.
Brazil	Estimated imports totaled $1 million, while exports were negligible.	No foreign firm's operations in Brazil have been identified.	No measure specific to solar power and solar energy services trade has been identified.
Canada	Estimated imports and exports were negligible.	No foreign firm's operations in Canada have been identified.	No measure specific to solar power and solar energy services trade has been identified.
China	Estimated imports totaled $3 million, while exports were negligible.	Manufacturing: Kyocera (Japan) and SolarWorld (Germany) (joint ventures with Chinese firms to make PV modules); Suntech Power Co. (Chinese-Australian joint venture in solar cell production). Services: RWE Schott Solar (Germany) (contracted to provide mini-grid solar power plants in rural villages); Shell Solar (Netherlands) (purchase and install systems); SMA (Germany) (joint venture to provide training and technical support for Chinese solar project and sales partners).[3]	No measure specific to solar power and solar energy services trade has been identified.
Costa Rica	Estimated imports and exports were negligible.	No foreign firm's operations in Costa Rica have been identified.	No measure specific to solar power and solar energy services trade has been identified.

See footnotes at end of table.

Table 5-3—*Continued*
Extent of solar energy services trade, by certain countries; foreign operations or investments in such countries; and impediments to trade or market development

Country	Solar power services trade in 2004[1]	Foreign operations or investments[2]	Measures affecting trade
European Union	Estimated imports totaled $44 million while exports totaled $66 million	Manufacturing: Kyocera (Japan) and RWE Schott Solar (Germany) in Czech Republic; Sanyo (Japan) in Hungary; Sharp (Japan) in United Kingdom; SolarWorld (Germany) in Sweden. For additional examples, see entries for selected EU member states France, Germany, Italy, the Netherlands, and Spain.	No measure specific to solar power and solar energy services trade has been identified.
France	Estimated imports totaled $1 million, while exports were negligible.	No foreign firm's operations in France have been identified.	No measure specific to solar power and solar energy services trade has been identified.
Germany	Estimated Imports totaled $18 million, while estimated exports totaled $66 million.	Manufacturing: First Solar (U.S.); Evergreen Solar (U.S.) (production joint venture with German firm Q Cells). Services: Konarka Technologies (U.S.) (acquired R&D labs).	No measure specific to solar power and solar energy services trade has been identified.
India	Estimated imports totaled $5 million, exceeding exports totaling $1 million.	Manufacturing: BP Solar (U.K.); Solarwall (U.S.) (joint venture with Indian firm to manufacture solar air heaters). Services: BP (joint venture with Indian firm TATA (design, engineer, manufacture, supply, and install solar PV and solar heating systems); Shell Solar (Netherlands) (oversee sales and installation, and train Indian engineers and technicians for after-sale service of solar home systems).[3]	Joint ventures with Indian firms are required in order for foreign firms to participate in the provision of construction, architecture, and engineering services in India.[4]
Italy	Estimated imports totaled $3 million, while exports were negligible.	No foreign firm's operations in Italy have been identified.	No measure specific to solar power and solar energy services trade has been identified.

See footnotes at end of table.

Table 5-3—*Continued*
Extent of solar energy services trade, by certain countries; foreign operations or investments in such countries; and impediments to trade or market development

Country	Solar power services trade in 2004[1]	Foreign operations or investments[2]	Measures affecting trade
Japan	Estimated imports totaled $45 million, while exports totaled $57 million.	Manufacturing: Shell Solar (Netherlands)(partnership with Japanese firm Showa); RWE Schott Solar (Germany) (partnership with Japanese firm Kobelco).[3]	Non-Japanese industry sources perceive that Japanese Government incentives favor mainly Japanese solar firms and that market power exists between such firms and builders of housing tracts on which solar systems are installed. Problems with transparency were also cited.[5]
Mexico	Estimated imports totaled $3 million, while exports were negligible.	Manufacturing: Kyocera (Japan) and Sanyo (Japan).	No measure specific to solar power and solar energy services trade has been identified.
Morocco	Estimated imports and exports were negligible.	Manufacturing: Al-Afandi Solar Wafers & Cells (Saudi Arabia). Services: Isofotón (Spain) (concession from the Moroccan electric utility company to install solar systems not connected to an electricity grid at 37,000 households).[6]	No measure specific to solar power and solar energy services trade has been identified.
Netherlands	Estimated imports totaled $2 million, while exports were negligible.	No foreign firm's operations in the Netherlands have been identified.	No measure specific to solar power and solar energy services trade has been identified.
South Africa	Estimated imports totaled $2 million, while exports were negligible.	Manufacturing: Photowatt (based in France; Canadian-owned) (joint venture in South Africa to transfer technology, and install and operate a solar cell assembly plant).[3] Services: KES (joint South African subsidiary of French firms EDF and Total Energie; under contract to install solar home PV systems and provide maintenance and customer service for 20 years).	No measure specific to solar power and solar energy services trade has been identified.
South Korea	Estimated imports totaled $1 million, while exports were negligible.	Services: Sun Power (U.S.) (joint venture) (design and installation services for a large solar PV power station by 2006).	No measure specific to solar power and solar energy services trade has been identified.

See footnotes at end of table.

Table 5-3—*Continued*
Extent of solar energy services trade, by certain countries; foreign operations or investments in such countries; and impediments to trade or market development

Country	Solar power services trade in 2004[1]	Foreign operations or investments[2]	Measures affecting trade
Spain	Estimated imports totaled $1 million, while exports were negligible.	Manufacturing: BP Solar (U.K.); Sustainable Energy Technologies Ltd. (Canada) (partnership with Spanish firm Gabriel Benmayor SA to manufacture inverters in Spain for southern European markets, including Spain). Services: Distributed Solar Power Inc. (U.S.) (project development, equipment leasing, and management services in conjunction with the sale of land used to establish and operate small solar power farms in Spain).	Feed-in tariffs on solar PV projects generating 100 kWh or more are cited as being less favorable than those on projects generating less than 100 kWh.[6]
Thailand	Estimated imports totaled $1 million, while exports were negligible.	Services: RWE Schott Solar (Germany) (contracted to construct solar farm).	No measure specific to solar power and solar energy services trade has been identified.
United States	Estimated imports totaled $5 million, while exports totaled $23 million.	Manufacturing: BP Solar (U.K.); Shell Solar (Netherlands); Sharp (Japan); Kyocera (Japan); Conergy (Germany); RWE Schott Solar (Germany); ASiMI (Norway). Services: RWE Schott Solar (systems integration); Kyocera (design, systems integration, and construction).	Non-U.S. industry sources cited warranties, liability, and diverse and complex regulatory requirements among U.S. States as impediments encountered in the U.S. solar PV market.[5]

[1] McIlvaine Co., estimates provided to USITC staff via e-mail, June 25, 2005. Estimates are included for engineering and construction management services.
[2] Information on foreign operations was obtained from company websites unless otherwise noted.
[3] European Commission, Joint Research Center, *PV Status Report 2004: Research, Solar Cell Production and Market Implementation of Photovoltaics*, no. EUR 21390 EN, Oct. 2004, found at *http://fotovoltaica.com/pvstatus2004.pdf*, retrieved June 21, 2005.
[4] United States Trade Representative (USTR), *2004 National Trade Estimate Report on Foreign Trade Barriers*, 2004, p. 222.
[5] Industry representative, interview by USITC staff, Bonn, Germany, Apr. 11, 2005.
[6] Industry representative, interview by USITC staff, Madrid, Spain, Apr. 18, 2005.

CHAPTER 6
BIOMASS ENERGY

This chapter provides information on both developed- and developing-country markets for biomass power and related services and equipment, with special emphasis on the markets in Australia, Brazil, Canada, Chile, China, Costa Rica, the European Union (Finland, Germany, Poland, Sweden, and United Kingdom), India, Japan, Korea, Mexico, Thailand, and the United States. These countries were chosen for special emphasis based on the size of their biomass power markets, and based on the USTR's request for information on developed- and developing-country markets, as well as information on markets with which the United States has established, or is in the process of negotiating, a free trade agreement.[1]

Overview

Biomass, historically a dominant source of the world's energy supply, remains the primary energy source for a significant portion of the rural population in many developing countries, and is the most utilized of the renewable energy sources covered in this study. Biomass, having been displaced by fossil fuels for energy generation for many purposes, is now being reexamined as a renewable fuel source in both developed and developing countries. Technological advances, government programs, efficiency gains, and environmental concerns have renewed interest in the oldest of renewable energy sources. Biomass has the potential to provide significant amounts of energy with much lower net greenhouse gas emissions than non-renewable fossil fuels.[2] However, the cost of electricity produced using conventional steam turbine combustion technology is substantially higher than the estimated cost of generating electricity from a new natural gas-turbine power plant. Anecdotal evidence and estimates suggest the existence of substantial cross-border trade in services related to biomass energy development, and that there are few barriers to either investment or trade in those services. However, data and anecdotal evidence suggest the existence of significant tariff barriers in goods and equipment utilized in biomass energy facilities. The cost and availability of biomass fuels, improvements in fuel handling and energy generation technologies, the continued development of small off-grid systems and liquid fuels, and government support will all affect the future market for biomass energy-related services and equipment.

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[1] For more information on the USTR's request, see appendix A of this report.

[2] Although much of the utilization of biomass requires combustion, energy from biomass is generally considered greenhouse gas neutral in that the amount of carbon that biomass absorbs during its relatively short growing cycle equates to the amount of carbon released during its combustion. Pollution Probe, *Primer on Renewable Energy Technologies*, Toronto, Canada, 2003, p. 43. However, burning biomass can produce air emissions of concern such as the indoor air pollution created in households where wood is burned for heat and cooking. World Health Organization, *The World Health Report*, found at *http://www.who.int/whr/2002/chapter4/en/index7.html*, retrieved June 14, 2005, p. 2.

Technologies and Methods

All societies burn wood and other biomass materials for heat, cooking, and other traditional uses. In advanced applications, biomass is used to generate heat, steam, and electricity; and to provide fuel for vehicles.[3] Although the principal use of biomass energy remains the traditional task of home heating and cooking,[4] this chapter focuses primarily on the more advanced commercial and industrial technologies and applications.

According to the U.S. Department of Energy (DOE), biomass is any organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal wastes, and other waste materials.[5] This basic definition, however, may differ somewhat from that used in some countries, and/or in some renewable energy programs.[6]

Biomass utilization technology is more complex than other forms of renewable energy because it uses a greater variety of energy sources and mechanical and chemical processes. There is a basic differentiation among technologies both at the biomass feedstock level and at the energy extraction level. The fundamental distinction is whether the feedstock is a readily available waste material or by-product or whether it is a plantation crop grown specifically as a feedstock for a particular energy extraction facility. The waste materials may include bark, roundwood or forestry slash,[7] paper mill or municipal sewage sludge,[8] municipal solid waste, and bagasse,[9] or other agricultural residues such as rice hulls, straw, or corn stover.[10] Examples of biomass feedstock plantation crops being used or studied include switchgrass, willow, poplar, birch, and

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[3] Although this study is not addressing fuel for transportation, liquid and gaseous fuels produced from biomass may be used for both transportation and for other applications, e.g., landfill gas or sewage treatment plant gas to run engines for power or electricity at those facilities.

[4] Several African countries have developed new, more efficient cookstoves, some of which are able to capture over 40 percent of the potential energy in wood, compared to the less than 10 percent conversion rate of traditional models. Climate Institute, *Green Energy*, found at *http://www.climate.org/topics/green/biomass.shtml*, retrieved Feb. 8, 2005.

[5] U.S. Department of Energy, Biomass Research and Development Initiative, Definition of Terms, found at *http://www.bioproducts-bioenergy.gov/about/definition.asp*., retrieved Mar. 3, 2005.

[6] For example, Germany excludes municipal solid waste incinerators from designation as a renewable energy source. For Brazil, biomass includes wood; vegetable waste such as wood waste and crop waste; animal materials and wastes; sulphite lyes (also known as black liquor, a sludge that contains the lignin digested from wood for paper making); and other solid biomass. World Resources Institute, *Earth Trends*, found at *http://earthtrends.wri.org/pdf_library/country_profiles/Ene_cou_076.pdf*, retrieved Mar. 16, 2005.

[7] Slash refers to limbs cut off tree trunks and brush pulled up for site access that can be chipped for use as fuel.

[8] Sludge refers to partly decomposed residue left over after coarse filtration and passing sewage through bacterial decomposition to remove easily oxidized wastes.

[9] Bagasse is sugar cane residue left after crushing to extract sugar syrup.

[10] Corn stover is the plant material left after the corn is harvested. Corn stover can be chopped and then utilized in various energy extraction applications.

bamboo.[11] For waste materials, future efficiency gains are likely to come through improvements in resource identification, collection, and handling, while efficiency gains in plantation crops may come from improvements in yields and production, harvesting, and transportation.[12]

Biomass energy extraction technologies comprise direct combustion, co-firing, gasification, pyrolysis, anaerobic digestion, and fermentation, and can be classified into distinct physio-chemical categories, each entailing different processes and utilizing somewhat different equipment. Each category has fundamental thermodynamic limits that affect its operating scale, and most are not yet adaptable to large, utility-scale operation.

Direct combustion, the most common technology of biomass energy extraction, involves the burning of biomass, with excess air, often in a low pressure atmospheric fire-tube, water-tube, or fluidized bed boiler.[13] Augers or belt conveyors are often used to move the biomass into the combustion chamber where the material is burned, producing steam or hot water in a boiler. Steam is used to produce electricity in steam turbine generators, with excess steam and heat available for use in other plant processes and building heating. The simultaneous production of heat and electricity is termed cogeneration and is also commonly called combined heat and power (CHP).

Co-firing, a second form of direct combustion, is simply the addition of biomass feedstocks into high-efficiency, generally coal-fired boilers as a supplementary fuel source.[14] For utilities and other power generating companies with coal-fired capacity, co-firing with biomass may represent a low cost renewable energy option, and it may assist in reducing greenhouse gases and emissions of certain air pollutants such as sulfur dioxide and nitrogen oxides.[15]

Most biomass can be used in direct combustion but some dry biomass feedstocks produce large amounts of ash which reduces efficiency and increases costs, while drying wet biomass feedstocks can itself consume large quantities of energy. However, biomass can also be used to produce fuels for engines, generators, and fuel cells in addition to power plants. Advanced gasification technologies and pyrolysis (discussed below) convert biomass feedstocks into liquid fuels and synthesis gases (syngas). Other

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[11] Plantation crops are being studied with respect to several characteristics such as growth rates, productivity, ease of harvesting, transportation, conversion to fuel, and fuel value.

[12] U.S. Department of Energy, National Renewable Energy Laboratory, untitled database, found at *http://www.nrel.gov/analysis/power_databook/pdf/2.pdf*, retrieved Feb. 1, 2005.

[13] Fire-tube and water-tube boilers have an open firebox where combustion gases pass through tubes surrounded by the boiler water (fire-tube) or a firebox in which water-filled tubes pass through the firebox (water-tube). Fluidized bed boilers have a firebox filled with granular material such as sand. Hot air is pumped into the bottom of the bed which also contains the water tubes.

[14] Co-firing generally means substituting 5 to 20 percent biomass, by weight, for fossil fuels. U.S. Department of Energy, National Renewable Energy Laboratory, untitled database, found at *http://www.nrel.gov/analysis/power_databook/pdf/2.pdf*, retrieved Feb. 1, 2005.

[15] U.S. Department of Agriculture, Forest Products Laboratory, *Wood Biomass for Energy*, found at *http://www.fpl.fs.fed.us*, retrieved Mar. 26, 2005, p. 2.

thermochemical processes can produce a hydrocarbon fuel comparable to heating oil as well as other liquid fuels such as alcohols, ketones, and esters.[16]

Gasification for power production involves heating (partially burning) a biomass feedstock in an oxygen-starved environment to produce syngas which has a low to moderate caloric fuel value.[17] Syngas is then used as fuel to produce electricity in a gas turbine and generator set. Syngas may be used in a higher efficiency combined cycle power generation plant that includes a gas turbine cycle in addition to the steam turbine cycle.[18] Syngas can also be used as a raw material to produce chemicals such as ammonia and liquid fuels such as methanol.[19]

Pyrolysis involves heating the biomass feedstock at high temperatures in the absence of oxygen which causes the biomass to decompose. This process produces a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide). The gas produced is then cooled to a liquid and a solid charcoal. The primary purpose of pyrolysis is to obtain the liquid fuel which can be burned like petroleum to generate electricity. Fuels obtained from pyrolysis are more easily stored, transported, and burned than solid biomass feedstocks.[20]

Anaerobic digestion is a widely practiced technology, from simple biogas reactors using animal dung to produce fuel for tractors in developing countries, to sewage sludge digestors common at sewage treatment plants or recovery of methane from waste lagoons at dairy farms or from landfills where the digestion occurs underground. Anaerobic digestion is a process by which organic matter is decomposed by bacteria in the absence of oxygen to produce low to medium calorific biogas (a mixture of methane and carbon dioxide). The reaction may be 'seeded' with methanoforming bacteria in the more industrialized operations, or rely on such bacteria present naturally in the soil. This technology is used to power gas turbines for local electricity production and has the added benefit of capturing and utilizing methane, a recognized greenhouse gas.[21]

Aerobic fermentation is a widely used method of making liquid fuels (e.g., ethanol), mostly for spark-ignition internal combustion engines. While the main use of ethanol is as fuel for transportation, it is used in some, principally off-grid areas to power spark ignition engines to turn generators to produce electricity.[22] A final technology is a

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[16] Pollution Probe, *Primer on Bioproducts*, Toronto, Canada, 2003, found at *http://www.pollutionprobe.org/Publications/Primers.htm*, p. 27, retrieved Mar. 17, 2005.

[17] Biomass feedstocks and the derived gases have heat values that are low relative to that of fossil fuels. For example, compared to wood chips, coal has about 2.25 times as much heating value, and petroleum products have about 3.25 times as much heating value, on an equal weight basis. Weast, ed., *Handbook of Chemistry and Physics*, 66th ed. CRC Press, Boca Raton, FL, p. 99.

[18] Combined cycle process produces electricity from burning fuel, using combustion gases to turn a combustion turbine and also using the combustion gas to create steam which is used in a second cycle to turn a steam turbine, which increases the efficiency of the plant.

[19] Pollution Probe, *Primer on Bioproducts*, found at *http://www.pollutionprobe.org/Publications/Primers.htm*, retrieved Mar. 17, 2005, p. 27.

[20] Ibid.

[21] U.S. Department of Energy, National Renewable Energy Laboratory, untitled database, found at *http://www.nrel.gov/analysis/power_databook/pdf/2.pdf*, retrieved Feb. 1, 2005.

[22] Industry representatives, interviews by Commission staff, Rio de Janeiro, Brazil, Dec. 20, 2004.

relatively simple refining process through which another liquid fuel known as biodiesel can be made from the fatty acids or oils from renewable plant and animal sources (even from waste oils from fast food restaurants). Biodiesel is used by itself, or blended with diesel fuel, as fuel for transportation or to power generators in off-grid or micro-grid applications.[23]

Technological constraints and economic factors in acquiring and managing large volumes of materials have generally meant that biomass feedstocks are not economically attractive options for centralized grid-oriented power stations and thus are used primarily in industrial settings. Gasification technologies, including combined cycle plants, are being increasingly evaluated as ways of overcoming at least some of these constraints, even though gasification systems require more capital equipment and have more intricate control engineering problems than direct combustion systems.[24]

Market Size and Characteristics

Market for biomass power and services

Biomass is a bulky and low heat value fuel that cannot be economically shipped beyond a short collection radius. Thus, most biomass energy technologies are best suited to small-to-moderate scale industrial facilities, rather than grid-connected central station electricity production, because the power production can be tailored to the facility's own industrial power needs and fuel availability with the surplus or deficit electricity sent to, or received from, the power grid. However, there are a few pure power producing biomass plants in the United States (fueled by wood or municipal solid waste) and more such power plants around the globe. Biopower (biomass generated electricity) is included in most renewable energy portfolio schemes or incentive programs.

Globally, approximately 10-15 percent of current energy supply is from biomass. However, the utilization of biomass in developed countries is in sharp contrast to that in developing countries. In developed countries, biomass generally accounts for 3-4 percent of total energy supply, and most biomass is used to produce electricity and process heat in cogeneration systems.[25] In developing countries as a whole, about 10-15 percent of the energy supply on average comes from biomass, though that share increases substantially to about 50-60 percent in developing countries of Asia, and 70-90 percent in Africa, with wood being the principal feedstock.[26] In the countries covered in this chapter, biomass generated electricity ranges from 0.1 percent of total electricity production in China to 12.9 percent of total electricity production in Finland (see table 6-1 at end of chapter).

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[23] Barnes, Douglas F., Van Der Plas, Robert, and Floor, Willem, "Tackling the Rural Energy Problem in Developing Countries," undated article, found at *http://www.worldbank.org/fandd/english/0697/articles/020697.htm*, retrieved June 26, 2005, p. 7.

[24] U.S. Department of Energy, National Renewable Energy Laboratory, untitled database, found at *http://www.nrel.gov/analysis/power_databook/pdf/2.pdf*, retrieved Feb. 1, 2005.

[25] Larson, Eric D. and Kartha, Sivan, "Expanding Roles for Modernized Biomass Energy," *Energy for Sustainable Development*, Vol. IV, No. 3, October 2000, p. 15. The authors note that supportive policies in some countries (such as Sweden, Finland, and Austria) raise these figures to 15-20 percent.

[26] Ibid.

Industry estimates suggest that the global market for biomass power is substantial, having yielded approximately $16.3 billion in revenues from electricity generation during 2004.[27] Finland was the largest market for biomass-generated electricity in 2004, having accounted for an estimated $4.6 billion, or 28 percent, of global revenues in this industry sector. Other markets that reportedly accounted for a significant share of global biomass power revenues included the United States (16 percent), Japan (10 percent), and Sweden (7 percent).[28]

According to DOE, biomass was the leading source of renewable energy in the United States in 2003, providing nearly half of all renewable energy and 4 percent of total energy production. Biopower is reportedly the largest source of non-hydro renewable electricity, in terms of generation, in the United States. About 70 percent of biopower makes use of forest product industry and agricultural industry residues and the remaining use municipal solid waste as the feedstock.[29] Agricultural and forestry industries are also the most common biomass feedstocks used for generating industrial process heat and steam and for producing a variety of bioproducts.[30]

While a variety of biomass feedstocks may be used in direct combustion operations to generate electricity, the most common feedstock is wood or wood waste. In the United States, most of the facilities using wood or wood waste are combined heat and power (CHP) facilities in the industrial sector, many of which are in pulp and paper mills or paperboard manufacturing operations (figure 6-1). Some CHP facilities have buy-back agreements with local utilities to purchase net excess generation, but less than 5 percent of these CHP facilities are actually owned and operated by investor- or municipally-owned electric utilities. However, some biopower facilities are owned and operated by non-utility generators, such as independent power producers, that have power purchase agreements with local utilities.[31]

While some biomass energy facilities at times sell power to the grid or to other users, most industrial CHP facilities are net consumers of electricity. Thus, power plants that burn principally wood or municipal solid waste, commonly termed waste-to-energy plants (WTE), and fossil fuel power plants that co-fire with biomass, are among the few net producers of electricity among the major biomass producers.

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[27] An explanation of the data estimation methodology employed by McIlvaine Co. is included in chapter 1. McIlvaine Co., estimate provided to USITC staff via e-mail, June 23, 2005.

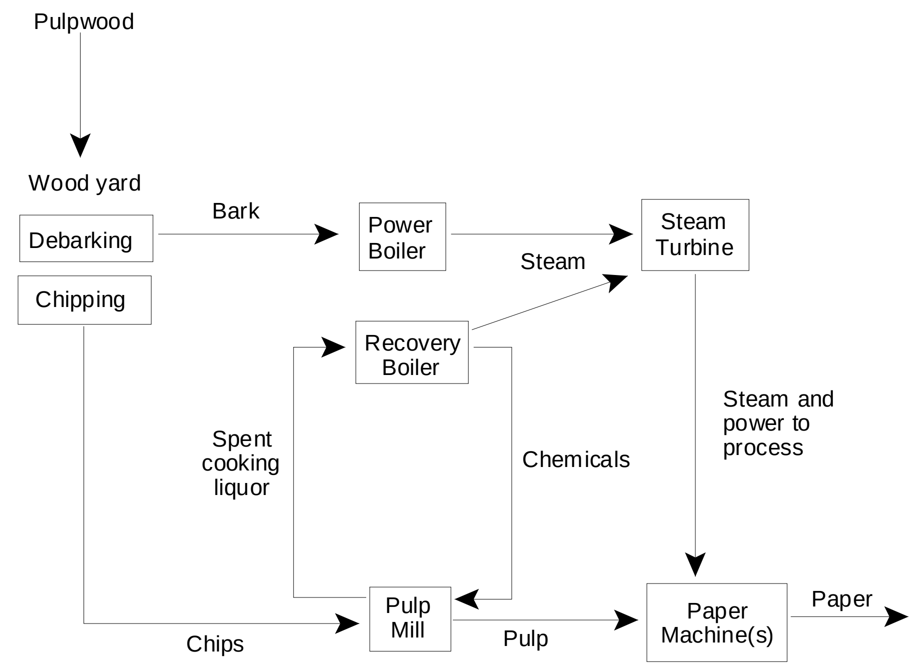
[28] Ibid.

[29] World Resources Institute, Green Power Market Group, found at *http://www.thegreenpowergroup.org/biomass.html*, retrieved Mar. 28, 2005, p. 1.

[30] U.S. Department of Energy, *Biomass Program: Biomass Today*, found at *http://www.eere.energy.gov/biomass/biomass_today.html*, retrieved Mar. 17, 2005.

[31] World Resources Institute, Green Power Market Group, found at *http://www.thegreenpowergroup.org/biomass.html*, retrieved Mar. 28, 2005, p. 1.

Figure 6-1
Typical pulp and paper mill - steam and power flows



Source: Adapted from A.F.&P.A., Kenneth W. Britt, ed., *Handbook of Pulp and Paper Technology, 2nd ed.*, (New York, Van Nostrand Reinhold Co., 1970, p. 138, and J. Steben Anderson and John M. Movacik, "Gas Turbine Considerations in the Pulp and Paper Industry," *Tappi Journal*, Mar. 1991, p. 125.

Several services– including construction and engineering, among others– are provided in conjunction with the generation of power from biomass fuels. Official data on the size of this services market are not available. However, industry estimates indicate that services[32] related to the development of biomass power facilities worldwide totaled approximately $1.7 billion in 2004.[33] Finland accounted for about $480 million, or 28 percent, of such services in the same year, followed by the United States (23 percent), Romania (7 percent), Japan (7 percent), and France (6 percent).[34]

The principal barrier to development of biomass energy is the price of biopower relative to the price of electricity produced from other sources, particularly fossil fuels. For example, one estimate of the cost of generating electricity from biomass ranges from 2.9 to 6.7 cents per kWh whereas the estimated cost of generating electricity from a

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[32] The biomass energy services estimates produced by McIlvaine Co. reflect engineering and construction services provided in conjunction with the establishment of a biomass power facility. McIlvaine Co., e-mail to USITC staff, June 29, 2005.

[33] McIlvaine Co., estimates provided to USITC staff via e-mail, June 23, 2005.

[34] Ibid.

combined-cycle natural gas power plant is 2.8 cents per kWh.[35] The wide range of costs for biopower reflect technological differences. The estimated cost using conventional combustion technology ranges from 5.2 to 6.7 cents per kWh, while the cost using landfill gas is estimated at 2.9 to 3.6 cents per kWh, and the cost of producing electricity from anaerobic digestion of animal manure is 3.7 to 5.4 cents per kWh.[36]

The relatively high price of biopower, coupled with the high capital cost of biomass electric generation systems, magnify the effects of the costs and complexities associated with increased utilization of biomass feedstocks and fuels. For example, the factors often cited with regard to biomass cogeneration include the seasonal and geographical availability and price of biomass; competing uses for the resource base; access to the grid (power purchase agreements and liberalization of the electricity supply); government plans and targets for electricity generated from renewable resources; the perceived risk for financiers; and lack of incentives for developers and entrepreneurs.[37]

Given that the key producers of biomass energy are industrial facilities that consume essentially all of the biomass energy they produce to support their principal outputs, such as paper, sugar, and rice, the difficulties and expenses associated with upgrading their power systems to create excess electricity for grid customers are daunting. In addition to high capital costs, both solid fuel and biogas systems have significant operating difficulties and high operation and maintenance costs.[38] For facilities that produce bioenergy by methods other than cogeneration with readily available waste or byproducts, the lack of assurance of long-term fuel supplies (e.g., plantation crops) at relatively fixed prices is a deterrent to development and expansion of such power plants. The absence of financial support, both in the form of capital cost improvements and in the tariffs (prices) received for electricity delivered to the grid, also inhibits the expanded use of biomass resources in many countries.[39]

Market for equipment and technologies

Biomass systems range from small stoves used in homes for heating or cooking to power plants used by centralized utilities to produce electricity. New system designs and technological improvements in electrical generation have increased interest in biomass as a viable renewable energy resource. As noted above, wood is the most common source of fuel for all these systems. The forest products industry consumes 85 percent of the wood waste used for energy in the United States, and in this way the industry is able to generate more than half the energy it consumes. Gasification technologies using

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[35] The differences between the costs of electricity produced from biomass and that produced from natural gas power plants affect the demand for services primarily in the sense that engineering and construction firms may specialize in the design, engineering, and construction of particular systems utilizing various fuels. Thus, the relative costs associated with various technologies may affect the selection of the firms that supply such services rather than the amount of such services.

[36] Oregon Department of Energy, *Biomass Energy: Cost of Production*, "Estimated Costs of Biomass Energy Facilities," found at *www.energy.state.or.us/biomass/Cost.htm*, retrieved Aug. 2, 2005.

[37] Wilkins, Gill, *Technology Transfer for Renewable Energy*, The Royal Institute of International Affairs and Earthscan Publications Ltd., London, 2002, p.3.

[38] Industry officials, interviews by Commission staff, Brasilia, Brazil, Dec. 22, 2004.

[39] Industry officials, interviews by Commission staff, San Jose, Costa Rica, Dec. 6 and 8, 2004, and Sao Paulo, Brazil, Dec. 17, 2004.

biomass byproducts (e.g., bark and spent black liquor) from the pulp and paper industry aid chemical recovery as well as generate process steam and electricity.[40]

The industrial sector produces thermal output and electricity from biomass primarily from CHP facilities in the paper, chemical, and food-processing industries. Power plants that generate electricity also produce useful heat and steam through CHP technology using all biomass fuel (e.g., wood or municipal waste) or co-firing biomass with a fossil fuel such as coal.[41]

Most of the electricity, heat, and steam produced by industry are consumed on-site. However, some manufacturers sell excess power to the grid, and grid-connected biomass electrical generating capacity in the United States generally utilizes relatively small direct-combustion boiler and steam turbine technology. The average biomass power plant capacity is 20 MW, as large biomass power plants (e.g., over 75 MW) are often impractical owing to fuel cost and availability. Gathering, transporting, and storage costs make it difficult to take advantage of scale economies associated with building large biomass conversion facilities.[42]

The technologies described in the previous section, and used predominantly by industrial facilities, make use of a wide variety of equipment.[43] This equipment includes augers, conveyers, grinders, and choppers for feedstock handling and conditioning; steam boilers and steam turbines for direct combustion of solid feedstocks and for the larger biogas facilities; gas turbines for biogas from landfills and anaerobic digesters; micro turbines, spark ignition and diesel engines, and generators for small biogas applications; and anaerobic digesters, various types of tanks, vats, process controls, and other process equipment and instrumentation for gasification, pyrolysis, and fermentation processes. In addition, there are small modular systems, some of which are suited to residential applications.

Such equipment is available for many fuel types, combustion and conversion processes, and generation capacities. Some equipment manufacturers and distributors provide system design and integration services, system monitoring, and permitting assistance and financing, along with the equipment. Engineering companies provide services such as system design, procurement, construction, construction management, permitting assistance, and system testing and monitoring for biomass energy producers and consumers.

There are hundreds of firms providing various pieces of this equipment in the United States, and many more around the world. Given that much of this equipment has multiple uses, official data on the size of the market specifically for biomass energy systems are not readily available. Furthermore, since most of the biomass energy is captive production/consumption, utilizes forest and agricultural industry residues, and

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[40] James R. Arcate, *Biomass Charcoal for PFBC Power Plants*, found at *http://www.techtp.com/archives/bioenerg.htm*, retrieved Mar. 27, 2005, p. 1.

[41] U.S. Department of Energy, *Industrial Process Heat and Steam*, found at *http://www.eere.energy.gov/biomass/industrial_process.html*, retrieved Mar. 17, 2005.

[42] James R. Arcate, *Biomass Charcoal for PFBC Power Plants*, found at *http://www.techtp.com/archives/bioenerg.htm*, retrieved Mar. 27, 2005, p. 1.

[43] Selected types of this equipment are listed in table 1-3.

remains concentrated in a few industries in much of the world, the market for this equipment is essentially secondary to that of the primary products of the industries.

Trade and Investment

Biomass Power Services

While official data on cross-border trade and investment in biomass related services do not exist, industry estimates suggest that cross-border trade in engineering and construction services related to installation of new biomass facilities was valued at $178 million in 2004 (see table 6-2 at end of chapter).[44] Finland was the leading importer of such services, with $45 million, or 25 percent of the market, followed by the United States ($41 million), Romania ($18 million), Japan ($14 million), and France ($9 million). Leading exporters of the subject services included the United States, with $55 million, or 31 percent of the market in 2004, as well as Finland ($35 million), Germany ($19 million), Japan ($17 million), and France ($14 million).[45]

Barriers to trade in biomass related services appear to be few, other than the barriers to the establishment and operation of engineering and consulting firms, such as professional licensing and limitations on movement of persons. The barriers to trade and investment for biomass energy related equipment and services are basically the same barriers that exist with respect to the development of biomass and other renewable energy projects.

While access to the grid is generally not a substantial barrier, the cost of utility interconnections is relatively high primarily because of the generally small size of biomass energy facilities.[46] Utilities and government officials cite lack of experience, extensive permitting requirements, and the time required as significant barriers to dealing with small biomass and other renewable energy projects.[47]

Equipment and Technologies

Owing to the dual-use nature of most biomass related equipment, the share of trade in such goods cannot be discerned from official trade data that include equipment used in multiple industries. However, one industry source estimated the value of global trade in material handling and size reduction equipment, combustion units, turbines, air pollution control equipment, and water treatment equipment for use in biomass facilities at $1.98 billion in 2004. Finland was the leading importer of such goods with $500 million, or 25 percent of the market, followed by the United States ($450 million), Romania ($200 million), Japan ($150 million), and France ($100 million). The United States dominated exports of such goods with $610 million, or 31 percent of the market

[44] McIlvaine Co., estimates provided to USITC staff via e-mail, June 23, 2005.
[45] Ibid.
[46] Commission staff interview with industry officials, Rio de Janeiro, Brazil, Dec. 21, 2004.
[47] Ibid.

in 2004, followed by Finland ($400 million), Germany ($222 million), Japan ($200 million), and France ($150 million).[48]

Barriers to trade in biomass related equipment are usually in the form of fairly substantial duties on such equipment, particularly in developing countries. For example, the applied tariffs on boilers are as high as 14 percent while those for steam turbines can be up to 23 percent.[49]

Future Prospects

Biomass technologies provide large amounts of heat throughout the world.[50] These technologies also are proven electricity-generation options, with global installed capacity of 35,000 MW, about 10,000 MW of which are in the United States.[51] Virtually all of the installed capacity is based on mature, direct-combustion technology, and prospects for additional future installations may depend on further improvements in both the production and handling of biomass feedstocks and in the efficiency of steam boilers and turbines. However, future efficiency improvements may focus on co-firing of biomass in existing coal-fired boilers, as well as the introduction of high-efficiency gasification, combined-cycle systems, fuel cell systems, and modular systems for a variety of primarily off-grid installations.[52]

Biomass power plants are generally small-scale compared with fossil fuel power plants, often supplying either captive heat and power to the producer or electricity to local distribution networks. Captive use and limited distributed local power generation limits the cost and environmental impact of fuel transportation, and reduces or eliminates the costs of reinforcing or upgrading electricity distribution systems. Biomass has some attractions over some other renewable energy sources since it is not an intermittent resource and can be supplied on a continuous basis to fuel base load plants. Thus, biomass systems may play an increasing role in supplying power through distributed generation and in areas beyond the reach of national grid systems.

Biomass is the only renewable energy source that can be converted into liquid fuel. Substantial quantities of biomass come from both rural and urban areas each year, particularly in the form of waste products. Therefore, gasification and pyrolysis for synthesis of liquid fuel are promising processes to utilize this available renewable

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[48] Ibid.

[49] *World Integrated Trade Solution Database*, The World Bank and the United Nations Conference on Trade and Development, retrieved June 27, 2005.

[50] Improvements in cookstove design and distribution would reportedly improve efficiency, reduce indoor air pollution, and reduce pressure on certain forest resources, as well as release feedstocks from basic cooking and residential heating for commercial and industrial applications. Government official, interview by Commission staff, May 27, 2005.

[51] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Frequently Asked Questions, found at *http://www.eere.energy.gov/biomass/electricalpower.html*, retrieved Aug. 1, 2005, p. 1. In the United States, the 7,000 MW is fueled primarily by forest product and agricultural residues, and there is an additional 2,500 MW of municipal solid waste-fired capacity, which is often not counted as part of biomass power, as well as 500 MW of landfill gas-fired and other capacity. Thus, the estimate of global capacity may be understated.

[52] Industry representative, telephone interview by Commission staff, Mar. 15, 2005.

resource for fuel production for use in more flexible electricity generation applications as well as for transportation.

Finally, the opportunities for increased trade and investment in equipment and services used in the development and operation of biomass systems for utility scale electricity generation may be limited by problems such as scale, long-term assurances of feedstock supplies, restrictions on using municipal solid waste as a feed stock, and technical limitations. However, the opportunities for increased trade in equipment and services used to develop smaller scale bio-mass systems for use in commercial, industrial, and residential applications appear to be more plentiful.

