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Measures to Promote Renewable Energy and the Technical Challenges Involved

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1 Introduction

With the Kyoto Protocol taking effect in February 2005, industrialized countries are stepping up efforts to reduce greenhouse gas emissions. In Japan, for example, the drive for renewable energy use is gaining momentum, with the Ministerial Meeting on Promotion of Comprehensive Energy Measures deciding in April 2005 to promote renewable energy sources that emit less carbon dioxide (CO_2). A tightening world oil market - due to rising oil demand in China, India and other Asian countries, and growing oil consumption in the U.S. - is another factor accelerating the introduction of these alternatives.

Under such circumstances, efforts to develop and promote various types of renewable energy source (e.g., wind, photovoltaic and biomass power) are growing both at home and abroad. Although renewable energy is still more expensive than fossil fuel energy, the factors described above suggest that its world market could expand rapidly in the years ahead.

This article points out that the key to developing renewable energy sources is the introduction of promotional programs, along with the improvement of the efficiency and the cost effectiveness of the power generation systems involved. It also describes how such promotional programs are drastically shifting from "technology push" (centered on research and development) to "demand pull" (associated with economic incentives) and sheds light on the problems associated with Japan's relevant laws and systems. The article finally focuses on the immediate challenge posed by the connection of distributed power sources to commercial power grids.

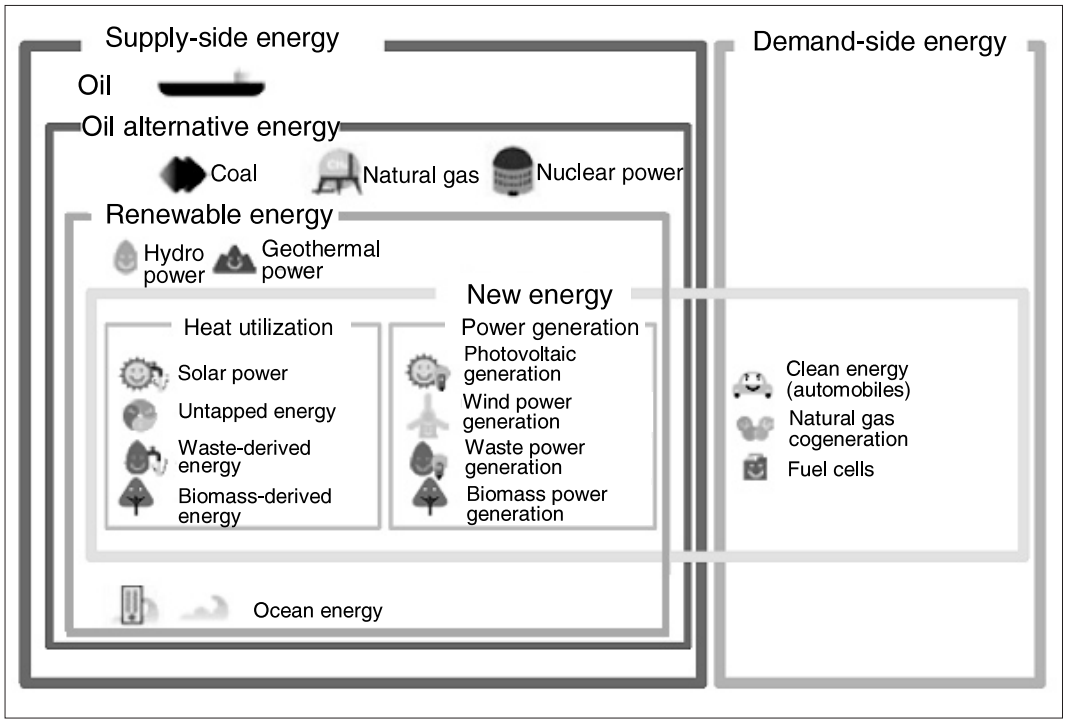
2 Approaches to promote renewable energy

This chapter addresses 1) the definition of renewable energy, 2) factors promoting the introduction of renewable energy, 3) various approaches to promoting renewable energy, and 4) the current status of and problems with the relevant domestic laws and programs already in place, such as the Renewables Portfolio Standard Law, surplus-power purchase contracts and green power programs.

2-1 Definition of renewable energy

As opposed to the energy derived from depletable fossil fuel, "renewable energy" is inexhaustible because it is produced from ever present natural phenomena. Figure 1 shows various types of renewable energy sources. The New Energy Law (1997) defines "new energy" as "a type of energy that is becoming technologically viable and essential as an alternative to oil (oil alternative energy), but has yet to become widespread due to its economic constraints". The term "new energy", however, is rarely used in other countries. Instead, it is commonly referred to as "renewable energy", which includes hydro, geothermal and ocean energy. This international definition is also adopted in this article.

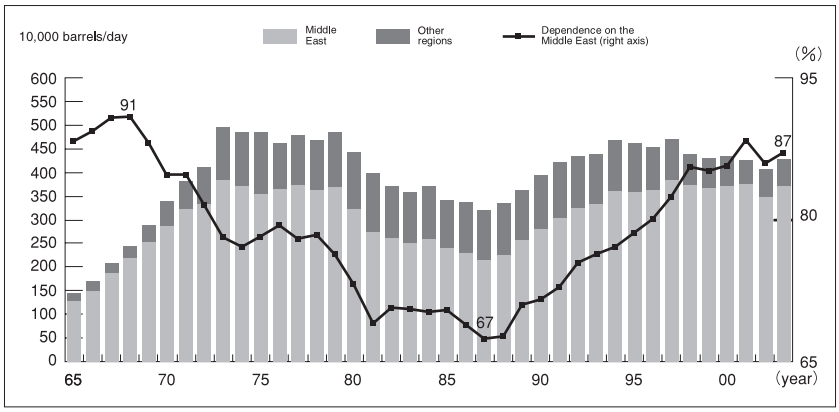
Figure 1 : Renewable energy and new energy



* Biomass includes black liquor and scrap wood. Untapped energy includes snow ice cryogenic energy but excludes waste-derived energy.