Table 6-1
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics[1]	Consumers of biomass power	Key market participants
Australia	Biomass: 2,434 GWh Waste: 0 GWh Total Electricity Production: 222,182 GWh Biopower: 1.1% of Total Electricity Production In 1997, generating capacity from landfill gas was about 72 MW[2] In 1997, sewage gas generation capacity was about 7 MW. In 1997, bagasse provided about 2% of Australia's total primary energy consumption.[3]	Virtually all industrial production for captive consumption.	Sugar Mills Pulp and Paper Industry Wood Products Industry
Brazil	Biomass: 11,404 GWh Waste: 0 GWh Total Electricity Production: 344,645 GWh Biopower: 3.3% of Total Electricity Production **Sugar Cane Bagasse:** Generating capacity: 1,000,000 KW Electricity generation: 14,798 TJ Total use from combustion: 689,200 TJ Total energy production: 723,701 TJ[5] Renewable Energy Targets: 3,300 MW (partially biomass) by 2016[6] As of April 2005, a total of 28 biomass projects to generate 646 MW reportedly have been qualified under the PROINFA program. Most use sugarcane bagasse, but some use rice hulls, orange bagasse, wood chips, and wood waste.	Virtually all industrial production for captive consumption.	Pulp and Paper Industry Wood Products Industry Sugar Mills Sao Paulo state accounts for 60% of sugar cane production nationally and about 50% of installed power, which is 1,800 MW.[4] The Brazilian Orange Industry also has several bagasse power operations.[7]

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
Canada	Biomass: 8,169 GWh Waste: 0 GWh Total Electricity Production: 601,495 GWh Biopower: 1.4% of Total Electricity Production Second source notes that total electricity derived from wastes is currently 750 GWh with a potential to double over the next decade.[8] Biogas production: 9,200 TJ Generating capacity: 85,300 kW Electricity generation: 2,421 TJ Total energy production: 20,441 TJ[9] Canada produces 6% of its energy needs from biomass compared to 3% for the EU 15 and 3% for the US.[10]	Nearly all is industrial production for captive consumption. Small amount of biomass energy is consumed for residential district heating.	Pulp and Paper Industry Wood Products Industry Municipal Landfills
Chile	Biomass: 1,664 GWh Waste: 0 GWh Total Electricity Production: 45,483 GWh Biopower: 3.7% of Total Electricity Production Total Energy Production, 2000: 8,299 Mtoe Renewables, excluding hydroelectric: 4,047 Mtoe Primary solid biomass (includes fuelwood): 4,040 Mtoe Biogas and liquid biomass: 7 Mtoe[11]	Virtually all industrial production for captive consumption.	Pulp and Paper Industry Wood Products Industry

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
China	Biomass: 2,438 GWh Waste: 0 GWh Total Electricity Production: 164,0478 GWh Biopower: 0.1% of Total Electricity Production **Municipal solid waste** BIogas production: 334 TJ Electricity generating capacity: 265,000 kW Electricity generation: 17,698 TJ Total energy production: 18,032 TJ **Sugar cane bagasse** Electricity generating capacity: 60,980 kW Electricity generation: 4,142 TJ Direct use from combustion: 2,824 TJ Total energy production: 6,966 TJ **Agricultural residues - hog manure** Biogas production: 173 TJ Electricity generating capacity: 1,700 kW Electricity generation: 115 TJ Direct use from combustion: 753 TJ Total energy production: 1,041 TJ[13]	Virtually all industrial production for captive consumption.	Pulp and Paper Industry Sugar Mills Rice Mills Biogas Plants from Animal Wastes
Costa Rica	Biomass: 53 GWh Waste: 0 GWh Total Electricity Production: 7,485 GWh Biopower: 0.7% of Total Electricity Production	Virtually all industrial production for captive consumption.	Sugar Mills

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	**Market size & characteristics**	**Consumers of biomass power**	**Key market participants**
European Union	The European Commission's White Paper for a Community Strategy seeks to double the share of renewable energies in gross domestic energy consumption from 6% to 12% in the EU by 2010.[14] In 2001, total biomass production for energy purposes was 56 Mtoe. To achieve the 12% target, 74 Mtoe more are needed by 2010.[15] In 2001 Biomass accounted for 3-4% of total primary energy consumption. Total production from biomass fired power stations was 37 TWh, or 1.5% of production. **Biomass resource distribution:** Municipal Solid Waste: 11% Forestry: 20% Energy Crops: 39% Agriculture Residues: 24% Landfill Gas: 0% Industrial Waste: 6%[16]	Majority of biomass CHP produced by industry for captive consumption. Minority of biomass produced for residential district heating.	Pulp and Paper Industry Wood Products Industry Waste to Energy Plants 10 of the EU 15 Member States have biomass capacity, led by Sweden and Finland, both of which have large forest industries using significant CHP. Austria also has a significant biomass energy capacity.
Finland	Biomass: 9,626 GWh Total Electricity Production: 74,899 GWh Biopower: 12.9% of Total Electricity Production	Majority of biomass CHP produced by industry for captive consumption, but significant amount of biomass used for residential district heating.	Pulp and Paper Industry Wood Products Industry District Heating Services

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
Poland	Biomass: 494 GWh Waste: 195 GWh Total Electricity Production: 76,348 GWh Biopower: 0.9% of Total Electricity Production (0.7% in 2001[16]) Biogas production: 1,189 TJ Renewable Energy Targets: 5-6% of Total Primary Energy Supply by 2010 and 8-10% by 2020; 8% of electricity output by 2010[17]	Majority of biomass CHP produced by industry for captive consumption. Minority of biomass produced for residential district heating.	Pulp and Paper Industry Wood Products Industry -Biggest share of biomass is expected to be from small installations that produce electricity or heat and from co-generation plants.

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
Germany	Biomass: 3,790 GWh Waste: 9,158 GWh Total Electricity Production: 57,1645 GWh Biopower: 2.2% of Total Electricity Production (1.2% in 2001[18]) Biomass represented 69% of renewable energy supply. **Municipal solid waste** Electricity generating capacity: 555,000 kW Electricity generation: 9,526 TJ Direct use from combustion: 19,787 TJ Total energy production: 29,313 TJ **Forestry/wood-processing** Electricity generation: 842 TJ Direct use from combustion: 20,147 TJ Total energy production: 20,989 TJ **Agricultural residues - liquid manure** Electricity generation: 320 TJ Direct use from combustion: 135 TJ Total energy production: 455 TJ **Landfill gas** Electricity generating capacity: 170,000 kW Electricity generation: 2,491 TJ Direct use from combustion: 2,000 TJ Total energy production: 4,491 TJ **Sewage gas** Electricity generating capacity: 92,000 KW Electricity generation: 129 TJ Direct use from combustion: 2,800 TJ[19] Total energy production: 2,929 TJ Renewable Energy Target : 12.5% of electricity output by 2010[20]	Majority of biomass CHP produced by industry for captive consumption. Minority of biomass produced for residential heating.	Pulp and Paper Industry Wood Products Industry Waste to Energy plants Land Fills The market for biomass boilers with automatic feeders has grown recently. Some 9,000 pellet boilers are estimated to have been installed between 1998 and 2001. Moreover, some 80 large CHP plants were installed between 1998 and 2001.

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
Sweden	Total Electricity Production: 146,052 GWh From Biomass: 3,674 GWh Biopower: 2.5% of Total Electricity Production	Majority of biomass CHP produced by industry for captive consumption. Minority of biomass produced for residential district heating.	Pulp and Paper Industry Wood Products Industry District Heating

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
United Kingdom	Biomass: 39,17GWh Waste: 1,451 GWh Total Electricity Production: 387,112 GWh Biopower: 1.4% of Total Electricity Production In 2003 the National Fossil Fuel Obligation (NFFO) had spurred the development of 440 projects with 1,104 MW of capacity, led by landfill gas (471 MW), municipal and industrial waste (236 MW), biomass (107 MW) and sewage gas (25 MW).[21] **Municipal solid waste** Electricity generating capacity: 158,600 kW Electricity generation: 4,892 TJ Direct use from combustion: 1,340 TJ Total energy production: 6232 TJ **Forestry/wood-processing** Direct use from combustion: 29,740 TJ **Agricultural residues - straw** Direct use from combustion: 3,015 TJ **Agricultural residues - poultry litter, farm waste** Electricity generating capacity: 83,880 kW Electricity generation: 1,852 TJ **Landfill gas** Electricity generating capacity: 309,000 kW Electricity generation: 6,131 TJ Direct use from combustion: 586 TJ Total energy production: 6,717 TJ **Sewage gas** Electricity generating capacity: 91,300 kW Electricity generation: 1,476 TJ Direct use from combustion: 2,261 TJ Total energy production: 3,737 TJ **General industrial and hospital waste** Direct use from combustion: 2,010 TJ[22] Renewable Energy Target : 10% of electricity by 2010[23]	Majority of biomass CHP produced by industry for captive consumption.	Pulp and Paper Industry Wood Products Industry Waste to Energy Plants Most of this capacity uses poultry litter; one is a straw-fired plant that can also be fueled by energy crops and some are relatively small "captive power" plants at forestry and farm sites. Biogas plant capacity grew from 90 MW in 1990 to 510 MW in 2000.

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
India	Biomass: 22,080 GWh Waste: 3,456 GWh Total Electricity Production: 1,097,167 GWh Biopower: 2.3% of Total Electricity Production Installed capacity from renewables exceeds 3% of total power generation capacity.[24] Generation potential from renewable energy sources is estimated at 100,000 MW out of which, only about 3,500 MW has been exploited. India has plans to electrify of 18,000 remote villages and to meet 10 percent of the country's power supply through renewable energy by the year 2012.[25]	Majority of biomass CHP produced by industry for captive consumption.	Sugar Mills Rice Mills Textile Industry Wood Products Industry
Japan	Biomass: 1,849 GWh Waste: 0 GWh Total Electricity Production: 596,543 GWh Biopower: 0.3% of Total Electricity Production In 2001, biomass represented 32% of total renewable energy use. Production of biomass has not changed significantly over the past decade and was some 204,550 TJ in 2001[26] **Municipal solid waste** Electricity generating capacity: 829,000 kW **Sugar cane bagasse** Electricity generating capacity: 27,000 kW **Forestry/wood-processing** Electricity generating capacity: 50,000 kW[27]	Majority of biomass CHP produced by industry for captive consumption. Majority of biomass electricity consumed by those taking power from the grid.	Pulp and paper industry Municipal Solid Waste Plants The Ministry of Economy, Trade and Industry (METI), through New Energy Development Organization (NEDO), has reportedly funded projects which focus on R&D for co-firing technology, small-scale distributed generation systems, gasification, and biodiesel and fuel ethanol production from cellulosic biomass.

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	**Market size & characteristics**	**Consumers of biomass power**	**Key market participants**
Korea	Biomass: 310 GWh Waste: 482 GWh Total Electricity Production: 328,986 GWh Biopower: 0.2% of Total Electricity Production Biomass Production was 7,133 TJ in 2001[28] Landfill gas has emerged as an important renewable resource. **Agricultural residues - leaves & branches**: Direct use from combustion: 1,526 TJ **Industrial waste:** Direct use from combustion: 61,798 TJ[29]	Majority of biomass CHP produced by industry for captive consumption.	Rice Mills Wood Products Industry Anaerobic digesters are utilized in Korea to dispose of municipal food waste, processing up to 15 tonnes of waste per day.[30]
Mexico	Biomass: 470 GWh Waste: 0 GWh Total Electricity Production: 215,158 GWh Biopower: 1.1% of Total Electricity Production Total Renewable Energy Capacity - 10,906 MW, 401 MW from Biomass[30] Installed Renewable Electricity Generation Capacity, 1990-2001: 0.87 MW[31]	Majority of biomass CHP produced by industry for captive consumption.	Wood Products Industry Sugar Mills

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
Thailand	Biomass: 2,042 GWh Waste: 0 GWh Total Electricity Production - 109,013 GWh Biopower: 1.9% of Total Electricity Production Capacity: Bagasse: 316 MW Paddy Husk : 6 MW Waste: 2.5M W Wood Chips: 135 MW[33] **Municipal solid waste** Electricity generating capacity: 2,500 kW **Sugar cane bagasse** Electricity generating capacity: 301,000 kW Electricity generation: 4,605 TJ Direct use from combustion: 113,045 TJ Total energy production: 117,650 TJ **Agricultural residues** - paddy husk Electricity generation: 3,548,TJ Direct use from combustion: 30,373 TJ Total energy production: 33,921,TJ[34]	Majority of biomass CHP produced by industry for captive consumption.	Rice Mills Sugar Mills Cottage Industries

See footnotes at end of table.

Table 6-1--*Continued*
Characteristics of selected markets for biomass power and biomass energy services

Country	Market size & characteristics	Consumers of biomass power	Key market participants
United States	Biomass: 45,806 GWh Waste: 24,611GWh Total Electricity Production: 4,017,509,GWh Biopower: 1.8% of Total Electricity Production Biomass Generation Capacity: 9,733 MW out of 96,165 MW[34] Biomass use grew 7.5% from 1990 to 2001 from 62.3 Mtoe to 67 Mtoe. Biomass represented 68% of renewables in 2001. **Municipal solid waste/Landfills electricity** Generating capacity: 2,862,000 kW Electricity generation: 71,405 TJ Direct use from combustion: 217,722 TJ Total energy production: 289,127 TJ **Forestry/wood-processing** Electricity generating capacity: 6,726,000 kW Electricity generation: 124,712 TJ Direct use from combustion: 2,306 ,026 TJ Total energy production: 2,430,738 TJ **Wood pellets** Direct use from combustion: 8,872 TJ **Other biomass electricity** Generating capacity: 10,602,000 kW Electricity generation: 11,328 TJ Direct use from combustion: 102,084 TJ Total energy production: 113,412 TJ Biomass is the single largest source of non-hydro renewable electricity. In 2002, the 9,733 MW of capacity included about 5,886 MW of forest product and agricultural residues, 3,308 MW of generating capacity from municipal solid waste, and 539 MW of other capacity such as landfill gas.[35]	Majority of biomass CHP produced by industry for captive consumption. Biomass currently supplies over 3% of the U.S. total energy consumption — mostly through CHP production by the pulp and paper industry and electrical generation with forest industry residues and municipal solid waste (MSW).	Pulp and Paper Sugar Mills Other forest products industries In general, the wood wastes generated by modern mills are highly utilized; indeed, forest mills are the largest biomass energy users in the nation today, generating more than half of their large energy requirement on-site.[36] Of the many possible conversion technologies for expanded biomass use, two of the most promising are the sugar platform and the thermochemical platform.[37]

1 Unless otherwise noted, production and capacity data are from 2002. Source: International Energy Agency, Renewable Energy Information, 2004, various pages.
2 Australian Department of Agriculture, Fisheries and Forestry, DPIE (1997), found at *http:// www.daff.gov.au/*.
3 Biomass Energy Systems, Bush, Harris & Ho Trieu, 1997, found at *http://www.reslab.com/au*.
4 May 2005 Brazil Market Research, Thermal Power Generation, p. 4, found at *http://www.buyusainfo.net/docs/x_8850385.pdf*.
5 2004-2005 World Energy Solutions, Inc., found at *http://www.worldenergy.com*.
6 Johannesburg Renewable Energy Coalition, Renewable Energy target Table, found at *http://www.iea.org/textbase/pamsdb/jr.aspx*.
7 US Commercial Service, Brazil Market Overview, Renewable Energy - Biomass, Feb. 2005.
8 International Energy Agency, Renewable Energy Market & Policy Trends In IEA Countries, pp. 181 and 191.
9 2004-2005 World Energy Solutions, Inc., found at *http://www.worldenergy.com*.

[10] http://www.policy.biotec.or.th/page/biotech%20status/ biobase%20industry%20in%20cananda%202001.pdf.
[11] The World Resources Institute, found at *http://earthtrends.wri.org/text/energy-resources/country-profile-37.html*.
[12] 2004-2005 World Energy Solutions, Inc., found at *http://www.worldenergy.com*.
[13] European Energy Commission Action Plan, found at *http://europa.eu.int/comm/energy/res/biomass_action_plan/index_en.htm*.
[14] Overview of Biomass for Power Generation in Europe (Jorgensen).
[15] Ibid.
[16] International Energy Agency, Renewable Energy Market & Policy Trends In IEA Countries, p. 206.
[17] Johannesburg Renewable Energy Coalition. Renewable Energy target Table, found at *http://www.iea.org/textbase/pamsdb/jr.aspx*.
[18] International Energy Agency, Renewable Energy Market & Policy Trends In IEA Countries, pp. 291, 299, 301-302.
[19] 2004-2005 World Energy Solutions, Inc., found at *http://www.worldenergy.com*.
[20] International Energy Agency, Renewable Energy Market & Policy Trends In IEA Countries, p. 410.
[21] International Energy Agency, Renewable Energy Market & Policy Trends In IEA Countries, p. 623.
[22] 2004-2005 World Energy Solutions, Inc., found at *http://www.worldenergy.com*.
[23] International Energy Agency, Renewable Energy Market & Policy Trends In IEA Countries, pp. 627-628.
[24] The Energy & Resources Institute, found at *http://www.teriin.org/news/terivsn/issue47/main.htm*.
[25] Ibid.
[26] International Energy Agency, Renewable Energy Market & Policy Trends In IEA Countries, p. 441.
[27] 2004-2005 World Energy Solutions, Inc., found at *http://www.worldenergy.com*.
[28] Biomass Energy Systems, found at *http://reslab.com.au/resfiles/biomass/text.html*.
[29] 2004-2005 World Energy Solutions, Inc., found at *http://www.worldenergy.com*.
[30] Renewable Energy Development in Mexico, Jose Antonio and Medina Ross (2004), found at *http://www.gtz.org.mx/business-forum/2.4_Medina_RoleofSENER.pdf*.
[31] An Energy Overview of Mexico, Department of Energy Report, found at *http://www.fe.doe.gov/international/Western%20Hemisphere/mexiover.html*.
[32] US Commercial Report - Thailand, Mar. 20, 2003, ID # 111968, pp. 3 and 9.
[33] 2004-2005 World Energy Solutions, Inc., found *http://www.worldenergy.com*.
[34] International Energy Agency, Renewable Energy Market & Policy Trends In IEA Countries, pp. 645, 650.
[35] U.S. Department of Energy, Energy Efficiency and Renewable Energy, found at *http://www.eere.energy.gov/biomass/electrical_power.html*.
[36] Texas State Energy Conservation Office, Texas Renewable Energy Resources, found at *http://www.infinitepower.org/resbiomass.htm*.
[37] 2002 EIA Renewable Energy Annual Report, Kitisorn Sookpradist, found at *http://www.eia.doe.gov*.

Table 6-2
Extent of biomass energy-related services trade, by certain countries

Country	Market	Cross-border trade	
		Imports	Exports
	Millions of dollars		
Australia	3	0	0
Brazil	57	9	0
Canada	6	0	0
Chile	2	0	0
China	30	0	0
Costa Rica	([1])	([1])	([1])
European Union	([1])	([1])	([1])
Czech Republic	1	0	0
Poland	7	1	1
Finland	480	45	35
Germany	16	2	19
Sweden	36	3	5
United Kingdom	29	2	5
India	([1])	([1])	([1])
Japan	120	14	17
Korea	3	0	0
Mexico	1	0	0
Thailand	3	0	0
United States	391	41	55

[1] Not available.

Source: McIlvaine, unpublished estimates for 2004. The biomass energy services estimates reflect engineering and construction services provided in conjunction with the establishment of a biomass power facility.

CHAPTER 7
GEOTHERMAL ENERGY

This chapter provides information on both developed- and developing markets for geothermal power services and equipment, with emphasis on markets in Australia, Canada, China, Costa Rica, El Salvador, the European Union, Iceland, Indonesia, Italy, Japan, Mexico, New Zealand, the Philippines, Thailand, and the United States. These countries were selected to provide a mix of current market leaders, as well as markets indicating strong potential for future growth.[1]

Overview

Geothermal energy is clean, reliable, and abundant in certain locations.[2] As such, it can be one of the most productive components of a country's renewable energy portfolio. In the United States, geothermal energy generates 40 percent more electricity than wind technologies, and 26 times as much as solar energy.[3] In Japan, geothermal energy accounts for close to twice as much electricity production as wind.[4] However, despite geothermal energy's advantages and potential, the resource is not widely utilized. Usually this is because conventional generating technologies that rely on fossil fuels are cheaper and their technologies are better established. Also, would-be developers may lack the financial or technical resources to develop geothermal resources that would likely be more cost effective than fossil fuel-based alternatives.[5]

Trade in goods and services relating to geothermal energy face few formal barriers; however, in many markets, regulatory procedures may weaken geothermal's economic viability.[6] Bureaucratic approval processes, which can cause lengthy delays and add costs to projects, are reportedly more of a challenge to developers than technical problems. Geothermal investors also have encountered public resistence because of the perceived negative effects geothermal development may have on the environment and on regional tourist industries.[7] Technical and financial risks, as more fully explained

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[1] For more information on the USTR's request, see appendix A of this report.

[2] The most efficient geothermal power plants emit, on average, 136 grams of carbon dioxide per kilowatt-hour of electricity generated compared to 128,000 g/kWh and 225,000 g/kWh of carbon dioxide for a power plant fueled by natural gas or coal, respectively. European Renewable Energy Council (EREC), "Renewable Energy Sources - Geothermal," found at *http://www.erec-renewables.org/sources/geothermal.htm*, retrieved Mar. 27, 2005.

[3] U.S. Department of Energy, Energy Information Administration (DOE/EIA), *Renewable Energy Trends 2003*, July 2004, found at *http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea.pdf*, retrieved Apr. 12, 2005.

[4] Industry representative, interview by USITC staff, Tokyo, Japan, Nov. 5, 2004.

[5] Drilling, exploration, and other geothermal development activities can be extremely costly and speculative undertakings, requiring considerable insurance coverage and up-front investment. Such factors prevent development in many areas where highly productive geothermal energy would likely be available. Government official, interview by USITC staff, Berlin, Germany, Apr. 13, 2005.

[6] New Zealand Geothermal Association, *Climate Change Consultation Paper*, found at *http://www.nzgeothermal.org.nz/MfEclimatechange17Dec2001.pdf*, retrieved Jun. 27, 2005.

[7] Industry representative, interview by USITC staff, Pisa, Italy, April 8, 2005.

later in the chapter, are perhaps the most significant barriers to geothermal development worldwide.

Geothermal energy is used to generate electricity in more than 20 countries. Direct use of geothermal energy is even more widespread. Worldwide, installed geothermal electricity capacity is approximately 8,000 megawatts,[8] which produces about 49,000 gigawatthours of electrical energy per year.[9] Total electricity production from geothermal energy increased 3 percent per year during 1997-2001.[10] The United States leads the world in geothermal power production, accounting for about one-fourth of total installed capacity, followed by the Philippines, Mexico, Indonesia, and Italy.[11] In addition to electrical power generation, geothermal energy has many direct-use applications including heating buildings, melting snow on streets and sidewalks, recreation (e.g., spas), heating greenhouses, and aquiculture. In the near future, geothermal electricity generation is likely to have the highest profile, both in terms of policy promotion and actual development, particularly in certain developing countries such as the Philippines and El Salvador, where the resource already accounts for 22 percent and 12 percent of total electricity generation, respectively.[12]

Technologies and Methods

Heat extracted from geothermal resources can be utilized directly, or can be converted to electrical energy. Direct applications tap thermal springs and wells that are generally of much lower temperature than those necessary to generate electricity.[13] Lower temperature resources are much more numerous than high-temperature resources, and are usually more accessible. Consequently, developing low temperature resources is often significantly less expensive. The most straightforward direct heating systems distribute hydrothermal water through a series of pipes to houses, buildings, greenhouses, or other areas that are warmed by radiant heat exchange. The hydrothermal water may also be circulated through heat exchangers, where the energy is transferred to a separate working fluid that is then distributed. In comparing direct and power generating applications, one of the most significant differentiating characteristics is that direct use must occur within close proximity of the resource, while electricity generated by geothermal energy can be distributed longer distances.

Electricity production using geothermal energy is based on conventional steam turbine and generator equipment. However, the specific technologies used by geothermal fueled

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[8] Geothermal accounts for about 0.4 percent of the world's total electrical generating capacity. The World Bank Group, *Geothermal Energy - Markets*, found at *http://www.worldbank.org/html/fpd/energy/geothermal/markets.htm*, retrieved Mar. 27, 2005.

[9] Energy & Geoscience Institute, The University of Utah, *Geothermal Energy*, found at *http://www.egi.utah.edu/geothermal/GeothermalBrochure.pdf*, retrieved Mar. 27, 2005.

[10] United Nations Development Programme, *World Energy Assessment:Overview 2004 Update*, found at *http://www.undp.org/energy/docs/WEAOU_full.pdf*, retrieved June 27, 2005.

[11] International Energy Agency (IEA), *Renewables for Power Generation: Status & Prospects*, 2003, p. 123.

[12] Industry representative, interview by USITC staff, Costa Rica, Dec. 10, 2004.

[13] Direct use applications use geothermal reservoirs providing low-to moderate-temperature water (68ºF to 302ºF). Office of Energy Efficiency and Renewable Energy, DOE, *Direct Use of Geothermal Energy*, found at *http://www.eere.energy.gov/geothermal/directuse.html*, retrieved Mar. 27, 2005.

power plants differ from site to site so as to maximize the resource's unique characteristics. Generally, the reservoir's temperature, pressure, and fluid composition– whether primarily vapor or liquid– determine the most appropriate power plant configuration.[14] The three primary types of geothermal power plants are dry steam, flash steam, and binary-cycle. Many services– such as exploration, drilling, and reservoir analysis and management– and equipment associated with steam, flash, and binary-cycle technologies are essentially the same for the three types of systems.[15]

Geothermal resources may be in the form of hot water, steam, or a combination of the two. High-temperature dry steam reservoirs are generally considered the most desirable.[16] This is because vapor-dominated generating plants are the most productive and the least expensive to install, as they require the simplest production technology.[17] However, such reservoirs are fairly scarce.[18] In such systems, pressurized steam is piped directly from the reservoir into a turbine, spinning a generator that produces electricity. The condensed steam is then used either as a source of water for the plant or is injected back into the underground reservoir, which reduces potential sources of pollution and extends the life of the hot water resource. These plants emit only excess steam and limited quantities of polluting gases or noxious fumes.

Liquid dominated geothermal resources, which provide superheated hot water under pressure, are much more abundant than dry steam resources. Flash and binary technologies are designed for use with liquid dominated resources. Flash technologies (figure 7-1) are generally used when the geothermal resource has a temperature of 350˚F or higher. The process generally involves piping the hot water to one or more separators, within which the pressure is lowered, causing the water to boil explosively, or flash, into steam. The pressurized steam rotates a turbine that activates a generator, which produces electricity. For very high temperature resources, the fluid can be manipulated to flash more than once to recover even more energy from the same resource. When all useable heat has been extracted, the fluid is then injected back into the reservoir. Worldwide, flash technology is the most common process used by geothermal power plants.[19]

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[14] Site variability produces a wide range of capital costs and production costs. Costs at geothermal plants using low temperature, low pressure wells may be more than double those of generation facilities that are supplied with high temperature steam. Industry representative, interview with USITC staff, Tokyo, Japan, Nov. 8, 2004.

[15] Industry representative, interview with USITC staff, Tokyo, Japan, Nov. 5, 2004.

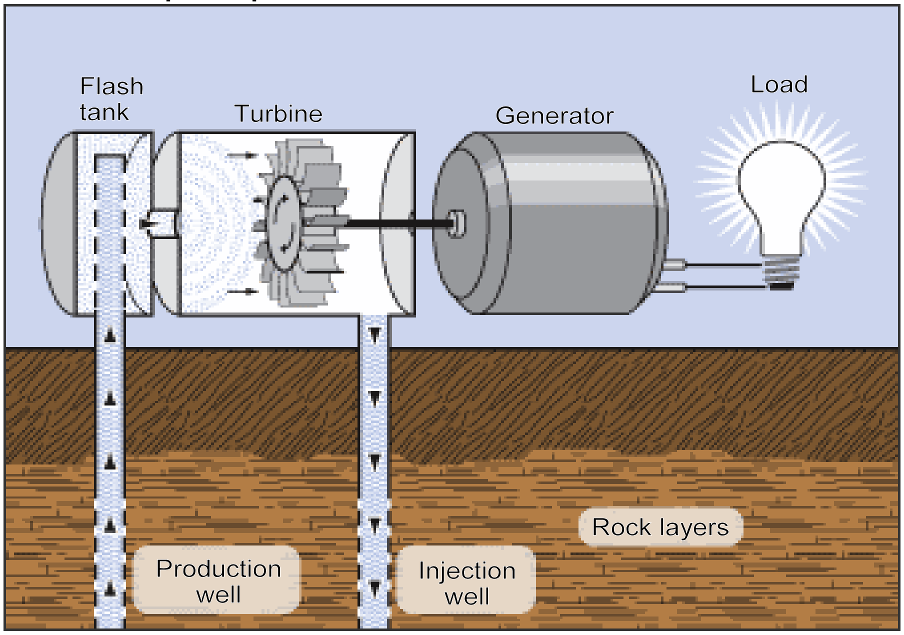
[16] Dry steam, flash, and binary-cycle technologies operate within a range of temperatures that at times may overlap. The main distinction between the technologies, and what determines which is most applicable for a given project, is that dry steam implies virtually no liquid content, allowing for a simplified power generation process, while flash and binary systems are designed to accommodate a mixture of steam and liquid.

[17] Worldwide, dry steam power plants account for 23 percent of the geothermal-based production of electricity. John W. Lund, *The Basics of Geothermal Power Conversion*, Geo-Heat Center, Oregon Institute of Technology.

[18] The Geysers is the only commercial dry steam geothermal facility in the United States. Renewable Energy Policy Project, "Geothermal Power Technology," found at *http://www.crest.org/geothermal/geothermal_brief_power_technologyandgeneration.html*, retrieved Mar. 9, 2005.

[19] European Renewable Energy Council, *Renewable Energy Sources - Geothermal*, found at *http://www.erec-renewables.org/sources/geothermal.htm*, retrieved Mar. 3, 2005.

Figure 7-1
Flash steam power plant



Note.—Schematic diagram does not show all components and processes of system.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy, found at *http://www.eere.energy.gov/geothermal/powerplants.html#dry*, retrieved Aug. 15, 2005.

When the geothermal resource has a temperature below 350˚F, binary cycle technologies (figure 7-2) are generally used.[20] The binary and flash processes are similar, except that with binary systems, the geothermal fluid is passed through a heat exchanger where the geothermal fluid causes a secondary working fluid to vaporize, which like flashed steam, produces energy that drives a turbine.[21] A cooling system is used to condense the vaporized working fluid, which is then recycled back through the heat exchanger, forming a closed-loop system that is kept separated from the geothermal fluid to avoid contamination. As with the flash cycle, the geothermal fluid exiting a binary plant is injected back into the underground reservoir, where it is naturally reheated for reuse. Although more efficient than steam plants, binary plants are more equipment-intensive and therefore have higher energy conversion costs. However, energy reclamation costs are lower because binary cycle plants are able to use lower temperature fluids, which are

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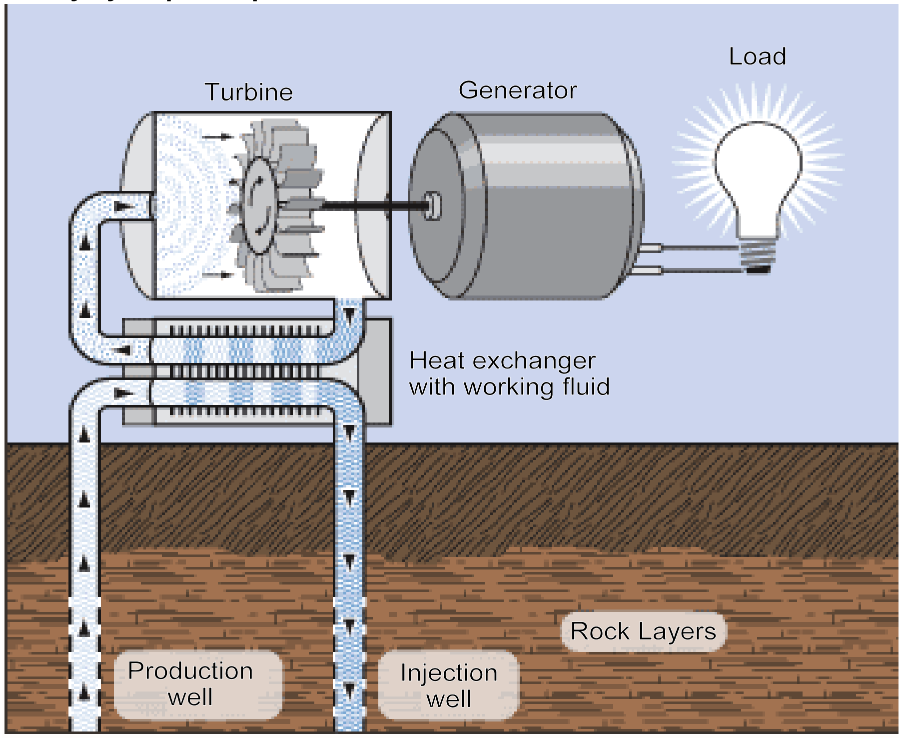
[20] The lower temperature limit of binary-cycle technology is currently approximately 212˚F, below which the required size of the heat exchangers would make the plant uneconomical. Research is underway to increase the efficiency of heat exchangers, which would increase their range of operation. Government official, interview by USITC staff, Berlin, Germany, Apr. 13, 2005.

[21] Renewable Energy Policy Project, Geothermal Power Technology, *http://www.crest.org/geothermal/geothermal_brief_power_technologyandgeneration.html*, retrieved Mar. 9, 2005.

Figure 7-2
Binary cycle power plant



Note.—Schematic diagram does not show all components and processes of system.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy, found at *http://www.eere.energy.gov/geothermal/powerplants.html#dry*, retrieved Aug. 15, 2005.

generally found closer to the surface and therefore require less drilling.[22] In hybrid plants, flash and binary cycles can be combined in sequence for more efficient geothemal to electrical energy conversion.[23]

As noted, flash technology is by far the most widely-used geothermal energy technology, although many smaller-scale binary cycle plants and hybrid plants[24] have been installed in recent years. Another developing geothermal technology is "hot dry rock" (HDR), which is not a power generating technology, but a way to create the input

[22] Exploration can account for as much as 60 percent of the cost of a geothermal power project. Most of the cost is related to drilling wells. American Society of Mechanical Engineers, "U.S. Energy Research and Development Needs in the New Millennium," June 20, 2001, found at *http://www.asme.org/gric/ps/2001/01-30.html#5.5*, retrieved Mar. 27, 2005.

[23] Energy & Geoscience Institute at the University of Utah, *Geothermal Energy*.

[24] The World Bank Group, *Geothermal Energy - Markets*, found at *http://www.worldbank.org/html/fpd/energy/geothermal/markets.htm*, retrieved Feb. 17, 2005.

resource for the previously mentioned technologies.[25] HDR involves forcing water through a previously dry region of fractured, hot rock, and pumping the water to the surface after it has been heated. The process has been proven successful, yet it largely remains uneconomical.[26] In the United States, HDR research and development is virtually nonexistent, although programs continue elsewhere, such as France and Germany.[27]

Among renewable energy resources, geothermal resources provide one of the most consistent, reliable sources of energy, as electricity production is not influenced by the weather or time of day.[28] Geothermal energy has an inherent storage capability,[29] making geothermal power plants good sources of baseload power.[30] Compared to more conventional generation processes, geothermal power offers substantial environmental advantages. As no fuels are combusted, air emissions produced by geothermal power generation are far below amounts produced by fossil fuel-based technologies.[31] Geothermal electricity generation produces some carbon dioxide emissions, but these are 15-20 times lower than the cleanest fossil-fuel power plants of the same size.[32] Although geothermal energy is one of the more benign power sources, careful siting,

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[25] Most of the accessible HDR resources will likely produce fluids in the moderate temperature range, for which binary heat extraction technology is most appropriate. HDR resources have not been developed commercially because of the generally higher development costs and long-term operational uncertainties. Office of Energy Efficiency and Renewable Energy, DOE, "Overview of Geothermal Technologies," found at *http://www.eere.energy.gov/consumerinfo/pdfs/geo_overview.pdf*, retrieved Mar. 27, 2005. However, there are several demonstration projects under development, including the hot dry rocks project in Soultz, on the French-German border. This project is jointly funded by the EU and private companies. Industry representatives, interviews with USITC staff, Pisa, Italy, Apr. 8, 2005.

[26] The amount of potential energy contained in HDR resources is estimated to be 300 times greater than that remaining in the fossil fuel resource base. However, most of the known HDR resources are of such low temperature that exploitation is not practical. Also, a large portion are available in areas where development is not economically feasible due to low demand or better alternatives. Nevertheless, the abundant resource's potential continues to attract proponents. Programs are underway in Europe, Australia, and Japan to develop the commercially viable HDR systems. Dave Duchane & Don Brown, "Hot Dry Rock Geothermal Energy Research and Development," *GHC Bulletin*, Dec. 2002, Los Alamos National Laboratory Associates, found at *http://geoheat.oit.edu/bulletin/bull23-4/art4.pdf*, retrieved Mar. 27, 2005.

[27] Energy Information Administration, *Renewable Energy Annual 1996*, *http://www.eia.doe.gov/cneaf/solar.renewables/page/geothermal/geothermalprf.pdf*, retrieved Mar. 9, 2005.

[28] Heat and fluids are usually extracted from geothermal resources at a greater rate than they are naturally replenished, even when the extracted fluid is pumped back into the reservoir. Consequently, geothermal aquifers have a finite useful life, and are not technically "renewable" resources, although they are usually grouped along with renewables. European Commission, "Renewables - Geothermal Energy," found at *http://europa.eu.int/comm/energy_transport/atlas/htmlu/geoint.html*, retrieved Feb. 23, 2005.

[29] Like energy stored in a battery, geothermal resources possess energy that is available on a consistent basis.

[30] Baseline power is the power load that electric utility companies deliver on a continuous basis.

[31] U.S. Environmental Protection Agency, *Electricity from Non-Hydroelectric Renewable Energy Sources*, found at *http://www.epa.gov/cleanenergy/renew.htm*, retrieved Mar. 7, 2004.

[32] Renewable Northwest Project, *Geothermal Energy Technology*, found at *http://www.rnp.org/RenewTech/tech_geo.html*, retrieved Mar. 27, 2005.

monitoring, and maintenance are necessary to avoid undesirable events such as groundwater contamination, the cooling of adjacent hot springs, or uncontrolled venting accidents, which could release large amounts of harmful gases.[33] Some commonly encountered disadvantages of geothermal energy include unsightly infrastructure and unpleasant smells.[34] Spent geothermal fluid also presents some potential hazards, but these are generally minimal as the fluid is commonly re-injected.[35]

Geothermal power plants vary in size depending on the extent of the energy resource and power demand, with existing plants ranging between 100 kW and 100 MW.[36] The technology is suitable for rural electrification and mini-grid applications, as well as supplying power to national grids. Major factors affecting cost are the depth and temperature of the resource, well productivity and longevity, environmental regulations, and project financing costs– including insurance– which may be significant where unstable economic markets or political systems exist.[37] When conditions are ideal, electricity can be produced using geothermal energy at costs ranging from 2 to 5 cents per kilowatt-hour, allowing geothermal producers to compete in most wholesale electricity markets (table 7-1).[38] Once on-line, geothermal plants generally have much lower operating and maintenance costs than conventional power plants.

As financial undertakings, geothermal power plants often are less attractive when compared to many conventional plants as well as to other renewable power producing ventures. This is due to the long-term nature of such projects,[39] as well as the many uncertainties associated with developing and running a geothermal generating plant.[40] Initial development costs can be substantial, as evaluating the quality of a resource requires investment in drilling and well tests.[41] Drilling typically accounts for 30 to 50 percent of a project's total costs, as more useful geothermal resources are generally

[33] Industry representative, interview with USITC staff, Tokyo, Japan, Nov. 5, 2004.

[34] Although limited compared to most other power generating technologies, geothermal energy has an environmental impact. To increase public acceptance of new plants, efforts have been focused on reducing the noise and sulfur smell emitted from geothermal plants, and improving the aesthetics of the plants as well as the related steam pipes. Industry representative, interview by USITC staff, Pisa, Italy, Apr. 8, 2005.

[35] Geothermal fluid often contains heavy metals and dissolved gasses. European Renewable Energy Council (EREC), *Renewable Energy Sources - Geothermal*, found at *http://www.erec-renewables.org/sources/geothermal.htm*, retrieved Mar. 3, 2005.

[36] The World Bank Group, "Geothermal Energy," found at *http://www.worldbank.org/html/fpd/energy/geothermal/*, retrieved Mar. 21, 2005.

[37] Ibid.

[38] International Energy Agency, *Renewables for Power Generation: Status & Prospects*, 2003, p. 19.

[39] New geothermal investment tends to take longer to become profitable as compared to conventional electricity generation projects. Industry representative, interview by USITC staff, Pisa, Italy, Apr. 8, 2005.

[40] The long-term potential of a geothermal resource is based on estimates. Consequently, many factors are unpredictable, such as sustainable temperature and pressure. Overexploitation at some facilities in California, for example, resulted in a lower than expected output.

[41] European Commission, "Geothermal - Barriers," found at *http://europa.eu.int/comm/energy_transport/atlas/htmlu/geoobar.html*, retrieved Feb. 23, 2005.

Table 7-1
Unit cost of power: Geothermal electricity production[1]

	Unit cost		
	High quality resource	Medium quality resource	Low quality resource
	US c/kWh		
Small plants (<5 MW)	5.0-7.0	5.5-8.5	6.0-10.5
Medium plants (5-30 MW)	4.0-6.0	4.5-7.0	([2])
Large pants (>30MW)	2.5-5.0	4.0-6.0	([2])

[1] The World Bank Group, *Geothermal Energy: An Assessment*, found at *http://www.worldbank.org/html/fpd/energy/geothermal/assessment.htm#economic*, retrieved June 17, 2005

[2] Normally not suitable.

found at greater depths.[42] The primary risk is failure to locate a useable heat resource after capital has been invested in surveys, exploration, and drilling. According to one industry representative, it is common to drill three wells for every one that proves to be productive.[43] Further, when potentially viable sites are identified, long-term potential is difficult to assess because a resource's production capacity can unexpectedly decrease or diminish to the point where it is no longer useful.[44] Given the uncertainty regarding returns on a financial investment in a geothermal power plant, the demand for services related to geothermal energy may, at certain stages, be reduced.

As mentioned above, geothermal energy is also used in direct use applications as a source of heat. Direct use systems are typically much more simple than generating plants, and rely on lower-tech, locally purchased services, goods, and equipment. The primary components of a direct use system typically includes collection apparatus or a production facility, such as a well, that brings the hot water to the surface and a mechanical system comprised of piping, heat exchangers, and controls. Piping, and its installation, both of which are usually locally sourced, typically accounts for more than half of the total costs of a direct system.[45]

[42] When present within markets, complimentary industries such as oil exploration may have an effect on the typical costs of a geothermal project.

[43] Industry representative, interview with USITC staff, Larderello, Italy, Apr. 7, 2005.

[44] University of Utah, 2001, The Energy & Geoscience Institute, found at *http://egi-geothermal.org*, retrieved Mar. 11, 2005.

[45] Geo-Heat Center, Oregon Institute of Technology, *Selected Cost Considerations for Geothermal District Heating*, found at *http://geoheat.oit.edu/bulletin/bull17-3/art21.htm*, retrieved Mar. 27, 2005.

Market Size and Characteristics

Worldwide, geothermal resources provide directly used heat capacity of 12,000 MW and electric power generation capacity of over 8,000 MW. While direct use applications account for the largest share of the global geothermal energy market, there is little data or other analytical information available on this market segment, due to the small-scale nature of many direct use applications. Thus, this section will focus on the electricity generation segment of the geothermal energy sector. Viable geothermal resources have been identified in more than 80 countries, yet only a small fraction have been exploited.[46] Twenty-four countries have at least one power plant that is powered by geothermal energy. Together, these facilities generate a total of 57 terawatt-hours of electricity per year, and account for 0.4 percent of total global electricity production.[47] Global geothermal capacity was 8,240 MW, or 0.26 percent of total world installed electrical generating capacity in 1999.[48] Since 1995, the worldwide average annual growth rate of installed geothermal electricity generation capacity has been approximately 5 percent a year.[49] Based on anticipated development of geothermal resources, geothermal energy could supply more than 5 percent of the world's electricity needs by 2020.[50] Research also indicates that worldwide demand for electricity generated from geothermal energy could grow 4 percent per year through 2010, particularly in certain developing economies of south east Asia and Latin America.[51]

Worldwide, more than 90 percent of installed geothermal power capacity is in the United States, the Philippines, Mexico, Italy, Japan, Indonesia, and New Zealand (table 7-2).[52] The United States is the largest producer of geothermal power, although demand for new geothermal capacity has declined in recent years (see table 7-3 at end of chapter). Within the European Union (EU), geothermal power generation is limited almost exclusively to Italy,[53] although many EU countries have put forth some effort toward developing this energy source. Most of these efforts involve feasibility studies and field assessments.[54] Countries including Austria, France, Italy, and Germany have been sufficiently encouraged by initial findings to continue activities designed to stimulate

[46] International Energy Agency's Renewable Energy Working Party, *Renewable Energy Policy - into the Mainstream*, Oct. 2002, found at *http://www.iea.org/textbase/nppdf/free/2000/Renew_main2003.pdf*.

[47] IEA, "Geothermal Energy for Electricity Generation," found at *http://www.iea.org/Textbase/work/2005/renewable/Session2/GeothermalIA_LR.pdf*, retrieved Mar. 27, 2005.

[48] Renewable Energy Policy Project, *Geothermal Power: FAQs*, found at *http://www.crest.org/articles/static/1/995653330_5.html*, retrieved Mar. 7, 2005.

[49] International Energy Agency, *Renewables for Power Generation: Status & Prospects*, 2003, p. 133.

[50] International Energy Agency, *Geothermal Energy*, found at *http://www.iea-gia.org/activities.asp*.

[51] European Commission, "Current and Future Deployment of Geothermal Energy Within the EU," found at *http://europa.eu.int/comm/energy_transport/atlas/htmlu/geopost2.html*, retrieved Feb. 23, 2005.

[52] International Energy Agency, *Renewables for Power Generation: Status & Prospects*, 2003, p. 131.

[53] European Commission, "Current and Future Deployment of Geothermal Energy Within the EU," found at *http://europa.eu.int/comm/energy_transport/atlas/htmlu/geopost2.html*, retrieved Feb. 23, 2005.

[54] Government official, interview by USITC staff, Berlin, Apr. 13, 2005.

Table 7-2
Top markets: Installed geothermal generating capacities world-wide from 1995 to end of 2003[1]

Country	1995	2003	Percent change
	———*MW*———		*1995-2003*
United States	2,816.7	2,020.0	(28.3)
Philippines	1,227.0	1,931.0	57.4
Mexico	753.0	953.0	26.6
Indonesia	309.8	807.0	160.7
Italy	631.7	790.5	25.1
Japan	413.7	560.9	35.6
New Zealand	286.0	421.3	47.3
Iceland	50.0	200.0	300.0
Costa Rica	55.0	162.5	195.5
El Salvador	105.0	161.0	53.3

[1] Huttrer, G.W., "The Status of World Geothermal Power Generation 1995-2000," *Geothermics*, 2001; and International Geothermal Association (IGA), found at *http://iga.igg.cnr.it/geo/geoenergy.php*, retrieved Mar. 9, 2005.

further development.[55] Even so, such activity is not likely to boost trade significantly in related equipment or services, as any resulting increases in demand are expected to be absorbed by domestic suppliers.[56] Other EU countries reduced or eliminated geothermal programs after the initial efforts did not prove encouraging.[57] Further, natural gas is readily available in most European countries and is generally a more economically competitive source of energy than geothermal resources.[58]

In recent years, countries in Asia and Central and South America have experienced relatively strong growth in the development of geothermal resources. Developing countries within these regions that have significant geothermal resources are likely to experience some of the world's highest growth rates for geothermal power as their demand for electricity is growing much faster than that of industrialized economies.[59] Within some of these high-growth markets, geothermal power has the potential to account for an increasingly significant portion of the country's overall energy needs.

[55] In Italy, rekindled interested in geothermal electricity has led to the development of new technologies, including deep drilling (3000-4000 meters) and reinjection techniques. Further, significant investment in new exploratory wells is expected in the Larderello area in the near future. Industry representative, interview by USITC staff, Pisa, Italy, Apr. 8, 2005.

[56] Industry representative, interview by USITC staff, Pisa, Italy, Apr. 8, 2005.

[57] European Commission, "Geothermal - Current RTD," found at *http://europa.eu.int/comm/energy_transport/atlas/htmlu/geortdc.html*, retrieved Feb. 23, 2005.

[58] European Commission, "Geothermal - Market Barriers," found at *http://europa.eu.int/comm/energy_transport/atlas/htmlu/geomark.html*, retrieved Feb. 23, 2005.

[59] Energy Information Administration (EIA), DOE, *International Energy Outlook 2004*, found at *http://www.eia.doe.gov/oiaf/ieo/highlights.html*, retrieved Mar. 27, 2005.

For example, in Indonesia and the Philippines,[60] demand for geothermal power generation is high, geothermal resources are plentiful, and government policy has promoted the expansion of geothermal electricity production.[61]

The market for geothermal energy is dependent, in part, on the costs and availability of alternative sources of energy. Like any other business venture, geothermal power production is governed by the economic laws of supply and demand. Historically, during periods of high fossil fuel prices, markets for geothermal energy and other types of renewable energy have grown. When oil prices increased in the 1970s, alternative fuels became more economically viable, especially when bolstered by favorable policy initiatives designed to protect the environment or promote greater reliance on domestic sources of energy. However, as fossil fuel prices became more competitive, energy producers returned to more conventional technologies and investors viewed new geothermal development with less enthusiasm.[62] The recent trend towards higher fossil fuel prices is likely to revive interest in geothermal energy, as well as other sources of renewable energy.[63]

Many non-market factors influence geothermal development in foreign markets. For example, because of the uncertainty and complexity of obtaining exploration licences and permits, developing geothermal power generation facilities can take much longer than other renewable energy technologies. Political risk may also be encountered, particularly in developing economies. Unexpected indirect costs of a power project, especially in developing countries, can significantly reduce a project's profitability.[64] However, one of the most common and significant obstacles that geothermal developers face is establishing and maintaining access to the national utility grid. Grid access is reportedly uneven and cumbersome, even in countries where, theoretically, power producers are entitled to connect.[65] Difficulties are reportedly due to bureaucratic requirements and formalities imposed by utility firms.

[60] Worldwide, the Philippines and Indonesia have achieved the largest gains in geothermal generating capacity in recent years. Office of Energy Efficiency and Renewable Energy, DOE, "Overview of Geothermal Technologies," found at *http://www.eere.energy.gov/consumerinfo/pdfs/geo_overview.pdf*, retrieved Mar. 27, 2005.

[61] The Government of the Philippines (GoP) incentives available for geothermal energy development and provision include recovery of operating expenses; exemption from taxes (except income tax, which is paid out of the GoP's share); exemption from paying tariff duties and compensating tax on machinery, equipment, and other materials imported for geothermal operations; depreciation of capital equipment over a 10 year period; favorable repatriation of capital equipment investment and remittance of earnings; simplified entry of alien technical and specialized personnel (including members of immediate families). Philippine Department of Energy, *Geothermal Resource Development*, found at *http://www.doe.gov.ph/geothermal/default.htm*, retrieved Mar. 27, 2005.

[62] Geothermal energy production in the United States peaked in 1987 and has since declined.

[63] Industry representative, telephone interview by USITC staff, Washington, DC, July 14, 2005.

[64] Indirect costs include administration, management, legal, insurance, permitting, and financing costs, as well as local taxes and royalties. The World Bank Group, *Geothermal Energy-Costs*, found at *http://www.worldbank.org/html/fpd/energy/geothermal/cost_factor.htm*, retrieved on Mar. 27, 2005.

[65] Industry representative, interview by USITC staff, Tokyo, Japan, Nov. 5, 2004.

Services related to geothermal energy production include exploration, drilling and production, installation, maintenance, monitoring, and operation services; resource management; technical and economic feasibility studies; geological surveying and mapping; evaluation of potential resources; temperature logging; thermal studies; training; well testing; and environmental impact assessments of energy development. The market for geothermal energy services is difficult to define and classify because of the complexity of the industry, owing to the number of services and the number of service providers, ranging from large to very small firms. Perhaps more significantly, many geothermal energy services are provided by firms for which other geological activities are the main line of business, such as petrochemical exploration and development.[66] Engineering and consulting firms also participate in the market, providing services exploration, field development, plant design, project analysis, management services, and geology and hydro-geology services. Expertise in geothermal services relating to electricity generation is found mainly in the United States, the United Kingdom, France, Germany, Italy, Japan, and New Zealand.[67]

Geothermal equipment generally includes power generation equipment and power plant control systems, as well as other components such as piping. Such equipment is not unique to the geothermal energy sector, having applications in a number of other industries. The international geothermal turbine and generator industry is led by six large firms: General Electric (U.S.); Ansaldo (Italy); Fuji, Mitsubishi, Toshiba (Japan); and Ormat (Israel-U.S.). The Japanese firms account for 73 percent of the global market; the European firms, 16 percent;[68] and the U.S. firms, approximately 8 percent.[69]

[66] For example, drilling, the most expensive part of geothermal energy production, is essentially the same technology used in the petroleum sector, so it is difficult to classify it as either a good or service specifically related to renewable energy. Industry representative, interview by USITC staff, Larderello, Italy, April 7, 2005; industry representative, interview by USITC staff, Costa Rica, Dec. 10, 2004.

[67] Compiling and ranking a comprehensive market participants' roster is impractical as geothermal services encompass a wide range of disciplines and industries including engineering, consulting, constructions, drilling, environmental, exploration, operations and maintenance, project development, and reservoir assessment. The exercise is further complicated as many geothermal operations are part of a multi-disciplinary firm or a firm where another line of business, such as oil field development, is the primary focus. A representative sample of firms providing geothermal services includes Bibb and Associates, Caithness Energy, Calpine Corporation, Century Resources, ENEL Green Power, GeothermEx Inc., JMC Geothermal Engineering Co. (Japan), Ormat International, Sinclair Knight Merz, Thermasource, Inc., UNOCAL Corp., and U.S. Geothermal Inc.

[68] Among European geothermal equipment suppliers, only a few large public utilities have both the capability and financial wherewithal to successfully challenge competing international suppliers. However, limited interest in these opportunities is evident, as they reportedly consider the geothermal market a minor one, particularly outside their own national boundaries. KAPA Systems (Athens) and European Geothermal Energy Council, *Overview of European Geothermal Industry and Technology*, found at *http://www.geothermie.de/egec-geothernet/market_perspektives_2000.htm*, retrieved Mar. 11, 2005.

[69] KAPA Systems (Athens) and European Geothermal Energy Council, *Overview of European Geothermal Industry and Technology*, found at *http://www.geothermie.de/egec-geothernet/market_perspektives_2000.htm*, retrieved Mar. 11, 2005.

Trade and Investment

Although direct use applications account for a greater share of global geothermal energy capacity than electricity generation, electricity generation results in a greater amount of trade and investment.[70] No data on trade and investment in the geothermal power generation sector are available. However, over the next 20 years, countries outside the United States are expected to spend a combined $25 to $40 billion developing and constructing geothermal power plants, creating a significant opportunity for suppliers of geothermal equipment and services.[71] Several South East Asian countries are likely to account for a significant share of these purchases of services and equipment. Exports of geothermal related goods and services to the Philippines and Indonesia have reportedly increased significantly in recent years, particularly from the United States and Japan.[72] Many Central and South American countries also have developing geothermal markets that offer good prospects for multinational suppliers of geothermal equipment and services.

Worldwide, deregulation of the power industry has allowed private developers to become more directly involved in both resource assessment and development, as has been the case in South East Asia.[73] However, many markets in South East Asia with strong geothermal development potential can reportedly be difficult to enter without a commercial presence. In Sept. 2002, a law was passed designed to end the State electric company Perusahaan Listrik Negara's (PLN) monopoly on electricity distribution, and allow private companies (both local and foreign) to sell power directly to consumers in Indonesia. In Jan. 2005, the law was declared unconstitutional and annulled. The constitutional court objected to the end of state management and regulation of power provision and pricing. Consequently, PLN retains the sole right to distribute and sell electricity, and independent power producers are only able to build power-generation plants in a joint venture with PLN.[74] Private operators have found success in such markets, particularly the high-growth Philippines and Indonesia,[75] through project financing strategies tools such as build-own-operate (BOO), build-own-operate-transfer (BOOT), and build-own-transfer (BOT).[76] In the process, private investors have significantly increased the speed of geothermal development in these countries. Among private developers, such turnkey construction contracts have become very popular, as they generally reduce financial risks. Worldwide, geothermal development faces few

[70] Industry representative, interview by USITC staff, Tokyo, Japan, Nov. 5, 2004.

[71] National Renewable Energy Laboratory, *Geothermal Today: 2003 Geothermal Technologies Program Highlights (Revised)*, May 1, 2004, found at *http://www.nrel.gov/docs/fy04osti/36158.pdf*, retrieved Mar. 27, 2005.

[72] Industry representative, interview by USITC staff, Tokyo, Japan, Nov. 5, 2005.

[73] The World Bank Group, Geothermal Energy - Markets, found at *http://www.worldbank.org/html/fpd/energy/geothermal/markets.htm*, retrieved Mar. 27, 2005.

[74] *The Economist*, The Economist Intelligence Unit, Executive Briefing: Indonesia, June 6, 2005, found at *http://eb.eiu.com/index.asp?layout=oneclick&country_id=1810000181*, retrieved July 14, 2005.

[75] U.S. firms are well represented among suppliers of equipment and services in the high-growth Southeast Asian markets. Industry representative, telephone interview by USITC staff, Washington, DC, July 14, 2005.

[76] KAPA Systems (Athens) and European Geothermal Energy Council (EGEC), *Overview of European Geothermal Industry and Technology*, found at *http://www.geothermie.de/egec-geothernet/market_perspektives_2000.htm*, retrieved Mar. 11, 2005.

formal barriers to trade and investment. Where impediments do exist, they are often related to prevailing competitive conditions such as perceived risk compared to other investment opportunities.

The geothermal electricity generation components that are most commonly traded internationally are turbines, generators, and pressure vessels. Other components such as piping are usually locally sourced. As discussed above, most of the equipment used in geothermal energy production are used in a variety of applications. Consequently, as noted in chapter 1, quantifying imports and exports of equipment that are manufactured and used exclusively for geothermal applications is not possible. However, analysis of trade data does allow for generalizations that likely reflect the actual nature and extent of merchandise trade in the geothermal power industry. For example, electric generators of various output capacities account for one of the largest shares of the geothermal equipment traded. The leading global exporters of generators of various sizes and uses are Canada, France, Germany, Italy, Japan, Russia, the United Kingdom, and the United States. The leading global importers are Brazil, Canada, China, Germany, Italy, Korea, the United Kingdom, and the United States. Heat exchangers are another dual-use product that are used extensively in geothermal power applications. The leading global exporters of heat exchangers are France, Germany, Italy, Japan, Korea, Sweden, and the United States. The leading global importers are Canada, China, Germany, France, Japan, Italy, Mexico, the United Kingdom, and the United States.

Future Prospects

In the future, non-economic factors are likely to play a greater role in geothermal development. In many countries, the social and environmental costs of burning fossil fuels, which are not currently captured in energy prices, are becoming more key in guiding policy.[77] Consequently, markets seeking to attract private sector investment are devising or currently offering state-backed insurance policies to underwrite both the drilling and reservoir assessment stages to help offset risks.[78] Further, geothermal energy technologies are improving and the costs of both the fluid-production (exploration, wells, and reservoir management) and electricity-conversion (power plant) components of this industry are expected to decrease in the near future, improving the viability of geothermal energy from a financial investment perspective.

Even so, the potential effect of these incentive programs and cost decreases is unknown as other factors also may exert significant influence on energy markets.[79] For example, although technologies are becoming more cost effective, many of the best and most accessible geothermal sites have been developed. Consequently, the remaining sites will tend to be much more expensive to develop and less profitable to operate. In the United States, significant growth is not expected in geothermal energy development, unless such development is encouraged by policies that mandate electricity generation from renewable sources.[80] Economic forecasts suggest that most renewable resources,

[77] Government official, interview by USITC staff, Tokyo, Japan, Nov. 8, 2004.
[78] Industry representative, interview by USITC staff, Bangkok, Thailand, Nov. 12, 2005.
[79] Geothermal growth forecast models, which typically utilize scenario analyses incorporating high/low economic growth and oil price assumptions, often produce a wide range of forecast results.
[80] Industry representative, telephone interview by USITC staff, Apr. 8, 2005.

including geothermal resources, will remain more costly than fossil-fueled alternatives through 2015.[81] However, strong growth in geothermal exploration and development is expected in many developing countries, which is likely to offer significant opportunities for providers of geothermal services and equipment.[82]

[81] EIA / DOE, *Quantitative Impacts of Electric Power Industry Restructuring on Fuel Markets*, found at *http://www.eia.doe.gov/cneaf/electricity/chg_str_fuel/html/chapter6.html*, retrieved Mar. 27, 2005.

[82] Industry representative, interview by USITC staff, Pisa, Italy, Apr. 8, 2005.

Table 7-3
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Australia	Installed geothermal generating capacity (2003): 150 kW.[1] Total electricity installed capacity (Jan. 2002): 45.3 million kW.[2] Total net electricity generation (2002): 210.3 billion kWh.[2] The predominant geothermal systems in Australia are direct use systems: near-surface geothermal heat pumps and hot spring geysers. Geothermal generated electricity is not expected to be available in Australia for some time, and when available, will likely involve development of hot dry rock geothermal resources. Preliminary hot dry rock activity is underway in South Australia (eg, Geodynamics' Habanero project in the Cooper Basin), but is generally still in exploration and development stages.	Mostly captive consumption.	A variety of firms, both domestic and foreign, provide geothermal related services in Australia. Petratherm (Minotaur Resources) is beginning a project to locate and develop areas of hot dry rocks in South Australia.[3] Other firm investing in exploration for geothermal energy in Australia include Geodynamics, Scopenergy, Perilya, and Green Rock Energy.[4] Century Resources (a division of Downer EDI Limited) provides engineering and infrastructure management services to sectors including geothermal in Australia, New Zealand, South East Asia, Hong Kong and the Pacific.[5]

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Canada	Geothermal power is not used to generate electricity in Canada. Total electricity installed capacity, Jan. 2002: 111.0 million kW.[2] Total net electricity generation, 2002: 548.9 billion kWh.[2] The predominant geothermal systems in Canada are direct use systems: near-surface geothermal heat pumps and hot spring geysers used for recreational activities. Comparatively low costs of hydroelectricity and fossil fuels have limited exploration and development of geothermal energy for electricity generation in Canada.[6] Further, Canada does not appear likely to undertake any large-scale development of geothermal energy in this area.[7]	Mostly captive consumption	A variety of firms, both domestic and foreign, provide geothermal related services in Canada, virtually all of which are related to direct use applications.

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
China	Installed geothermal generating capacity (2003): 28.2 MW[4] Total electricity installed capacity, Jan. 2002: 338.3 million kW.[2] Total net electricity generation, 2002: 1,575.1 billion kWh.[2] Geothermal power generation has not increased in China in more than 10 years.[8] Geothermal capacity is 0.006% of total electrical capacity and gross production is 0.004% of total production of electricity.[8] The development of geothermal power generation in China has been relatively slow, due to abundant hydro-electric resources in provinces with high-temperature geothermal resources. The largest power facility is located at Yangbajain (Tibet).[9]	Not available	Dept. of Industry & Electric Power (Tibet) Lhasa Geological & Mineral Resources Bureau (Tibet) Geothermal Council of China Energy Society (GCES) Ministry of Land and Resources China Geological Survey Bureau The UN Development Program (UNDP) has, since 1981, provided US$4 million in aid to boost construction of the Yangbajain Geothermal Power Station.[10] Provincial governments
Costa Rica	Installed geothermal generating capacity (2003): 162.5 MW.[1] Total electricity installed capacity, Jan. 2002: 1.65 million kW.[2] Total net electricity generation, 2002: 6.61 billion kWh.[2] Geothermal energy supplies about 20 percent of CR's total energy consumption. All of CR's geothermal power generation is concentrated at the Miravalles geothermal field in the Canton Bagaces province.[11]	Geoenergia de Guanacaste (GdG) sells power to the Insitituto Costarricense de Electricidad (ICE) under the Miravalles III Power Purchase Agreement (PPA), a construction plus 15-year BOT agreement.[12]	Instituto Costarricense de Electricidad (ICE) In 1997, ICE conducted an open international competitive bidding process to select a developer to Build Operate and Transfer (BOT) the Miravalles III geothermal project. The winner would provide development, acquisition, engineering, design, construction, operation and maintenance services.[13] GdG is a Costa Rican limited liability company that owns the Miravalles III Geothermal Project. GdG is owned by Oxbow (U.S.), Marubeni (Japan), and Jose Altmann & Co., a Costa Rican investor. The facility was constructed by Mitsubishi Corporation under a turnkey EPC contract.[12]

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
El Salvador	Installed geothermal generating capacity (2003): 161.0 MW[1] Total electricity installed capacity, Jan. 2002: 1.13 million kW.[2] Total net electricity generation, 2002: 4.29 billion kWh.[2] In 1996, the state-owned monopoly, Comisión Ejecutiva Hicroeléctrica del Río Lempa (CEL), was converted to an open, competitive market, with mostly private participants. Geothermal generation was separated into Geotérmica Salvadoreña S.A. de C.V., an independent company owned by CEL. El Salvador is Central America's largest producer of geothermal energy. In 2003, the country produced 0.97 Bkwh of geothermal electricity, representing approximately 21.9% of total electricity generated.[14]	Geothermal power is generally sold to electric utility companies for distribution.	Comisión Ejecutiva Hicroeléctrica del Río Lempa (CEL) Geotérmica Salvadoreña. S.A. de C.V. Inter-American Development Bank (IDB) - project supported construction of the 55 MW Berlín geothermal plant (two 27.5 MW units) and rehabilitation of the Ahuachapán geothermal plant.[15]

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
European Union	Relatively few countries in the European Union have the natural resources capable of economically producing geothermal energy. At the end of 2003, installed geothermal capacity in the European Union for production of electricity was 822.98 MW. Installed geothermal power capacity in the EU rose gradually in the 1990's, but the market potential remains limited unless costs can be brought down.[16] More than 96% of the EU's installed capacity is located in Italy (790.5 MW). In recent years, Italy has closed some of its oldest wells, reducing its installed capacity. Other countries generating electricity from geothermal energy include Portugal (16 MW), France (15 MW) (extension of the Bouillante site in Guadeloupe in 2003), Austria (1.25 MW), and Germany (0.23 MW).[17] Generation associated with this capacity was 5,152.2 GWh, a 7.2% increase over the 2002 figure.[18] Geothermal's share in consumption of electricity, EU (2002): 0.2%.[19]	Geothermal power is generally sold to electric utility companies for distribution.	Electricité de France (EDF) is participating in a European project for the construction of a hot dry rock facility in Soultz-sous-Forêts, in Alsace, France.[20] Siemens is one of the major companies worldwide in the field of power plant construction. Siemens, together with U.S. partner Exergy Inc., has specialized technology for small output geothermal power plants.[21]

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Italy	Installed geothermal generating capacity (2003): 790.5 MW.[1] Total electricity installed capacity, Jan. 2002: 69.1 million kW.[2] Total net electricity generation, 2002: 261.6 billion kWh.[2] Geothermal-produced electricity accounts for approximately 2% of total electricity production.[9] Geothermal resources account for 32% of Italy's renewable energy supply. Lardarello is the third largest geothermal field in the world.	Electric utility companies and captive consumption	The government agency ENEL controls all geothermal generation.[23] Turboden Ltd of Italy
Germany	In Germany, a new law pays €0.15/Kwh for geothermal energy for the first 15 years of plant's operation. (This is Germany's new feed-in tariff system.)[22] Germany is developing binary geothermal power plants that use low temperature water (90˚C-120˚C).[20]		

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Iceland	Installed geothermal generating capacity (2003): 202.0 MW[24] Geothermal electricity generation (2003): 1406 GWh.[24] Technical expertise and investment capital are available within market for geothermal development. Geothermal electricity generation accounts for 16% of total power output.[9] Worldwide, Iceland achieved one of the highest growth rates for geothermal electricity generation, with production increasing by 15.4% annually from 0.3 TWh to 1.5 TWh between 1990 and 2001. Three new geothermal power plants (totaling 210 MW capacity) are under construction; many more are under consideration.[24]	Geothermal power is generally sold to electric utility companies for distribution.	Reykjavik Energy Orkustofnun (National Energy Authority) RARIK (Iceland State Electricity) Sunnlensk Orka Ltd. (development company) Landsvirkjun (national power company) (owns electric power plants) Westfjord Power Company (Orkubu Vestfjarda) Mitsubishi Heavy Industries Ltd. (MHI) has provided turbines for geothermal power plants. Mitsubishi Electric Corp. has provided generators. Balcke-Dürr (Germany)- (condensers and cooling towers)

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Indonesia	Installed geothermal generating capacity (2003): 807.0 MW.[1] Indonesia has enormous geothermal resources. Geological surveys have identified over 200 useable resource sites, of which 70 are high-temperature reservoirs with an estimated total resource potential of nearly 20,000 MW.[9] The Indonesian Government reportedly plans to significantly increase utilization of geothermal energy by developing new fields and expanding existing fields. A government plan calls for geothermal energy to account for 7% of national power consumption.[9] Over the last decade, Indonesian geothermal power generation capacity has increased by as much as 10.5 percent annually, outpacing the United States and the Philippines.[25]	Geothermal power is generally sold to electric utility companies for distribution.	PT Pertamina (Persero) - state owned company for oil and gas. PT PLN (Persero) - Indonesian National power company. PT Geo Dipa Energi is a joint venture of PT Pertamina and PT PLN . Independent power producers include Amoseas Indonesia Inc. (joint venture between Chevron and Texaco), and Magma Nusantara (MNL).[23] Sinclair Knight Merz Joint Development and Construction: Marubeni Corporation (Japan), Pertamina, and Philippine oil and energy development company PNOC-Energy Development Corporation.[26] UGI (Unocal Geothermal Indonesia) BOT arrangements with Pertamina and PLN. Overseas Private Investment Corporation (OPIC, U.S.), Financier

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Japan	Installed geothermal generating capacity (2003): 560.9 MW.[1] Geothermal accounted for 21% of total renewable electricity generation in 2001. The best Japanese geothermal development sites are often adjacent to national parks and spas, therefore areas available for drilling tend to be small. To work within these constraints, the country's long-range goal is to build a greater number of small capacities facilities for small communities.[25] Japan is the world's leading manufacturer of geothermal equipment (70%).[20] Japan's energy policy includes efforts to encourage the introduction of alternative energy and to decrease dependence on petroleum. Goals include increasing geothermal's contribution to total energy supply from 0.2% (2000), to 0.6% by 2010.[27]	Geothermal power is generally sold to electric utility companies for distribution.	Major geothermal firms are Kyushu Electric Power Co, Tohuku Electric Power Company, Japan Metals and Chemicals, Tohuku Geothermal Power Company, Donan Geothermal Energy Company, and Hokkaido Electric Power Company. Geothermal development in Japan is primarily spread between about a dozen plants, many of which involve two or more of the above companies.[23] Marubeni (provides geothermal construction services throughout Southeast Asia) - financing and technical expertise and capability in the development, financing, construction and operation of power generating plants. Electric Power Development Co (EPDC)

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Mexico	Installed geothermal generating capacity (2003): 953.0 MW.[1] Geothermal electricity generation accounts for approximately 3% of total Mexican electric power output.[9] Mexico's primary geothermal region is Cerro Prieto along an offshore segment of the East Pacific Rise. The field produces 720 MW. Geothermal generation started in 1973 and has grown to 5,623 GWh, achieving an annual growth rate of 14.6 percent. Mexico's geothermal annual growth rate surpassed that of the U.S. in the 1990s.[25] Geothermal fields under development: Cerro Prieto in Baja California, Los Azufres in Michoacán and Los Humeros in Puebla.[28] Cerro Prieto is the second largest (after Geysers in CA) single source geothermal field in the world.	Geothermal power is generally sold to electric utility companies for distribution.	The Comisión Federal de Electricidad (CFE) controls power generation, transmission, and distribution nationwide, and Luz y Fuerza del Centro (LFC), is responsible for the distribution service in Mexico City and surrounding areas. Both are state owned enterprises.[29] Geothermal development is a joint effort between the Mexican Electric Company (CFE) and the nation's Electrical Research Institute (IIE).

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
New Zealand	Installed geothermal generating capacity (2003): 421.3 MW.[1] Geothermal resources account for 22% of New Zealand's renewable energy supply. Potential generation capacity of the geothermal resources located within the central North Island's Taupo Volcanic Zone (TVC) has been conservatively estimated at 2000 MW.[9] Over 400MW of plant capacity has been installed within the TVC. Another 9 MW has been installed at the top of the North Island with plans to expand this plant further. Geothermal generation accounts for approximately 7% of New Zealand's total electricity generation.[30]	Geothermal power is generally sold to electric utility companies for distribution.	Contact Energy Ltd. ORMAT International, Inc. Permission for Geotherm Group to build a $280 million, 60 MW geothermal station was granted in late December. The station will generate power using 70,000 tons of geothermal fluid per day sourced from the New Zealand Wairakei-Tauhara geothermal field. According to the New Zealand Herald, consent for the new station was slow because Environment Waikato has a single tapper policy, meaning only one operation can take from the field at a time.[31] Mighty River Power is a leading generator and retailer of electricity in New Zealand. DesignPower (and its specialist geothermal company GENZL), and PB Energy Services Mitsubishi Heavy Industries Ltd. (MHI) has provided turbines for geothermal power plants.

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Philippines	The Philippines is the second largest producer of geothermal power in the world, following the United States. With an installed generating capacity of 1,931 MW, geothermal energy accounts for 13 percent of the Philippines' power capacity. In 2002, the geothermal energy generation of 10,248 gigawatt-hour (GWh) of electricity provided 21 percent of the country's total electricity requirement.[32] The Philippines has thirteen geothermal power facilities. Installed capacity (MW) at major geothermal sites: Tiwi 330; Mak-Ban 426; Bac-Man 151; Tongonan, Palinpinon, Leyte 915; Mt. Apo 108.[33] A goal of the 2004-2013 Philippine Energy Plan is to reach a 55.0 percent self-sufficiency level by 2013, largely by the development of indigenous geothermal energy resources.[33] The Government's Philippine Energy Plan calls for increasing geothermal capacity by 526 MW by 2008.[9]	Geothermal capacity is usually sold to the Philippine National Oil Company-Energy Development Company (PNOC-EDC) for resale to the National Power Corporation of the Philippines (NAPOCOR) and then distributed locally.	Geothermal power production may be broken down in terms of steam field operators and power plant operators. The major steam field operators are the Philippines National Oil Company (PNOC) and Phillipine Geothermal Inc (PGI). Power station operators include the Philippine National Power Company (NPC) and several private producers (California Energy, Magma Power, and Oxbow Geothermal Corporation).[23] California Energy (CalEnergy) owns several Philippine projects backed by the Overseas Private Insurance Corporation (OPIC). Kiewit Construction Group C.E. Holt CE Cebu Geothermal Power Company (indirectly owned by CalEnergy); CE Luzon Geothermal Power Company, Inc. (wholly owned by CalEnergy subsidiaries); Visayas Geothermal Power Company (wholly owned indirectly by CalEnergy subsidiaries)

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
Thailand	Installed geothermal generating capacity (2003): 0.3 MW.[1] Total electricity installed capacity, Jan. 2002: 23.2 million kW.[2] Total net electricity generation, 2002: 102.4 billion kWh.[2] In 1989, a small (0.3 MW) binary-cycle power plant was installed in northern Thailand, and remains the sole Thai geothermal plant. Geothermal systems at San Kampaeng, Pai, and nine other locations are reported to be under further investigation, but to date Thailand's national program on geothermal energy has not been firmly established.[9] The Government of Thailand (GoT) provides incentives for energy efficiency and renewable energy. The Energy Conservation and Promotion Act of 1992 created the Energy Conservation Promotion (ENCON) Program. Funds for ENCON and the Energy Conservation Promotion Fund (ECF) (created in 1995) come from a tax on gasoline. The ECF provides financial assistance for energy efficiency and conservation efforts by both the public and private sectors.[34]	Not available	The Electric Generating Authority of Thailand (EGAT) Department of Energy Development and Promotion (DEDP) National Energy Policy Office (NEPO)

See footnotes at end of table.

Table 7-3—*Continued*
Characteristics of selected markets for geothermal power and geothermal energy services

Country	Market size & characteristics	Consumers of geothermal power	Key market participants
United States	Geothermal electricity production accounts for about 0.4% of total U.S. electricity generation and 27% of renewable energy (non-hydro) sources.[35] Electricity net generation from geothermal (2002): 14,491 million kWh.[36] Installed geothermal generating capacity (2003): 2020.0 MW.[37] The United States accounts for almost 40% of worldwide installed geothermal capacity.[38] Geothermal capacity growth was 2.7% from 1990 to 1998. The U.S. geothermal power industry is located exclusively in the western half of the United States.	Geothermal power is generally sold to electric utility companies for distribution.	Calpine Corporation (operator) is by far the largest market participant; with the smaller players being Caithness; Oxbow Geothermal; CalEnergy, including CalEnergy Operating Corporation (construction); and Geothermal Energy Partners.[23] California Energy (CalEnergy) is the world's largest geothermal company. GeothermEx is the largest geothermal energy consulting company in the Western Hemisphere.[39] Others: Northern California Power Agency (NCPA) (operator); Sierra Pacific Resources of Nevada; Unocal Geothermal; PG&E; Coldwater Creek Operating Company; Mission Energy; Santa Fe Geothermal; Northern California Power Association; Magma Power Company; Chevron Resources; East Mesa Operator; Ormat Energy Systems; California Energy Company; Pacific Enterprises; Trans-Pacific Geothermal Corp.; Barber-Nichols Co.; Caithness Corporation; Far West Electric Energy Fund, Ltd.; Nevada Geothermal Power Inc.; and U.S. Geothermal Inc.

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CHAPTER 8
OCEAN ENERGY

This chapter provides information on ocean energy markets with special emphasis on Australia, China, Canada, France, India, Italy, Japan, the Netherlands, the Philippines, the United Kingdom, and the United States. These countries were chosen for special emphasis based on developments in their ocean energy industries and on USTR's request for information on developed- and developing-country markets, as well as information on markets with which the United States has established, or is in the process of negotiating, a free trade agreement.[1]

Overview

The ocean energy market, which includes tidal, current, and wave energy technologies, is relatively small and recent compared to other renewable energy markets. Ocean energy research is primarily conducted by European and Asian countries, and more recently the United States, with the bulk of research focused on developing technologies that can make electricity from ocean energy economically viable. Currently, there are only a few ocean energy projects in place that have commercial application. Among these are the La Rance tidal power station in France, and two smaller tidal power stations in China and Canada. Other projects that have reached or are nearing commercial deployment include marine current facilities in North Devon, England, and New York City, as well as those involving wave energy devices in the United Kingdom and the United States. There are no comprehensive data on trade and investment in the ocean energy services market, but anecdotal information suggests that such activity largely comprises the design, construction, and installation of ocean energy systems in foreign markets. No significant non-tariff barriers have been identified within the ocean energy services sector. Industry sources expect large growth in this sector over the next decade due to technological advances and increased government support.[2]

Technologies and Methods

Ocean energy herein includes the application of tides, currents (marine or stream), or waves to produce power. Tidal energy captures high tides or wave crests to fill a water reservoir, from which water can be drained through a water turbine. Current energy uses the direct action of the water through a turbine or past a propeller inserted into the water. Wave energy uses the rise and fall of water to directly move an electrical generator or to indirectly compress a gas or move a self-contained hydraulic fluid through a turbine

[1] For more information on USTR's request, see appendix A of this report.
[2] Ocean Energy Conference 2005, Washington, DC, Apr. 26-28, 2005.

connected to an electrical generator.[3] There is a significant amount of overlap in the tidal, current, and wave energy technologies, and the distinctions are based on the type of motion harnessed or the system location: onshore, nearshore, or offshore.

Tidal Power

The oldest and most established system for harnessing tidal energy is the Tidal Power Station (TPS), which creates a tidal basin or reservoir, whereby the high tide fills a basin behind a man-made dam, or barrage (figure 8-1). As the water buildup drains upon the tide ebb, the water flows through traditional hydropower turbines which rotate to create electricity. Until recently, the tidal inflow was through a channel, only collecting potential energy in the rising water level and generating electricity upon drainage back to the ocean. However, newer technologies allow the water to flow through the turbines bidirectionally, turning the turbines while rising and ebbing, essentially doubling the electrical generation time.[4] When the tide level nears its extremes, gates are opened, water flows through the turbines, and the turbines turn an electric generator to produce electricity. This energy can be delivered to customers, or used to operate pumps to increase the tidal basin level for later use. There are only about 40 locations on earth with a sufficient magnitude of tidal oscillations to efficiently produce electricity.[5] Since dam-building across an estuary is expensive,[6] the best sites are those with a narrow natural bay.