Source: Prepared by STFC based on References[2, 3]

Figure 2 : Japan's dependence on Middle Eastern oil



Reference: "Energy Production, Supply and Demand Statistics", the Ministry of Economy, Trade and Industry

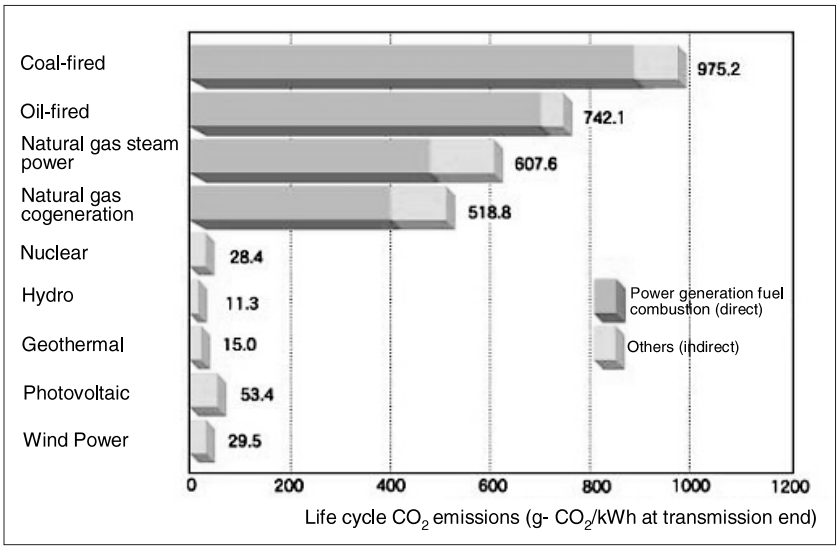
Note: the 2003 figures are preliminary estimates. Source: Reference[4]

2-2 *Factors promoting the introduction of renewable energy*

Two major factors promoting the introduction of renewable energy are 1) stabilization, diversification and decentralization of energy supply and 2) global warming countermeasures.

Oil prices began to surge in the latter half of 2004 due to rising oil demand in China, India and other Asian countries, and growing oil consumption in the U.S. Prices are now hovering between US$40-55 per barrel. With this in mind, it is now widely accepted that the introduction of renewable energy to diversify and decentralize energy sources contributes to shoring up the energy supply structure. Japan's dependence on oil as its primary energy supply dropped from over 70% in the 1970s to 49.4% in 2001. By contrast, its dependence on Middle Eastern oil has been on the rise since the latter half of the 1980s, as shown in Figure 2. Japan's energy supply structure is heavily dependent on

Figure 3 : Life cycle CO_2 emissions of power generation systems



The amount of CO_2 emitted is calculated by taking into account all energy consumed by a series of operations such as mining, construction work, transportation, refining, power generation and maintenance work. For example, coal-fired power generation includes mining, coal dressing, transportation, power generation and ash discharge. In the case of nuclear power generation, the calculation is based on the gas diffusion method (once-through type). Natural gas steam power generation is a system in which natural gas-fired boilers produce the steam which drives the power generation turbines. Natural gas cogeneration uses high-temperature gas produced by the combustion of natural gas to drive gas turbines and produce steam, which in turn drives steam turbines.

Source: Reference[5]

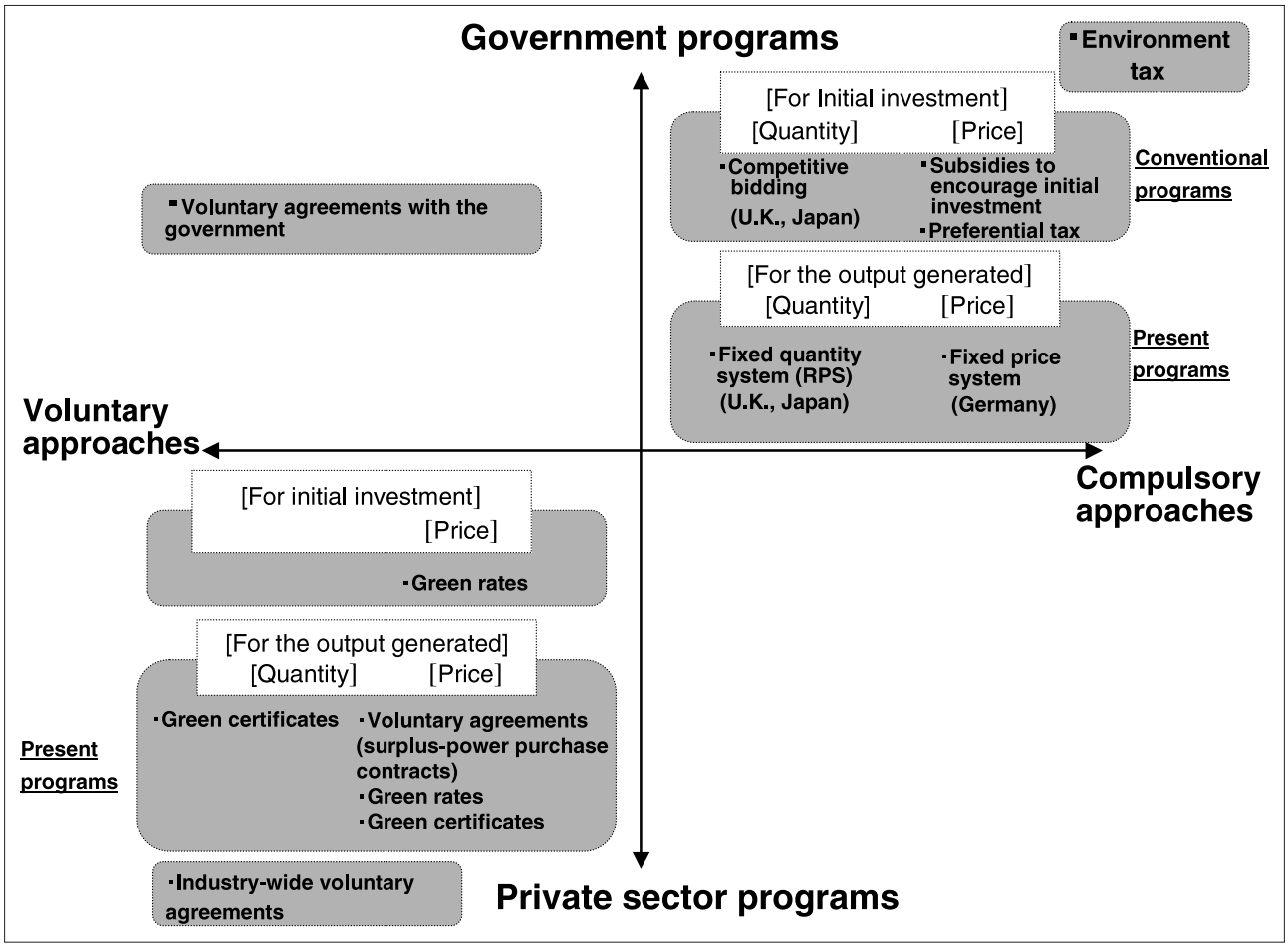
imported energy, especially on Middle Eastern oil, which makes its energy supply security fragile. On the other hand, all renewable energy is being produced domestically, as described below.