Current Power

Tidal technologies are often used in-stream for harnessing the power of ocean currents or tides. Industry sources report that current energy is a hundred times denser than that contained in other forms of renewable energy, and that it is more consistent and

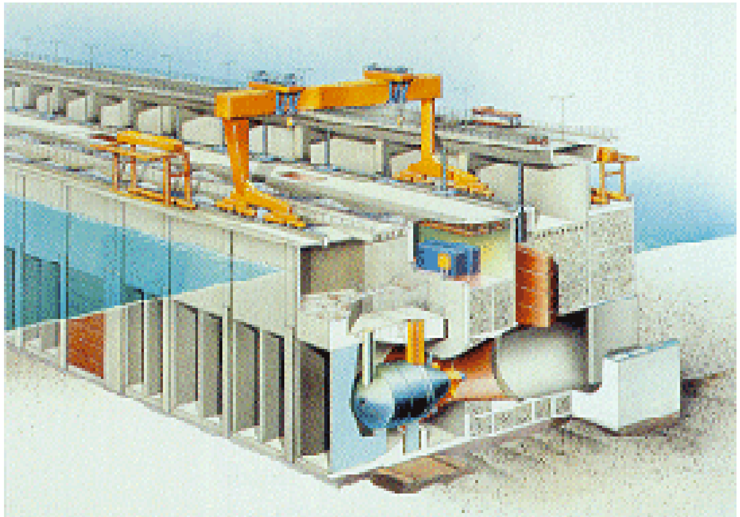
[3] USDOE, "Energy Savers: A Consumer Guide to Energy Efficiency and Renewable Energy," found at *http://www.doe.gov,* retrieved Mar. 9, 2005; European Commission, Atlas project, "Renewables Overview: Tidal Energy," found at *http://europa.eu.int/comm/energy_transport/atlas/home.html*, retrieved Mar. 16, 2005; and UN, "Energy Resources,"*U.N. Atlas of the Oceans*, retrieved Mar. 16, 2005.

[4] "Tidal Power - Energy from the Sea," found at *http://www.darvill.clara.net/altenerg/tidal.htm*, retrieved July 29, 2005.

[5] TPS generation capacity depends primarily upon the tidal height differential of the region, but also upon the tidal pool size and the type and number of turbines. Based upon the latest state-of-the-art technology, a tidal wave height differential of at least 13 to 16 feet is necessary to be economically efficient in creating electrical energy from tides. USDOE, "Energy Savers: A Consumer Guide to Energy Efficiency and Renewable Energy."

[6] "Tidal power - energy from the sea," found at *http://www.darvill.clara.net/altenerg/tidal.htm*, retrieved July 29, 2005.

Figure 8-1
Tidal barrage



Source: European Commission, Atlas project, "Renewables Overview: Tidal Energy," found at *http://europa.eu.int/comm/Energy_transport/atlas/home.html*, retrieved Mar. 9, 2005.

predictable; even calm seas have significant currents.[7] Submerged turnstiles or turbines, connected to a generator, spin with the tidal currents (figure 8-2). The turbines may be configured in several rows, called *tidal farms*, or in a string across larger distances, such as between islands or across a river mouth, called *tidal fences*. Because water delivers greater force than air, a standard 49-foot diameter tidal turbine can generate as much energy as a 197-foot diameter wind turbine, and only requires tide speeds of 4-6 miles per hour.[8] Optimal conditions are near shorelines at 60- to 100-foot depths.

Wave Power

Another method of generating power from the ocean is to extract mechanical energy from the wave motion near shore, which can theoretically yield much more energy than tides. Thus, countries with large coastlines and rough sea conditions are particularly favored.[9] Though commonly overlapping with tidal power, wave power systems are

[7] Current energy systems, also called stream or marine energy systems, are often a mixture of tidal and wave energy technologies and are often categorized as one or the other. Those systems which function near shore and harness the tidal flow are often considered tidal, whereas those operating offshore are commonly considered wave. For the purposes of this report, current power is distinguished from tidal and wave power as that which generates electricity from the movement of the ocean or river through or by a rotating device. John Roberson, "Deep Water Generator Puts Wave Power to the Test," *Times Online*, Personal Tech, Apr. 11, 2005.

[8] USDOE, "Energy Savers: A Consumer Guide to Energy Efficiency and Renewable Energy."

[9] The best waves are from 40 to 60 degrees latitude north and south, according to *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, p. 19.

Figure 8-2
“Seaflow” device undergoing maintenance in North Devon, U.K.

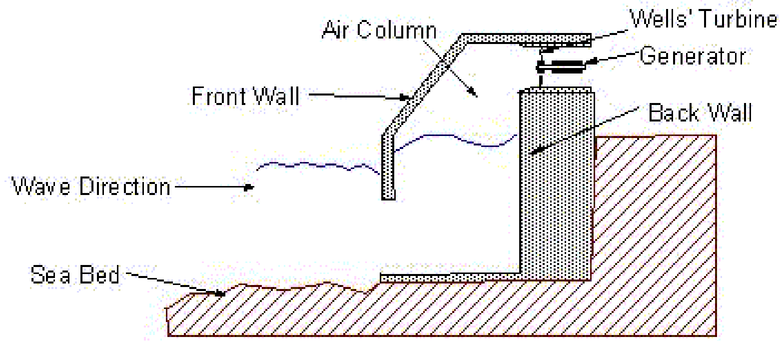
Source: This image is copyright protected, and used with permission from Marine Current Turbines™.

distinct and include several types of devices. A multitude of wave power systems have been developed, and are broadly categorized into three types: onshore, nearshore, and offshore.

Onshore systems are built along the shoreline and are designed to extract the energy of breakwaters. They require a significant structure, as in a tidal barrage, but do not require an estuary or large reservoir. Three types have been developed: the oscillating water column (OWC), the tapered channel system (TAPCHAN), and pendulor wave power. OWC technology uses a partially submerged structure, open to the sea, with a sealed air chamber above the water level (figure 8-3). As the water level rises, the air is compressed and forced through turbines; and the water ebb draws in more air.[10] TAPCHANs force waves into a narrowing channel, thus causing the water to increase in height. The waves eventually overflow into an elevated reservoir, from which water is drawn through turbines and released back into the sea, utilizing low-head turbine technology. Islands are the best environments in which to employ this system because it requires a combination of a small tidal range and natural shoreline cliffs; few opportunities exist beyond islands. Pendulor wave-power, developed by China, uses a

[10] The OWC process also allows water to be filtered through the pumps by reverse osmosis to provide desalinated water.

Figure 8-3
Oscillating water column



Source: European Commission, Atlas project, "Renewables Overview: Wave Energy," found at *http://europa.eu.int/comm/energy_transport/ atlas/home.html*, retrieved Mar. 9, 2005.

hinged flap over a box inlet. The flap moves back and forth with the motion of the waves and operates a hydraulic pump and generator.[11]

Nearshore devices utilize the same technologies as onshore systems, but operate on a fixed seagoing platform, usually at water depths of less than 66 feet.[12] Some of these devices channel waves through internal turbines and then back into the sea. Offshore wave systems use the bobbing motion of the waves on hinged pontoons or fixed buoys to either directly produce electricity through the bobbing motion applied to a generator or indirectly generate electricity by moving a contained hydraulic fluid through a turbine connected to a generator. Sea floor pressure transducers, operating in depths over 130 feet, are connected to a high-pressure hydraulic pump that delivers a pressurized seawater stream to shore for generation.

In summary, the primary advantage of ocean energy is the natural prevalence of resources and the relatively high energy capacity per unit of volume. Tidal energy systems are far more advanced and commercially available than wave or current energy systems. However, there are a limited number of economically exploitable tidal sites worldwide.[13] Land disturbance issues involved in developing tidal barrages and tidal fences further limit the development of tidal systems, and have led to recent developments in offshore or submerged tidal turbines, and tidal lagoons, which have less

[11] *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 27.

[12] T.W. Thorpe, "An Overview of Wave Energy Technologies: Status, Performance and Costs," *Wave Power: Moving towards Commercial Viability*, Nov. 30, 1999, found at *http://www.wave-energy.net/Library/An%20Overview%20of%20Wave%20Energy.pdf*, retrieved May 18, 2005.

[13] Forty sites with the potential to develop tidal energy have been identified worldwide. Of these, only half are estimated to be commercially viable. For a complete list of such sites, see European Commission, Atlas project, "Tidal Energy: World-Wide Market and Potential," found at *http://europa.eu.int/comm/energy_transport/atlas/html/tidalpot.html*, retrieved Mar. 16, 2005.

environmental impact.[14] At the same time, wave and current energy potential is enormous, but is yet to reach full-scale development. In general, offshore systems enjoy far greater energy potential than systems developed near the shoreline, but shoreline devices have the advantage of relatively easier construction and maintenance.

Market Size and Characteristics

There is little available data on the amount of electricity generated from tidal, current, and wave energy technologies because, with few exceptions, such technologies have not reached commercial deployment. However, EU data on installed electric-generating capacity from tidal energy in 1996, the most recent year for which such data is available, measured the worldwide total at 261.4 megawatts (MW).[15] Of that number, the EU accounted for 240 MW, or 92 percent of the total, due exclusively to the La Rance facility in France.[16] Separately, the potential for electric power generation from waves has been estimated at more than 2 billion MW annually, with a probable target of approximately 5.5 million megawatt-hours per year by 2010.[17] Wave-power rich areas of the world include southern Africa, Australia, northern Canada, the western coast of Scotland, and the northeastern and northwestern coasts of the United States.[18] Finally, analysts estimate that the capacity for electric power production from marine current energy is 450,000 MW, although presently there are only two such projects being tested for commercial deployment.[19]

The existing market for tidal, current, and wave energy is quite small. Of the three forms of ocean energy, tidal energy is the most developed. At present, there are only a few tidal energy projects with commercial application, and new development activity is limited. The lack of new development is partly due to the high capital costs associated with the construction of tidal barrages, the adverse impact that the installation of such barrages has on the environment, and the technical risks related to the assessment and siting of large civil engineering projects.[20] By contrast, current and wave technologies are only now reaching demonstration stage, and few commercial installations have been contracted. Like tidal energy, the capital costs to build a commercial facility for current- or wave-generated electric power are high. As a result, the cost per kilowatt-hour of

[14] Reportedly, tidal barrages may affect the timing and flow of ocean currents, and may also have a negative impact on the ecosystem. European Commission, Atlas project, “Tidal Energy: Market Barriers,” found at *http://europa.eu.int/comm/energy_transport/atlas/home.html*, retrieved June 14, 2005.

[15] *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 14.

[16] European Commission, Atlas project, “Renewables Overview: Tidal Energy,” found at *http://europa.eu.int/comm/energy_transport/atlas/home.html*, retrieved Mar. 16, 2005; and *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 6.

[17] European Commission, Atlas project, “Renewables Overview: Wave Energy,” found at *http://europa.eu.int/comm/energy_transport/atlas/home.html*, retrieved June 17, 2005.

[18] USDOE, “Energy Savers: A Consumer Guide to Energy Efficiency and Renewable Energy.”

[19] *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 7.

[20] According to one industry report, construction costs of a tidal barrage are $2.4 million per megawatt (MW), compared to construction costs of $1 million per MW for wind power projects. *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 17; and European Commission, Atlas project, “Renewables Overview: Tidal Energy,” found at *http://europa.eu.int/comm/energy_transport/atlas/home.html*, retrieved Mar. 16, 2005.

electricity generated from current or wave energy is less competitive than that generated from conventional fossil fuels.[21] Nonetheless, despite the challenges associated with the continued development of tidal, current, and wave energies, many countries are engaged in new projects to test and market these technologies (see table 8-1 at end of chapter).

Tidal

The La Rance tidal barrage is the first and only facility built for the commercial generation of electricity from tidal energy. The barrage began operation in 1967, with an installed capacity of 240 MW, and it currently generates 640 million kilowatt-hours (kWh) of electricity on an annual basis.[22] Several factors have led to the long-term success of the La Rance barrage. For example, despite the facility's relatively high development costs, the barrage has reportedly been able to generate electricity at rates that are competitive with other regional electric power plants.[23] The facility, which produces a large volume of electricity on a reliable basis, is also an important contributor to the local electric power market.[24] In addition, construction of the barrage has brought external benefits to the region that have outweighed environmental concerns. For instance, a two-lane road has been built atop the barrage walls that has aided traffic flow in the area. The barrage also serves as an important local tourist attraction, bringing economic benefits to the region.[25]

Apart from the La Rance barrage in France, two other countries–Canada and China–have developed tidal energy facilities that now produce electricity on a commercial basis, and a number of countries have also built experimental tidal power stations. The tidal facility in Canada is located at Annapolis Royal, in the Bay of Fundy. The facility, which became operational in 1984, was originally constructed to demonstrate the use

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[21] One estimate places the electric power costs of the most efficient wave energy technology at 7.5 cents/kWh, compared to 2.6 cents/kWh for electricity produced from coal, and 3 cents/kWh from combined-cycle natural gas turbine technology. T.W. Thorpe, "An Overview of Wave Energy Technologies: Status, Performance and Costs," *Wave Power: Moving towards Commercial Viability*, Nov. 30, 1999, London, retrieved May 18, 2005; and Practical Ocean Energy Management Systems, Inc., "Ocean Wave Technical FAQ," found at *http://www.poemsinc.org/FAQwave.html*, retrieved Aug. 2, 2005.

[22] Between 1961 and 1966, the La Rance barrage operated as a demonstration project. *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 13.

[23] Reportedly, the average price of electricity generated from the La Rance facility is 18.5 cents/kWh. Andy Lightfoot, "Introduction to Tidal Energy," found at *http://www.ceet.niu.edu/faculty/vohra/tech%20484/paper.htm*, retrieved June 21, 2005.

[24] Ibid.

[25] Peter Clark, Rebecca Klossner, and Lauren Kologe, "Tidal Energy," CAUSE, Final Project, Nov. 13, 2003, found at *http://www.ems.psu.edu/*, retrieved June 21, 2005.

of a newly-developed Straflo turbine to harness tidal power.[26] The Annapolis station has a total generating capacity of 20 MW, making it the second-largest commercial tidal facility in the world.[27] In China, there are currently seven separate tidal power stations in operation with a combined generating capacity of 11 MW.[28] The largest of these, the Jiangxia facility, was built in 1980, and has a generating capacity of 3.2 MW.[29]

Several countries have developed plans to construct new tidal barrages, or tidal power stations, including, for example, Australia, Canada, India, Russia, and the United Kingdom. The most ambitious of these are the U.K.'s Severn Barrage, which would deploy more than 200 turbines to generate 8,640 MW of electric power, and a Russian facility located in the Sea of Okhotsk that would have the potentialto produce 6,800 MW of electricity.[30] Although services related to facilities planning and design have been completed for both of these projects, neither is currently under development. In the case of the Severn Barrage, lack of progress is reportedly the result of studies indicating that electric power production from the facility would not be economically profitable.[31] Overall, Europe leads the world in the provision of services pertaining to the design, construction, and operation of tidal barrages. Recent research and development expenditures have been largely concentrated on potential site evaluations, and the reduction of financial, technical, and environmental uncertainties.[32]

Finally, as a means of circumventing some of the primary drawbacks of tidal barrages– namely, high upfront capital costs and adverse environmental effects– work has been undertaken on alternative technologies to harness tidal energy. In particular, a U.S.-

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[26] Straflo is the brand name of the turbine, which was invented in Switzerland and manufactured by the Canadian operations of the General Electric Corporation. Following the completion of the tidal barrage in Canada, Straflo turbines have since been deployed elsewhere, although the turbine used at the Annapolis Royal station is the largest such turbine deployed in the world. Va Tech Hydro company website, "Straflo Turbines," found at *http://www.vatech-hydro.at/view.php3?r_id=527&LNG=EN*, retrieved June 22, 2005; and Nova Scotia Power, "About Us: Hydro Power from Rivers," found at *http://www.nspower.ca/*, retrieved June 22, 2005. Tidal Electric company website, "Technology: History of Tidal Power," found at *http://www.tidalelectric.com/*, retrieved June 22, 2005.

[27] Department of Energy, Nova Scotia, "Tidal," found at *http://www.gov.ns.ca/*, retrieved June 22, 2005.

[28] China began developing tidal power stations in the late 1950s and, at one point, had a total of 40 stations in operation. The majority of these were subsequently taken out of service because of siting or design concerns. *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 14.

[29] China New Energy, "Table 1: List of Main Tidal Power Stations," found at *http://www.newenergy.org/english/ocean/casestudy/tide/*, retrieved June 21, 2005.

[30] The costs of building the Severn Barrage are estimated to be between $18 million and $22 million. *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 14; and Friends of the Earth, "A Severn Barrage or Tidal Lagoons?" *Briefing*, Jan. 2004, found at *http://www.foe.co.uk/resources/briefings/severn_barrage_lagoons.pdf*, retrieved June 20, 2005.

[31] Ibid.

[32] The U.K. Government tidal energy program, which spent $26 million from 1978 to 1994, involved industry consortia, government, consultancies, and research institutions, each of which had specific expertise in tidal energy or estuaries. The work involved site-specific feasibility studies of tidal energy and its environmental effects. UN, "Energy Resources,"*U.N. Atlas of the Oceans*, found at *http://www.oceansatlas.com/unatlas/-ATLAS-/chapter8.html*, retrieved Mar. 16, 2005.

based company, Tidal Electric, has developed what is termed a "tidal lagoon."[33] Unlike a tidal barrage which is situated close to the shoreline and can thus block the flow of water from rivers or estuaries to the ocean, tidal lagoons are located offshore.[34] According to Tidal Electric, this innovation can resolve the resulting environmental and economic problems of barrage technology.[35] In addition, industry analysts report that electricity can be generated more efficiently from tidal lagoons than from barrages.[36] Tidal Electric has also developed a computer program which uses data on equipment performance and tidal variation to simulate electricity generation, water flows, and water storage. This program, in turn, allows electric power output to be adjusted based upon demand, thus optimizing tidal lagoon operation and resolving production variability.[37] The company is seeking to construct a tidal lagoon demonstration facility in the Swansea Bay, located along the coast of Wales. The project will reportedly cost between $64 million and $73 million to complete, and is expected to produce 30 MW of electricity.[38]

Current

The harnessing of energy from marine currents, also known as tidal stream technology, has lagged other forms of ocean energy research.[39] However, because tidal stream technology does not involve the financial or environmental risks associated with tidal barrages, countries have continued to pursue development of this technology. Noteworthy projects involving marine current energy are underway in North Devon, England and in New York City. Other projects, involving the installation of tidal fences, defined earlier in the chapter, are also planned.[40] The tidal project in North Devon is designed to harness energy from offshore currents through the placement of a single large turbine in coastal waters.[41] Installation of the turbine was completed in 2003 at a cost of nearly $6 million, largely funded by the British government and the European

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[33] A tidal lagoon is a manmade structure built by placing walls on the seabed to create a self-contained body of water, or lagoon. Water that flows in and out of the lagoon as a result of the tides is used to power hydroelectric turbines placed at the foot of the lagoon's walls.

[34] Hearing testimony before the Commission, Apr. 19, 2005.

[35] Tidal Electric company website, "Technology: Introduction," found at *http://www.tidalelectric.com/*, retrieved June 22, 2005.

[36] Friends of the Earth, "A Severn Barrage or Tidal Lagoons?" *Briefing*, Jan. 2004, found at *http://www.foe.co.uk/resources/briefings/severn_barrage_lagoons.pdf*, retrieved June 20, 2005.

[37] Tidal Electric company website, "Technology," found at *http://www.tidalelectric.com/technology.htm*, retrieved Mar. 10, 2005.

[38] Nigel Holloway, "The Power of the Moon," *Forbes*, July 21, 2003, found at *http://www.forbes.com/global/2003/0721/042.htm*, retrieved June 20, 2005.

[39] World Energy Council, "EC Survey of Resources 2001: Marine Current Energy," found at *http://www.worldenergy.org/*, retrieved June 10, 2005.

[40] Peter Osbourne, "Electricity from the Sea," *Fujita Research Report*, Sept. 1998, found at *http://www.fujitaresearch.com/*, retrieved June 23, 2005.

[41] The turbine, which generates 300 kW of electricity, is brand named "Seaflow" and its manufacture was led by U.S.-based Marine Current Turbines. *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 8.

Commission.[42] A second phase of the project is planned involving the installation of a larger, more expensive turbine that would be connected to the U.K.'s electric power grid by 2006.[43] Separately, in New York City, U.S.-based Verdant Power has been awarded a $4.5 million contract to install six hydroelectric turbines in the city's East River. Scheduled to start in the summer of 2005, the project will be the first commercial farm of tide-powered turbines in the world.[44]

Another adaptation of tidal stream technology, tidal fences, is also undergoing development and testing. Numerous tidal fence demonstrations have been planned, including those in Italy and the Philippines. The project in Italy, which is funded by the European Commission, entails the installation of 100 turbines along the Strait of Messina between the island of Sicily and the Italian mainland. The tidal fence is expected to generate a total of 25 MW of power.[45] In the Philippines, a much larger tidal fence under development would generate an average daily electric output of 1,100 MW at a total installation cost of $2.8 billion.[46] The project is slated for completion in 2006.[47]

Wave

Wave energy has been the target of several government-sponsored research and development programs. These programs have resulted in the introduction of new technologies to harness wave energy, some of which are now being tested for commercial use.[48] Significant national-level programs that have targeted wave energy development include the Danish program, which operated between 1998-2004, the Indian program begun in 1983, and the U.K.'s program, which was in effect during 1974-83. Other countries such as Japan, Ireland, Norway, and Portugal have made important contributions to wave energy research through collaborations between academia and private industry.[49]

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[42] "Local Support for Tidal," *Renew*, Issue No. 154, Mar.-Apr. 2005, found at *http://eeru.opn.ac.uk/*, retrieved June 23, 2005; and BBC, "Offshore Turbine Powers for Success," May 2, 2004, found at *http://www.bbc.co.uk/news_features/2004/tidal_turbine.shtml*, retrieved June 23, 2005.

[43] This device, also manufactured by Marine Current Turbines, is brand named "Seagen" and will have a total generating capacity of 1,000 kW. "Local Support for Tidal," *Renew*, Issue No. 154, Mar.-Apr. 2005, found at *http://eeru.opn.ac.uk/*, retrieved June 23, 2005.

[44] Helen Pearson, "Tidal Flow to Power New York City," *Water Conserve - A Water Conservation Portal*, found at *http://www.waterconsere.info/articles/reader.asp?linkid=34336*, retrieved May 19, 2005; and Roland Piquepaille's Technology Trends, found at *http://radio.weblogs.com*, retrieved June 23, 2005.

[45] European Commission, Atlas project, "Tidal Energy: Current RTD," found at *http://europa.eu.int/comm/energy_transport/atlas/home.html*, retrieved June 23, 2005.

[46] Peter Osbourne, "Electricity from the Sea," *Fujita Research Report*, Sept. 1998, found at *http://www.fujitaresearch.com*, retrieved June 23, 2005.

[47] "Tidal Projects Around the World," *Renew*, Issue No. 154, Mar.-Apr. 2005, found at *http://eeru.opn.ac.uk/*, retrieved June 23, 2005.

[48] European Commission, Atlas project, "Renewables Overview: Wave Energy," found at *http://europa.eu.int/comm/energy_transport/atlas/home.html*, retrieved Mar. 16, 2005.

[49] *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, pp. 28-32.

Wave energy research and development efforts have resulted in the development of onshore, nearshore, and offshore wave energy devices and equipment. One of the most notable onshore devices developed to date is the Mighty Whale, an oscillating water column (OWC) designed in Japan.[50] As the largest (60 MW) and perhaps the most famous onshore system, the Mighty Whale has been operating as a prototype device since 1998.[51] Both Australia-based Energetech and U.K.-based ART Ltd. have also developed OWCs that have the potential for commercial deployment.[52] Separately, the Land Installed Marine Powered Energy Transformer (LIMPET), a nearshore device, is the first commercial-scale wave energy system to generate grid power. LIMPET utilizes OWC technology and is deployed in Islay, Scotland.[53] Several offshore wave devices are also under development. For example, the Pelamis,[54] a hinged floating cylinder manufactured by U.K.-based Ocean Power Delivery Ltd., generates power that is directed toward the national power grid. Another offshore device, the PowerBuoy, is comprised of an array of buoys that rise and fall, creating mechanical stroking that drives an electrical generator. Development of the PowerBuoy was undertaken by the U.S. firm Ocean Power Technologies and funded by the U.S. Navy. The device was installed for commercial deployment off the coast of Hawaii in 2003.[55]

Despite the development of the wave energy devices mentioned above, no wave power systems have achieved long-term commercial application for the generation of electricity. Only three commercial projects are currently in place— the LIMPET, the Pelamis, and the PowerBuoy. Of these three devices, the LIMPET has been in operation the longest, having been connected to the U.K.'s national grid in 2000. The remaining wave energy devices are still undergoing development for demonstration-sized trials.[56]

Trade and Investment

Although there are no comprehensive data pertaining to trade and investment in the ocean energy industry, anecdotal evidence indicates that such activity is largely focused on non-generation services, including the design, construction, and installation of ocean power systems. More specifically, service providers in foreign markets primarily supply testing and analysis services associated with potential site evaluation for current and tidal energy projects, or for the development of wave energy prototype devices, and

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[50] The Mighty Whale was developed by the Japan Marine Technology Center. *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 21.

[51] "Wave Energy Research and Development at JAMSTEC," JAMSTEC, found at *http://www.jamstec.go.jp/jamstec/MTD/Whale/*, retrieved May 19, 2005; and "'Mighty Whale' in Operation in Gokasho Bay," Ministry of Education, Culture, Sports, Science and Technology, Press Release, July 22, 1998, found at *http://www.mext.go.jp/english/news/1998/07/980704.htm*, retrieved May 19, 2005.

[52] *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, pp. 20-21.

[53] Wavegen company website, found at *http://www.wavegen.co.uk/what_we_offer_limpet.htm*, retrieved May 19, 2005.

[54] Ocean Power Delivery Ltd company website, found at *http://www.oceanpd.com/default.html*, retrieved May 19, 2005.

[55] Ocean Power Technologies company website, found at *http://www.oceanpowertechnologies.com/technology*, retrieved May 19, 2005; and David Blackwell, "First Hawaiian Buoy Benefits Ocean Power," *Financial Times*, Sept. 2, 2004.

[56] *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, pp. 20-26, and p. 32.

architecture, engineering, construction, and installation services such as those pertaining to the development of tidal power systems. Companies participating in overseas projects include Australia's Energetech, Canada's Blue Energy, U.K. firm Ocean Power Delivery, and U.S.-based Ocean Power Technologies and Tidal Electric.

Energetech, Ocean Power Technologies, and Ocean Power Delivery are each undertaking wave energy projects in foreign markets. Energetech, through its U.S.-based subsidiary, has completed design work on a wave energy device to be installed off the coast of Rhode Island. The estimated cost of the project is $3.5 million, and it is expected to commence operation in 2006.[57] Ocean Power Technologies is involved in two overseas projects to build wave power stations. The first project is located off the northern coast of Spain and is being pursued by the company through a joint venture with Spanish renewable energy firm Iberdrola (see table 8-2 at the end of the chapter).[58] The second project involves the construction of a wave power station in France, which will include deployment of the company's PowerBuoy device.[59] The project is being undertaken by Ocean Power Technologies' European subsidiary, Total Energie Développement, based in France, and Iberdrola. Finally, in May 2005, Ocean Power Delivery received its first order for Pelamis wave energy converters from a Portuguese consortium led by the Chilean electric power firm, Enersis. The devices will be used in the initial phase of construction of a commercial wave farm near the northern coast of Portugal. The project is estimated to cost nearly $10 million.[60]

Apart from wave energy projects, Blue Energy and Tidal Electric are involved in overseas marine current and tidal energy projects. Blue Energy is leading the construction of the Philippines' tidal fence to harness marine current energy. The project will be configured under the build-own-operate-transfer (BOOT) system, allowing the Philippine Government to assume ownership of the facility within 25 years.[61] In August 2004, Tidal Electric signed an agreement with a municipal government in China to build a tidal lagoon that would result in the production of 300 MW of electric power.[62] According to the firm's representatives, the civil engineering work for

[57] "GreenWave Rhode Island," Sept. 2004, found at *http://www.energetech.com.au/content/rhode_island.html*, retrieved June 24, 2005.

[58] The project is scheduled for completion in 2007. "Ocean Power Technologies, Inc. Signs Agreement with Iberdrola S.A. for Spanish Wave Power Station," news release, Mar. 1, 2004, found at *http://www.oceanpowertechnologies.com*, retrieved June 24, 2005.

[59] "Ocean Power Technologies Ltd. Signs Agreement with Total and Iberdrola for the Development of a Wave Power Station in France," news release, June 20, 2005, found at *http://www.oceanpowertechnologies.com*, retrieved June 24, 2005.

[60] "Order Signed to Build World's First Wave Farm in Portugal," May 19, 2005, found at *http://www.oceanpd.com*, retrieved June 24, 2005.

[61] Claire Soares, "Tidal Power: The Next Wave of Electricity," *Pollution Engineering*, July 1, 2002, found at *http://www.pollutionengineering.com*, retrieved June 24, 2005.

[62] Renewable Energy Access, "China Endorses 300 MW Ocean Energy Project," Nov. 2, 2004, found at *http://www.renewableenergyaccess.com*, retrieved June 24, 2005.

Tidal Electric's overseas projects is performed by local engineers. The firm has also identified several Chinese manufacturers from whom to purchase tidal equipment.[63]

The equipment used for the production of electric power from ocean energy includes dual-use products that are also found in other industries. These products include electrical generators (HS subheading 8501), hydraulic turbines (HS subheadings 8410.11, 8410.12, 8410.13, and 8410.90), propeller turbines, low-temperature vapor turbines, caissons, gears, switches, and AC adaptors. Similarly, much of the support equipment for offshore tidal systems, such as marine power cabling, power connectors, lattice masts, and other structural equipment, are also used in the offshore oil and gas industries and, as such, are not identified exclusively with ocean energy. Therefore, available export and import data on the aforementioned product categories serve only as an approximate indication of the nature and extent of merchandise trade in the ocean energy sector.

Only one six-digit HS category– HS subheading 8907.90, other floating structures– includes products that are used specifically, but not exclusively, in the ocean energy industry. Trade data for HS subheading 8907.90 indicates that Finland was by far the largest exporter of other floating structures in 2003, accounting for $387 million, or 54 percent, of total world exports of such products.[64] The next largest exporters of other floating structures in 2003 were Lithuania and the Netherlands, each accounting for 7 percent, and the United Kingdom and the United States, each accounting for 6 percent. Trade data for the Netherlands, the United Kingdom, and the United States appear consistent with the development of the ocean energy industry in these countries. For example, the Netherlands has developed a popular wave energy device called the Archimedes Wave Swing,[65] while the United States has deployed another wave energy device called the PowerBuoy, mentioned earlier in the chapter. In addition, the United Kingdom is home to several ocean energy firms including Ocean Power Delivery, Sea Power of Scotland, and Wavegen.[66] The United States is the world's largest importer of other floating structures, accounting for $254 million, or 53 percent, of world imports in 2003. Other leading importers of these products include Thailand, accounting for 13 percent of total imports, followed by China (7 percent), the Netherlands (6 percent), and the Republic of Korea (3 percent).[67]

[63] Hearing testimony before the Commission, Apr. 19, 2005.

[64] Despite the relatively high number of exports of "other floating devices" recorded for Finland, there is no qualitative evidence to suggest that Finland has developed a large ocean energy industry. The discrepancy may be explained by the fact that HS subheading 8907.90 also includes floating structures that are not used for ocean energy production, but for other purposes, such as maritime navigational aids. "Waterways in Finland," found at *http://www.fma.fi-palvelut-tieopalvelut-esittet-vesivaylat_esite_en.pdf*, retrieved July 5, 2005.

[65] Archimedes Wave Swing website, found at *http://www.waveswing.wwxs.net*, retrieved July 5, 2005.

[66] *The Ocean Energy Report,* ABS Energy Research, London, Ed. 2, 2005, p. 32.

[67] *World Integrated Trade Solution Database*, The World Bank and the United Nations Conference on Trade and Development, retrieved June 29, 2005.

Many of the countries selected for special emphasis in this report maintain high tariffs on imports of other floating structures. For instance, Australia, Brazil, Canada, Mexico, and Thailand each maintain tariffs of 15 percent or higher.[68] The 25 members of the European Union impose a minimum tariff rate of 4.2 percent and a maximum tariff rate of 50 percent on other floating structures. Only two of the subject countries– Japan and the United States –maintain zero tariffs with respect to this product category.

Future Prospects

Industry officials recognize that electricity produced from ocean energy is not cost competitive with electricity produced from other types of renewable energy or conventional fossil fuels. The high costs of ocean power are largely the result of high capital costs associated with R&D, resource definition, and site access. For example, as noted earlier in the chapter, there are few tidal energy sites worldwide that are considered to be commercially viable. However, industry officials note that technological advances in the development of other forms of renewable energy, such as solar and wind energies, have decreased the capital costs of developing these technologies and have led to a corresponding decrease in the price of electricity produced from these sources. Thus, the ocean energy industry seeks government support and guaranteed sales incentives to proceed with the continued development of ocean energy technologies until such technologies become commercially viable.[69]

Industry officials have also identified synergies between the ocean energy industry and the offshore oil and gas industries. For example, many offshore ocean energy systems use foundational and power cabling systems developed for offshore oil and gas platforms.[70] In addition, decommissioned oil and gas platforms may be used for installing electric power generating systems that harness energy from ocean currents.[71] Finally, several research institutes are exploring opportunities to develop floating offshore systems that would capture ocean thermal energy, current energy, and wave energy in one system.[72] The major technical hurdle for these hybrid systems is energy storage. At least one industry analyst predicts that once the issue of energy storage is resolved, hybrid systems will be able to produce electricity at rates that are competitive with other energy sources.[73]

[68] This tariff rate is not applicable with respect to certain free trade agreements such as NAFTA and the U.S.-Australia FTA.

[69] Ocean Energy Conference 2005, Washington, DC, Apr. 26-28, 2005.

[70] Industry sources, interviews by USITC staff at the Ocean Energy Conference 2005 Exhibit, Washington, DC, Apr. 26-27, 2005.

[71] Ocean Energy Conference 2005, Washington, DC, Apr. 26-28, 2005.

[72] Gunther J. Weisbrich, President, ENECO-Tx, "WARP™—A Breakthrough for Combined Wind, Ocean and Tidal Current Energy Technology," Ocean Energy Conference 2005, Washington, DC, Apr. 27, 2005.

[73] Tim Dolan, President, Enabling Technologies, "Oceans of Hydrogen," Ocean Energy Conference 2005, Washington, DC, Apr. 26, 2005.

Table 8-1
Characteristics of selected markets for ocean power and ocean energy services

Country	Market size & characteristics[1]	Consumers of ocean power	Key market participants[2]
Australia	Installed or planned capacity: Derby Hydro Power received a $1 million grant from the Australian Greenhouse Office's Renewable Energy Commercialization Program for the development of a 50 MW tidal power station in Derby, Australia.[3] Energetech and partner Primergy installed a parabolic floating oscillating water column with a generating capacity of 500 MWh per year in June 2005 at Port Kembla.[4] The device is scheduled to be connected to the local grid by the late summer of 2005.[5] Powercor Australia Ltd., Ocean Power Technologies, and the Australian Greenhouse Office developed the PowerBuoy wave energy device in 2001. An offshore, pilot pump-to-shore device (Ceto), was commissioned from Seapower Pacific Pty Ltd. for use beginning in June 2005 for a period of two years.[6]	The Port Kembla plant will supply power for 500 homes via delivery through the local utility.	Siting Firms: Derby Hydro Power Ocean Energy manufacturers: Current: HydroGen Ocean Power Technology Outback Marine Australia Pty. Ltd. Redarc Electronics Rich Electric Wave: Renewable Energy Gippsland Ltd Seapower Pacific Pty Ltd. Current & Wave: Energetech Australia Pty Ltd. Retail electricity sellers: Integral Energy Powercor R&D organizations: New South Wales Water Research Laboratory Primergy
Canada	Installed capacity: A tidal power station with a generating capacity of 20 MW was built at Annapolis Royal, Bay of Fundy.	Nova Scotia Power[7]	Ocean Energy manufacturers: Tidal & Current: Blue Energy Canada Inc.

See footnotes at end of table.

Table 8-1—*Continued*
Characteristics of selected markets for ocean power and ocean energy services

Country	Market size & characteristics[1]	Consumers of ocean power	Key market participants[2]
China	Installed or planned capacity: Seven tidal power stations and one tidal flood station, with a total capacity of 11 MW, were commissioned during 1956-1970. The largest of these facilities were located at Jiangxia (with a generating capacity of 3 MW) and Baishakou (with a generating capacity of 960 kW).[8] A wave energy pendulor device, with a generating capacity of 500 kW, was developed at Daguan Island. The device is reportedly still under construction.	None identified.	Ocean Energy manufacturers: Current: D & J Power Co., Ltd. Wave: Guangzhou Institute of Energy Conversion (GIAC), Chinese Academy of Sciences Tianjin Institute of Ocean Technology (TIOT), State Oceanic Administration
Denmark	Installed or planned capacity: In Nissum Bredning, the Wave Dragon, a floating tapered channel system device with a generating capacity of 36 kW, was deployed as a prototype in 2003. A refurbished unit will be redeployed in 2005 to a more productive site, for $5.3 million. Full installation is targeted for 2007.[9]	None identified.	Ocean Energy manufacturers: Tidal & Wave: Wave Dragon ApS Wave: WavePlane International A/S R&D & financial support: Danish Wave Energy Program 1998-2004, Danish Energy Agency
France	Installed or planned capacity: The La Rance tidal power station, with a total generating capacity of 240 MW, was commissioned in 1966. It currently generates 640 million kWh of electricity per year. In June 2005, French firm Total Energie Développement signed an agreement with U.S. firm Ocean Power Technologies and Spanish firm Iberdrola to build a wave power station in France.	The La Rance tidal power station provides 90 percent of the electric power used in Brittany, France.	Operations & management firms: EDF Iberdrola S.A. Total Energie Développement S.A.S.

See footnotes at end of table.

Table 8-1—*Continued*
Characteristics of selected markets for ocean power and ocean energy services

Country	Market size & characteristics[1]	Consumers of ocean power	Key market participants[2]
Germany	No installations or demonstrations found.	None	Engineering and R&D: IEE, University of Kassel Voith Siemens Hydro, subsidiary of Voith Group
Greece	Installed or planned capacity: In Amorgos, deployment of the IPS buoy/Hosepump (also known as the Swedish Hosepump) is planned for use in desalination and electricity production.	None	Ocean Energy manufacturers: Wave & Hybrid: Daedalus Informatics
India	Installed or planned capacity: In Trivandrum, a 150 kW oscillating water column demonstration took place in 1991. The device has been upgraded to a generating capacity of 1.1 MW.[10] In Durgaduani, a feasibility study is underway, sponsored by the Ministry of Non-Conventional Energy Sources, to develop a 3 MW tidal power station.[11]	None identified.	Ocean Energy manufacturers: Current: Arti Products Ti Anode Fabricators R&D and financial support: West Bengal Renewable Energy Development Agency National Institute of Ocean Technology (succeeded India Institute of Technology's early work), sponsored by Department of Ocean Development, Government of India
Indonesia	Installed or planned capacity: In Baron, Java, a Norwegian team led by Indonor AS has been contracted to build a 1.1 MW tapered channel system.[12]	None	Contracting Agency: Chartered Institution of Water and Environmental Management (CIWEM)
Italy	Installed or planned capacity: In 2004, a demonstration tidal fence facility was planned between Sicily and the Italian mainland.	None	R&D: University of Naples

See footnotes at end of table.

Table 8-1—*Continued*
Characteristics of selected markets for ocean power and ocean energy services

Country	Market size & characteristics[1]	Consumers of ocean power	Key market participants[2]
Ireland	Installed or planned capacity: In Eire, a 131-foot McCabe Wave Pump demonstration took place in 1996 with the support of the EU's JOULE energy program and the EU Marine Research Measure of the Fisheries Operational Program.	None	Operations & management firms: Hydam Technology R&D: University College Cork Funding: Irish government EU JOULE Program
Japan	Installed or planned capacity: Oscillating water columns have been launched as prototypes in several areas of Japan, including Hokkaido. The "Mighty Whale" oscillating water column was developed as a prototype in 1998 in Gokasha Bay.	None identified.	R&D organizations: Japan Marine Science and Technology Center (JAMSTEC) Muroran Institute of Technology
Malaysia	No installations or demonstrations found.	None	Ocean Energy manufacturers: Current: Indah Letrick (M) Sdn Bhd
Maldives	The Government of the Maldives has ordered a floating wave power vessel from Sea Power Ltd., based in Sweden.[8]	None	Contracting Agency: The Republic of the Maldives
Netherlands	No installations or demonstrations found.	None	Ocean Energy manufacturers: Wave: Archimedes Wave Swing BV Teamwork Techniek
New Zealand	No installations or demonstrations found.	None	Ocean Energy manufacturers: Current: CruzPro

See footnotes at end of table.