The other major factor involves a political issue: global warming countermeasures, or the Kyoto Protocol target. The 3rd session of the Conference of Parties to the United Nations Framework Convention on Climate Change (COP3), which was held in December 1997 in Kyoto, adopted a protocol that mandates industrialized countries to reduce their CO_2 and other greenhouse gas emissions by at least 5% below 1990 levels between 2008 and 2012. Specifically, Japan, the U.S. and the EU are obliged to achieve 6%, 7% and 8% reductions, respectively. With the Kyoto Protocol taking effect in February 2005, industrialized countries are stepping up efforts to reduce greenhouse gas emissions, although the U.S. has seceded from the Protocol. As shown in Figure 3, renewable energy is far more environmentally friendly than fossil fuel in terms of CO_2 emissions. This is a major incentive to promote its adoption.

2-3 Promotional programs

Because of the factors described above, promotional programs for renewable energy around the world are drastically shifting from "technology push" (centered on research and development) to "demand pull" (associated with economic incentives). These promotional programs, coupled with technological development, hold the key to promoting renewable energy. Figure 4 shows a variety of promotional programs as categorized by two measures: whether they are "compulsory" or "voluntary," and "public" or "private." For example, conventional programs that encourage initial investment through government subsidies and special tax cuts for renewable energy facilities are giving way to economic incentives that increase in proportion to the amount of "green power" generated. Typical economic incentives include the fixed price system introduced in Germany in 1990, in which power companies purchase the electricity generated from renewable energy at fixed prices, and a competitive bidding system adopted in the

Figure 4 : Promotional programs for renewable energy



Source: Prepared by STFC based on Reference[6]

U.K. at about the same time. In addition, fixed quantity systems such as RPS were developed in the latter half of the 1990s, followed by various programs adopted in Japan, Europe and the U.S. For example, power companies' voluntary programs to purchase surplus power, and green power programs on the part of consumers (green rates, tradable green certificates, etc.). The current status of and problems with Japan's RPS law, surplus-power purchase contracts and green power programs are discussed below.

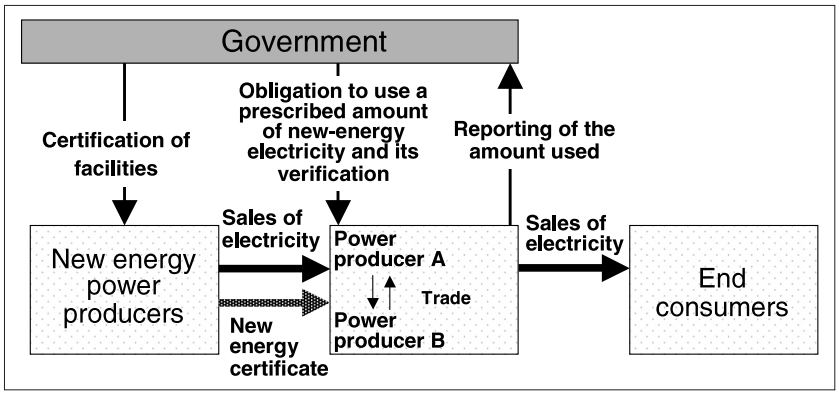
(1) The Renewables Portfolio Standard Law

The fixed quantity system, or the RPS system, is a system that obliges power producers to use a prescribed amount of new energy. It was fully adopted in Japan in 2003 as part of the Law on Special Measures for the Utilization of New Energy, etc. This system is designed to ensure the security of energy supply through the promotion of new energy and mandates power producers to use new energy electricity in proportion to the amount of electricity they sell each year. New energy, in this particular case, refers to those categories described in Section 2-1 (wind, photovoltaic and biomass power generation), run-of-river type hydro power generation (with an output of less than 1,000 kW) and binary geothermal power generation*1, but does not include large-scale hydro power generation.

Figure 5 outlines Japan's RPS system through which power producers are obliged to use new energy electricity in proportion to the amount of electricity they sell each year. This includes general power producers (a total of 10 power producers including Hokkaido Electric Power and Okinawa Electric Power), special power producers*2 and PPS (power producer and supplier) operators*2. These three types of power producer are hereinafter referred to collectively as "power producers".

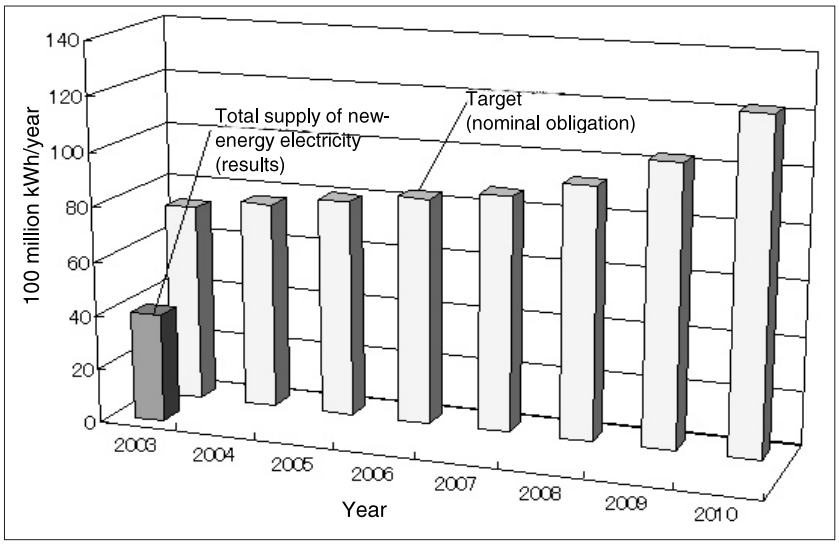
Power producers are expected to promote new energy electricity use through each of the following three alternatives:

Figure 5 : Overview of Japan's RPS system



Source: Reference[10]

Figure 6 : Targets for the use of new-energy electricity



Source: Prepared by STFC based on Reference[10]

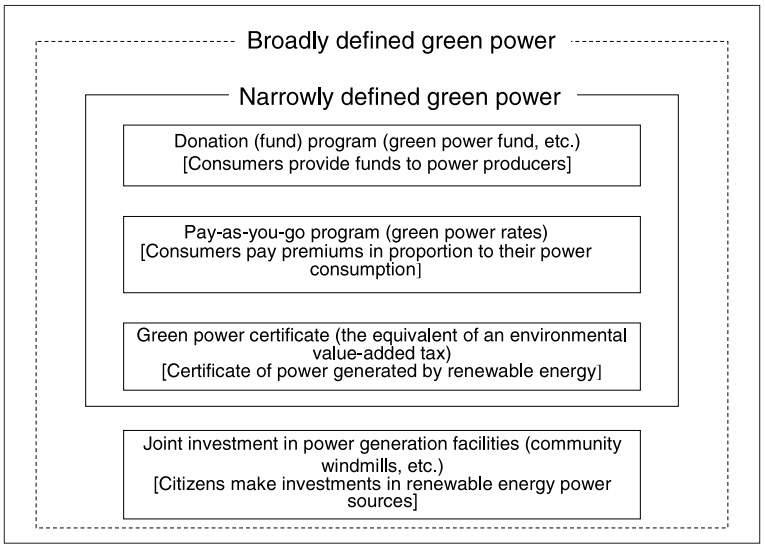
(i) Generate "new energy electricity" independently
(ii) Purchase "new energy electricity" from others
(iii) Obtain "new energy certificates" from others

A "new energy certificate" is a type of "credit" which power producers can purchase from others in order to achieve their targets for the use of a prescribed amount of new energy electricity.

Those who fail to fulfill this obligation without reasonable cause are fined up to one million yen. This kind of penalty, however, is unlikely to provide a good incentive for the adoption of new energy. A more efficient approach would be to impose a surcharge on power producers, based on the proportion of "non-fulfillment" of the obligation in terms of kWh (Penalty program)[7]. Power producers, by definition, do not include self-generation plants mostly dependent on fossil fuels (i.e., those who generate power primarily for captive consumption). Greenhouse gas emissions from such self-generation plants account for some 15% of the total emissions from the energy conversion sector[8]. Self-generation plants should therefore be regulated in the future[9].

The government consults with the Advisory Committee for Natural Resources and Energy every four years to set a target for the use of new energy electricity over the next eight years. The current target, as shown in Figure 6, is set for 2010: 12.2 billion kWh/year or 1.35% of the total power supply, which is too small an amount to create fluidity in the market. With only this target, power producers and power plant builders

Figure 7 : Four categories of green power programs



Source: Reference[6]

cannot formulate adequate long-term financing plans. A more ambitious target should therefore be set, looking towards 2020 and beyond.

The review of the RPS law started in June 2005, as scheduled at the time of its introduction. This review is likely to take account of comparable systems abroad, which are later described in Chapter 3.

The obligation to introduce new energy inevitably results in connecting diverse distributed power sources (wind/photovoltaic power generation, etc.) to commercial power grids, regardless of the size of their output. As discussed in Chapter 4, however, there are some challenges to be addressed in achieving this - e.g., development of more advanced power generation systems and cost reduction technologies, and institutional/technical problems associated with the connection of many distributed power sources to commercial power grids.

As defined in Section 2-1, "renewable energy" in this article also includes hydro power generation. If large-scale hydro power generation, which is not covered by the RPS law, is taken into account, Japan's target for the use of renewable energy accounts for some 6% of total primary energy consumption.

(2) Surplus-power purchase contracts

As part of their voluntary initiatives to promote new energy, general power producers have been purchasing surplus power generated by wind and photovoltaic power plants since 1992. This program was expanded to include cogeneration and other self-generation plants in 1993, and commercial wind power plants with an output of less than 2,000 kW in 1998. Under this program, the unit purchase price of surplus power is fixed for each new energy source, and a purchase menu is made public. In particular, surplus power generated by wind power plants (excluding commercial plants) and photovoltaic power plants is purchased at the same price as that of the general power producers: about ¥27/kWh for ordinary households (the time-of-day electric rate). With regard to commercial wind power plants, a commercial wind power generation menu is in place to ensure a long-term, stable purchase program. Tokyo Electric Power Company (TEPCO) sets the price at about ¥11/kWh for plants contracted for 15 years, which is much higher than the fuel equivalent of thermal power generation (¥4-6/kWh).

(3) Green power programs

Green power programs offer several types of power to consumers. While the RPS system involves obligations and offers incentives to power producers, this program is designed to encourage consumers to take voluntary initiatives to promote the use of renewable energy. Green power programs, as shown in Figure 7, can be broadly classified into four categories.

The green power market has grown to a

significant size. For example, the total contract amount of green power certificates reached ¥2.5 billion within four years of their introduction[6]. However, there are some problems in developing this market further. For one thing, the costs of purchasing the certificates are generally treated as donations under the current tax system and hence are levied along with corporate tax. This is the biggest problem because it makes their purchase more expensive than other environmental measures and therefore hampers the introduction of renewable energy. Measures should be taken to permit these costs to be treated as expenses.

Meanwhile, in line with these green power programs, the private power producers have launched consumer-oriented voluntary initiatives to develop products and services focused on the "environmental value" of renewable energy. This raises the need for a new system to ensure compatibility between these consumer-oriented approaches and the supply-oriented RPS system. One of the incompatibilities in the current system is that it has no mechanism for avoiding the double counting (double selling) of green power certificates and RPS-based new energy certificates.

3 Developments in major countries where Renewable energy is being introduced

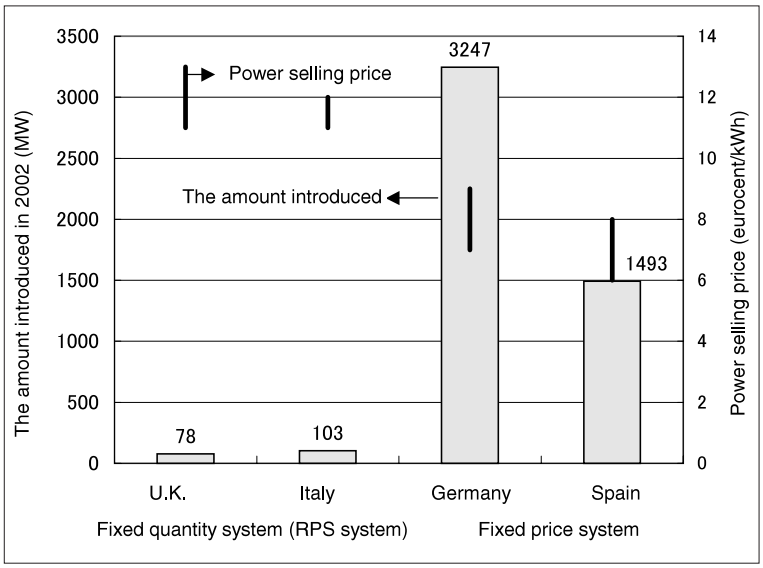
This chapter provides an overview of recent developments in Europe, North America and other parts of the world where renewable energy is being introduced, and compares them with Japan's fixed quantity system (the RPS system) in order to make recommendations for further improvements in Japan.

3-1 Europe

As part of its measures to curb global warming, in October 2001 the European Union (EU) issued the "Renewables Directive"[11], which set the target of doubling the proportion of renewable energy in primary energy use from 6% in 1998 to 12% in 2010 (or 21% in terms of total power consumption)[1]. Specifically, Germany, France and the U.K. are expected to meet targets of 12.5%, 21% and 10%, respectively[1].

The fixed price system is in place in Germany, Spain and Portugal, and the fixed quantity system (the RPS system) is in place in the U.K., Sweden and Italy. As shown in Figure 8, wind power generation has expanded dramatically in

Figure 8 : Development of wind power generation through the use of the fixed quantity system (RPS system) and fixed price system



Fixed quantity system, adopted by U.K. and Italy, and the fixed price system, adopted by Germany and Spain

Source: Prepared by STFC based on Reference[6]

Germany and Spain through the use of the fixed price system. In Germany, the proportion of renewable energy in total power consumption increased from 4.6% in 1998 to 10% in the first half of 2004, thanks in part to the Renewable Energy Law based on the fixed price system. The advantage of the fixed price system is that the purchase price of renewable energy power is secured over the long term, which in turn reduces the business risks that power producers and suppliers are exposed to. This suggests that if Japan fails to achieve its target for the introduction of renewable energy, it should consider adopting similar follow-up measures such as setting a minimum purchase price for a certain period of time.

The EU Renewables Directive described above stipulates that priority should be given to connecting renewable energy power sources to commercial power grids. The EU also actively encourages the development of technologies, such as an innovative control technology for stand-alone power generation systems to meet a potential increase in renewable energy sources and their storage[12].

3-2 North America

The U.S. has a preferential tax system to promote renewable energy. In addition, the RPS law is in force in 17 states including California, New York and Arizona, and these states have their own targets for the introduction of renewable energy. The RPS system works well in some states, while it has been suspended in others. Although the federal RPS law has yet to be enacted, President Bush announced in April 2005 that a budget of about US$1.9 billion was earmarked for the promotion of renewable energy over the next decade[13]. Moreover, the "Renewable Energy Bill" is under consideration by the Committee on Environment and Natural Resources. The bill aims to increase the use of renewable energy as a proportion of total energy supply to at least 3% between 2007 and 2009, 5% in 2012 and 7.5% in and after 2013[1].

With respect to grid connection, the U.S. has promoted since the 1990s efforts to enable stand-alone power sources - including those using renewable energy - to connect to commercial power grids. As part of these efforts, a group led by the Federal Energy Regulation Commission (FERC) is setting standards for the connection of small-scale power generation systems with an output of 20 MW or less, the category to which the majority of stand-alone renewable energy power sources belong[14].

In Canada, hydro power generation has long played a major role in the country's energy supply and now meets some 60% of the domestic power requirement. The State of Ontario plans to introduce "Green Power Standard" in 2006 as a renewable energy promotional program[1]. However, there have been no national-level initiatives so far in Canada.

3-3 China and Brazil

In February 2005, the Chinese government promulgated the Renewable Energy Law, which is scheduled for introduction on January 1, 2006. With the aim of promoting the development and use of renewable energy, this law provides preferential tax, finance and price treatment to renewable energy sources, and mandates power companies with commercial power grids to purchase renewable energy power. Its medium- to long-term objective is to raise renewable energy as a proportion of total primary energy consumption to 10% by 2010 (a total of 60.45 GW, comprising 50 GW from small-scale hydro power, 4 GW from wind power, 6 GW from biomass power and 450 MW from photovoltaic power). When this law takes effect, renewable energy power producers are expected to have more opportunities for connection to commercial power grids. The interconnection price to the grids is fixed for the first 30,000 hours (about 3.4 years) and will thereafter be pegged to market rates. In this Chinese system, the price varies depending on the type of renewable energy source.

In Brazil, about 40% of the country's primary energy consumption is supplied by hydro power, biomass power and other renewable energy sources. The government is implementing a program to guarantee the purchase of renewable energy power over the next two decades. In particular, Rio de Janeiro City is poised to promote wind, photovoltaic and small- to

Table 1 : Renewable energy promotional programs in major industrialized countries