Table 8-1—*Continued*
Characteristics of selected markets for ocean power and ocean energy services

Country	Market size & characteristics[1]	Consumers of ocean power	Key market participants[2]
Norway	Installed or planned capacity: An oscillating water column and a tapered channel device had been developed for deployment in the 1980s, but currently neither device is in operation.	None	Ocean Energy manufacturers: Wave: Norwave AS R&D and management: Indonor AS Groener AS Oceanor ASA University of Bergen Norwegian University of Science and Technology Oceanographic Company of Norway ASA
Portugal	Installed or planned capacity: In Pico, Azores, two 500 kW turbo-generators were commissioned in 1999 as part of the Marine Environment and Technology Centre (MARETEC) of Portugal. In Faro, two companies, Wavegen and SEV, jointly developed an onshore oscillating water column at a cost of $8.5 million. In Póvoa de Varim, the first commercial wave farm has been under development since May 2005. The project is led by a consortium under the Chilean firm Enersis.[13] The Archimedes Wave Swing, a wave energy device developed in the Netherlands, was deployed at Viana do Castelo in 2001.[14]	Pelamis is expected to meet the average electricity demand of more than 1,500 Portuguese households.	R&D: Industrial Technology, Portuguese Ministry of Economy Instituto Superior Técnico, Technical University of Lisbon Marine Environment and Technology Centre (MARETEC),[15] research center of the Portuguese Institute of Marine Research (IMAR) Retail electricity sellers: Enersis SGPS SEV NUON

See footnotes at end of table.

Table 8-1—*Continued*
Characteristics of selected markets for ocean power and ocean energy services

Country	Market size & characteristics[1]	Consumers of ocean power	Key market participants[2]
Russia	Installed or planned capacity: In Kislogubsk, a tidal power station was commissioned in 1968. The station was originally designed to be experimental, and had a total generating capacity of 400 KW.[16]	None identified.	Commissioning agency: Government of Russia
Spain	Installed or planned capacity: In 2004, U.S. firm Ocean Power Technologies signed an agreement with Spanish firm Iberdrola to develop a wave power station in northern Spain.[17]	None	Ocean Energy manufacturers: Construction & Offshore platforms NAVACEL, SA
Sweden	Installed or planned capacity: The Swedish Hosepump was developed as a demonstration project during 1983-84.	None	Ocean Energy manufacturers: Tidal & Wave: Sea Power International AB
Turkey	No installations or demonstrations found.	None	Ocean Energy manufacturers: Current: GEMES Endüstriyel Elektronik Ltd. Pti. Upscom

See footnotes at end of table.

Table 8-1—*Continued*
Characteristics of selected markets for ocean power and ocean energy services

Country	Market size & characteristics[1]	Consumers of ocean power	Key market participants[2]
United Kingdom	Installed or planned capacity: Off the coast of North Devon, England, Marine Current Turbines installed a wave energy device in 2003. The device will be connected to the local electric power grid in late 2005.[18] A wave energy device known as the Land Installed Marine Powered Energy Transformer (LIMPET) was developed for demonstration in Islay, Scotland in 1991. The device is now connected to the electric power grid. In the Shetland Islands, Sea Power of Scotland Ltd. (a U.K. subsidiary of Swedish firm Sea Power) has been contracted by Scottish Power and Southern Energy to supply electricity.[19]	Islay LIMPET feeds the local grid and has a 15-year power purchase agreement with several large Scottish electricity suppliers.	Ocean Energy manufacturers: Tidal: SMD Hydrovision Current: Marine Current Turbines Ltd. (MCT), a subsidiary of IT Power The Merlin Group Wave: ART Ltd Ocean Power Delivery Ltd (OPD) Wavegen Sea Power of Scotland Ltd Tidal & Wave: The Engineering Business Ltd Engineering: Bendalls Engineering, a subsidiary of Carrs Milling Plc Corus UK Ltd Seacore Ltd R&D facilities: New and Renewable Energy Centre[20] University of Edinburgh (Wide Wave Tank) Retail electricity sellers: IT Power Ltd Scottish Power and Southern Energy

See footnotes at end of table.

Table 8-1—*Continued*
Characteristics of selected markets for ocean power and ocean energy services

Country	Market size & characteristics[1]	Consumers of ocean power	Key market participants[2]
United States	Installed or planned capacity: Ocean Power Technologies deployed the PowerBuoy off the coast of Hawaii in 2003. A second PowerBuoy is scheduled to be deployed in the same area in 2006.[21] U.S.-based Verdant Power has deployed six hydroelectric turbines in New York City's East River to harness energy from marine currents. The project was scheduled to begin commercial operations in the summer of 2005.	The PowerBuoy will supply electricity to local consumers. The Verdant turbine farm will supply electricity to 200 homes.	Ocean Energy manufacturers: Tidal & Wave: Tidal Electric, Inc. Current: Energy Systems Inc. McLan Electronics, Inc. Ocean Wave Energy Company RODI Power Systems, Inc. Suntara Energy Verdant Power Wave: Aqua Energy Group Ltd 374 Electric Power Corporation Ocean Power Technologies (OPT) Marine Turbines: UEK Corporation

[1] Pilot, demonstration, installed, and planned facilities are compiled from "Tidal Energy" and "Wave Energy," European Commission, Atlas project, found at *http://europa.eu.int/comm/energy_transport/atlas/html/renewables.html*, retrieved Mar. 9, 2005; *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005; and various company websites.

[2] *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, appendix.

[3] Tidal Power Systems, found at *http://reslab.com.au/resfiles/tidal/text.html*, retrieved June 12, 2004.

[4] The project will be completed with a grant of $574,000 from the Australian Government's Renewable Energy Commercialisation Programme. *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, pp. 25-30.

[5] Energetech company website, found at *http://www.energetech.com.au/index.htm*, retrieved June 14, 2005.

[6] John Roberson, "Deep Water Generator Puts Wave Power to the Test," *Times Online*, Apr. 11, 2005, found at *http://technology.timesonline.co.uk/article/0,,20409-1565224,00.html*, retrieved May 18, 2005.

[7] On average, renewables account for about 9 percent of Nova Scotia's electricity generation. Nova Scotia Department of Energy website, found at *http://www.gov.ns.ca/energy/AbsPage.aspx?siteid=1&lang=1&id=1344*, retrieved July 5, 2005.

[8] *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, p. 30.

[9] "Offshore Power Production to the Grid," found at *http://www.wavedragon.net/news/270603.htm,* retrieved June 14, 2005.

[10] "Indian Wave Energy," found at *http://www.niot.res.in/m1/mm1.html*, retrieved May 19, 2005.

[11] Government of India, Ministry of Non-Conventional Energy Resources, "Tidal Energy" found at *http://mnes.nic.in/frame.htm?majorprog.htm*, retrieved Aug. 3, 2005; and *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, p. 20.

[12] *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, p. 29.

[13] "Order Signed to Build World's First Wave Farm in Portugal," Ocean Power Delivery, Ltd., press release, May 19, 2005, found at *http://www.oceanpd.com/docs/OPD%20Enersis%20Press%20Release.pdf*, retrieved May 20, 2005; and "Latest News," Ocean Power Delivery, found at *www.oceanpd.com/LatestNews/default.html*, retrieved May 19, 2005.

[14] *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, p. 31.

[15] The Marine Environment and Technology Centre (MARETEC) is a research center of the Portuguese Institute of Marine Research (IMAR), a non-profit organization comprised of members from the academic community involved in marine technology.

[16] Four other Russian Federation sites were studied for much larger facilities in the late 1960s – Lumbov (67 MW), Mezen Bay (15,000 MW), Penzhinsk Bay (87,400 MW), and Tugur Bay (6,800 MW). Only Tugur was determined as a feasible site. Design work began in 1972, but the site still remains under development.

[17] "Ocean Power Technologies, Inc. Signs Agreement with Iberdrola S.A. for Spanish Wave Power Station," news release, Mar. 1, 2004, found at *http://www.oceanpowertechnologies.com*, retrieved June 24, 2005.

[18] According to *The Ocean Energy Report*, Marine Current Turbines was created as a part of IT Power, and partnered with a consortium of U.K. and German companies – Seacore Ltd, IT Power, Bendalls Engineering (a subsidiary of Carrs Milling Plc), Corus UK Ltd, and IEE of the University of Kassel (Germany) – to advance the project.

[19] The contract was awarded under the Scottish Power and Southern Energy Renewables Obligation Third Order (SRO3).*The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, p. 32.

[20] New and Renewable Energy Centre website, found at *http://www.narec.co.uk*, retrieved June 14, 2005.

[21] Ocean Power Technologies company website, found at *http://www.oceanpowertechnologies.com/technology*, retrieved May 19, 2005; and David Blackwell, "First Hawaiian Buoy Benefits Ocean Power," *Financial Times*, Sept. 2, 2004.

Table 8-2
Extent of ocean power and ocean energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Type of measure affecting trade	Description of measure
Australia	Energetech has a U.S. subsidiary engaged in the development of a wave energy project off the coast of Rhode Island.[1]	None identified	Australia maintains up to a 5 percent (15 percent bound) tariff on imports of other floating structures.	Can negatively impact cross-border trade.
Brazil	None identified.	None identified.	Brazil maintains a 14 percent (35 percent bound) tariff on imports of other floating structures.	Can negatively impact cross-border trade. Specialized equipment can often be sourced offshore, but all else must be sourced domestically, in practice, to meet the 70 percent requirement.
Canada	Blue Energy is a leading turbine technology firm and has participated in projects in foreign markets, such as the Philippines.[2]	None identified.	Canada maintains a zero to 15.5 percent (zero to 15.7 percent bound) tariff on imports of other floating structures.	Can negatively impact cross-border trade.
China	China has exported a few Academy of Science symmetrical wave turbines to Japan.[3]	None identified.	China maintains an 8 percent tariff on imports of other floating structures.	Can negatively impact cross-border trade.

See footnotes at end of table.

Table 8-2—*Continued*
Extent of ocean power and ocean energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Type of measure affecting trade	Description of measure
Denmark	The WavePlane was tested in Japan (by NKK) from September 2002 to April 2003.[4]	None identified.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Reportedly, in practice, the national agenda to use only domestic technology has made trade problematic. Can negatively impact cross-border trade.
France	None	None identified.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.
Germany	Voith Group, through its subsidiary Voith Siemens Hydro, purchased Wavegen of Inverness (Scotland) on May 24, 2005.[5] IEE, of the University of Kassel, partnered with a U.K. consortium of companies to develop the Seaflow Project, which started in 2003 and is expected to be connected to the grid late in 2005.[6]	Wavegen of Inverness (Scotland) purchased by Voith.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.
Greece	None identified.	None identified.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.
India	India has reportedly ordered two McCabe Wave Pumps from Ireland.	None identified.	None identified.	None identified.

See footnotes at end of table.

Table 8-2—*Continued*
Extent of ocean power and ocean energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Type of measure affecting trade	Description of measure
Indonesia	A Norwegian team, led by Indonor and using Norwave technology, has been granted a contract to build a tapered channel facility at Baron on Java.[7]	None identified.	Indonesia maintains a zero to 30 percent tariff on imports of other floating structures.	Can negatively impact cross-border trade.
Ireland	University College Cork participated in European Wave Energy Research Program and the development of the Atlas.	None identified.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.
Japan	The Danish WavePlane was tested (by NKK) from September 2002 to April 2003.	None identified.	None identified.	None identified.
Maldives	The Government of Maldives has ordered a Sea Wave (Sweden) floating wave power vessel.[8]	Swedish technology tested.	Maldives maintains a 25 percent (30 percent bound) tariff on imports of other floating structures.	Can negatively impact cross-border trade.
Mexico	None	None identified.	Mexico maintains an 18 percent (35 percent bound) tariff on imports of other floating structures.	Can negatively impact cross-border trade.
The Netherlands	Dutch companies and a Portuguese utility entered into a joint venture to deploy a wave energy device called the Archimedes Wave Swing.[9]	Dutch technology applied by Portuguese utility.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.

See footnotes at end of table.

Table 8-2—*Continued*
Extent of ocean power and ocean energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Type of measure affecting trade	Description of measure
New Zealand	None identified.	None identified.	New Zealand maintains a zero to 5 percent (zero to 15 percent bound) tariff on imports of other floating structures.	Can negatively impact cross-border trade.
Norway	Norway has exported Norwave technology, engineering, and project management services to Indonesia to build a tapered channel system facility.[10]	Norwegian technology applied in Indonesia.	Norway maintains a zero to 5 percent tariff on imports of other floating structures.	Can negatively impact cross-border trade.
Portugal	A Portuguese consortium, led by Enersis, ordered $10.1 million in Ocean Power Delivery (U.K.) Pelamis wave energy converters in May 2005.[11] The Viana do Castelo Archimedes Wave Swing facility involved a local utility and several Dutch interests, including the inventor and the developer. The components were manufactured in Romania.[12]	 Dutch technology and investment, and Romanian manufacturing, used to develop Viana do Castelo facility.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.
Scotland	Wavegen of Inverness was purchased by Voith Siemens Hydro, a subsidiary of Voith Group (Germany) on May 24, 2005.	None identified.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.

See footnotes at end of table.

Table 8-2—*Continued*
Extent of ocean power and ocean energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Type of measure affecting trade	Description of measure
Spain	Iberdrola entered into a joint venture with Ocean Power Technologies (U.S.) to build a 1.25 MW station off the coast of Spain.[13]	U.S. technology contracted to provide wave energy.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.
Sweden	Sea Wave has signed a letter of intent to deliver a floating wave power vessel to the Maldives. Sea Power International AB (Sweden) signed a contract offered by Scottish Power and Southern Energy to supply energy for 15 years to the Shetland Islands. Sea Power established the subsidiary Sea Power of Scotland Ltd. to carry out the project.[14]	Swedish technology contracted to supply Maldives. Swedish technology contracted to U.K. (Scotland) energy installation.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.
Thailand	None identified.	None identified.	Thailand maintains a zero to 10 percent tariff on imports of other floating structures.	Can negatively impact cross-border trade.
United Kingdom	Ocean Power Delivery Ltd. received a Portuguese contract for $10.1 million for the purchase of Pelamis wave energy converters.[15]	U.K. technology contracted for Portuguese wave energy.	The 25 members of the European Union impose a minimum tariff rate of 4.2 percent on other floating structures, and a maximum tariff rate of 50 percent.	Can negatively impact cross-border trade.

See footnotes at end of table.

Table 8-2—*Continued*
Extent of ocean power and ocean energy services trade, by certain countries, and measures affecting such trade

Country	Cross-border trade	Foreign operations	Type of measure affecting trade	Description of measure
United States	Ocean Power Technologies entered into a joint venture with Iberdrola (Spain) to build a 1.25 MW station off the coast of Spain.	U.S. technology contracted for Spanish installation.	Permitting to the continental shelf for renewable energy has no federal jurisdiction. The first 3 miles must be handled by the appropriate state.	Can negatively impact cross-border trade.

[1] See Energetech company website, found at *http://www.energetech.com.au/*, retrieved Aug. 3, 2005.

[2] Claire Soares, "Tidal Power: The Next Wave of Electricity," *Pollution Engineering*, July 1, 2002, found at *http://www.pollutionengineering.com*, retrieved June 24, 2005.

[3] *The Ocean Energy Report*, ABS Energy Research, London, Ed. 2, 2005, p. 32.

[4] See WavePlane company website, found at *http://www.waveplane.com/news.htm*, retrieved Aug. 3, 2005.

[5] New Energy Finance, "Week in Review," found at *http://www.newenergyfinance.com/NEF/Newsletters/Issue_032.htm*, retrieved Aug. 3. 2005.

[6] The British Wind Energy Association, "Marine Renewable Energy Devices," found at *http://www.bwea.com/marine/devices.html*, retrieved Aug. 3, 2005.

[7] *The Ocean Energy Report*, p. 29.

[8] *The Ocean Energy Report*, p. 30.

[9] Archimedes Wave Swing website, found at *http://www.waveswing.com/*, retrieved Aug. 3, 2005.

[10] *The Ocean Energy Report*, p. 29.

[11] "Order Signed to Build World's First Wave Farm in Portugal," Ocean Power Delivery, Ltd., press release, May 19, 2005, found at *http://www.oceanpd.com/docs/OPD%20Enersis%20Press%20Release.pdf*, retrieved May 20, 2005; and "Latest News," Ocean Power Delivery, found at *www.oceanpd.com/LatestNews/default.html*, retrieved May 19, 2005.

[12] *The Ocean Energy Report*, p. 31.

[13] Ocean Power Technologies, Inc. Signs Agreement with Iberdrola S.A. for Spanish Wave Power Station," news release, Mar. 1, 2004, found at *http://www.oceanpowertechnologies.com*, retrieved June 24, 2005.

[14] *The Ocean Energy Report*, p. 32.

[15] "Order Signed to Build World's First Wave Farm in Portugal," May 19, 2005, found at *http://www.oceanpd.com*, retrieved June 24, 2005.

CHAPTER 9
CONCLUSION

Renewable energy markets are growing rapidly in developed and developing economies, principally in response to global concerns regarding electricity security and environmental quality. However, the share of renewable production in total electricity production is uneven across countries, ranging from nearly 20 percent in Denmark and Costa Rica to less than 1 percent in some developing countries. Overall, the renewable share of electricity production is small globally, standing at 2.5 percent in OECD countries and 0.9 percent in non-OECD countries.

Historically, cost has been the major obstacle to past renewable energy growth. The cost of generating electricity from renewable sources, excepting biomass, is higher than that for most fossil fuels. Electricity from biomass is roughly comparable in cost to electricity from coal, natural gas, and nuclear energy, and lower cost than that from fuel oil. The incorporation of external costs (which reflect the health and environmental consequences of fossil fuel use) in perceived prices would make wind and geothermal energy more price competitive relative to conventional energy sources, but this remains a topic of discussion mostly in academic circles, rather than policy circles. The cost of solar photovoltaic generation currently remains significantly higher than the cost of electricity generation from other renewable sources, even accounting for the effects of lower external costs. Because ocean energy is in its infancy, its overall cost competitiveness is largely unknown.

Government policies have played a prominent role in the development of certain renewable energy sectors. Some of these policies, specifically market deployment policies, target renewable energy. Others, focused on R&D, electric power reform, and economic development, target the entire energy sector, though each has components specific to renewable energy. Market deployment policies such as investment incentives, tax measures, incentive tariffs, legislative obligations, and voluntary programs appear to have had some success in improving the economic case for wind and solar energy. Geothermal and biomass energy have been less affected by government policies. Where geothermal energy has been available, it has been used for many years, reducing the need for government promotion. Electricity generation from biomass, which continues to be the largest of the renewable energy sectors considered in this report, has required less assistance owing to longstanding economic incentive to incinerate biomass for heat and electricity in industrial settings. Government support of tidal energy presently focuses more on research and development than implementation.

Market deployment policies do not entirely supplant market incentives and disciplines, but rather promote or require greater demand for renewable energy among consumers and electric utilities, and rely on market forces to achieve policy goals from that point onward. Implementing these policies in combinations of two or more, governments have relied on supply and demand relationships between consumers and utilities, on the one hand, and renewable energy generators, equipment manufacturers, and service providers on the other, to achieve greater production and usage of renewable energy. Long-term deployment policies, which make the investment environment more predictable, seem to have worked best. There is evidence from the United States and

Denmark that short-term deployment policies tend to work less well, hindering private sector investment by reducing investor certainty. The principal questions about market deployment policies remain whether they will foster competition sufficient to drive down renewable energy prices, and whether they create among renewable energy generators reliance on continued assistance.

There is some market data that suggests that market deployment policies - regarding wind energy in Germany, Spain, and the United States, and solar energy in Germany and Japan - have driven down the cost of wind and solar energy generation, principally by reducing equipment prices. Long-term deployment policies that created greater demand for renewable energy sufficiently enticed energy generators to augment capacity to meet current and anticipated future demand. For instance, cumulative solar PV installations increased in Germany and Japan by an annual average of 48 percent and 41 percent, respectively, during 1992-2003. To increase capacity, generators turned to renewable energy equipment and service suppliers, usually from their home market. Whether by achieving economies of scale or learning by doing as they increased production levels, equipment manufacturers succeeded in lowering production costs. For instance, during 1989-2001, the cost of wind turbines decreased by 30 percent, while the production costs of solar modules declined by 5 percent per year over the last decade. Lower equipment costs reduced the fixed cost of adding generation capacity, enabling generators to reduce electricity rates.

The trade implications of the process discussed above have been significant. Manufacturers from countries with early, long-term deployment policies, with the time to reduce production costs and improve product quality through incremental technological advances, captured large shares of the global market in many instances. In 2004, for instance, ten firms located in Germany, Spain, and the United States accounted for 68 percent of the global market for wind power equipment. In that same year, firms located in Japan held a 49-percent share of the world market for solar PV cells and modules, while firms in Europe (primarily Germany) held 26 percent.

Trade in services appeared to follow closely behind goods trade, with those gaining services experience in the home market following client equipment firms into foreign markets. In 2004, firms from Germany, Spain, and the United States were the largest providers of wind energy services such as engineering and consulting, wind farm development, and niche wind services. Firms located in Japan, Germany, and the United States were the largest providers of solar energy services such as installation, maintenance, and repair of solar products and systems. Firms with pronounced design capabilities developed in the home market won turnkey systems contracts and investment opportunities in foreign markets, the best example being the expansion of Japanese solar products manufacturers and designers into multiple foreign markets. With few identifiable impediments specific to trade and investment in renewable energy services and equipment, firms have largely been able to capitalize on the competitive skills bred in home markets.

APPENDIX A
REQUEST LETTER

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF THE UNITED STATES TRADE REPRESENTATIVE
WASHINGTON, D.C. 20508

DOCKET NUMBER 2386 Office of the Secretary Int'l Trade Commission

JUL 12 2004

The Honorable Stephen Koplan
Chairman
U.S. International Trade Commission
500 E Street, SW
Washington DC, 20436

Dear Chairman ~~Koplan~~ Steve:

As you know, members of the World Trade Organization (WTO) have been engaged in negotiations under the General Agreement on Trade in Services (GATS) since January 2000. Negotiations on services are also underway as part of an effort to establish bilateral and regional free trade agreements between the United States and a number of its trading partners. These bilateral, regional, and multilateral negotiations are intended to liberalize services trade by reducing or eliminating measures that limit effective market access.

With these negotiations in mind, two concise reports on discrete segments of the environmental and energy services industries would be of interest to my office. Further information about such services markets will also be useful in carrying out environmental reviews of current and future WTO agreements and bilateral free trade agreements. Certain environmental and energy services– such as, *inter alia*, air and noise pollution abatement services and renewable energy services– are of significant importance to the global economy in terms of both market size and the role of such industries in achieving sustainable development. Government efforts to address environmental degradation and industry efforts to increase efficiency and maintain favorable environmental records have increased demand for environmental and energy services. Trade in such services ensures that all economies have access to reliable environmental technologies, and thus facilitates global environmental protection.

Therefore, I request, pursuant to authority delegated by the President under section 332(g) of the Tariff Act of 1930, that the U.S. International Trade Commission conduct two investigations and prepare reports. The first of these reports should cover air and noise pollution abatement services, and the second should cover renewable energy services. Each of these reports should, to the extent possible, (1) provide an overview of foreign and domestic markets for the subject services; (2) examine trade and investment in the subject services markets, including barriers affecting such trade and investment, if any; and (3) if possible, discuss existing regulatory practices that generate demand for the subject services. With regard to the geographic coverage of these reports, the Commission should endeavor to include examples from both developed- and developing-country markets. In addition, the Commission is encouraged to include examples– as appropriate– from those economies with which the United States has established, or is in the process of negotiating, a free trade arrangement. To the extent possible, these reports should also present information on trade and market conditions for those goods related to the subject environmental and energy services. The Commission is encouraged to include information gathered through public hearings and other consultations with interested parties.

The Commission is requested to deliver a report on the air and noise pollution abatement services industry no later than April 1, 2005. For the purpose of this report, I urge the Commission to define air and noise pollution abatement services to include control services of indoor or outdoor air pollution originating from stationary or mobile sources; services related to the trade of air pollution emission rights; services related to the monitoring, assessment, or control of acid rain; services related to the study of the relationship between air pollution and climate; noise pollution abatement and control services; testing and monitoring of air or noise pollution; and other services incidental to air and noise pollution abatement.

The Commission is requested to deliver a report on the renewable energy services industry no later than October 1, 2005. For the purpose of this report, I urge the Commission to define the renewable energy industry to include the use of renewable power sources– including wind, solar energy, biomass fuels, tidal energy, and geothermal energy– in heating or electricity generation; the sale of renewable energy; geological analysis, resource assessment, and other services incidental to the evaluation, planning, or siting of a renewable energy project or facility; design, construction, and installation services for renewable energy equipment and facilities; the operation, management, and monitoring of renewable energy projects or facilities; decommissioning services; services incidental to the issuance of renewable energy certificates; research and development services related to renewable energy; and other services incidental to the development and use of renewable power sources.

My office intends to make the Commission's reports available to the general public in their entirety. Therefore, the reports should not contain any confidential business or national security classified information.

The Commission's assistance in this matter is greatly appreciated.

Thanks!

Sincerely,

Bob

Robert B. Zoellick

APPENDIX B
FEDERAL REGISTER NOTICE

trade and market conditions for those goods related to the subject environmental services. For the purpose of this study, air and noise pollution abatement services are defined to include control services of indoor or outdoor air pollution originating from stationary or mobile sources; services related to the trade of air pollution emission rights; services related to the monitoring, assessment, or control of acid rain; services related to the study of the relationship between air pollution and climate; noise pollution abatement and control services; testing and monitoring of air or noise pollution; and other services incidental to air and noise pollution abatement.

The USTR asked that the Commission furnish its report by April 1, 2005, and that the Commission make the report available to the public in its entirety.

The USTR letter also requests an investigation on renewable energy services. In response, the Commission has instituted Investigation No. 332–462, Renewable Energy Services: An Examination of U.S. and Foreign Markets, which is due to the USTR on October 1, 2005.

Public Hearing: A public hearing in connection with the investigation will be held at the U.S. International Trade Commission Building, 500 E Street SW., Washington, DC, beginning at 9:30 a.m. on October 20, 2004. All persons shall have the right to appear, by counsel or in person, to present information and to be heard. Requests to appear at the public hearing should be filed with the Secretary, United States International Trade Commission, 500 E Street SW., Washington, DC 20436, no later than 5:15 p.m., October 5, 2004. Any prehearing briefs (original and 14 copies) should be filed not later than 5:15 p.m., October 7, 2004; the deadline for filing post-hearing briefs or statements is 5:15 p.m., November 4, 2004. In the event that, as of the close of business on October 5, 2004, no witnesses are scheduled to appear at the hearing, the hearing will be canceled. Any persons interested in attending the hearing as an observer or non-participant may call the Secretary of the Commission (202–205–1806) after October 5, 2004, for information concerning whether the hearing will be held.

Written Submissions: In lieu of or in addition to participating in the hearing, interested parties are invited to submit written statements (original and 14 copies) concerning the matters to be addressed by the Commission in its report on this investigation. Commercial or financial information that a submitter desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform with the requirements of section § 201.6 of the Commission's Rules of Practice and Procedure (19 CFR 201.6). All written submissions, except for confidential business information, will be made available in the Office of the Secretary to the Commission for inspection by interested parties. The Commission will not include any confidential business information in the report it sends to the USTR. To be assured of consideration by the Commission, written statements relating to the Commission's report should be submitted to the Commission at the earliest practical date and should be received no later than the close of business on November 4, 2004. All submissions should be addressed to the Secretary, United States International Trade Commission, 500 E Street SW., Washington, DC 20436. The Commission's rules do not authorize filing submissions with the Secretary by facsimile or electronic means, except to the extent permitted by section 201.8 of the Commission's Rules of Practice and Procedure (19 CFR 201.8) (see Handbook for Electronic Filing Procedures, *ftp://ftp.usitc.gov/pub/reports/electronic_filing_handbook.pdf*). Persons with questions regarding electronic filing should contact the Secretary (202–205–2000 *edis@usitc.gov*).

Persons with mobility impairments who will need special assistance in gaining access to the Commission should contact the Office of the Secretary at 202–205–2000. General information concerning the Commission may also be obtained by accessing its Internet server (*http://www.usitc.gov*).

List of Subjects

WTO, GATS, air and noise pollution abatement services.

Issued: August 5, 2004.

By order of the Commission.

Marilyn R. Abbott,

Secretary to the Commission.

[FR Doc. 04–18315 Filed 8–10–04; 8:45 am]

BILLING CODE 7020–02–P

INTERNATIONAL TRADE COMMISSION

[Investigation No. 332–462]

Renewable Energy Services: An Examination of U.S. and Foreign Markets

AGENCY: International Trade Commission.

ACTION: Institution of investigation and scheduling of public hearing.

DATES: Effective August 3, 2004.

SUMMARY: Following receipt of a request on July 12, 2004 from the United States Trade Representative (USTR), the Commission instituted investigation No. 332–462, Renewable Energy Services: An Examination of U.S. and Foreign Markets, under section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)).

FOR FURTHER INFORMATION CONTACT: Information specific to this investigation may be obtained from Lisa Ferens, Project Leader (202–205–3486; *lisa.ferens@usitc.gov*), Jennifer Baumert, Deputy Project Leader, (202–205–3450; *jennifer.baumert@usitc.gov*), or Richard Brown, Chief, Services and Investment Division (202–205–3438; *richard.brown@usitc.gov*), Office of Industries, U.S. International Trade Commission, Washington, DC, 20436. For information on the legal aspects of this investigation, contact William Gearhart of the Office of the General Counsel (202–205–3091; *willam.gearhart@usitc.gov*). Hearing impaired individuals are advised that information on this matter can be obtained by contacting the TDD terminal on (202) 205–1810.

Background: As requested by the USTR, the Commission's report will, to the extent possible, (1) provide an overview of foreign and domestic markets for renewable energy services; (2) examine trade and investment in renewable energy services markets, including barriers affecting such trade and investment, if any; and (3) if possible, discuss existing regulatory practices that generate demand for the subject services. USTR has requested that the Commission's study include examples from both developed- and developing-country markets. In addition, the USTR has asked the Commission to include examples—as appropriate—from those economies with which the United States has established, or is in the process of negotiating, free trade arrangements. To the extent possible, the Commission is also requested to present information on trade and market conditions for those goods related to the subject renewable energy services. For the purpose of this study, renewable energy services are defined to include: the use of renewable power sources—including wind, solar energy, biomass fuels, tidal energy, and geothermal energy—in heating or electricity generation; the sale of renewable energy; geological analysis, resource assessment, and other services incidental to the evaluation, planning, or siting of a renewable energy project or facility; design, construction, and installation services for renewable energy equipment and facilities; the operation, management, and monitoring of renewable energy projects or facilities; decommissioning services; services incidental to the issuance of renewable energy certificates; research and development services related to renewable energy; and other services incidental to the development and use of renewable power sources.

The USTR asked that the Commission furnish its report by October 1, 2005, and that the Commission make the report available to the public in its entirety.

Public Hearing: A public hearing in connection with the investigation will be held at the U.S. International Trade Commission Building, 500 E Street SW., Washington, DC, beginning at 9:30 a.m. on April 19, 2005. All persons shall have the right to appear, by counsel or in person, to present information and to be heard. Requests to appear at the public hearing should be filed with the Secretary, United States International Trade Commission, 500 E Street SW., Washington, DC 20436, no later than 5:15 p.m., April 5, 2005. Any prehearing briefs (original and 14 copies) should be filed not later than 5:15 p.m., April 7, 2005; the deadline for filing post-hearing briefs or statements is 5:15 p.m., May 5, 2005. In the event that, as of the close of business on April 5, 2005, no witnesses are scheduled to appear at the hearing, the hearing will be canceled. Any persons interested in attending the hearing as an observer or non-participant may call the Secretary of the Commission (202–205–1806) after April 5, 2005, for information concerning whether the hearing will be held.

Written Submissions: In lieu of or in addition to participating in the hearing, interested parties are invited to submit written statements (original and 14 copies) concerning the matters to be addressed by the Commission in its report on this investigation. Commercial or financial information that a submitter desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform with the requirements of section § 201.6 of the Commission's Rules of Practice and Procedure (19 CFR 201.6). All written submissions, except for confidential business information, will be made available in the Office of the Secretary to the Commission for inspection by interested parties. The Commission will not include any confidential business information in the report it sends to the USTR. To be assured of consideration by the Commission, written statements relating to the Commission's report should be submitted to the Commission at the earliest practical date and should be received no later than the close of business on May 5, 2005. All submissions should be addressed to the Secretary, United States International Trade Commission, 500 E Street SW., Washington, DC 20436. The Commission's rules do not authorize filing submissions with the Secretary by facsimile or electronic means, except to the extent permitted by section 201.8 of the Commission's Rules of Practice and Procedure (19 CFR 201.8) (see Handbook for Electronic Filing Procedures, *ftp://ftp.usitc.gov/pub/reports/electronic_filing_handbook.pdf*). Persons with questions regarding electronic filing should contact the Secretary (202–205–2000 *edis@usitc.gov*).

Persons with mobility impairments who will need special assistance in gaining access to the Commission should contact the Office of the Secretary at 202–205–2000. General information concerning the Commission may also be obtained by accessing its Internet server (*http://www.usitc.gov*).

List of Subjects

WTO, GATS, renewable energy services.

Issued: August 5, 2004.

By order of the Commission.

Marilyn R. Abbott,

Secretary to the Commission.

[FR Doc. 04–18314 Filed 8–10–04; 8:45 am]

BILLING CODE 7020–02–P

DEPARTMENT OF JUSTICE

Notice of Lodging of Consent Decree Under the Comprehensive Environmental Response, Compensation and Liability Act

In accordance with 28 U.S.C. 50.7 and Section 122 of the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"), 42 U.S.C. 9622, notice is hereby given that on July 14, 2004, a proposed consent decree in the action of *United States* v. *3M Company, et al.*, C.A. No. 2:04-cv-3331 (HAA), was lodged with the United States District Court for the District of New Jersey. The Consent Decree resolves the claims of the United States against the defendants in this action for implementation of the fill area remedy ("Operable Unit Two") at the Scientific Chemical Processing ("SCP")—Carlstadt Superfund Site located in Carlstadt, New Jersey ("Site") and for reimbursement of past response costs relating to the Site.

The Complaint in this action alleges that the defendants are liable to the United States under Sections 106 and 107 of the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"), 42 U.S.C. 9606, 9607, as generators and/or transporters of materials containing hazardous substances that were disposed of at the Site. The defendants in this action are:

3M Company; Air Products and Chemicals, Inc.; Akzo Nobel Coatings, Inc.; Altje, Inc.; American Cyanamid—Lederle Labs—Shulton, Inc.; American Standard Companies; Ashland Inc.; ATOFINA Chemicals, Inc.; BASF Corporation; Bayer Chemicals Corporation; Bee Chemical Company; Benjamin Moore & Co.; Ber Mar Manufacturing Corp.; Borden Chemical, Inc.; Bristol-Myers Squibb Company; Browning-Ferris Industries of New Jersey; Chemcoat Inc.; Chemical Pollution Control, Inc. of NY; Ciba Specialty Chemicals Corporation; CNA Holdings, Inc.; Congoleum Corporation; Crown Beverage Packaging Company, Inc.; Cycle Chem, Inc.; Dri Print Foils, Inc.; DuPont Company; Exxon Mobil Corporation; ExxonMobile Oil Corporation; General Electric Company; General Motors Corporation; Hoffmann-La Roche, Inc.; Honeywell International Inc.; ISP Environmental Services Inc.; John L. Armitage & Co.; Johnson & Johnson; Kirker Enterprises, Inc.; L.E. Carpenter & Company; Lucent Technologies Inc.; Mack Trucks, Inc.; Magid Corp.; Mallinckrodt Baker, Inc.; manor Care of American, Inc.; Manor Care Health Services, Inc.; Marisol, Inc.; Merck & Co., Inc.; Monroe Chemical, Inc.; Nepera, Inc.; New England Laminates Co.; Inc.; Northrop Grumman Systems Corporation; Occidental Chemical Corporation; PAXAR Corporation; Permacel, Inc.; Pfizer Inc.; Pharmacia Corporation; Portfolio One, Inc.; Revlon Consumer Products Corporation; Roche Vitamins Inc.; Rohm and Haas Company; Schenectady International, Inc.; Seagrave Coatings Corp. (NJ); Siegfried (USA), Inc.; Simon Wrecking Company, Inc.; SmithKline Beecham Corporation; Technical Coatings Co.; The Continental Group Inc.; The Dow Chemical Company; The Warner Lambert Co., LLC; Union Carbide Corporation; United Technologies Corporation; and VIACOM Inc.

Under the proposed Consent Decree, the settling defendants will reimburse to

APPENDIX C
RENEWABLE ENERGY SERVICES IN THE GENERAL AGREEMENT ON TRADE IN SERVICES (GATS)

Table C-1
Nature of GATS commitments on services related to renewable energy: Services incidental to mining

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	Part	Full	Commitments on these services only apply to consultancy on a fee or contract basis relating to mining and oil field development.
Austria	All	Full	Commercial presence is required for the provision of services through mode 4.
Brazil	No specific commitments in this sector.	None	—
Canada	All	Full	—
Chile	No specific commitments in this sector.	None	—
China	No specific commitments in this sector.	None	—
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	No specific commitments in this sector.	None	—
European Union	All	Partial	With regard to the provision of services through mode 3, access for mining engineers is restricted to natural persons in Spain and Portugal. Portugal requires residency for the provision of services through mode 4.
Iceland	No specific commitments in this sector.	None	—
India	No specific commitments in this sector.	None	—
Indonesia	No specific commitments in this sector.	None	—
Israel	All	Partial	The provision of services through modes 1 and 2 is unbound.

See footnote at end of table.

Table C-1—*Continued*
Nature of GATS commitments on services related to renewable energy: Services incidental to mining

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Japan	No specific commitments in this sector.	None	—
Korea	Part	Partial	Market access for the provision of services through modes 1 and 2 is unbound. Korea has not scheduled any commitments for site preparation work for mining.
Malaysia	No specific commitments in this sector.	None	—
Maldives	No specific commitments in this sector.	None	—
Mexico	No specific commitments in this sector.	None	—
Morocco	No specific commitments in this sector.	None	—
New Zealand	No specific commitments in this sector	None	—
Norway	No specific commitments in this sector.	None	—
Philippines	No specific commitments in this sector.	None	—
Thailand	All	Partial	Thailand's specific commitments in this sector apply to services incidental to mining at oil and gas fields. The provision of services through mode 1 is unbound.
Turkey	All	Partial	Market access for the provision of services through mode 1 requires establishment, and national treatment for the provision of services through mode 1 by real persons requires Turkish nationality. With regard to market access for the provision of services through mode 3, petroleum and mining laws specify that services incidental to mining require an operating license.
United States	All	Full	—

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-2
Nature of GATS commitments on services related to renewable energy: Certain related scientific and technical consulting services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	Part	Full	Commitments on these services only apply to assembly and assessment of land and geographic related information; practice of the science of measurement; use of that information for the purpose of planning and implementing the administration of the sea. May involve surveying activities on, above, or below the surface of the land or sea.
Austria	All	Full	Commercial presence is required for the provision of services through mode 4.
Brazil	No commitments in this sector.	None	—
Canada	All	Partial	With regard to the provision of services through modes 1, 2 and 4, commercial presence is required for market access and accreditation of land surveyors in Saskatchewan. Market access and accreditation of land surveyors is reserved for permanent residents in Newfoundland, and for Canadian citizens in Manitoba, Nova Scotia and Quebec. Quebec maintains a citizenship requirement for market access and accreditation for professional technologists, chemists and subsurface surveying personnel, as well as for land surveyors. Residency is required for accreditation of applied science technologists/technicians in British Columbia, cadastral surveying personnel in Ontario, geoscientists in Newfoundland, and land surveyors in Ontario and British Columbia. Accreditation in Ontario is reserved for those trained in that province. Federal and subnational tax measures may limit national treatment with regard to the provision of services performed in Canada related to the exploration and development of a mineral resource, petroleum or natural gas.
Chile	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-2—*Continued*
Nature of GATS commitments on services related to renewable energy: Certain related scientific and technical consulting services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
China	Part	Partial	Commitments only apply to offshore oil-field services, geological, geophysical and other scientific prospecting services and subsurface surveying services. The provision of services through mode 3 is allowed only in the form of petroleum exploitation in cooperation with Chinese partners.
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	No specific commitments in this sector.	None	—
European Union	No specific commitments in this sector.	None	—
Iceland	All	Full	—
India	No specific commitments in this sector.	None	—
Indonesia	No specific commitments in this sector.	None	—
Israel	All	Full	—
Japan	Part	Partial	Commitments in this sector do not apply to services related to petroleum, petroleum products, gas, minerals and surveying. The provision of surface surveying and map-making services for the land in Japan through modes 1 and 2 require commercial presence, except for surveying which does not use Basic Survey or Public Survey data, surveying for small areas, or surveying not requiring high accuracy. Some of Japan's horizontal commitments may affect national treatment for the provision of services through mode 3 in this sector.
Korea	Part	Full	Commitments do not cover surface surveying services or map-making services.