Country	Japan	U.K.	Italy	Sweden	Germany	Spain
System	Fixed quantity (RPS) system				Fixed price system	
Year of introduction	2003	2002	2002	2003	2000	2002
Description	Obligation to obtain certificates (credits) in proportion to part of the power sold	Same as on the left	Same as on the left	Same as on the left	Obligation to purchase all renewable energy power generated	Same as on the left
Target	Power producers and suppliers	Power producers and suppliers	Power producers (including private power producers), power importers	End users (excluding the manufacturing industry)	Power producers and suppliers	Power producers and suppliers
2010 introduction target	1.35% of total power supply (obligatory amount)	10.4% of total power supply (obligatory amount)	3.05% of total power supply (2006); target for 2007 and beyond still to be set	16.9% of total power supply (obligatory amount) (or 60% with large-scale hydro power generation included)	12.5% of total power supply	29.4% of total power supply (including large-scale hydro power generation)
Incentives for power producers	• Banking of certificates *1 for the benefit of targets and power producers	• Guarantee for the continuation of the system until 2027	• Guarantee for the minimum purchase price by commercial grid companies • Priority given to renewable energy power for the connection to commercial power grids	• Guarantee for the minimum purchase price until 2008	• Guarantee for the fixed purchase price over 20 years from the start-up of facilities; 8.7 eurocents/kWh (about 11.3yen) for newly-built on-shore wind power stations	• Guarantee for the fixed purchase price without restriction on terms; 6.5 eurocents/kWh (about 8.4yen) for newly-built on-shore wind power stations • The period for which the purchase price is guaranteed varies for each energy source (e.g., 15 years)
Target energy	Photovoltaic Wind Geothermal Hydro (conduit types with an output of less than 1,000 kW) Biomass	Photovoltaic Wind Hydro (small-scale plants inaugurated in and after 1990) Geothermal Biomass Wave Tidal Waste (originating from non-fossil fuels) Landfill/Sewage Sludge	Photovoltaic Wind Hydro Geothermal Wave Tidal Biomass Waste (originating from non-fossil fuels) Mixed combustion	Photovoltaic Wind Hydro (existing plants with an output of less than 1.5 MW or those inaugurated in and after July 2002) Geothermal Biomass Wave Tidal Waste (originating from non-fossil fuels)	Photovoltaic Wind Hydro (with an output of less than 5 MW) Geothermal Biomass (with an output of less than 20 MW) Landfill/Sewer gas (with an output of less than 5 MW) Mine gas	Photovoltaic Wind Hydro Geothermal Wave Tidal Biomass (including mixed combustion) Waste (including non-biomass resources) *all with an output of less than 50 MW

*1 A system where a surplus of new energy electricity in a given year can be carried forward to the following year in order to be counted as an achievement.

medium-scale hydro power generation[15].

3-4 Promotional programs around the world

Current promotional programs for renewable energy around the world can be broadly classified into either the fixed quantity system (the RPS system) or the fixed price system. Table 1 summarizes typical promotional programs in major countries so that they can be compared with Japan's programs. As explained in Section 3-1, countries adopting the fixed price system have taken the lead in introducing wind power generation. Since the fixed price system secures the purchase price of renewable energy power over the long term, it has served as a powerful incentive to power producers. This proves the effectiveness of approaches that provide long-term assurance of the power purchase price.

Overseas RPS systems could be useful models when Japan reviews its own system. The candidates include a medium- to long-term assurance program in the U.K., guaranteed minimum purchase price programs in Italy and Sweden, and a program in Italy that gives priority to renewable energy power for connection to commercial power grids. As pointed out in Chapter 2, Japan's target of increasing the use of new energy power to 1.35% of the total power supply by 2010 is too modest compared with those of other countries. With such a small size, Japan's renewable energy market will have little fluidity. For better results, Japan should, while still maintaining the current framework of the RPS law, set a more ambitious target and introduce schemes for guaranteed purchase prices and long-term assurance to minimize the business risks of power producers and suppliers[16].

4 Problems associated with the connection of renewable energy power sources to commercial power grids

To increase the amount of renewable energy being introduced on the market, a greater number of distributed power sources, such as wind and photovoltaic power generation systems, need to be connected to commercial power grids. These power generation systems are, however, still in the development phase and hence their connection to the grids poses some immediate and critical problems. This chapter outlines these problems and their possible solutions.

4-1 Renewable energy as a distributed power source

A renewable energy system functions as a distributed energy system in which the electricity produced from specific resources is stored locally or supplied to commercial power grids as needed. Table 2 outlines how each renewable energy system acts as a distributed power source.

When large amounts of renewable energy are introduced as distributed power sources, a system that coordinates their operations with those of grid power is essential for ensuring effective utilization and maintaining supply reliability and quality. Such a system should be able to work with the existing power grid system to regulate the output of distributed power sources and the facilities connected to the grid in response to fluctuations in power demand.

Table 3 shows the output stability and controllability of each renewable energy system when used as a distributed power source. Wind and photovoltaic power generation systems are inferior to small-scale hydro and biomass power generation in both output stability and controllability because they are subject to weather conditions, and there is little chance that the former technologies will develop dramatically in five years' time or so. Despite these drawbacks, however, the targets for the introduction of wind and photovoltaic power generation are set at 3,000 MW and 4,820 MW, respectively, for 2010 (see Figure 9).

With such targets already in place, a lot of distributed power sources with unstable output and poor controllability will have to be connected to commercial power grids, necessitating a variety of measures to coordinate the connection between the two. The next section explains in detail the issues to be addressed and the countermeasures to be adopted.

Table 2 : Renewable energy systems as a distributed power source

Renewable energy	Solar light	Solar heat	Wind	Biomass	Geothermal	Small-to-medium sized hydro
Resources	Solar light energy (about 1 kW/m^2)	Solar heat energy (about 1 kW/m^3)	Wind power energy (proportionate to the third power of the area of blades, the air density and the wind speed)	Wood biomass, livestock waste, construction waste, food waste, etc.	Geothermal energy (hot high-pressure water and steam)	The potential energy of water
Conversion technology	Solar energy is converted directly into electricity through the photoelectric effect of semiconductors	Solar energy is converted into heat through solar energy collectors	The rotational energy of windmills is converted into electricity through generators	Biomass is converted into heat energy through direct combustion, chemical gasification processes, etc; it can be converted into electricity through motors and generators	Heat energy is used directly; geothermal energy can be converted into electricity through motors and generators	The potential energy of water is converted into the rotational energy of water turbines, which produce electricity through generators
Storing technology	Essential in controlling output	Thermal storage tanks are necessary	Essential in controlling output	Wood biomass is processed into chips, pellets, liquid fuels, etc. for storage purposes	Thermal storage tanks and power storage technology are necessary for controlling output	Power storage technology is necessary for controlling output
Network	Connectable to a power network through AC/DC converters	Supplied to some areas through a heat supply network	Connected to a power network in most cases	Connected to a local heat supply network or a power network	Connected to a power network in most cases	Connected to a power network in most cases
System	Residential rooftop systems are becoming widespread	Residential rooftop systems are becoming widespread, with applications extending to hot-water supply and air conditioning, etc.	Connected to commercial power grids in most cases	Used to supply heat and surplus electricity to adjacent areas	Connected to commercial power grids in most cases, with heat used for heating systems, greenhouses, snow-melting systems, etc.	Used to power irrigation systems

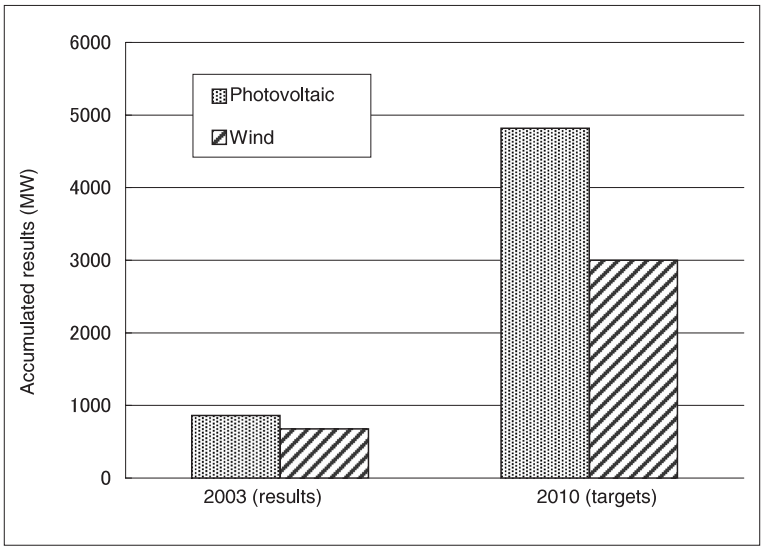
Source: Prepared by STFC based on Reference[17]

Table 3 : Output stability and controllability as a distributed power source

Energy source	Distributed power source	Output characteristics	
		Stability	Controllability
Renewable energy	Photovoltaic	×	×
	Wind	×	×
	Small-scale Hydro	○	×
	Biomass	○	△

" ○ ", " △ " and "×" mean "good", "fair" and "poor" characteristics, respectively.
Source: Reference[17]

Figure 9 : Wind and photovoltaic power generation in Japan; results and targets



Source: Prepared by STFC based on References [18, 19]

4-2 Problems associated with the connection to commercial power grids and their possible solutions

A "power grid" is a general term for a system in which electricity generated by power plants (hydro, thermal, nuclear, etc.) is supplied to users via transmission lines, transformer stations and distribution lines. In most cases, those distributed power sources currently in operation are connected to the power grids of general power producers. Distributed power sources, when connected to commercial power grids, need not be equipped with backup power sources for use in an emergency or during regular maintenance because the grids accommodate fluctuations in power demand. Wind power plants also benefit from the connection as the grids supply an exciting current to the rotor windings of induction generators. Distributed power sources are thus absolutely dependent on the connection to commercial power grids for their stable operation and performance. However, various problems are expected when a large number of distributed power sources, including renewable energy power sources, are connected to these grids. Table 4 summarizes the issues affecting commercial power grids (power source planning and assurance of safety, supply reliability and quality) and those affecting distributed power sources (assurance of safe operation).

In the area of power supply planning, there is a need for techniques to more accurately predict the output of distributed power sources based on weather forecasts. Such techniques will enable the creation of more reliable operating schedules incorporating expected daily demand. On the safety and supply reliability front, failures in commercial power grids may develop into full-blown accidents and result in power disruptions in adjacent areas when they are connected to distributed power sources. Key technologies to prevent such accidents and disruptions include: a system where failures in commercial power grids or distributed power sources are detected immediately so that the latter can be disconnected from the distribution lines, and a system that prevents interference between individual operation detectors installed in distributed power sources. On the quality side, potential difficulty in controlling the voltage and frequency of power requires several types of new technologies. For example, there should be technologies to simultaneously control multiple distributed power sources, those to transmit grid information for control purposes, and those to control supply and demand in order to alleviate any adverse impacts on the voltage and frequency through a network of distributed power sources equipped with power storage systems.

Since the start of 2005, general power producers have begun to put a ceiling on the amount of wind power electricity they receive on the grounds of "constraints on the part of

Table 4 : Problems associated with the connection of distributed power sources to commercial power grids and possible countermeasures

Target	Category	Problems	Countermeasures
Power grids, and users without distributed power sources	Power source planning	• Difficulties in predicting the introduction and location of distributed power sources increase the uncertainty associated with medium- to long-term plans for commercial power supply facilities. • Difficulties in predicting the output of distributed power sources for the next week (or, for that matter, the next day) increase the uncertainty associated with operating schedules forecasting daily power demand.	• Techniques to predict the introduction, location and demand for distributed power sources • Advanced techniques to predict the output of distributed power sources, based on weather forecasts
	Assurance of safety and supply reliability (Protection coordination)	• Failures in commercial power grids may develop into full-blown accidents and result in power disruptions in adjacent areas when they are connected to distributed power sources. • Accidents and failures in distributed power sources may have adverse impacts on commercial power grids. • Distributed power sources may end up operating individually or being reverse-charged when commercial power grids fail.	• A system where failures in commercial power grids or distributed power sources are detected immediately in order to disconnect the latter from distribution lines • Short-circuit current control techniques • A system to prevent interference between individual operation detectors when multiple distributed power sources are connected to one another
	Quality assurance	• The voltage fluctuates significantly in distribution lines when they are connected to distributed power sources. • The more distributed power sources there are connected, the harder it will be to control the frequency of power. • Distributed power sources may generate harmonic current.	• Techniques to optimize the locations of in-line voltage regulators that work in concert with distributed power sources, or techniques to regulate and adjust the voltage in distributed power sources • Load frequency control for the mass introduction of distributed power sources*1 • Simultaneous control of multiple distributed power sources • Power supply technology that controls harmonic current generated by distributed power sources • A system to transmit grid information for control purposes •A network of distributed power sources — each quipped with a power storage system — to alleviate any adverse impacts on the voltage and frequency of power
Distributed power sources	Assurance of safe operation	• Accidents in commercial power grids, grid switches, momentary drops in voltage, sudden load changes, etc. may result in shutdowns.	• A system where failures in commercial power grids or distributed power sources are detected immediately in order to disconnect the latter from distribution lines.