See footnote at end of table.

Table C-2—*Continued*
Nature of GATS commitments on services related to renewable energy: Certain related scientific and technical consulting services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Malaysia	No specific commitments in this sector.	None	—
Maldives	No specific commitments in this sector.	None	—
Mexico	No specific commitments in this sector.	None	—
Morocco	No specific commitments in this sector.	None	—
New Zealand	No specific commitments in this sector.	None	—
Norway	All	Full	Norway's commitments on services in this sector apply to parts of the sector not relating to offshore activities.
Philippines	No specific commitments in this sector.	None	—
Thailand	No specific commitments in this sector.	None	—
Turkey	No specific commitments in this sector.	None	—
United States	Part	Partial	Commitments do not cover land surveying for the purpose of establishing legal boundaries, aerial surveying and aerial map-making. With regard to market access for the provision of services through modes 1, 2 and 3, for those functions where an engineering degree is required, the US limitations on engineering also apply.

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-3
Nature of GATS commitments on services related to renewable energy: Services incidental to energy distribution

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	Part	Full	Commitments on these services only apply to consultancy services related to the transmission and distribution on a fee or contract basis of electricity, gaseous fuels and steam, and hot water to household, industrial, commercial and other users.
Austria	No specific commitments in this sector.	None	—
Brazil	No specific commitments in this sector.	None	—
Canada	No specific commitments in ths sector.	None	—
Chile	No specific commitments in this sector.	None	—
China	No specific commitments in this sector.	None	—
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	No specific commitments in this sector.	None	—
European Union	No specific commitments in this sector.	None	—
Iceland	No specific commitments in this sector.	None	—
India	No specific commitments in this sector.	None	—
Indonesia	No specific commitments in this sector.	None	—
Israel	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-3—*Continued*
Nature of GATS commitments on services related to renewable energy: Services incidental to energy distribution

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Japan	No specific commitments in this sector.	None	—
Korea	No specific commitments in this sector.	None	—
Malaysia	No specific commitments in this sector.	None	—
Maldives	No specific commitments in this sector.	None	—
Mexico	No specific commitments in this sector.	None	—
Morocco	No specific commitments in this sector.	None	—
New Zealand	No specific commitments in this sector.	None	—
Norway	No specific commitments in this sector.	None	—
Philippines	No specific commitments in this sector.	None	—
Thailand	No specific commitments in this sector.	None	—
Turkey	No specific commitments in this sector.	None	—
United States	All	Full	—

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-4
Nature of GATS commitments on services related to renewable energy: Engineering and integrated engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	All	Full	—
Austria	All	Partial	In order to receive national treatment for the provision of services through mode 1, submission of plans for approval by the competent authorities require co-operation with an established supplier of planning services. Commercial presence is required for market access and national treatment for the provision of services through mode 4.
Brazil	Part	Partial	Brazil has made no commitments of any kind for the provision of integrated engineering services, and has excluded from its commitments on engineering services. With regard to the provision of engineering design services n.e.c. and other engineering services during the construction and installation phase. Brazil has undertaken no commitments for the provision of services through modes 1 and 2 for this sector. With regard to the provision of services through mode 3, Brazil requires foreign providers to form a *consórcio* (legal entity) with a Brazilian provider in order to gain market access. The Brazilian partner must maintain control of the *consórcio* and the objective must be clearly defined in the establishing contract.
Canada	All	Partial	With regard to the provision of services through modes 1, 2 and 4, commercial presence is required for market access and accreditation of consulting engineers in Manitoba. Permanent residency is required for market access and accreditation of engineers in British Columbia, Newfoundland, Alberta, New Brunswick and Ontario, and citizenship is required for market access and accreditation in Quebec. Engineers must be residents of Saskatchewan for accreditation and national treatment in that province.

See footnote at end of table.

Table C-4—*Continued*
Nature of GATS commitments on services related to renewable energy: Engineering and integrated engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Chile	Part	Partial	Commitments for engineering services are limited to a number of subsectors and apply only to the provision of services through mode 3. Subsectors included are engineering design services for industrial processes and production, engineering design services relating to sanitary works, mechanical engineering design services, electrical engineering design services, chemical and process engineering design services, and environmental engineering design services. Commitments do not apply to integrated engineering services.
China	All	Partial	Market access for the provision of services through mode 1 requires cooperation with Chinese professional organizations, except for scheme design. With regard to market access for the provision of services through mode 3, only joint ventures with foreign majority ownership are permitted. Within five years after China's accession, wholly foreign-owned enterprises will be permitted. In order to receive national treatment for the provision of services through mode 3, foreign service suppliers shall be either registered architects/engineers in their home country, or enterprises engaged in engineering services in their home country.
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	Part	Full	Commitments in this sector apply only to advisory and consultative engineering services.
European Union	All	Partial	In Greece, Italy and Portugal, commitments do not apply to the provision of services through mode 1. In Spain, Italy and Portugal, access to the provision of services through mode 3 is restricted to natural persons; however in Italy and Portugal, professional association among natural persons is permitted. With regard to the provision of services through mode 4, Greece requires Greek nationality and Italy and Portugal require residence.

See footnote at end of table.

Table C-4—*Continued*
Nature of GATS commitments on services related to renewable energy: Engineering and integrated engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Iceland	All	Full	—
India	Part	Partial	India has not scheduled any commitments for integrated engineering services. The provision of engineering services through modes 1 and 2 is unbound. Market access for the provision of services through mode 3 is only permitted through incorporation, with a foreign equity ceiling of 51 percent.
Indonesia	Part	Partial	Commitments on engineering services do not cover advisory and consultative engineering services, engineering design services for industrial processes and production, or engineering design services, n.e.c. All integrated engineering services are covered. With regard to the provision of services through mode 2, market access is not limited, but national treatment is unbound. The provision of services through mode 3 requires the establishment of a joint operation by establishing a representative office, and the establishment of a joint venture company by fulfilling the requirements as specified in Indonesia's Horizontal Measures and its Foreign Capital Investment Law. In order to receive national treatment, the foreign company's joint operation or venture must be with a local partner which is a member of the Indonesian Contractors' Association. The foreign company must also pay a registration fee for a license for its representative office, good for 3 years.
Israel	Part	Full	Israel has not scheduled any commitments for integrated engineering services.
Japan	Part	Full	Japan excludes architectural services and civil engineering consulting services from its commitments on engineering and integrated engineering services, except to the extent that they are necessary for civil engineering. Engineering design services for buildings are excluded. Commitments in this sector do not apply to services related to petroleum, petroleum products, gas or minerals. Some of Japan's horizontal commitments may also affect national treatment for the provision of services through mode 3 in this sector.

See footnote at end of table.

Table C-4—*Continued*
Nature of GATS commitments on services related to renewable energy: Engineering and integrated engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Korea	All	Full	—
Malaysia	All	Partial	National treatment for the provision of services through modes 1 and 2 requires services provided by foreign persons to be authenticated by a professional engineer or other relevant professional registered in Malaysia. With regard to market access for the provision of engineering services through mode 3, services may be supplied only by a natural person. For integrated engineering services contracts awarded in Malaysia, the provision of services through mode 3 is possible only through a representative office or a locally incorporated joint-venture with Malaysian individuals or Malaysian-controlled corporations. The establishment of such a joint venture is only for the duration of the project. The aggregate foreign equity in the joint venture may not exceed 30 percent.
Maldives	No specific commitments in this sector.	None	—
Mexico	Part	Partial	Mexico has not scheduled any commitments for integrated engineering services. Market access for the provision of services through mode 3 allows foreign investment only up to 100 percent of the registered capital of enterprises. Mexico maintains special degree and licensing requirements for architects and engineers.
Morocco	No specific commitments in this sector.	None	—
New Zealand	Part	Partial	New Zealand has not scheduled specific commitments for integrated engineering services. With regard to national treatment for the provision of services through modes 1 and 3, certification of certain works involving health and safety is limited to Registered Engineers, who, to become registered, must ordinarily be resident in New Zealand.
Norway	All	Full	—

See footnote at end of table.

Table C-4—*Continued*
Nature of GATS commitments on services related to renewable energy: Engineering and integrated engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Philippines	No specific commitments in this sector.	None	—
Thailand	Part	Partial	Thailand has not scheduled specific commitments for integrated engineering services. The provision of engineering services through mode 1 is unbound.
Turkey	Part	Full	Turkey has not scheduled any commitments for integrated engineering services. Market access for the provision of services through mode 2 is unlimited for foreigners once they have become temporary members of the related Union of Chambers.
United States	All	Full	Market access for the provision of services through mode 4 in the District of Columbia requires licensure in the District and U.S. citizenship. National treatment for the provision of services through mode 4 requires licensure and in-state residency in Idaho, Iowa, Kansas, Maine, Mississippi, Nevada, Oklahoma, South Carolina, South Dakota, Tennessee, Texas and West Virginia.

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-5
Nature of GATS commitments on services related to renewable energy: Distribution services, including commission agents, wholesale trade, and retail services that apply to fuels, related products, and brokerage of electricity

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	Part	Partial	Commitments on mode 1 apply only to mail-order retailing.
Austria	Part	Full	Commitments do not cover distribution of ignitable articles.
Brazil	Part	Partial	Commission Agents' services are not covered. Wholesale trade services of solid, liquid and gaseous fuels and related products are not included. Brazil has scheduled full commitments for the provision of the remaining services in this sector through mode 3 only.
Canada	Part	Partial	Commitments do not cover wholesale trade services in agricultural raw materials.
Chile	No specific commitments in this sector.	None	—
China	Part	Partial	The provision of commission agents' services and wholesale trade services through mode 1 is unbound. The provision of retailing services is unbound except for mail order.
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-5—*Continued*
Nature of GATS commitments on services related to renewable energy: Distribution services, including commission agents, wholesale trade, and retail services that apply to fuels, related products, and brokerage of electricity

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
European Union	Part	Partial	In France, the provision of commission agents' services through mode 1 is unbound for traders and brokers working in any of 20 markets of national interest. The same condition applies to the provision of commission agents' services in France through mode 4. In Italy, the provision of commission agents' services is unbound. Italy, Spain and Portugal require residency in order to receive national treatment for the provision of commission agents' services through mode 4. Spain, Italy and Portugal also require residency for national treatment in the provision of wholesale trade services through mode 4. The provision of retailing services through mode 1 is unbound except for mail order.
Iceland	All	Partial	Commitments do not include trade in arms, alcoholic beverages, tobacco and pharmaceutical products.
India	No specific commitments in this sector.	None	—
Indonesia	No specific commitments in this sector.	None	—
Israel	No specific commitments in this sector.	None	—
Japan	All	Full	Some of Japan's horizontal commitments may affect national treatment for the provision of services through mode 3 in this sector.

See footnote at end of table.

Table C-5—*Continued*
Nature of GATS commitments on services related to renewable energy: Distribution services, including commission agents, wholesale trade, and retail services that apply to fuels, related products, and brokerage of electricity

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Korea	Part	Partial	Market access for the provision distribution services through modes 1 and 2 is unbound. Commitments on commission agents' services do not apply to sales on a fee or contract basis of agricultural raw materials. Korea excludes commission agents' services of future contracts. An economic needs test is also required for market access to the mode 3 provision of wholesale trade of gaseous fuels and related products. With regard to market access for the provision of services through mode 3, retailing services for gaseous fuels are subject to an economic needs test.
Malaysia	No specific commitments in this sector	None	—
Maldives	No specific commitments in this sector	None	—
Mexico	Part	Partial	Mexico has scheduled no commitments for commission agents' services. Wholesale trade of petroleum-based fuels and coal are not included. Retail sales of combustible liquid gas, charcoal, coal and other non-petroleum based fuels are excluded
Morocco	No specific commitments in this sector	None	—
New Zealand	Part	Full	Commitments do not apply to commission agents' services or wholesale trade services for agricultural raw materials.
Norway	Part	Partial	Commitments do not apply to commission agents' services. With regard to national treatment in the provision of retailing services through mode 3, two years' prior residency in Norway is required for the manager of the branch of a foreign company and for the majority of the board members of a foreign-controlled company. The provision of retailing services through mode 4 requires two years' prior residency in Norway for the manager of the branch of a foreign company.

See footnote at end of table.

Table C-5—*Continued*
Nature of GATS commitments on services related to renewable energy: Distribution services, including commission agents, wholesale trade, and retail services that apply to fuels, related products, and brokerage of electricity

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Philippines	No specific commitments in this sector.	None	—
Thailand	Part	Partial	Commitments only apply to commission agents' services. The provision of services through mode 1 is unbound. With regard to national treatment for the provision of services through mode 3, no limitations apply as long as foreign equity participation does not exceed 49 percent.
Turkey	No specific commitments in this sector.	None	—
United States	Part	Partial	Commitments do not apply to the wholesale or retail trade of alcoholic beverages, firearms, and military requipment. Market access for the wholesale trade of alcoholic beverages through modes, 1, 2 and 3 is unbound.

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-6
Nature of GATS commitments on services related to renewable energy: Maintenance and repair of equipment, except transportation-related equipment

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	No specific commitments in this sector.	None	—
Austria	Part	Full	Commitments do not cover vessels, aircraft and other transport equipment, firearms or ammunition.
Brazil	No specific commitments in this sector.	None	—
Canada	All	Full	—
Chile	No specific commitments in this sector.	None	—
China	No specific commitments in this sector.	None	—
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	No specific commitments in this sector.	None	—
European Union	All	Full	—
Iceland	All	Full	—
India	No specific commitments in this sector.	None	—
Indonesia	No specific commitments in this sector.	None	—
Israel	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-6—*Continued*
Nature of GATS commitments on services related to renewable energy: Maintenance and repair of equipment, except transportation-related equipment

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Japan	All	Partial	The provision of services through mode 1 is unbound due to technical infeasibility. Some of Japan's horizontal commitments may affect national treatment for the provision of services through mode 3 in this sector.
Korea	All	Full	—
Malaysia	No specific commitments in this sector.	None	—
Maldives	No specific commitments in this sector.	None	—
Mexico	Part	Partial	Commitments in this sector apply only to the provision of repair and maintenance services for industrial machinery and equipment, professional technical equipment and instruments, and equipment for general use, not assignable to any specific industry. With regard to market access for the provision of these services through mode 3, foreign investment can equal up to 49 percent of the registered capital of enterprises.
Morocco	No specific commitments in this sector.	None	—
New Zealand	No specific commitments in this sector.	None	—
Norway	All	Full	
Philippines	No specific commitments in this sector.	None	—
Thailand	All	Partial	Thailand's commitments in this sector specifically indicate office machinery and equipment, including computers, but other equipment is not excluded. The provision of services through mode 1 is unbound. With regard to national treatment for the provision of services through mode 3, no limitations apply as long as foreign equity participation does not exceed 49 percent.

See footnote at end of table.

Table C-6—*Continued*
Nature of GATS commitments on services related to renewable energy: Maintenance and repair of equipment, except transportation-related equipment

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Turkey	No specific commitments in this sector.	None	—
United States	All	Full	—

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-7
Nature of GATS commitments on services related to renewable energy: Management consulting and related services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	All	Full	—
Austria	All	Full	—
Brazil	All	Partial	Brazil's commitments on market access and national treatment in this sector apply to services provided through mode 3 only.
Canada	All	Partial	With regard to the provision of services through modes 1 and 4, Quebec maintains a citizenship requirement for market access and use of the titles Professional Administrator, Certified Management Consultant and Industrial Relations Counsellor. Market access and accreditation for agrologists providing services through modes 1, 2 and 4 is reserved for permanent residents in Newfoundland and citizens in Quebec. No limitations exist on national treatment except as indicated in the horizontal commitments.
Chile	Part	Partial	The provision of public relations services and other management consulting services is not covered in Chile's schedule of commitments. Among the services that are covered, commitments apply only to the provision of services through mode 3.
China	All	Partial	The provision of services through mode 3 is permitted only in the form of joint ventures, with foreign majority ownership permitted. Within six years of China's accession, foreign firms will be permitted to establish wholly foreign-owned subsidiaries.
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-7—*Continued*
Nature of GATS commitments on services related to renewable energy: Management consulting and related services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
European Union	All	Full	—
Iceland	All	Full	—
India	No specific commitments in this sector.	None	—
Indonesia	No specific commitments in this sector.	None	—
Israel	All	Full	—
Japan	All	Full	Some of Japan's horizontal commitments may affect national treatment for the provision of services through mode 3 in this sector.
Korea	All	Full	—
Malaysia	Part	Partial	Malaysia has scheduled commitments covering advisory, guidance and operation assistance services concerning the management of the transmission of non-conventional energy and advisory, guidance and operation assistance on environmental management services including risk assessment services. For these subsectors, market access for the provision of services through mode 3 is only possible through a locally incorporated joint venture with Malaysian individuals or Malaysian-controlled corporations or both, and Bumiputera shareholding in the joint venture must equal at least 30 percent.
Maldives	No specific commitments in this sector.	None	—
Mexico	All	Partial	In order to receive market access for the provision of services through mode 3, foreign investment may equal up to 100 percent of the registered capital of enterprises.
Morocco	All	Partial	The provision of services through modes 1 and 2 is unbound.

See footnote at end of table.

Table C-7—*Continued*
Nature of GATS commitments on services related to renewable energy: Management consulting and related services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
New Zealand	No specific commitments in this sector.	None	—
Norway	All	Full	—
Philippines	No specific commitments in this sector.	None	—
Thailand	Part	Partial	Thailand's commitments in this sector apply to general management consulting services only. Market access for the provision of services through mode 3 is not limited as long as foreign equity participation does not exceed 49 percent.
Turkey	All	Full	—
United States	All	Full	—

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-8
Nature of GATS commitments on services related to renewable energy: Construction and related engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	All	Partial	The provision of services through mode 1 is unbound due to technical infeasibility.
Austria	All	Partial	The provision of services through mode 1 is unbound due to technical infeasibility. Commercial presence is required for the provision of services through mode 4.
Brazil	Part	Partial	Brazil has undertaken no commitments for provision of services through modes 1 and 2 for any of the services in this sector. No limitations are placed on national treatment of firms for the provision of services through mode 3. Building completion and finishing, special construction work, and renting of equipment related to construction or demolition with an operator are excluded from these commitments.
Canada	Part	Partial	With regard to national treatment for the provision of general construction services for buildings through mode 3, a non-resident contractor who will be consuming or using tangible personal property in Ontario is required to deposit with the Treasurer 4 percent of the amount to be paid under the contract or post a guarantee bond for the same. In Newfoundland, a deposit of 6 percent of the contract amount or a bond equivalent is required from non-resident contractors. Market access for cross-border (mode 1) water power site development in Ontario is limited to permit-holders who apply and are incorporated in that province; this limitation also applies to national treatment for the provision of services through mode 4. Commitments do not apply to cabotage for the cross-border (mode 1) provision of general construction services for civil engineering, pre-erection work at construction sites, including excavation, earthmoving and site work (with the exception of site preparation for mining), special trade construction work and renting of equipment with operator for construction or demolition of buildings or civil engineering works, with operator.

See footnote at end of table.

Table C-8—*Continued*
Nature of GATS commitments on services related to renewable energy: Construction and related engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Chile	No specific commitments in this sector.	None	—
China	Part	Partial	The provision of services through mode 1 is unbound due to technical infeasibility. Commitments on renting services related to equipment for construction or demolition of buildings or civil engineering works, with operator are limited to the rental and leasing services of construction and/or demolition machines with operator which are owned and used by foreign construction enterprises in their supply of services. With regard to the provision of services through mode 3, wholly foreign-owned enterprises can only undertake the following four types of construction projects: those wholly financed by foreign investment and/or grants; those financed by loans of international financial institutions and awarded according to the terms of loans; Chinese-foreign joint construction projects with foreign investment equal or more than 50 percent; and Chinese-foreign joint construction projects with foreign investment less than 50 percent but technically difficult to be implemented by Chinese construction enterprises alone. With regard to national treatment for the provision of service through mode 3, existing registered capital requirements for joint-venture construction enterprises are slightly different from those of domestic enterprises.
Costa Rica	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-8—*Continued*
Nature of GATS commitments on services related to renewable energy: Construction and related engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Egypt		Partial	Egypt has not scheduled any commitments on pre-erection work at construction sites, general construction work for buildings, or building completion and assembly. Commitments on construction work for civil engineering apply only to bridges, elevated highways, tunnels and subways, waterways, harbors, dams and other water work, long-distance pipelines, communication and power lines, and construction for mining and manufacturing. Commitments on special trade construction work apply only to steel bending and erection (including welding) and other special trade construction. Commitments on installation apply only to gas fitting construction. Commitments on electrical work apply only to fire alarm construction, other electrical construction, and lift and escalator construction. The provision of services through modes 1 and 2 is unbound. With regard to market access for the provision of services through mode 3, commercial presence is only allowed for joint-venture companies, and foreign capital equity shall not exceed 49 percent of the total capital required for the project.
El Salvador	No specific commitments in this sector.	None	—
European Union	All	Partial	The provision of site investigation work and excavating and earthmoving work through mode 1 is unbound due to lack of technical feasibility. With regard to the provision of services through mode 3, Italy grants exclusive rights for the construction, maintenance and management of highways and the airport of Rome, and Portugal grants exclusive rights for the maintenance and management of highways. With regard to the provision of services through modes 3 and 4, Greece maintains a nationality condition for managers of the board of directors of construction companies supplying in the public sector.
Iceland	Part	Full	Iceland has scheduled no commitments for pre-erection work at construction sites, special trade construction work or renting services related to equipment for construction or demolition of buildings or civil engineering works, with operator.
India	Part	Partial	Commitments in this sector apply only to construction work for civil engineering of roads and bridges. Construction of warehouses and industrial buildings, residential and non-residential buildings is excluded. India’s commitments in this sector are unbound, with the exception of national treatment for the provision of services through mode 3. Market access for the provision of service through mode 3 is only allowed through incorporation, with a foreign equity ceiling of 51 percent.

See footnote at end of table.

Table C-8—*Continued*
Nature of GATS commitments on services related to renewable energy: Construction and related engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Indonesia	Part	Partial	Commitments do not apply to installation work, building completion and finishing services, site investigation work, site formation and clearance work, or construction work for one- and two-dwelling buildings. The provision of all other services in this sector through mode 1 is unbound. With regard to the provision of services through mode 2, market access is not limited, but national treatment is unbound. The provision of services through mode 3 requires the establishment of a joint operation by establishing a representative office, and the establishment of a joint venture company by fulfilling the requirements as specified in Indonesia's Horizontal Measures and its Foreign Capital Investment Law. In order to receive national treatment, the foreign company's joint operation or venture must be with a local partner which is member of the Indonesian Contractors' Association. The foreign company must also pay a registration fee for a license for its representative office, good for 3 years.
Israel	No specific commitments in this sector.	None	—
Japan	All	Partial	Commitments in this sector exclude services related to mining. The provision of services through mode 1 is unbound due to technical infeasibility. Some of Japan's horizontal commitments may affect national treatment for the provision of services through mode 3 in this sector.
Korea			The provision of services through mode 1 is unbound due to technical infeasibility, except for site investigation work, to which no limitations apply. Commitments do not cover excavating and earthmoving work or renting services related to equipment for construction or demolition of buildings or civil engineering works, with operator. Market access for the provision of services through mode 3 requires licenses, issued on a yearly basis, and adherence to limits on contract amounts. A compulsory subcontract system is in place for the provision of general construction services through mode 3.
Maldives	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-8—*Continued*
Nature of GATS commitments on services related to renewable energy: Construction and related engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Malaysia	Part	Partial	Malaysia has scheduled no commitments on renting services related to equipment for construction or demolition of buildings or civil engineering works, with operator. The provision of services through mode 1 is unbound due to technical infeasibility. Market access for the provision of services through mode 3 is only possible through a locally incorporated joint venture with Malaysian individuals or Malaysian-controlled corporations or both. Aggregate foreign shareholding in the joint venture must not exceed 30 percent.
Mexico	Part	Partial	Commitments for this sector do not cover general construction work for warehouses and industrial buildings, public entertainment buildings, or hotel, restaurant and similar buildings. Commitments on general construction work for civil engineering are limited to industrial buildings (excluding electric power stations and plants for the piping of oil and oil products), highways (except elevated highways), streets, roads, railways and airfield runways, and local pipelines and cables and ancillary works. Maritime and river works, highway and transport works, and track construction are also excluded from general construction for civil engineering. Commitments on building completion and finishing work are limited to electrical, plumbing and drainage installations, with the exception of telecom and other special installations. Assembly and erection of prefabricated constructions is not included. Mexico has not scheduled any commitments on renting services related to equipment for construction or demolition of buildings or civil engineering works, with operator. The provision of all scheduled services in this sector through modes 1 and 2 is unbound. With regard to market access for the provision of services through mode 3, foreign investment is allowed only up to 49 percent of the registered capital of enterprises
Morocco	All	Partial	The provision of services through modes 1 and 2 is unbound. With regard to market access for the provision of services through mode 3, a foreign enterprise established in Morocco must associate Moroccan enterprises through any form of association (joint venture, subcontracting, etc.).
New Zealand	Part	Partial	The provision of services through mode 1 is unbound due to technical infeasibility. New Zealand has not scheduled any commitments on renting services related to equipment for construction or demolition of buildings or civil engineering works, with operator.

See footnote at end of table.

Table C-8—*Continued*
Nature of GATS commitments on services related to renewable energy: Construction and related engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Norway	All	Partial	For the provision of all services through mode 4 except installation and assembly work, a building contractor and the supervisor in charge of the work must have lived in Norway for at least one year and continue to be a resident in Norway. Exceptions are granted under special circumstances. If the contractor moves from Norway, the applicant will not be approved before residency is resumed. With regard to the provision of installation and assembly work services through mode 4, foreign exams giving equivalent competence in electrical work, plumbing and water sanitation may be recognized on a case by case basis.
Philippines	No specific commitments in this sector.	None	—
Thailand	Part	Partial	Thailand's commitments in this sector apply only to construction work for buildings, construction work for civil engineering, and installation work. The provision of services through mode 1 is unbound. With regard to market access for the provision of services through mode 3, no limitations apply as long as foreign equity participation does not exceed 49 percent.
Turkey	Part	Partial	Commitments do not apply to pre-erection work at construction sites, special trade construction work or renting services related to equipment for construction or demolition of buildings or civil engineering works, with operator. Market access for the provision of services through mode 1 requires responsible engineers and architects of the firms to be temporary members of the related Union of Chambers. Foreign contractors or foreign establishments contracting solely or jointly with national firms for engineering or architecture-related works, whether with public entities or real and legal persons in the public or private sectors, may employ foreign specialists only with the approval of the Ministry of Public works, which is based on the opinion of the Union of Chambers. Engineers and architects in activities other than those mentioned could be employed at the decision of the Ministry of Public Works with the consent of the Administrative Committee of the Union of Chambers. Persons employed under these conditions may not work in other activities other than those mentioned above. Foreign engineers and architects providing services through mode 1 who wish to stay longer than one month in Turkey must become a temporary member of the related Union of Chambers.

See footnote at end of table.

Table C-8—*Continued*
Nature of GATS commitments on services related to renewable energy: Construction and related engineering services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Turkey—*Continued*			National treatment for the provision of services through mode 1 is limited in that public entities will give priority to domestic firms for projects that are not subject to patent and that can be carried out with technologies available in Turkey. This preference does not apply in the case of projects financed by international institutions. A ratio for this preference in the issuance of government tenders is determined by the relevant ministry and can be up to 15 percent in favor of national companies. This ratio and preference system should be mentioned in the bid contract. With regard to market access for the provision of services through mode 3, the establishment by a non-resident of an ordinary partnership, which is not a legal entity, is subject to the Ministry to which the Undersecretariat of Treasury and Foreign Trade is attached. This does not apply to an ordinary partnership formed for international tenders in Turkey.
United States	Part	Partial	Commitments do not apply to marine dredging. The provision of services through mode 1 is unbound. With regard to market access for the provision of services through mode 4, in addition to horizontal commitments, an in-state office must be maintained by all contractors in Michigan.

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-9
Nature of GATS commitments on services related to renewable energy: Pipeline transportation of fuels

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	All	Full	—
Austria	No specific commitments in this sector.	None	—
Brazil	No specific commitments in this sector.	None	—
Canada	No specific commitments in this sector.	None	—
Chile	No specific commitments in this sector.	None	—
China	No specific commitments in this sector.	None	—
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	No specific commitments in this sector.	None	—
European Union	No specific commitments in this sector.	None	—
Iceland	No specific commitments in this sector.	None	—
India	No specific commitments in this sector.	None	—
Indonesia	No specific commitments in this sector.	None	—
Israel	No specific commitments in this sector.	None	—
Japan	No specific commitments in this sector.	None	—
Korea	No specific commitments in this sector.	None	—
Malaysia	No specific commitments in this sector.	None	—
Maldives	No specific commitments in this sector.	None	—
Mexico	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-9—*Continued*
Nature of GATS commitments on services related to renewable energy: Pipeline transportation of fuels

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Morocco	No specific commitments in this sector.	None	—
New Zealand	All	Full	—
Norway	No specific commitments in this sector.	None	—
Philippines	All	Partial	The Philippines has scheduled commitments covering all transport services. Market access by foreign corporations or associations organized under the laws of the Philippines for the provision of services through mode 3 requires 60 percent Filipino ownership of the capital of any public utility. With regard to the provision of services through mode 4, only aliens qualified to hold technical positions may be employed within the first five years of operation of the enterprise, and their stay is not to exceed five years upon entry. Each employed alien should have at least two Filipino understudies.
Thailand	No specific commitments in this sector.	None	—
Turkey	No specific commitments in this sector.	None	—
United States	No specific commitments in this sector.	None	—

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-10
Nature of GATS commitments on services related to renewable energy: Storage and warehouse services, particularly bulk storage services of liquids and gases

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	Part	Partial	Commitments do not cover maritime storage and warehousing services. The provision of services through mode 1 is unbound due to technical infeasibility.
Austria	All	Partial	The provision of services through mode 1 is unbound due to technical infeasibility.
Brazil	All	Partial	Brazil has undertaken no commitments for provision of services through modes 1 and 2 for services in this sector. No limitations are placed on market access or national treatment of firms for the provision of services through mode 3.
Canada	Part	Partial	Commercial presence is required for the provision of storage and warehouse services by licensed customs brokers through modes 1, 2 and 3. For provision of these services through mode 4, the licensed customs broker must be a permanent resident. A corporation providing storage and warehouse services must be incorporated in Canada and the majority of its directors must be Canadian citizens or permanent residents, and a partnership providing these services must be composed of persons who are Canadian citizens or permanent residents.
Chile	No specific commitments in this sector.	None	—
China	No specific commitments in this sector.	None	—
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-10—*Continued*
Nature of GATS commitments on services related to renewable energy: Storage and warehouse services, particularly bulk storage services of liquids and gases

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
El Salvador	No specific commitments in this sector.	None	—
European Union	All	Partial	Commitments do not apply to storage and warehouse services in ports. The provision of services through mode 1 is unbound due to technical infeasibility.
Iceland	All	Partial.	The provision of services through mode 1 is unbound due to technical infeasibility.
India	No specific commitments in this sector.	None	—
Indonesia	No specific commitments in this sector	None	—
Israel	No specific commitments in this sector	None	—
Japan	Part	Partial	Services related to petroleum and petroleum products are not included in Japan's commitments. The provision of services through mode 1 is unbound due to technical infeasibility. Some of Japan's horizontal commitments may affect national treatment for the provision of services through mode 3 in this sector.
Korea	Part	Partial	The provision of services through mode 1 is unbound due to technical infeasibility. Commitments on this sector do not apply to storage or warehouse services in ports or services for agricultural, fishery and livestock products.
Malaysia	No specific commitments in this sector	None	—
Maldives	No specific commitments in this sector	None	—
Mexico	No specific commitments in this sector.	None	—
Morocco	No specific commitments in this sector	None	—
New Zealand	No specific commitments in this sector	None	—

See footnote at end of table.

Table C-10—*Continued*
Nature of GATS commitments on services related to renewable energy: Storage and warehouse services, particularly bulk storage services of liquids and gases

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Norway	No specific commitments in this sector.	None	—
Philippines	All	Partial	The provision of services through mode 1 is unbound due to technical infeasibility.
Thailand	All	Partial	The provision of services through mode 1 is unbound due to technical infeasibility. With regard to national treatment for the provision of services through mode 3, no limitations apply as long as foreign equity participation does not exceed 49 percent.
Turkey	No specific commitments in this sector.	None	—
United States	No specific commitments in this sector.	None	—

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide services related to renewable energy through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

Table C-11
Nature of GATS commitments on services related to renewable energy: Technical testing and analysis services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Australia	No specific commitments in this sector.	None	—
Austria	All	Full	—
Brazil	No specific commitments in this sector.	None	—
Canada	All	Full	—
Chile	No specific commitments in this sector.	None	—
China	All	Partial	With regard to the provision of services through mode 3, foreign service suppliers which have been engaged in inspection services in their home countries for more than three years may establish joint-venture technical testing and analysis companies with a minimum of US$350,000 in registered capital. Within four years after China's accession, wholly foreign-owned subsidiaries will be permitted.
Costa Rica	No specific commitments in this sector.	None	—
Egypt	No specific commitments in this sector.	None	—
El Salvador	No specific commitments in this sector.	None	—
European Union	All	Partial	In Italy, the provision of services through mode 1 is unbound for the professions of biologist and chemical analyst. Italy restricts market access for mode 3 provision of services by biologists and chemical analysts to natural persons. Market access for the provision of services through mode 3 is reserved for natural persons in Spain in the case of chemical analysis, and in Portugal in the case of the professions of biologist and chemical analyst. Italy and Portugal require residency for biologists and chemical analysts in order to receive national treatment for the provision of services through mode 4.

See footnote at end of table.

Table C-11—*Continued*
Nature of GATS commitments on services related to renewable energy: Technical testing and analysis services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Iceland	All	Full	—
India	All	Partial	The provision of technical testing and analysis services through modes 1 and 2 is unbound. Market access for the provision of services through mode 3 is only permitted through incorporation, with a foreign equity ceiling of 51 percent
Indonesia	All	Partial	The provision of services through modes 1 and 2 is unbound for government-funded projects. The provision of services through mode 3 requires joint operation through a representative office in Indonesia, and in order to receive national treatment, the Indonesian participant in the joint operation must be a member of the Indonesian Consultants' Association. The provision of services in this sector through mode 4 is unbound except for directors and technical experts.
Israel	No specific commitments in this sector.	None	—
Japan	No specific commitments in this sector.	None	—
Korea	No specific commitments in this sector.	None	—
Malaysia	Part	Partial	Commitments do not cover technical inspection services. Market access for the provision of services through mode 3 is only possible through a locally incorporated joint venture with Malaysian individuals or Malaysian-controlled corporations or both, and Bumiputera shareholding in the joint venture must equal at least 30 percent.
Maldives	No specific commitments in this sector.	None	—
Mexico	No specific commitments in this sector.	None	—
Morocco	No specific commitments in this sector.	None	—
New Zealand	No specific commitments in this sector.	None	—

See footnote at end of table.

Table C-11—*Continued*
Nature of GATS commitments on services related to renewable energy: Technical testing and analysis services

Member country	Do commitments apply to all or part of the sector?	Did the member country schedule full or partial commitments?[1]	Nature of limitations listed in the GATS schedule
Norway	All	Full	—
Philippines	No specific commitments in this sector.	None	—
Thailand	Part	Partial	Commitments do not include testing and analysis services of physical properties, testing and analysis services of integrated mechanical and electrical systems, or technical inspection services. The provision of services through mode 1 is unbound. With regard to national treatment for the provision of services through mode 3, no limitations apply as long as foreign equity participation does not exceed 49 percent.
Turkey	No specific commitments in this sector.	None	—
United States	No specific commitments in this sector.	None	—

[1] Most measures regarding the supply of services through the presence of natural persons (mode 4) are addressed in a member country's horizontal commitments. Thus, for the purposes of this table, a full commitment is any commitment that grants full market access or national treatment to foreign individuals or firms that provide renewable energy services through cross-border supply (mode 1), consumption abroad (mode 2), and commercial presence (mode 3).

Source: Compiled by the U.S. International Trade Commission from individual countries' GATS Schedules of Specific Commitments.

APPENDIX D
HEARING SCHEDULE

CALENDAR OF PUBLIC HEARING

Those listed below appeared as witnesses at the United States International Trade Commission's hearing:

Subject:	Renewable Energy Services: An Examination of U.S. and Foreign Markets
Inv. No.:	332-462
Date and Time:	April 19, 2005 - 9:30 a.m.

Sessions were held in connection with this investigation in the Main Hearing Room (room 101), 500 E Street, S.W., Washington, D.C.

ORGANIZATION AND WITNESS:

International Energy Agency ("IEA")
Paris, France

Richard Sellers, Head, Renewable Energy Unit,
IEA

Enercorp LLC
Washington, D.C.

Alexander Karsner, Managing Director,
Enercorp LLC

National Association of Regulatory Utility Commissioners ("NARUC")
Washington, D.C.

Richard E. Morgan, Commissioner, District of Columbia
Public Service Commission

<u>ORGANIZATION AND WITNESS (continued):</u>

PJM Interconnection LLC (“PJM”)
Norristown, PA

Scott Miller, III, Executive Director, Strategic Planning, PJM

Renewable Energy and International Law Project (“REIL Project”)
Washington, D.C.

Leslie Parker, Managing Director, REIL Project

Renewable Energy Policy Project (“REPP”)
Washington, D.C.

George Sterzinger, Executive Director, REPP

Tidal Electric Limited
Simsbury, CT

Peter W. Ullman, Chairman, Tidal Electric Limited

Sharp
Washington, D.C.

Christopher O’Brien, Vice President Strategy & Government Relations, Sharp Solar

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APPENDIX E
POSITION OF INTERESTED PARTIES

International Energy Agency (IEA)

The International Energy Agency (IEA)[1] is an intergovernmental body that monitors and analyzes the global energy market. The IEA also serves as an advisory body on matters of energy policy to both the public and private sectors of its 26 member states.[2]

The IEA indicates that three factors affect renewables' market prospects: the availability of natural energy resources, the maturity of renewable technologies, and government policy. First generation renewables - hydropower, biomass power, and geothermal power - reached maturity in the early 1900s in locations with appropriate resource endowments and strong local demand. These technologies spread throughout developing countries as costs declined and demand for energy increased. Second generation renewables - mainly solar power and wind power - experienced growth due to government R&D funding and market deployment policies. However, R&D funding for renewables has ebbed and flowed, beginning at $65 million in 1974, peaking at $2 billion in 1980, and then declining to $600 million in 1987. Further, renewable energy R&D represented just 8 percent of total government energy R&D funding during 1974-2002. World Bank funding of renewable energy projects, too, has remained small, accounting for 2 percent of total energy funding in 1990 and 4 percent in 2003.

The IEA indicates that market deployment policies will improve market learning and, consequently, drive down the costs of second generation technologies. Cost declines could be accelerated by removing trade barriers and coordinating deployment strategies, which would reduce deployment costs and achieve scale economies in the production of renewable energy equipment.

Enercorp LLC

Enercorp LLC[3] is a private company that constructs both grid-connected and distributed wind power stations in multiple markets. Enercorp emphasizes the unique features of each type of renewable energy, noting that they differ in terms of technology, application, maturity, services components, and business models. Consequently, the firm believes that trade policymakers should not negotiate over them together, but rather treat them separately. Enercorp also notes that the global market for renewable energy is bifurcated, with developed and developing countries approaching renewable energy with different environmental and economic objectives in mind. Enercorp states that development of the global renewable energy markets is hindered by erratic pricing, discriminatory grid access, and inconsistent regulatory policies and practices. The firm advocates greater harmonization and implementation of best regulatory practices as means to develop the global market to its full potential.

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[1] Richard Sellers, Head of Renewable Energy Unit, International Energy Agency, hearing testimony before the Commission, Apr. 19, 2005; and written submission to the Commission, Apr. 7, 2005.

[2] The International Energy Agency, *About the IEA*, found at *http://www.iea.org*, retrieved on June 20, 2005.

[3] Alexander Karsner, Managing Director, Enercorp LLC, hearing testimony before the Commission, Apr. 19, 2005; and written submission to the Commission, Apr. 6, 2005.

National Association of Regulatory Utility Commissioners

The National Association of Regulatory Utility Commissioners (NARUC)[4], is an association of individual State public utility commissions. NARUC controls the prices and services of energy providers to maintain well-operated utilities. It is NARUC's belief that the integration of renewable energy into the energy market would have positive effects. Specifically, the association highlights benefits such as energy independence, energy price stability, and energy security.

NARUC believes that the key U.S. players in the promotion of renewables are the States themselves. Citing eighteen states and the District of Columbia as examples, the Association recommends renewable portfolio standards (RPS) as the best way to incorporate renewable energy into the mainstream. Public funding, or greater support for funding of demonstration projects and education on renewables, is also recommended.

PJM Interconnection, LLC

PJM Interconnection, LLC (PJM)[5] is an independent grid operator, which serves approximately fifty million people, covering a region of thirteen states and the District of Columbia. PJM was established in 1992 as a direct outcome of the Energy Policy Act, which authorized a competitive energy market in the United States. PJM contends that as an independent grid operator, it inherently provides unhindered grid access to renewables. PJM bases this claim on its non-discriminatory interconnection standards, which it states traditional utilities do not provide due to their vertical integration.

PJM believes there is great opportunity for wind technology to provide a significant part of its electricity supply. PJM strongly believes state endorsed renewable portfolio standards, along with a competitive market, will provide sufficient economic incentive to propel renewable energy into the mainstream of the energy market.

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[4] Richard E. Morgan, Commissioner, District of Columbia, National Association of Regulatory Utility Commissioners, hearing testimony before the Commission, Apr. 19, 2005; and written submission to the Commission, Apr. 19, 2005.

[5] Scott Miller, III, Executive Director, Strategic Planning, PJM Interconnection LLC, hearing testimony before the Commission, Apr. 19, 2005; and written submission to the Commission, Apr. 4, 2005.

Renewable Energy and International Law Project (REIL)

The Renewable Energy and International Law Project (REIL)[6] is an international partnership that researches international law to find both barriers and opportunities which may exist for the development of renewable energy markets. The aim of this project is to facilitate trade in renewable energy. Part of their research focuses on the way individual country regulations might affect the provision of renewable energy services, particularly in terms of competitiveness in foreign markets. Preliminary research has concluded that the existence of regulatory barriers is due, in part, to the fact that international trade laws were designed and written largely for the fossil fuels market. According to REIL, there is a predisposition to conventional energy in international law codes which must be adjusted to reflect the enormous difference between trade in conventional versus renewable energy. REIL studies suggest that opening the door to international renewable energy trade would tap into the market potential of the developing world, especially with respect to the need for rural electrification.

Renewable Energy Policy Project (REPP)

The Renewable Energy Policy Project (REPP)[7] works primarily in the United States and has aided six states in the promotion and development of their renewable portfolio standards. Some of REPP's research has focused on the success of renewable energy as determined by the price of fossil fuel, which it finds has a direct relationship with interest rates. The statistical conclusion they reached showed that when fossil fuel prices rise, renewable energy is favored.

Renewable energy is known to be environmentally beneficial. REPP's research emphasizes renewables' economic benefits as well. REPP data concludes seventy-five to eighty percent of the investment demand from new renewables projects would flow to the areas of the United States that have the largest populations and have suffered the most from the loss of industrial jobs. For the further development of renewable energy, REPP suggests the establishment of an international coalition to promote wind technology, so far the most successful of the renewables. REPP believes that the benefits from such efforts will more than compensate for the costs involved, both in terms of lower electricity production costs and an increase in market size for wind technology.

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[6] Leslie Parker, Managing Director, Renewable Energy and International Law Project, hearing testimony before the Commission, Apr. 19, 2005; and written submission to the Commission, Apr. 8, 2005, and May 5, 2005.

[7] George Sterzinger, Executive Director, Renewable Energy Policy Project, hearing testimony before the Commission, Apr. 19, 2005; and written submission to the Commission, Apr. 1, 2005, and Apr. 13, 2005.

Tidal Electric, Limited

Tidal Electric, Limited[8] establishes tidal power stations across the globe. While some tidal technologies are still in the experimental phase or have negative environmental impacts, Tidal Electric works primarily with tidal lagoons. These are mature, predictable sources of tidal energy that have garnered support from different environmental groups. The UK has implemented a Renewable Obligations order to launch renewables into the marketplace. According to Tidal Electric, this order does nothing to initiate interest in new technologies; instead, the obligation supports established energy sources, such as wind technology. The company's view is that UK legislation does not foster developing onshore or offshore wind technologies, making the UK a market better suited for experimental storage devices or innovation in transmission. The company is moving forward with projects in Canada, Australia, and China.

University of Minnesota

The University of Minnesota[9] strongly encourages the active study of renewable energy architecture and engineering. Drawing on conclusions from a study of undergraduate student projects on solar energy engineering and design beginning in 1982, they contend that the exposure of such material to undergraduates through projects can promote a continued focus on renewable technologies during graduate and professional study. This would result in innovation within the renewable energy market. The more efficient and advanced renewable technology becomes, the more feasible it is for renewables to hold a large share of the energy market. The University of Minnesota strongly advocates an increase in support for renewable energy education at the university level.

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[8] Peter Ullman, Chairman, Tidal Electric Limited, hearing testimony before the Commission, Apr. 19, 2005; and written submission to the Commission, Apr. 19, 2005.

[9] Joel H. Goodman, University of Minnesota, written submission to the Commission, Mar. 17, 2005.

Sharp Electronics, Solar Systems Division

Sharp Electronics[10] is the largest producer of photovoltaic (PV) solar energy generation systems worldwide. In the years 2000 through 2004, Sharp has experienced tremendous and steady growth in demand for their solar systems. The company attributes this growth to an increase in pro-solar legislation in certain markets, increasing awareness about environmental concerns, better education and market exposure for alternative energies, steadily declining equipment costs, and more advanced and efficient products. In Japan, the price of PV system installation has been driven down by seventy percent in the last ten years.

Sharp Electronics strongly promotes trade liberalization of PV system components such as solar cells, solar modules and panels, and PV generators. Citing United States Department of Energy data, Sharp claims that global electricity demand will increase by over seventy percent during the period of 2001-2025, and demand from developing countries will comprise 41 percent of that total during the same time period. They contend that this demand exceeds the production capacity available to Sharp within the United States. Sharp therefore advocates the elimination of both export and import tariffs and other non-tariff barriers in the U.S. PV market so as to expand demand in the world market for PV products.

Cargill

Cargill[11] is an agricultural company offering food, agriculture, and risk management products and services to the global market.[12] The company set and exceeded its own corporate-wide energy efficiency goals, and seeks to obtain 10 percent of its consumed energy from renewable sources by the year 2010. Currently, 6 percent of Cargill's global energy consumption is from renewable sources. However, Cargill produces this renewable energy for its own operations - it does not sell it in the marketplace.

Cargill operates six beef processing plants using a biogas recovery system, a process involving the use of leftover organic matter from the beef processing to produce methane and carbon dioxide gases. These gases are then funneled to a steam boiler and burned for energy. Cargill estimates that this system has saved its beef business unit $6 million annually in energy costs, as well as lowered green house gas emissions between all its beef facilities by 21,000 metric tons. As the entire operation is completed within their facility and is not subject to outside regulation, the company has limited experience with market barriers. Cargill's position is that regulatory agencies should promote and provide regulatory schemes.

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[10] Christopher O'Brien, Vice President Strategy and Government Relations, Sharp Electronics, Solar Systems Division, hearing testimony before the Commission, Apr. 19, 2005; and written submission to the Commission, Apr. 19, 2005.

[11] Marty Muenzmaier, Director, Federal Relations, Cargill, written submission to the Commission, May 10, 2005.

[12] Cargill, *About Cargill*. Found at ***http://www.cargill.com/about/index.htm***, retrieved on Aug. 3, 2005.

Electric Reliability Council of Texas (ERCOT)

Electric Reliability Council of Texas (ERCOT)[13] is an independent non-profit company that oversees grid connection in Texas.[14] ERCOT is the program administrator for the Renewable Energy Credit (REC) program in Texas, and also provides public reports on the current electrical situation. The REC program was established by the Texas legislature as part of the deregulation of the state retail electric market, with the goal of increasing renewable energy generation by 2,000 megawatts, or 3 percent of total energy usage, by 2009. The RECs have proven to be a success, allowing the state to reach its renewable energy target three years early. RECs are a credit earned by an electricity generation company for each megawatt-hour of renewable energy they produce. These RECs can be traded or sold on the open market for up to 3 years, or companies may bundle RECs with their energy contracts.

ERCOT believes that the REC program has been a successful incentive for renewable energy development. However, they note several obstacles that remain in the market, specifically for wind energy. The first is the business risk associated with building projects ahead of demand; the second is the high cost of expanding transmission capacity. The coupling of these two issues hinders the ready supply of renewable energy in Texas. Additionally, there is the problem of storing wind energy. As of today, only 10 percent of wind energy produced is considered to be operational for peak times. ERCOT recommends providing for reactive (voltage) support systems to increase the reliability of wind energy.

The University of Texas of the Permian Basin

The University of Texas of the Permian Basin (UTPB)[15] is conducting research in geothermal energy development through their Center for Energy and Economic Diversification. Present research at the Center seeks ways to work around the current major barriers to geothermal power expansion. One concern associated with geothermal technology is the necessary drilling for geothermal heat. UTPB points out that holes left by oil drilling, numbering over 600,000 in Texas alone, can be converted for geothermal energy production, thus going hand in hand with oil and natural gas production.

There are many opportunities available for geothermal energy development, both in terms of efficiency and the potential for job creation. Geothermal energy plants also provide substantial full-time employment; in a discussion with Ormat, UTPB learned that a 50 MW binary geothermal plant might employ between 40 to 50 people full time for the day-to-day operation of the plant. This could translate into 40,000 or more new jobs at a plant producing 60,000 MW of new energy. Research by the Geothermal Heat Pump Consortium, Inc. has shown that ground surface heat pumps with closed-loop piping systems can provide heating, cooling and hot water for homes and commercial buildings, and could save a homeowner between 25 and 50 percent on utility bills versus

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[13] Thomas F. Schrader, President and CEO, ERCOT, written submission to the Commission, Apr. 4, 2005.

[14] ERCOT, *About ERCOT*, found at ***http://www.rcot.com/AboutERCOT/Index.htm***, retrieved on August 3, 2005.

[15] Richard Erdlac, PhD, Research Scientist, University of Texas of the Permian Basin, written submission to the Commission, Apr. 22, 2005.

a conventional energy system. The University strongly endorses the development of more geothermal and other alternative energy solutions, given that energy problems are an unavoidable eventuality.

United Nations Foundation

The United Nations (UN) Foundation[16] recognizes that the expansion of trade often opens the door for social and economic development. The UN Foundation finds that conventional energy use is in need of reform, and it recognizes the commercial viability of energy from ethanol, solar power and wind power. However, their focus is on ensuring a level playing field for renewable technologies and moving away from a "business as usual" approach, which it claims will result in 60 percent more energy consumption, an additional $16 trillion in investment, and nearly 2 billion people without access to energy by the year 2030.

In a 2002 study on biofuels, the Foundation found that, with certain improvements, biofuels have the potential to provide for sustainable growth, particularly in the case of bio-energy derived from sustainable agricultural practices. Despite its benefits, biofuels face import tariffs and blending rate limitations, which impede the use and development of biofuel energy where it could be most beneficial - developing nations. The Foundation recommends that international organizations concentrate their efforts to endorse free trade in biofuel and other renewables. They also note that economic incentives coupled with energy policies have been known to increase market development. In conclusion, they believe that energy security is crucial to social and economic stability in developing countries, and renewables, particularly biofuels, will be most effective in that regard.

General Electric Company

General Electric (GE)[17] works with wind, hydro, solar, geothermal, and biomass technologies. The company provides equipment and services, but does not itself generate electricity from these sources. GE finds the most significant factor in the viability of renewable energy technology worldwide has been government policies and programs, including renewable portfolio standards, guaranteed grid access and feed-in tariffs, renewable energy certificates, and investment tax credits, among others. GE quotes research that shows that these policies work best in combination, and stresses that to provide the best incentives, such policies need to encourage long-term growth. The benefits of this combined approach are seen in Germany, which has maintained constant support of renewable technology and now exports it worldwide, including to the United States. The U.S., conversely, has had start and stop policies that greatly impede the market growth of renewable energy. GE feels that renewable energy will be more viable if countries fully liberalize their marketplaces and eliminate other obstacles including foreign exchange controls, high customs duties, and a lack of grid access.

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[16] Melinda L. Kimble, Senior Vice President for Programs, United Nations Foundation, written submission to the Commission, May 5, 2005.

[17] Timothy Richards, General Electric Company, written submission to the Commission, May 5, 2005.

GE's solution to improve domestic renewable energy technology would require the U.S. government to form concrete renewables incentives and make sustainable energy an across-the-board priority. A lead agency within the Department of Energy could analyze and comment on incentives, barriers, and other issues affecting the global renewables market. Government aid might also be directed to the development and deployment of renewable energy projects in the marketplace. Most importantly, in an effort to offset the risk associated with new business, the government would need to establish policies that will provide long-term stability for renewable energy.

APPENDIX F
SELECT RENEWABLE ENERGY POLICIES

Table F-1
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Australia	Renewable Energy Innovation Investment Fund (REIIF)	1997-present	This program is designed to promote the commercialization of renewable energy by providing venture capital funds to emerging hi-tech companies that specialize in the development of renewable energy technologies . The Australian Government also provides funding through the program.[1]	Research and development
	Renewable Energy Action Agenda (REAA)	2000-present	A government action plan to encourage public participation in the promotion of renewable energy technology in the market.[2]	Public awareness; voluntary programs
	Green Power Scheme	1997-present	This program is carried out by the Sustainable Energy Development Authority (SEDA) of the New South Wales government to promote renewable energy, and resulted in an investment of AUS$ 26 million in renewable energy sources.[2]	Green pricing
	Renewable Energy Commercialisation Programme	1999-present	The program provides government funding for renewable energy projects with strong commercial viability, and that contribute to the reduction of greenhouse gas emissions.[3]	Capital grants
	Mandatory Renewable Energy Target	2000-present	The Mandatory Renewable Energy Target was established under Australia's Renewable Energy (Electricity) Act of 2000 to increase the proportion of electricity generated from renewable sources by electric power distributors. The policy requires that Australia generate a minimum of 9,500 gigawatt-hours (GWh) of electric power from renewable energy sources by 2010. Under the program, electric power distributors are encouraged to purchase electricity from qualifying eco-plants that generate power from solar photovoltaic (PV), wind, biomass, and other renewable technologies.[4]	Legislative obligations
	Renewable Remote Power Generation Programme (RRPGP)	2000-present	This program was established to help mitigate the use of diesel-generated electricity in remote areas of Australia by providing financial assistance for electric power generation from renewable energy sources. Under the program, the Australian Government provides a maximum of 50 percent of the capital costs associated with the purchase and installation of renewable energy equipment.[5]	Capital grants

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Australia–*Continued*	White Paper on Energy	2004-present	In June 2004, the Australian Government published a white paper on energy policy, entitled "Securing Australia's Energy Future." Among other things, the white paper addresses the development of renewable energy technologies and Australia's long-term response to climate change.[6]	General administrative policy
	Renewable Energy Development Initiative (REDI)	2004-present	REDI was established as part of Australia's White Paper on Energy to support the commercial development of renewable energy technologies and services. The program is jointly administered by the Australian Department of Industry, Tourism, and Resources, and the Department of Environment and Heritage.[7]	Capital grants
Brazil	Law 10438: Program of Incentives for Alternative Electricity Sources (PROINFA - Programa de Incentivo a Fontes Alternativas de Energia Elétrica)	2002-present	This program increases the proportion of electricity derived from renewable energy sources to 10 percent of annual consumption in twenty years. Electricity yielded from onshore wind, biomass, and other renewables will be bought by Electrobas, the national electric company, from a PROINFA Generator at preferential prices and then sold to eligible plants. The Brazilian National Development Bank (BNDES) can fund up to 70 percent of the capital costs. Further, each plant will be supplied by the PROINFA generator with Renewable Energy Certificates in proportion to the amount of clean energy produced.[8]	Guaranteed prices; feed-in tariffs; legislative obligations; tradable certificates; third-party financing
Canada	Renewable Energy Deployment Initiative	1998-2007	This initiative offers economic incentives to promote the use of renewable energy sources in the production of space and water heating and cooling.[2]	Consumer grants; voluntary programs
	Canadian Renewable Energy Network (CanREN)	2003-present	This program was established to educate the public about using renewable energy as an alternative energy source. The program also maintains a database of renewable energy technologies in Canada and promotes the marketing of renewable energy.[2]	Public awareness
Costa Rica	Third National Energy Plan	2000-2015	Carried out by the Ministry of Environment and Energy (MINAE), this policy makes meeting energy needs a priority. It also stipulates that whenever possible biomass, solar, and wind technologies should be used to produce energy, and that more research into alternative energy sources is a necessity for the well-being of the country.[9]	General administrative policy

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Costa Rica—*Continued*	National Rural Electrification Program	2000-2010	Part of the Third National Energy Plan, this program aims to bring electricity to rural off-grid areas. The ultimate target is for 99 percent of households to have electricity by 2010.[9]	General administrative policy
European Union	Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001	2001-present	The directive sets forth guidelines established by the European Community to promote renewable energy sources. Member states must obtain 22.1 percent of their electricity from renewable energy sources by 2010.[10]	Legislative obligations; tradable certificates
	The 6th Framework Program	2002-2006	This program provides funds for the development of renewable energy technologies in coordination with the EU renewable energy policy.[11]	Research and development; capital grants
	Organizations for the Promotion of Energy Technologies (OPET)	1991-present	OPET is a global network of 48 countries that supports innovation in renewable energy sources. OPET also promotes the international marketing of European renewable energy technology for the advancement of EU citizens.[12]	Research and development
Austria	Promotion Instrument for Electricity from Renewables (PIER)	1997-present	PIER provides government funding in the form of capital grants and guaranteed prices for the generation of electricity from renewable sources.[2]	Capital grants; feed-in tariffs; guaranteed prices
	Renewable Energy Targets	2000-present	Introduced as part of the Energy Liberalisation Act of 2000, renewable energy targets require electric power distributors to purchase up to 4 percent of the electricity that they sell to end users from qualifying eco-plants.[2]	Legislative obligations
	Dwelling Improvement Act and Housing Promotion Subsidies	2003-present	This program provides subsidies for the construction of new homes that use renewable energy sources. The program has been most successful in promoting the use of solar and biomass energies.[2]	Consumer grants/rebates
	Labeling of Electricity Bills	2000-present	This policy is a part of the Energy Liberalization/ Electricity Act of 2000. It requires that electric power suppliers make publicly available information on the types of energy used to produce electricity.[2]	Public awareness
	Housing Creation and Refurbishment	2001-present	A part of the income tax code that permits a deduction of up to 25 percent of money spent on residential renewable energy technology for biomass and solar energy.[2]	Tax exemptions

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Belgium	Tax Deduction for Environment-Friendly Investments	1992-present	The program provides capital grants and tax incentives for investment in non-polluting energy sources and energy efficiency. Biomass, geothermal, solar, and wind energies are targeted under this program.[2]	Capital grants; tax credits
	Electricity Market Regulation	1999-present	This law was amended in 2001 to give priority for transmission grid access to power producers that generate "green" electricity. In addition, separate rules on grid access also enabled end users who purchased a large amount of electricity from renewable sources to choose their own suppliers.[2]	General administrative policy
	Green Certificate Scheme	2001-present	To encourage the production of electricity from renewable energy sources, the federal government issues "green certificates" in association with power generated from renewables. Similar programs have been in established in the regions of Flanders and Wallonia.	Legislative obligations; tradable certificates
	UREBA (Wallonia Region)	2003-present	This program provides an investment subsidy of up to 50 percent for renewable energy technology development for public buildings.[2]	Consumer grants/rebates
	Electricity Distribution (Flemish Region)	2004-present	This legislative policy requires that grid operators provide free distribution of electricity from renewable energy sources.[2]	Net metering
Czech Republic	State Energy Policy	2004-present	This policy requires that by 2030 approximately 15 to 16 percent of the country's total primary energy supply and 17 percent of electricity use come from renewable sources . The main renewable technology expected to be used is biomass.[13]	Legislative obligations
	Energy Management Act (Act No. 406/2000)	2001-present	This act instituted a variety of policies to promote smart energy use, including a requirement for energy efficiency in heat and electricity production and mandatory energy planning. The act also required the government to draft a National Energy Policy on future energy prospects. There is also a section requiring the establishment of a domestic program entitled "Energy Efficiency and Use of Renewable and Waste Energy Sources."[13]	General administrative policy

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Czech Republic—Continued	Bill on the Promotion of Power and Heat Generation from Renewable Energy Sources	2003-present	This bill provides incentives for investment in renewable energy by promising that initial costs will be regained and a profit will be made for at least fifteen years. This policy also aims to increase the proportion of renewable energy sources used in electricity production to 8 percent by 2010.[13]	Guaranteed prices; feed-in tariffs; legislative obligations; tradable certificates
	State Program to Support Energy Saving and Use of Renewable Energy and Secondary Sources	1991-present	This program provides incentives for the use of renewable energy in place of fossil fuels through a series of tax breaks and investment incentives.[2]	Consumer grants/rebates; tax exemptions; tax credits
Cyprus	Action Plan for the Promotion of RES and Energy Conservation	2002-2010	This program provides government-sponsored financial incentives for the promotion of renewable energy sources, with the objectives of doubling the contribution of renewable sources to Cyprus's total energy supply and increasing renewable electric power generation to account for 6 percent of the country's electricity supply by 2010.[14]	Legislative obligations
	New Grant Scheme for Energy Conservation and Promotion of the Utilization of Renewable Energy Sources	2004-present	This initiative is part of the Action Plan for the Promotion of RES and Energy Conservation, and succeeds a previous grants scheme that was effective during 1999-2003. The program provides financial incentives to increase the deployment of renewable energy in Cyprus.[14]	Capital grants; feed-in tariffs
Denmark	The Energy Research Program (ERP)	1976-present	ERP finances projects in renewable energy technology up to 100 percent to enhance the strength of Danish companies in the global energy market. The projects have been most successful with wind and biomass technologies, though all renewable energy sources are eligible.[15]	Research and development
	National Strategy for Sustainable Development	2002-present	This piece of legislation states the importance of promoting renewable energy and environmental protection both domestically and internationally.[2]	Public awareness

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Estonia	Energy Act	1997-present	This act went into effect in 1998 and outlines a series of actions to develop a stable electricity market in Estonia. One such measure requires electricity traders to promote energy efficiency and renewable energy.[16]	Legislative obligations
	Sales Tax Act	until 2006	There is no sales tax levied on electricity generated from wind and other renewable technologies.[17]	Tax exemptions
Finland	Finnish Energy Strategy	1997-present	This policy outlined the role of renewables in Finland's energy strategy in contributing to the reduction of carbon emissions and energy security.[16]	General administrative policy
	National Climate Strategy	2001-present	A response to the EU's obligations under the Kyoto Protocol, Finland's National Climate Strategy requires the country to reduce greenhouse gas emissions to pre-1990 levels between the years 2008 and 2010. The program promotes the increased use of renewable energy sources.[18]	Legislative obligations
	Action Plan for Renewable Energy Sources	1999-present	The Action Plan, which was revised in 2002, is part of the National Climate Strategy of 2001. The objective of the program is to increase the use of renewable energy sources by 50 percent above 1995 levels. Further, the plan calls for greatly increasing the marketability of Finnish renewable energy technology. The main focus of the program is biomass energy, but wind and solar energies are also mentioned.[2]	Legislative obligations; capital grants; investment tax credits
France	Campaign SOS Climat	2001-present	This campaign informs the public of the merits of environmental protection and renewable energy use.[2]	Public awareness
	Renewable Energy Feed-In Tariffs	2001-present	This legislation establishes feed-in tariffs for wind, biomass, solar, and other renewable energy technologies.[2]	Guaranteed prices; feed-in tariffs

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Germany	Electricity Feed-In Law (EFL) (Strom-Einspeisungs-Gesetz, StreG)	1991-2000	This law required utility companies to purchase a percentage of their electricity from renewable energy sources. Renewable electricity rates were calculated based on the previous year's electricity rates. The program applies to all renewable technologies, though specifically mentions biomass, solar, and wind energy.[19]	Guaranteed price; feed-in tariff
	Fourth Energy Research Program	1996-2004	The program establishes a basic outline to address how research and development funds would be assigned for public projects. The technologies supported include bioenergy, solar, wind, geothermal, and others.[19]	Research and development
	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG)	2000-present	This policy replaces the Electricity Feed-in Law. The act focuses on the goals of the EU directive and aims for the country to produce 12 percent of electricity from renewable energy sources by 2010. The act also attempts to balance the price burden of renewable energy by shifting some of the feed-in tariff to grid operators, and requiring all electric utilities to purchase equal amounts of renewable energy.[2]	Legislative obligations; guaranteed prices; feed-in tariffs
Greece	Law 2244/94	1994-present	This was the first piece of legislation established in Greece to encourage the production of electricity from renewable energy. Provisions in the law address electricity production by independent power producers and self-generators.[14]	General administrative policy; guaranteed prices; feed-in tariffs
	Aid to Market Penetration of Renewables: New Development Law	1998-present	This program provides grants for investments in power generation from renewable energy and tax deductions for the use of solar heating in residential and service areas.[14]	Capital grants; tax credits
	Law 1559/85	1985-present	This law allows groups, other than approved electricity suppliers, to produce electricity solely from renewable energy sources. The electricity produced may only be used for the needs of the individual group, and any excess electricity must be sold to the Public Power Corporation (PPC).[2]	Net metering

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Greece—Continued	Law 2364/95	1995-present	This law created the Board for Energy Planning and Control. The law also allows for an income tax exemption of up to 75 percent of the purchase price of renewable energy equipment for residential homes. This incentive has been most successful with solar water heater technology, though all renewables are eligible.[2]	Tax exemptions
	National Operational Program for Competitiveness	2000-2006	This program is aimed at increasing the demand for and investment in renewable energy by offering grants for the development of private renewable energy units.[2]	Consumer grants/rebates
Hungary	Energy Conservation and Energy Efficiency Improvement Action Program	1999-present	The program is a ten-year initiative adopted to replace the National Energy Saving and Energy Efficiency Improvement Program of 1995. The program promotes increased heat production from biomass, geothermal, waste, and solar energies and establishes the "20,000 Roofs with Solar Collectors by 2010" program.[13]	Legislative obligations
	Electricity Act	2001-present	This legislation liberalizes the Hungarian electricity market and makes the use of renewable energy obligatory. The act also allocates revenue from feed-in tariffs to profit certain independent electric utilities that use renewable energy sources.[2]	Guaranteed prices; feed-in tariffs
	Electricity Act - Green Certificates Scheme	2001-present	This is a clause within the Electricity Act that allows for the use of tradable certificates in the newly-liberalized electricity market.[2]	Tradable certificates
	Energy Savings Action Plan	1996-present	This plan promotes energy efficiency through support of better technology, the use of clear bill labeling, access to information on renewable energy, and the promotion of further technological research.[2]	Public awareness
	National Energy Savings Program (NEP)	2003-present	This program promotes the use of renewable energy sources instead of fossil fuels and supports the elimination of pollution through financial subsidies. It also aligns the country's energy policy with that of the EU.[2]	Consumer grants/rebates

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Ireland	Renewable Energy Research, Development, and Demonstration	2002-present	This legislation allocates funds for projects on renewable and other alternative energy technologies. The goal of this program is to increase the marketability of renewable energy sources, as well as to continue research on new technologies.[2]	Research and development
	Green Paper on Sustainable Energy	1999-present	The Green Paper is a proposal from the Department of Public Enterprise that recommends the use of taxes to promote renewable energy and to discourage high carbon emission technology.[2]	Legislative obligations
	Sustainable Energy Ireland (SEI)	2002-present	This is a federal agency established by the Sustainable Energy Act to replace the Irish Energy Centre. SEI's main function is to promote renewable energy sources to state officials and the general public. The agency also focuses on overall energy efficiency, decreasing pollution, and supporting further research on renewable energy.[2]	Public awareness
	Promotion of European Programs	2002-present	These programs are implemented by Sustainable Energy Ireland to increase public awareness of the current state of renewable energy. The programs also focus on disseminating information about the European Union's actions in regard to renewable energy, including data on the European Sixth Framework Program (FP6) and the Intelligent Energy for Europe (EIE) program.[2]	Public awareness
Italy	Provision of CIPE 137	1998-present	A response to the ratification of the Kyoto Protocol that specifically requires Italy to lower carbon emissions through the use of renewable energy sources.[2]	Legislative obligations
	2% Renewables Target - Green Certificates	1999-present	A part of the 1999 Electricity Liberalization Act and Decrees, this legislation makes it obligatory for 2 percent of energy to be produced from renewable sources. The requirement can also be met by acquiring green certificates from other companies.[2]	Legislative obligations; tradable certificates
	Legislative Decree 387/03 Implementing Directive 2001/77/EC	2003-present	This piece of legislation aligns Italy's national energy goals with those set out by the EC Directive 2001/77/EC. The program includes government requirements for research and development, and outlines renewable energy standards.[2]	Legislative obligations

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Italy—Continued	Voluntary Agreement: ENEL	1999-present	This agreement between ENEL, Italy's electric power company, and the Ministry of the Environment requires ENEL to lower carbon dioxide emissions by 20 percent from 1990 levels. Energy efficiency and renewable energy technologies must be included as tools in this process.[2]	Voluntary programs
	10,000 PV Roofs Program	2000-present	This program liberalizes sales of electricity made from solar photovoltaic (PV) equipment as part of the Italian National Agency for New Technologies, Energy, and Environment (ENEA) "10,000 PV roofs" project. The program applies to the purchase and sale of electricity between grid operators and small producers of electricity from solar PV sources.[2]	Net metering
Luxembourg	Energy Efficiency Law	1993-present	This law outlines rules for the conservation of energy and the use of renewable energy. The electricity market is subject to feed-in tariffs, with extra bonuses for the use of solar PV and wind technologies.[2]	Legislative obligations; feed-in tariffs
	Renewable Energy Guide	2001-present	This guide contains a database of information on renewable energy sources, and related technologies, as well as on government subsidies for renewable energy that are available to the public.[2]	Public awareness
	Reglement Grand-Ducal (17 juillet 2001)	2001-present	This policy establishes monetary incentives for the installation of renewable energy technology, particularly solar and wind technologies.[2]	Consumer grants/rebates
Netherlands	RD&D Program DEN (duurzame energie in Nederland)	2001-present	This program provides funding for renewable energy research initiatives.[2]	Research and development
	Energy Research Strategy (EOS)	2004-present	This program provides funds for projects in areas that were determined as a priority by the Ministry of Economic Energy. This includes energy efficiency, biomass research, offshore wind technology, and others.[14]	Research and development; capital grants
	REB (Regulating Energy Tax)	1997-present	This is a tax on electricity and gas used by small and medium consumers. Electricity from renewable energy sources is exempt from the tax, thereby allowing its price to be equal to electricity from conventional sources. Only electricity that has been officially assigned a Green Certificate is eligible for this exemption.[2]	Tax exemptions

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Netherlands—Continued	Energy Premium and Energy Performance Advice	2001-present	These two complementary programs, Energy Premium (EPR) and Energy Performance Advice (EPA), are funded under the REB tax bill. EPA provides advice to homeowners seeking energy alternatives, and EPR is a set of subsidies that can be used to offset the costs of installing renewable energy technology.[2]	Investment incentives
Portugal	Decree-Law 189/88	1988-present	Also known as the "Independent Power Production (IPP)" law, this legislation permits public and private independent power producers to sell electric power that is generated from renewable sources to the national transmission grid. This legislation was later followed by Decree-Law no. 168/99, which established greater transparency with respect to grid interconnection by renewable energy power producers.[20]	General administrative policy
	Portaria no. 383/2002 of April 10	2000-2006	This legislation establishes government subsidies for public- and private-sector investment in renewable energy and cleaner fuels. In general, subsidies cover up to 40 percent of the cost of new projects.[20]	Capital grants
	Cabinet Resolution no. 154/2001 of October 19	2001-2003	Established the "Energy Efficiency and Endogenous Energies" program, also known as the "E4 Programme". The program addresses energy security and efficiency, and promotes the use of renewable energy. The program was succeeded in 2003 by the Resolution of the Council of Ministries 63/2003, which addresses Portugal's commitments under the Kyoto Protocol and promotes increased production of electric power from renewable sources.[20]	General administrative policy
	Tax Incentives	2002-present	A program of the Ministry of Finance that promotes investment in renewable energy technology by providing tax credits to the private sector.[2]	Sales tax rebates
Slovakia	Energy Strategy and Policy of the Slovak Republic up to the year 2005	1993-2005	This policy focuses on lowering carbon dioxide emissions through a focus on more efficient use of energy and an emphasis on renewable energy sources, primarily biomass and geothermal technologies.[21]	General administrative policy
	Program Supporting Energy Conservation and the Utilization of Renewable Sources	2000-present	This program promotes the growth of renewable energy alternatives in Slovakia through research and development. Managed by the Ministry of Economy and carried out by the Slovak Energy Agency, the program funds development projects for biomass, geothermal, solar, and wind technologies. It also encourages energy efficiency and conservation.[21]	Research and development

See footnotes at end of table

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Spain	Electricity Law (Law 40/1994)	1994-1997	This law increased market security of renewable energy through price controls and a standard contract length.[21]	Guaranteed prices; feed-in tariffs
	Renewable Energy Promotion Plan	1999-2010	This piece of legislation outlines a national plan for 12 percent of all energy to be supplied through renewable energy sources by 2010.[21]	Legislative obligations
	RD&D Energy Program	2000-2003	This program funded projects that supported cleaner energy production, the development of new technologies that distribute and store energy, and energy efficiency.[2]	Research and development
	Plan on Renewables	2000-present	This plan mandates an increase in the share of energy from renewable sources from 6 percent to 12 percent, with particular focus on biomass, wind, and solar technologies.[2]	Legislative obligations
United Kingdom	UK Climate Change Program	2000-present	This program employs a combination of government requirements in hopes of decreasing greenhouse gas emissions by 2010. The policy is implemented as part of the commitment to the Kyoto Protocol and includes provisions for renewable energy use, such as incentives and obligations.[2]	Legislative obligations
	New and Renewable Research and Development Energy Program	2002-present	This program supports research and development in the area of renewable energy market viability. It focuses on solar PV and wind energy, among others.[2]	Research and development
	Renewable Obligation Order	2002-2027	This order is part of the UK Climate Change Program and is a government quota for the amount of energy that must be supplied by renewable sources. This is being implemented in part to achieve the 10 percent renewable energy source target by 2010.[2]	Legislative obligations; tradable certificates
	Renewable Energy Guarantee of Origin (REGO)	2003-present	This legislation established a system of green certificates that prove that the energy being produced is from renewable sources. These certificates are recognized across the EU and help producers carry out trade.[2]	Tradable certificates
India	Integrated Rural Energy Program (IREP)	1985-present	This program identifies the most cost effective mix of renewable and other energy sources to meet the cooking and lighting needs of the rural population. The country is divided into regions, known as "blocks". Each block is responsible for implementing the energy plan through the training of energy professionals and the promotion of public awareness.[22]	Capital grants

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
India—*Continued*	Renewable Energy Plan 2012	2002-2012	This program set out the renewable energy goals of the Ministry of Non-Conventional Energy Sources for the next ten years. The objective is to provide 10 percent of the state's electricity with renewable energy sources; to broaden the use of solar energy to both space and water heating; to develop the least expensive energy options for water pumping, irrigation, and drinking; and to provide electricity to all households through the Integrated Rural Energy Program (IREP). The program also intends to increase women's participation in the electrification process, and aims to extend the wood-stoves program.[23]	Third-party financing; capital grants
Japan	Awards Provided by the Ministry of Environment Initiatives	1998-present	The objective of this program is to reduce harmful greenhouse gas emissions. The program also promotes public knowledge of the importance of renewable energy.[2]	Public awareness
Korea	New and Renewable Energy RD&D Basic Plan	1987-2006	The net-metering component of this plan allows for excess electricity to be sold to the national grid. Electricity rates are established so as to provide incentives for investment in renewable energy technology.[2]	Net metering
	The Promotional Law of New and Renewable Energy Development Use and Dissemination	2002-present	This is a revision of the 1987 Promotional Law of New and Renewable Energy Development. The updated law guarantees state funds for the formation of a center dedicated to renewable energy use and dissemination. It also outlines a system for officially certifying that a plant produces new and renewable energy.[2]	Public awareness
Mexico	Program of Research and Technological Development for the Energy Sector (PIDTSE)	2002-2006	This program outlines ten initiatives to promote research and development policies and opportunities. The goal is to accelerate the modernization of technology through these ten initiatives. The program will focus on improving fossil fuel technology as well as developing and applying renewable energy sources through the year 2025.[24]	Research and development

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
Thailand	National Energy Conservation and Promotion Program	1994-present	This program aims to promote continued research and development on new energy technology, and to encourage renewable energy applications. A compulsory portion of the program applies specifically to buildings under construction, and government buildings. A voluntary portion of the program promotes renewable energy technology in rural areas, research and development on renewable energy sources, and the establishment of an energy service company. The program also establishes rules and regulations with respect to energy use, and promotes public awareness.[23]	Research and development; government purchases; capital grants
United States	Energy Tax Act of 1978	1978-present	The law originally provided a 10-percent tax credit to companies that invested in geothermal, solar, wind, and ocean thermal technologies. The law was subsequently amended in 1986 and 1992, and the scope of the tax credit was narrowed.[25]	Tax credits
	Public Utility Regulatory Policies Act (PURPA)	1978-present	PURPA was designed to decrease the United States' dependency on oil imports by requiring electric power utilities to purchase power from small producers using renewable energy sources, and from co-generators. Utilities were required to purchase such power at fixed costs.[25]	Incentive tariffs
	Energy Policy Act	1992-2003	This policy provided a tax credit for investment in geothermal and solar technologies, as well as for the production of electricity from biomass, geothermal, solar, and wind energies. Production tax credits were granted on a per kilowatt-hour basis.[2]	Tax credits
	Energy Efficiency & Renewable Energy Development	1990-present	The program provides federal funding for the research, development, and deployment of renewable energy technologies.[2]	Research and development

See footnotes at end of table.