*1 Continuous fluctuations in power demand can be classified into long-term, short-term and minute fluctuations. In particular, the control of short-term fluctuations is referred to as “Load Frequency Control”. With an increasing number of distributed power sources (each operating at a load of 100% around the clock) connected to commercial power grids, the power source capacity to control short-term fluctuations decreases, which makes frequency control difficult. Source: Prepared by STFC based on References[17, 20]

commercial power grids”. Underlying this trend is the fundamental issue of who should shoulder the cost of connecting distributed power sources to the grids. The need is arising to reconsider from the perspectives of cost and procedures what the fair and equitable rules for the connection of wind, photovoltaic and other unstable renewable energy power sources should be. This reconsideration should also take account of the public interest in promoting renewable energy, along with the aforementioned technical aspects. In particular, a compromise should be sought between “fairness” and “preference”[6].

5 Conclusion and Suggestions

The pressing need to reduce greenhouse gas emissions and the increasingly tight oil market are spurring countries around the world to promote renewable energy. Although the world market for renewable energy has developed to a certain extent, its costs are still higher than those of conventional energy sources such as fossil fuels. Thus, a variety of programs are

underway to promote renewable energy. For example, Germany has introduced the fixed price system that guarantees the purchase price of renewable energy power over the long term, while Italy and Sweden have adopted the fixed quantity system (the RPS system) that guarantees the minimum purchase price. A variety of green power programs are also being implemented by the private sector. Although basic factors such as the type of social system, economic conditions and electric power infrastructures vary from country to country, the achievements of the countries described above suggest that Japan should consider a further package of programs to promote renewable energy.

An increase in the amount of renewable energy on the market means the connection of a greater number of distributed power sources - such as wind and photovoltaic power generation systems - to commercial power grids. However, these power generation systems perform poorly in terms of output stability and controllability. The immediate challenges, therefore, are to develop more advanced power generation systems and cost reduction technologies, and to solve the institutional/technical problems associated with the connection of many distributed power sources to commercial power grids.

Based on the viewpoints described above, the following approaches are recommended as a way to promote the use of renewable energy in Japan and to develop technologies for its connection to commercial power grids.

(1) Promotional programs

(i) From the viewpoint of suppliers

— Review of the fixed quantity system (the RPS system) —

It is recommended that the government guarantees the purchase price of renewable energy power over the long term, while maintaining the framework of the current RPS system. This will help renewable energy power producers continue operating and other power producers avoid the risks of purchasing expensive renewable energy power. Specifically, the RPS system should be reviewed to set more ambitious targets for the use of renewable energy power between 2010 and 2020. At the same time, a minimum purchase price should be guaranteed for each power source to stabilize the price of renewable energy power. Both these measures will contribute to creating fluidity in the semi-public renewable energy market. In addition, penalties should be imposed on power producers in proportion to any failure to fulfill quotas (kWh) to provide a kind of "reverse incentive".

It is also recommended that the targets set for the next 15, or preferably 20, years should aim to ensure the continuity of the system over the long term. A program could also be considered where power producers bear the prime cost of power while the government contributes the "guaranteed minimum purchase price" of the "new energy certificate price" out of the special account of its energy budget or the revenue from the environment tax. Other costs should be shouldered by power consumers in the form of surcharges.

Meanwhile, regarding the improvement and the operation of commercial power grids, priority should be given to the promotion of renewable energy. All renewable energy power should be purchased, as a general rule, following the European and American approaches that combine an open-access policy and the idea of giving renewable energy power sources greater opportunities for connection to commercial power grids. Prerequisites for these arrangements are transparency in the cost of connecting renewable energy power sources to the grids, thorough discussions about how the cost should be shared, and the preparation and implementation of guidelines for the "public use" of renewable energy.

(ii) From the viewpoint of consumers

— Review of green power programs —

Private-sector green power programs offer opportunities for renewable energy power producers who are not certified under the national RPS system to have their own market. This also allows users such as citizens and companies to participate directly in various programs to promote renewable energy. These

programs should, however, be coordinated with the national RPS system. Specifically, there should be explicit rules that stop green power certificates and new energy certificates (based on the RPS system) from being double-counted, or "double-sold."

Currently, the costs of purchasing green power certificates are levied along with corporate tax, which makes green power programs more expensive than other environmental measures and hampers the introduction of renewable energy. Instead, they should be treated as expenses for the benefit of those who purchase the certificates.

(2) Technology development for the connection to commercial power grids

If a large number of distributed power sources that use renewable energy are connected to commercial power grids, the operators of either system can face several problems. Technologies should therefore be developed to address these problems. In particular, the following issues should be addressed immediately to ensure the reliable supply of electricity.

(i) Techniques that contribute to mapping out plans for power sources and their operations

Techniques to predict the introduction, locations and demand for distributed power sources should be developed to support medium- to long-term power source planning. At the same time, simulation techniques to quickly predict the output of distributed power sources based on weather forecasts should be improved to adjust supply to demand on a daily basis.

(ii) Techniques to ensure supply reliability and stable operations

Failures in commercial power grids may develop into full-blown accidents and result in power disruptions in adjacent areas when they are connected to unstable distributed power sources. Another potential risk is the interference between the operation detectors installed in individual distributed power sources connected to the grids, which can result in a decrease in detection sensitivity. These risks raise the need for a failure detection system which immediately disconnects distributed power sources from distribution lines, and a system that prevents interference between individual operation detectors.

(iii) Techniques to ensure the quality of power

The mass introduction of distributed power sources makes it difficult to maintain the quality of the power produced. There are mainly three technical areas that should develop to ensure power quality as measured by voltage and frequency: (1) the simultaneous control of multiple distributed power sources, (2) a system to transmit grid information for control purposes, and (3) supply and demand control to alleviate any adverse impacts on the voltage and frequency through a network of distributed power sources equipped with power storage systems or internal combustion power sources. By establishing a development structure, Japan should seek to incorporate these techniques and those mentioned in (ii) into a system that can control the output of distributed power sources in coordination with the operation of commercial power grids, according to the fluctuation in power demand.

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Glossary

*1 Binary geothermal power generation
A system where hot water and steam are used to boil pentane (a substance with a low boiling point) to produce steam, which is then used to drive power generation

turbines.

*2 Special power producer and PPS (power supplier and producer)
Special power producers are those who supply power to specific areas using their own power generation facilities and transmission lines. PPS refers to those producers who supply power to commercial-scale customers (with a contract demand of more than 50kW) via the transmission lines of general power producers (i.e., new entrants to the liberalized retail market).

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