Table F-1—*Continued*
Select renewable energy policies, by country

Country	Name of policy or program	Year(s) effective	Description	Type of policy
United States—*Continued*	Climate Change Action Plan (CCAP)	1993-present	This plan is a joint effort by multiple federal agencies to lower greenhouse gas emissions. The plan encourages renewable energy growth by lowering the initial costs of developing certain technologies.[2]	Voluntary programs
	Renewable Portfolio Standards (RPS)	Ongoing	Currently adopted by 19 U.S. states, renewable portfolio standards implement legislative requirements that obligate states to generate a certain proportion of electricity from renewable sources.[26]	Legislative obligations

[1] OECD, IEA, *Renewable Energy: Market Policy Trends in IEA Countries*, p. 121; and Australian Government, Department of Industry, Tourism and Resources, “Fact Sheet: Innovation Investment Fund (IIF),” found at *http://www.ausindustry.gov.au/*, retrieved Apr. 1, 2005.

[2] OECD Report. “Renewable Energy - Market and Policy Trends in IEA Countries.”

[3] Australian Government, Department of Industry, Tourism and Resources, “Renewable Energy Commercialisation in Australia–Introduction,” found at *http://www.industry.gov.au/*, retrieved Apr. 4, 2005.

[4] Australian Government, Department of the Environment and Heritage, Australian Greenhouse Office, “Mandatory Renewable Energy Target,” found at *http://www.greenhouse.gov.au/*, retrieved Apr. 1, 2005.

[5] Australian Government, Department of the Environment and Heritage, Australian Greenhouse Office, “Renewable Remote Power Generation Program (RRPGP),” found at *http://www.greenhouse.gov.au/*, retrieved Apr. 1, 2005.

[6] Australian Government, Department of Prime Minister and Cabinet, “Energy Reform,” *found at http://www.pmc.gov/au/*, retrieved Apr. 1, 2005.

[7] Australian Government, Department of Industry, Tourism and Resources, “Renewable Energy Development Initiative,” found at *http://www.industry.gov.au/*, retrieved Apr. 1, 2005.

[8] Johannesburg Renewable Energy Coalition (JREC), “Policies by Technology,” found at *http://www.iea.org/*, retrieved Apr. 8, 2005.

[9] “Costa Rica: National Off-Grid Electrification Programme Based on Renewable Energy Sources,” Mar. 2002, found at *http://www.gefweb.org*, retrieved Apr. 8, 2005.

[10] Official Journal of the European Communities, *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001*, published Oct. 27, 2001, found at *http://europa.eu.int/*, retrieved Mar. 25, 2005.

[11] Directorate-General Energy and Transport, “6th Framework Program for RTD (2002-2006): Overview of Short to Medium Term Priorities”, Sept. 22, 2004, found at *http://europa.eu.int/*, retrieved Apr. 18, 2005.

[12] *The Organizations for the Promotion of Energy Technologies - OPET Network,* found at *http://www.opet-network.net/*, retrieved Mar. 25, 2005.

[13] OECD*, IEA Renewable Database*, found at *http://www.iea.org/*, retrieved Apr. 8, 2005.

[14] JREC, “Policies by Technology,” found at *http://www.iea.org/*, retrieved Apr. 14, 2005; and RES Legislation in Portugal, updated June 21, 2002, found at *http://www.jrc.es/cfapp/eneriure/Tables/PRTables.pdf/*, retrieved Apr. 14, 2005.

[15] Danish Energy Authority, “Renewable Energy Danish Solutions,” found at *http://www.ens.dk/*, retrieved Apr. 8, 2005.

[16] National Energy Company, Easti Energia, “Legislation: Energy Act of Estonia,” found at *http://www.energia.ee/en/about?eergiaviewer_folderid=479*, retrieved Apr. 15, 2005; and Organizations for the Promotion of Energy technologies (OPET), “Sustainable Energy Technologies in the Baltic Sea Region: Estonia Country Overview,” found at *http://www.opet.dk/baltic/,* retrieved Apr. 15, 2005.

[17] Organizations for the Promotion of Energy Technologies (OPET), “Sustainable Energy Technologies in the Baltic Sea Region: Estonia Country Overview,” found at *http://www.opet.de/baltic/,* retrieved Apr. 15, 2005.

[18] Ministry of Trade and Industry in Finland, “National Climate Strategy and International Negotiations,” and “Renewable Energy Sources and Peat,” found at *http://www.ktm.fi/,* retrieved Apr.14, 2005.

[19] “Renewable Electricity Fact Sheets EU Countries: Germany,” found at *http://www.renewable-energy-policy.info/*, retrieved Apr. 8, 2005.

[20] JREC, “Policies by Technology,” found at *http://iea.org/,* retrieved Apr. 14, 2005; and RES Legislation in Portugal, updated June 21, 2002, found at *http://jrc.es/cfapp.eneriure/Tables/PRTables.pdf/*, retrieved Apr. 14, 2005.

[21] European Renewable Energy Council, “Renewable Energy Policy Review: Slovakia” found at *http://www.erec-renewables.org/*, retrieved Apr. 18, 2005, p. 15.

[22] Ministry of Non-Conventional Energy Sources, Government of India, found at *http://mnes.nic.in/*, retrieved Apr. 8, 2005.

[23] Global Issue Papers, “Transitioning to Renewable Energy An Analytical Framework for Creating an Enabling Environment*,”* June 2004, found at *http://www.boell.de*/, retrieved Apr. 8, 2005.

[24] General Directorate for Research into Urban, Regional, and Global Pollution, “Mexico's Advances With Regard to Climate Change,” 2001-2002, found at *http://www.ine.gob.mx/*, retrieved Apr. 8, 2005.

[25] Renewable Energy Policy Project (REPP), “U.S. Federal Policies: Tax Credits,” found at *http://www.crest.org/*, retrieved Apr. 11, 2005.

[26] Union of Concerned Scientists USA, “Table C-1: State Minimum Renewable Electricity Requirements (as of December 2004),” found at *http://www.ucsusa.org/*, retrieved Apr. 11, 2005.

APPENDIX G
PROJECT-BASED MECHANISMS

Introduction

Project-based mechanisms are market-based instruments designed to reduce greenhouse gas emissions. Such mechanisms typically follow the "baseline-and-credit" model, whereby project sponsors create tradeable emissions reduction units by developing projects that reduce emissions below an agreed-upon "baseline[1]" level. Under this model, the shortfall of emissions below the baseline is measured, verified, and registered, thereby creating emissions reduction "credits.[2]" Upon creation, credits can be sold to private firms, governments, or other entities for use against voluntary or mandatory emissions reduction commitments. Examples of typical emissions reduction projects include wind farms, small- and large-scale hydro-electric power plants, methane capture projects, and biomass projects.

Most emissions reduction projects contain a common set of standards which govern the creation of emissions reduction credits, setting a de facto standard of "quality." These standards include: (1) the establishment of a credible baseline; (2) the establishment of credible monitoring and verification procedures; (3) evidence that emissions reductions did not result from existing regulations; (4) evidence that emissions reductions would not have occurred without the project ("additionality"); (5) evidence that a project's emissions are not temporary; (6) evidence that emissions will not increase outside the project's boundary ("leakage").[3]

Project-based Mechanisms and the Kyoto Protocol

Following a decade of experimentation,[4] emissions reduction projects are increasingly being developed in conjunction with the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC).[5] For example, Article 12 of the

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[1] A project's baseline can be calculated in static or dynamic terms. Static baselines are calculated as either historical emissions or a counterfactual estimate of emissions in the absence of the project. By contrast, dynamic baselines are indexed to output levels. Richard Rosenzweig, Matthew Varilek, Ben Feldman, Radha Kuppalli, and Josef Janssen, "The Emerging International Greenhouse Gas Market," The Pew Center on Global Climate Change, Mar. 2002, p. 4-6, found at *http://www.pewclimate.org*, retrieved on Apr. 21, 2005.

[2] A credit is a "quantifiable and verifiable recognition of the reduction, avoidance, or sequestration of carbon dioxide or other greenhouse gases" resulting from an emissions reduction project. Evolution Markets, "Glossary of Terms," found at *http://www.evomarkets.com/ghg_glossary.html*, retrieved on Nov. 19, 2004.

[3] Richard Rosenzweig, Matthew Varilek, Ben Feldman, Radha Kuppalli, and Josef Janssen, "The Emerging International Greenhouse Gas Market," The Pew Center on Global Climate Change, Mar. 2002, p. iv, v, and 17, found at *http://www.pewclimate.org*, retrieved on Apr. 21, 2005.

[4] Early pilot programs and initiatives include, *inter alia*, the Climate Trust in Oregon; the Emissions Reduction Unit Procurement Tender (ERUPT) in the Netherlands; the Pilot Emissions Reduction Trading Program (PERT) in Ontario, Canada; and the pilot phase of international project-based emissions trading known as Activities Implemented Jointly (AIJ). Richard Rosenzweig, Matthew Varilek, Ben Feldman, Radha Kuppalli, and Josef Janssen, "The Emerging International Greenhouse Gas Market," *The Pew Center on Global Climate Change*, Mar. 2002, p. iv, found at *http://www.pewclimate.org*, retrieved on Apr. 21, 2005.

[5] Information on the UNFCCC and the Kyoto Protocol can be obtained at *http://unfccc.int*.

Kyoto Protocol provides the basis for the Clean Development Mechanism (CDM), an emissions reduction program that allows 41 industrialized countries and economies in transition (Annex I countries) to acquire credits known as "certified emissions reductions (CERs)" from projects in non-Annex I countries (i.e., developing countries).[6] Similarly, Article 6 authorizes the Joint Implementation (JI) mechanism, a program which allows Annex 1 countries to acquire credits known as "emissions reduction units (ERUs)" from projects in other Annex I countries, typically countries in Central and Eastern Europe.[7] Both CERs and ERUs can subsequently be used to fulfill mandatory emissions reduction commitments established under the Kyoto Protocol.

Prior to registration under CDM/JI rules, project developers must undergo a lengthy approval, monitoring, and verification process. For example, in a typical CDM exercise, a project developer must submit a project proposal, conduct due diligence and prepare approval documentation, negotiate project agreements, monitor emissions on a continual basis, and submit to successive rounds of emissions verification. The international prominence of the World Bank, its leading role in the project-based markets, and its commitment to purchase high quality emissions reductions has made its rules and procedures the unofficial standard for project development and evaluation. To illustrate the process, the life-cycle of a typical World Bank emissions reduction project is detailed in table G-1.

Market Characteristics

Market Segments

The market for project-based emissions reductions consists of three broad segments: the compliance segment, the voluntary segment, and the retail segment. In the compliance segment, public and private entities purchase emissions reduction credits to meet mandatory emissions reduction commitments.[8] Similarly, the voluntary segment consists of purchases made to comply with voluntary emissions reduction commitments. Last,

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[6] IETA, "Kyoto Mechanisms: Clean Development Mechanism," found at *http://www.ieta.com,* retrieved Sep. 20, 2004; Evolution Markets, "Glossary of Terms," found at *http://www.evomarkets.com/ghg_glossary.html*, retrieved on Nov. 19, 2004; CO2e, "Glossary," found at *http://www.co2e.com/common/glossary.asp*, retrieved on Jan. 4, 2005; and Point Carbon, "Glossary of Keywords," found at *http://www.pointcarbon.com*, retrieved on Apr. 26, 2005.

[7] IETA, "Kyoto Mechanisms: Joint Implementation," found at *http://www.ieta.com,* retrieved Sep. 20, 2004; Evolution Markets, "Glossary of Terms," found at *http://www.evomarkets.com/ghg_glossary.html*, retrieved on Nov. 19, 2004; CO2e, "Glossary," found at *http://www.co2e.com/common/glossary.asp*, retrieved on Jan. 4, 2005; and Point Carbon, "Glossary of Keywords," found at *http://www.pointcarbon.com*, retrieved on Apr. 26, 2005.

[8] Examples of mandatory commitments include the Kyoto Protocol and the European Union Emissions Trading Scheme (EU-ETS).

Table G-1
World Bank Carbon Finance Business (CFB) Project Cycle

Step	Time	Activities	Avg. Cost
1. Proposal Review	3 mos.	1. *Project Idea Note* (PIN) submitted and reviewed 2. If PIN is acceptable, sponsor begins preparation of *Carbon Finance Document* 3. Host Country endorsement requested 4. *Letter of Intent* issued	$25K
2. Carbon Asset Due Diligence	2 mos.	1. *Project Design Document* (PDD), baseline study, and emissions reductions projections prepared 2. Monitoring plan prepared 3. Validation documents prepared by World Bank Carbon Finance Business (CFB) and sponsor. 4. *Letter of Approval* (LoA) requested from Host Country 5. CFB staff begin technical, financial, environmental, and social due diligence	$55K
3. Validation Process	2 mos.	1. CFB contracts independent validator and submits documents 2. Validator examines PDD, including baseline study and monitoring plan 3. Document posted for 30-day public comment period 4. Validator issues report/opinion 5. Registration request submitted 6. Project registered under the CDM	$25K
4. Negotiation of Project Agreements	3 mos.	1. Project appraisal and related documentation prepared 2. CFB prepares and negotiates term sheet and draft *Emissions Reduction Purchase Agreement* (ERPA) 3. Due diligence and World Bank internal approvals secured 4. ERPA signed after receipt of LoA 5. ERPA becomes effective after financial approval	$160K
5. Construction, Start-Up, and Monitoring	1-3 yrs	1. Upon completion of construction, CFB contracts an independent verifier 2. Verifier checks that specifications of emissions monitoring plan are met and issues Initial Verification Report 3. Project developers monitor emissions in accordance with the monitoring plan	$25K
6. Verification and Certification	Up to 21 yrs	1. Verifier issues periodic verification report 2. Certified emissions reductions are issued by the CDM Executive Board 3. CFB pays project sponsor for "verified emissions reductions (VERs) 4. Emissions reductions transferred	$20-$45K
7. Project Completion			

Source: Alexandre Kossoy, PowerPoint Presentation entitled "World Bank Carbon Finance Business Project Cycle," *World Bank Carbon Finance Business*, March 2005, found at *http://www.carbonfinance.org*, retrieved on May 10, 2005 and World Bank, "Project Cycle," found at *http://www.carbonfinance.org/pcf/router.cfm?Page=ProjectCycle*, retrieved on Apr. 28, 2005.

the retail segment is composed of companies or individuals that purchase credits for the purpose of demonstrating social responsibility and/or promoting a particular brand.[9]

Market Participants

Compliance with emissions reduction regulations is the primary driver of the project-based markets. As a result, emissions reduction buyers, typically governments and private firms, are primarily motivated by current (or expected future) emissions reduction commitments at the international, national, or sub-national level. By contrast, project developers (sellers) are principally motivated by the revenue generated from the sale of such credits. Collectively, buyers and sellers are also motivated by the opportunity the demonstrate leadership, gain experience, inform public policy, and shape future rules/regulations.[10] Most participants are also motivated by the desire to reduce greenhouse gas emissions.

Governments purchased approximately 33 percent of the total emissions reductions credits traded during January 2004-April 2005. Of this group, European Union (EU) governments were the dominant purchasers, with the Government of the Netherlands purchasing approximately 16 percent of the credits exchanged during the period. Other important government purchasers include the governments of Austria, Denmark, and Sweden, which together accounted for approximately 4 percent of the total volume purchased.[11]

Private firms were also important purchasers during January 2004-April 2005. For example, UK-based companies purchased approximately 16 percent of the total emissions reductions credits exchanged during the period, while companies in other EU countries purchased approximately 24 percent. Similarly, private entities in Japan purchased approximately 21 percent, while (largely) private sector firms in New Zealand (7 percent), Canada (5 percent), the United States (4 percent), and Australia (3 percent) accounted for the remaining emissions reduction credits purchased during January 2004-April 2005.[12]

The complex, technical nature of emissions reduction projects has led some market participants to outsource the procurement of emissions reduction credits to carbon funds, buyer's pools, and other procurement facilities, collectively referred to as "carbon funds." Carbon funds benefit participants by reducing overall transaction costs and decreasing the need for in-house emissions procurement expertise. Moreover, by

[9] In the retail segment, buyers typically purchase small amounts of emissions reductions, which are subsequently removed from circulation. Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *World Bank Carbon Finance Business (CFB)* and the *IETA,* May 2005, p. 12, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

[10] Richard Rosenzweig, Matthew Varilek, Ben Feldman, Radha Kuppalli, and Josef Janssen, "The Emerging International Greenhouse Gas Market,*" The Pew Center on Global Climate Change*, Mar. 2002, pp. 7-9, found at *http://www.pewclimate.org*, retrieved on Apr. 21, 2005.

[11] Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*, May 2005, pp. 19-22, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

[12] Ibid.

investing in a broad range of projects, such funds allow participants to diversify their emissions reduction portfolio, thereby reducing the many risks associated with such activities.[13]

The World Bank established the first carbon fund, the Prototype Carbon Fund (PCF), in 1999. The PCF, which is now closed to outside investors, manages approximately $167 million on behalf of 23 shareholders in the public and private sector, including six governments and 17 oil and power companies based in Japan and Europe.[14] As of June 2005, the PCF had purchased approximately 23.1 million emissions reduction credits from 19 emissions reductions projects in 17 countries in Asia, Latin America, Africa, and Central and Eastern Europe (table G-2).[15] The PCF also lists 13 projects as "under development." Of these 32 projects, approximately two-thirds employ renewable energy technologies.[16]

The success of the PCF, combined with strong demand in both the public and private sectors, led the World Bank to establish five additional carbon funds: the Netherlands Clean Development Facility (2002), the Community Development Carbon Fund (CDCF; 2003), the Italian Carbon Fund (2003), the BioCarbon Fund (2004), and the Spanish Carbon Fund (2004).[17] Of these funds, the PCF and the CDCF were the most active, purchasing approximately 22 percent of the emissions reductions traded during January 2004-April 2005.[18] Although the World Bank currently dominates the carbon fund niche, due in large part to its first-mover position, several other carbon funds are currently under development or in the early stages of operation (table G-3).

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[13] Point Carbon, "Funding Fathers? Evaluation of carbon procurement vehicles," *Carbon Market Analyst*, May 3, 2005, found at *http://www.pointcarbon.com*, retrieved on May 9, 2005

[14] Government shareholders include the Government of Canada, Government of Finland, Government of the Netherlands, Government of Norway, Government of Sweden, and the Japan Bank for International Cooperation. Company shareholders include British Petroleum (UK), Chubu Electric Power Company (Japan), Chugoku Electric Power Company (Japan), Deutsche Bank (Germany), Electrabel (Belgium), Fortum (Finland), Gaz de France (France), Kyushu Electric Power Company (Japan), MIT Carbon (Japan), Mitsubishi Corporation (Japan), Norsk Hydro (Norway), RaboBank (Netherlands), RWE (Germany), Shikoku Electric Power Company (Japan), Statoil (Norway), Tohoku Electric Power Company (Japan), and Tokyo Electric Power Company (Japan). CFB, "Participants," found at *http://www.carbonfinance.org*, retrieved on Apr. 28, 2005.

[15] As of June 2005, the PCF had signed 19 Emissions Reduction Purchase Agreements (ERPAs). CFB, "PCF Projects," found at *http://www.carbonfinance.org*, retrieved on Apr. 28, 2005.

[16] CFB, "PCF Projects," found at *http://www.carbonfinance.org*, retrieved on Apr. 28, 2005.

[17] CFB, "Carbon Finance Products at the World Bank," found at *http://carbonfinance.org*, retrieved on May 31, 2005.

[18] When emissions reductions purchased by the CFB's various carbon funds are attributed to the CFB, rather than the fund's participants, World Bank purchases equaled approximately 22 percent of the emissions reduction credits sold during January 2004-April 2005. Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*, May 2005, pp. 19-22, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

Table G-2
World Bank Prototype Carbon Fund (PCF) and Community Development Carbon Fund (CDCF) Projects: Emissions reduction projects with a signed Emissions Reduction Purchase Agreement (ERPA)

Project Name	Fund	Country	Description	Contract	Emissions Reductions Purchased	Project Emissions Reductions
				$US millions	*MtCO2e*	*MtCO2e*
Plantar Sequestration and Biomass Use	PCF	Brazil	Charcoal produced from sustainably harvested plantations replaces coke for pig iron manufacture	$5.3	1,514,286	10,251,564
District Heating	PCF	Bulgaria	District heating system upgrades for the city of Sofia, Bulgaria	$4.34	1,084,000	1,539,715
Svilosa Biomass	PCF	Bulgaria	Biomass-based boiler (13.4 megawatt (MW)) displacing charcoal-based power generation	1.58	450,000	1,007,724
Chacabuquito Small Hydro	PCF	Chile	Hydro power plant (26 MW) displacing coal/gas power generation	4.06	1,000,000	2,752,000
Coal-bed Methane	PCF	China	Coal mine methane capture for use in power generation (120 MW)	17.0	4,000,000	49,046,000
Jepirachi Wind Farm	PCF	Columbia	Wind Farm (19.5 MW) displacing coal/gas power generation	3.2	800,000	1,168,000
Chorotega Wind Farm	PCF	Costa Rica	Wind Farm (8.4 MW) displacing thermal power generation	.92	262,660	323,850
Cote Small Hydro	PCF	Costa Rica	Hydro power plant (6.3 MW) replacing thermal power generation	.60	172,120	215,138
CEA Energy Efficiency	PCF	Czech Republic	Energy efficiency measures and renewable through Czech Energy Agency	2.00	500,000	500,000
El Canada Small Hydro	PCF	Guatemala	Hydro power plant (43 MW) displacing thermal power plants	7.5	2,000,000	2,883,600
Pannongreen Pecs Fuel Conversion Project	PCF	Hungary	Coal-fired power plant conversion to biomass	5.01	1,193,000	2,645,500
Indocement Sustainable Cement Production	PCF	Indonesia	Energy efficiency measures	10.80	0	11,313,017
Liepaja Solid Waste Management	PCF	Latvia	Methane capture and CO2 reduction	2.48	387,933	864,600
Umbrella Waste Management	PCF	Mexico	Waste-to-energy projects (21 MW)	6.3	1,500,000	3,513,000
Soil Conservation	PCF	Moldova	Afforestation Project	4.55	1,300,000	3,215,296

Table G-2—*Continued*
World Bank Prototype Carbon Fund (PCF) and Community Development Carbon Fund (CDCF) Projects: Emissions reduction projects with a signed Emissions Reduction Purchase Agreement (ERPA)

Project Name	Fund	Country	Description	Contract	Emissions Reductions Purchased	Project Emissions Reductions
				$US millions	*MtCO2e*	*MtCO2e*
North Wind Bangui Bay Wind Farm	PCF	Philippines	Wind farm (25 MW)	2.41	566,000	884,500
Afforestation	PCF	Romania	Afforestation Project	3.08	854,985	1,360,183
Durban Municiple Solid Waste	PCF	South Africa	Landfill methane capture	15.01	3,800,000	8,780,034
West Nile Electrification Project	PCF	Uganda	Hydro power plants (1.5 and 5.1 MW) replacing diesel-based power generation	3.90	1,300,000	1,884,102
Olavarria Landfill Gas Recovery Project	CDCF	Argentina	Landfill methane capture/destroy project	0.6	131,000	339,091
La Esperanza Hydro	CDCF	Honduras	Hydro Power Plant (12.7 MW)	1.4	310,000	339,091

Note: The emissions reductions detailed above are expected to be registered under the Kyoto Protocol's Article 12 (Clean Development Mechanism) and Article 6 (Joint Implementation); an additional 21 projects are currently under development.

Source: World Bank Carbon Finance Business, "List of World Bank Carbon Finance Projects," found at *http://www.carbonfinance.org*, retrieved on May 20, 2005.

Table G-3
Leading carbon procurement vehicles

Fund/Pool	Launched	Mandate	Public/ private share	Capitalization (May 2005)
			Percent	*Millions of dollars*
Baltic Sea Region Testing Ground Facility	2003	JI projects in Baltic Sea region	100 / 0	([1])
BioCarbon Fund	2003	Forestry-related CDM/JI projects	50 / 50	47
CAF-Netherlands CDM Facility		Government of Netherlands procurement	100 / 0	([1])
Community Development Carbon Fund	2003	Small-scale CDM projects	75 / 25	92
Danish Carbon Fund	2005	CDM/JI procurement for the Danish public & private sectors	50 / 50	([1])
EcoSecurities-Standard Bank Carbon Fund	2003	CDM/JI projects in the Baltic and Balkan states, Central and Eastern Europe, and Central Asia	([1])	([1])
European Carbon Fund	2004	CDM projects at the Emissions Reduction Purchase Agreement (ERPA)-level in Mexico, Brazil, Chile, Morocco, India, China, and South Africa	0 / 100	120
European Partnership Carbon Fund	Not launched	CDM/JI projects; procures for European companies and sub-national governments	([1])	([1])
GG-CAP	2004	CDM/JI projects at the ERPA-level in Europe, Canada, and Japan	0 / 100	185
ICECAP Ltd.	2004	CDM/JI projects in India, China, Brazil	([1])	([1])
Italian Carbon Fund	2004	CDM/JI projects; procurement for the Italian government, focusing on China, Latin America, the Balkans, and the Middle East	100 / 0	92
Japan GHG Reduction Fund	2004	CDM/JI projects; procurement for the Japanese public and private sectors	25 / 75	92
KfW Carbon Fund	2004	CDM/JI projects and project-based European Union Allowances	100 / 0	60
Merzbach Mezzanine Carbon Fund 1	2005	Debt financing facility for CDM/JI projects at the ERPA- level	0 / 100	92
Netherlands EBRD Carbon Fund	2003	Government of Netherlands procurement	100 / 0	([1])
Netherlands, European Carbon Fund	2004	Government of Netherlands procurement	100 / 0	([1])

See footnote at end of table.

Table G-3—*Continued*
Leading carbon procurement vehicles

Fund/Pool	Launched	Mandate	Public/ private share	Capitalization (May 2005)
			Percent	*Millions of dollars*
Netherlands Rabobank Carbon Procurement	2003	Government of Netherlands procurement	100 / 0	([1])
Multilateral Carbon Credit Fund	Not launched	ERUs, CERs,and EUAs	([1])	([1])
Prototype Carbon Fund	1999	CDM/JI; also buys verified emissions reductions (VERs)	35 / 65	167
Spanish Carbon Fund	2004	CDM/JI procurement for the Spanish public and private sectors	100 / 0	264

[1] Not available.

Source: Point Carbon, "Funding Fathers? Evaluation of Carbon Procurement Vehicles," *Carbon Market Analyst*, May 3, 2005, found at *http://www.pointcarbon.com*, retrieved on May 9, 2005; and Chandra Shekhar Sinha (World Bank), "State of the Carbon Market," Mar. 11, 2005, found at *http://www.carbonfinance.org*, retrieved on May 5, 2005.

Emissions reduction projects located in developing countries and economies in transition are the primary sellers of emissions reduction credits. As discussed above, examples of such projects include wind farms, hydro-electric power plants, and biomass projects. During January 2004-April 2005, approximately 45 percent of the emissions reduction credits sold worldwide originated in Asia, followed by 35 percent in Latin America, 14 percent in OECD countries, and 6 percent in transition economies. In terms of technology, HFC_{23} destruction projects supplied approximately 25 percent of the credits sold during January 2004-April 2005, while animal waste capture projects represented approximately 18 percent.[19] Other technologies, including hydro-electric, biomass, landfill capture, and wind projects, all accounted for less than 12 percent of the credits supplied during the period.[20]

[19] HFC_{23} destruction projects, which are located exclusively in Asian countries, generated large numbers of ERs (25 percent) from a relatively small number of projects. During Jan. 2004-Apr. 2005, Latin American countries supplied 46 percent of the ERs from non-HFC23 destruction projects, while Asian countries supplied 28 percent. Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA,* May 2005, pp. 22-23, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

[20] Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA,* May 2005, pp. 22-24, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

Market Activity

Emissions reductions credits are typically exchanged, on an over-the-counter basis, between buyer and seller counter-parties via project-specific contracts.[21] Since such credits are typically delivered at a future date, denoted by a credit's "vintage,[22]" such contracts can be considered *de facto* forward contracts.[23] The total volume of credits traded via project-based activities increased from approximately 17.9 million in 1998 to 107.0 million in 2004, representing a compound annual growth rate of 34.6 percent (table G-4; figure G-1). During the first four months of 2005, an additional 42.8 million emissions reduction credits were traded in project-based markets. During this seven year period, however, the composition of traded credits changed significantly. For example, in 1998 and 1999, credits purchased to meet voluntary commitments represented more than 99.5 percent of market. By 2004, however, this segment had declined to just 2.0 percent of the annual total, while credits traded for compliance purposes accounted for the remaining 98 percent.[24]

The unique nature of many emissions reduction projects makes it difficult to compare emissions reduction prices across transactions. As a result, the World Bank has constructed an indicative range of prices for two broad categories of compliance-based emissions reductions: "Not For Kyoto" emissions reductions (ERs) and "For Kyoto" emissions reductions. "For Kyoto" emissions reductions include CERs, ERUs, and verified emissions reductions (VERs).[25] During January 2004-April 2005, the weighted average price ranged from $1.20 for ERs to $6.04 for ERUs (figure G-2).[26]

Credit price differentials are largely attributed to three project-specific factors: registration risk, country risk, and project risk. Registration risk, for example, refers to the possibility that a project will fail to meet CDM/JI criteria, thereby failing to achieve "registration." Similarly, country risk refers to the possibility that a project will not received host country support in the early stages of the CDM/JI approval process. By contrast, project-risk refers to the risk that a registered CDM/JI project will fail to produce the expected amount of emissions reduction credits, or that the credits will not be delivered on the agreed-upon timetable (delivery risk). As a general rule, emissions reduction credits from projects judged to have low levels of risk in these three categories typically command relatively high prices, while those generated from

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[21] A universally-accepted, standard contract for project-based activities does not currently exist. Ibid.

[22] Vintage refers to the year in which emissions reductions are delivered. For example, 2008 vintage emissions reductions will be delivered in 2008.

[23] A forward contract is an agreement between two parties, buyer and seller, in which the former agrees to purchase an asset from the latter at a specified future date. The price is agreed in advance, although payment is typically deferred until the transaction date. Frank K. Reilly, "An Introduction to Derivative Markets and Securities," ch. in *Investment Analysis and Portfolio Management*, 4th ed, (Fort Worth, Texas: Dryden Press, 1994), p. 297.

[24] Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*, May 2005, p. 20, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

[25] Verified emissions reductions (VERs) are emissions reduction credits which have been verified by a third party. By contrast, emissions reductions (ERs) have not been verified.

[26] Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA,* May 2005, pp. 26-28, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

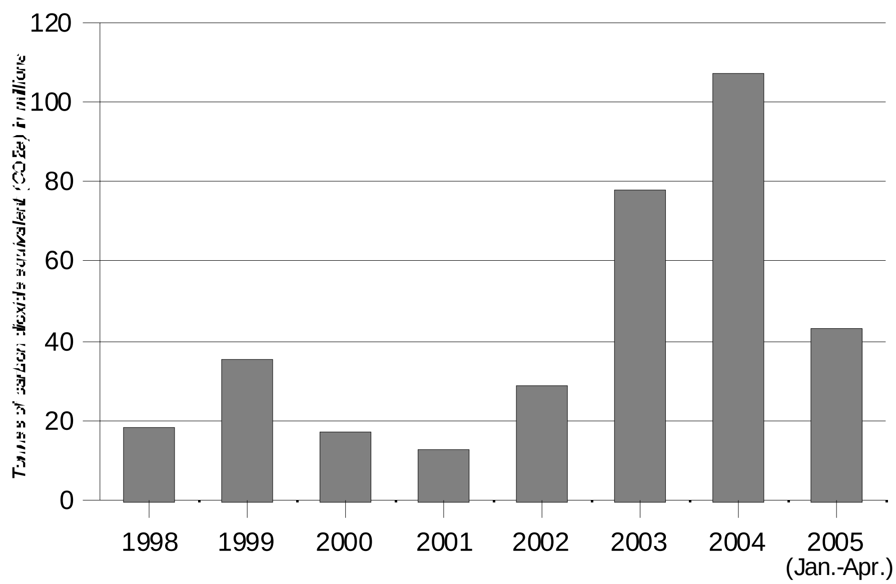
Table G-4
Annual emissions reduction volumes traded, Jan. 1998-Apr. 2005

Year	Compliance	Voluntary	Retail	Total
1998	0	17,907,448	69,090	17,976,538
1999	0	35,265,724	157,767	35,423,491
2000	387,933	16,507,407	199,085	17,094,425
2001	4,724,591	8,161,652	117,860	13,004,103
2002	14,676,748	13,893,209	207,010	28,776,967
2003	70,429,780	6,773,367	438,669	77,641,816
2004	104,600,758	2,299,050	110,281	10,701,089
2005 (Jan.-Apr.)	39,823,182	2,995,000	44,913	42,863,095
	234,642,992	103,802,857	1,344,675	339,790,524

Note: Data include all volumes up to 2012 vintage. Data for retail is incomplete. Volumes are measured in tonnes of carbon dioxide equivalent (CO2e).

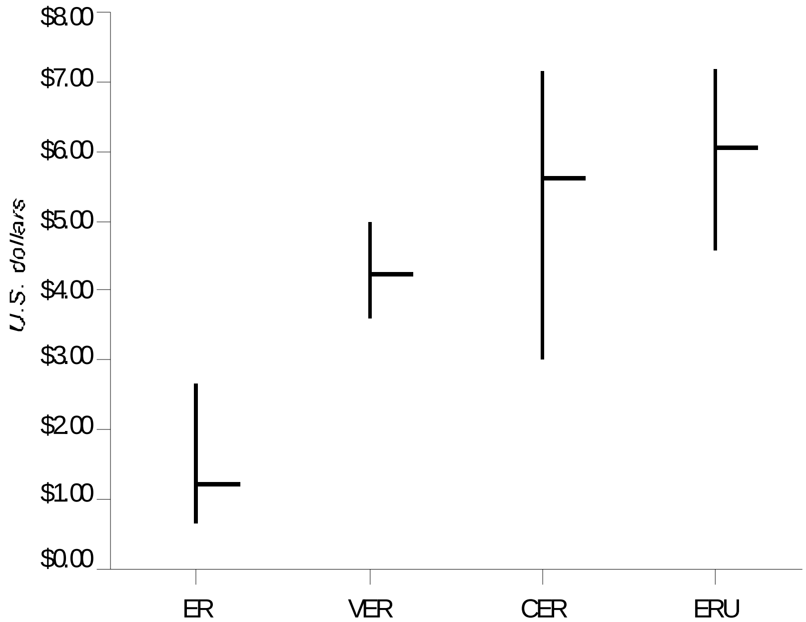
Source: Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *World Bank* and *International Emissions Trading Association (IETA)*, May 2005, pp. 19-22, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

Figure G-1
Annual volumes of emissions reductions trade, Jan. 1998 - Apr. 2005



Source: Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*, May 2005, pp. 22-24, found at *http://www.carbonfinance.org*, retrieved May 16, 2005.

Figure G-2
Prices/ranges for emissions reductions exchanged via project-based transactions, Jan. 04-Apr. 05



Source: Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*. May 2005, pp. 22-24, found at *http://www.carbonfinance.org*, retrieved May 16, 2005.

riskier projects typically attract relatively low prices.[27] Other factors affecting emissions reduction credits prices, several of which also incorporate risk considerations, include, *inter alia*, contract structure, seller creditworthiness, emissions reduction vintage and seniority, technological preferences, and confidence in a project's management team.[28]

Trade and Investment

In most project-based transactions, a buyer purchases emissions reductions from a project sponsor, typically on a forward basis, as opposed to making a debt or equity investment in an

[27] Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*, May 2005, pp. 25-28, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005; Point Carbon, "Viewpoint: Risk Delineation of CERs," *CDM & JI Monitor*, p. 1, Apr. 5, 2005, found at *http://www.pointcarbon.com*, retrieved May 11, 2005; and Point Carbon, "ViewPoint: CERs and EUAs - merging prices?," *CDM & JI Monitor*, p. 1, Jan. 25, 2005, found at *http://www.pointcarbon.com*, retrieved May 11, 2005.

[28] Various contractual features are used to allocate risk among counterparties. For example, contracts denominated in CERs or ERUs assign registration risk to the project-sponsor. By contrast, contracts denominated in VERs transfer registration risk to the purchaser. Other contractual features used to allocate risk between buyers and sellers include, *inter alia*, guarantee structures, upfront payments, penalties and default clauses, damage clauses, and disbursement schedules. Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*, May 2005, pp. 25-28, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

emissions reduction project. Although the vast majority of purchasers do not invest in emissions reduction projects, such purchasers nonetheless facilitate trade, investment, and technology transfer between countries, albeit indirectly. For example, the expected cash flow provided by annual emissions reduction purchases often improves a project's forecasted internal rate of return (IRR), increasing the likelihood of obtaining financial approval.[29] Indeed, the World Bank estimates that emissions reduction purchases by the PCF and CDCF have improved project IRRs by 0.8 percent to 10.0 percent (table G-5). In addition, the annual revenues provided by such transactions often increase financiers' confidence in emissions reduction projects, as payments are typically payable in strong currencies[30] and originate from blue-chip buyers such as OECD governments or the World Bank.[31]

Current Issues

The rules, mechanisms, and institutions associated with project-based activities are in the early stages of development. As a result, project developers often face a lack of clear guidelines and standards when trying to obtain CDM/JI approval. Some observers, for example, complain that the CDM Executive Board's (CDM EB) case-by-case approach to project review and registration is inefficient, time-consuming, and non-transparent. Other issues contributing to delays at the CDM EB include a severe shortage of financial resources and the volunteer/part-time status of its membership.

The Kyoto Protocol's expiration in 2012 also places pressure on the CDM EB to quickly approve projects in its pipeline. Given a typical construction time of 5-7 years, for example, many projects initiated after 2007 may not produce emissions reductions until after the 2012 deadline, rendering them ineligible for use under current Kyoto arrangements. Many market participants also express concern that the Kyoto Protocol's expiration will lead to an overall decline in the CDM/JI market.

The role of the World Bank is also a matter of much debate in the project markets. For example, some observers assert that the large-scale purchasing activities of the World Bank's carbon funds, combined with a shortage of viable CDM/JI projects, have crowded out other market participants. Relatedly, the Bank is criticized for using its market power to put downward pressure on the price of emissions reductions, reducing the viability of some emissions reduction projects. Some observers also contend that the World Bank's role as emissions reduction purchaser conflicts with its role as advisor to project developers in negotiations with the World Bank. The World Bank is also accused of dominating carbon fund management activities, with some observers pointing to recent decisions by the governments of Spain, Italy, and Denmark to contract management of their respective carbon funds to the World Bank, rather than outsource such services to the private sector.[32]

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[29] The internal rate of return (IRR) is a measure of investment return derived from a discounted cash flow (DCF) analysis; investments exhibiting IRR's in excess of the cost of capital are judged to be profitable. Graham Bannock and William Manchester, *International Dictionary of Finance* (London: The Economist Books, 1999), pp. 75-76. For more information on DCF techniques, please see Richard A. Brealey and Steward Myers, *Principles of Corporate Finance* (New York: McGraw, 2002).

[30] Most emissions reductions contracts are denominated in dollars, euros, or yen. Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*, May 2005, p. 25, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

[31] Frank Lecocq and Karan Capoor, State and Trends of the Carbon Market 2005, *CFB* and the *IETA*, May 2005, p. 25, found at *http://www.carbonfinance.org*, retrieved on May 16, 2005.

[32] Point Carbon, "Focal point: The World Bank's existential angst," *Carbon Market Monitor*, Mar. 18, 2005, pp. 5-7, found at *http://www.pointcarbon.com*, retrieved on May 12, 2005.

Table G-5
Impact of carbon purchases on project internal rate of return (IRR)

Technology	Change in IRR
Hydro-electric projects	0.8 - 2.6 percent
Wind energy projects	1.0 - 1.3 percent
Bagasse projects	0.4 - 3.6 percent
Energy Efficiency / district heating projects	~ 2.0 percent
Gas flare reduction projects	2.0 - 4.0 percent
Biomass projects	2.0 - 7.0 percent
Solid waste projects	5.0 - 10.0 percent

Note: IRR impacts are based upon an estimated emissions reduction price of $3.00.

Source: Helmut Schreiber (World Bank), PowerPoint presentation delivered to the Global Greenhouse Gas Emissions Trading Conference in Prague, Czech Republic, Apr. 15, 2004.