Challenges for Diffusion of Japan's Clean Coal Technologies◆

Koichi Mogi *

1. Introduction

In order to make efficient use of limited coal resources and reduce coal combustion's environmental load, we must improve thermal efficiency and conserve coal consumption at coal thermal power plants that are main coal consumers. In Asia, electricity demand has been growing remarkably with rapid economic and population growth. As coal thermal plants accounting for a large share of power generation, particularly, the introduction and diffusion of clean coal technologies have become challenges.

CCTs are designed to use coal efficiently and reduce coal combustion's environmental load. They are divided into three groups – highly efficient power generation technologies, low-grade coal utilization technologies and carbon dioxide capture and storage technologies. This report focuses on Japan's excellent technologies for highly efficient power generation (including super critical, ultra super critical and integrated coal gasification combined cycle technologies) and analyzes challenges for these technologies' diffusion in Asian countries and their solutions.

2. Coal characteristics and consumption outlook

Coal features a lower price per caloric value than other fossil fuels and coal deposits are abundant even in regions with less geopolitical risks. Coal thus excels in economic efficiency and supply stability. But it emits more carbon dioxide and air pollutants such as sulfur and nitrogen oxides. Like crude oil and natural gas prices, coal prices can shoot up in the international market. Moreover, high-quality coal resources are limited.

In Asian countries such as China and India, coal thermal power plants account for a large share of power generation due to lower generation costs and the availability of domestic and nearby coal resources. Coal consumption in these countries is expected to increase as their economies grow.

Table 2-1 Fossil Fuel Price Outlook

		2000	2010	2020	2030	2035
Crude oil US$/bbl	Real price	35	79	110	117	120
	Nominal price	28	79	134	173	197
LNG US$/t	Real price	297	564	746	753	754
	Nominal price	244	564	910	1,118	1,237
Steaming coal US$/t	Real price	43	107	114	117	120
	Nominal price	35	107	139	173	197

Source: Asia/World Energy Outlook 2011 (IEEJ)

◆ Under a contract with the Ministry of Economy, Trade and Industry, the IEEJ produced a research report titled "FY2010 East Asia Low-Carbon Technology Diffusion Research Project (Clean Coal Technology Diffusion Project)," which has been reorganized into this report with new information and data added under the above title. I thank the Ministry for its understanding about and cooperation in allowing me to publish this report.

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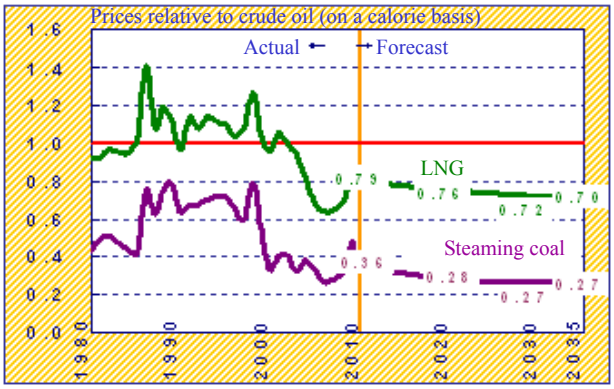
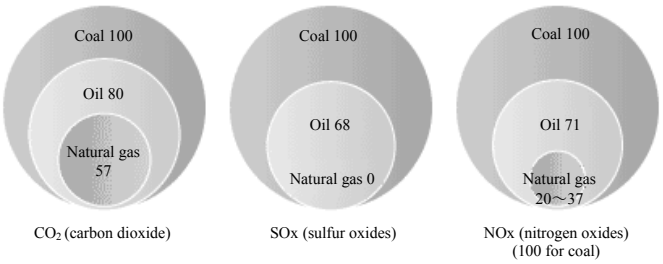
Figure 2-1 Prices Relative to Crude Oil (on a calorie basis)



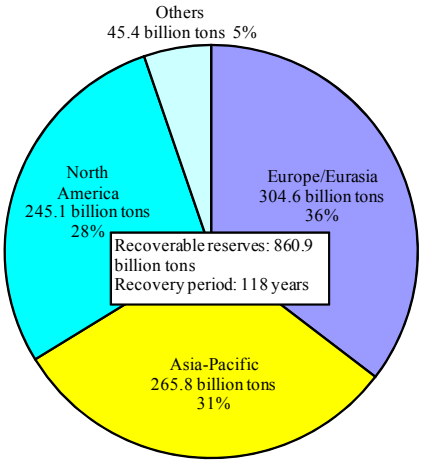
Source: Asia/World Energy Outlook 2011 (IEEJ)

Figure 2-2 Comparison of Emissions from Fossil Fuel Combustion



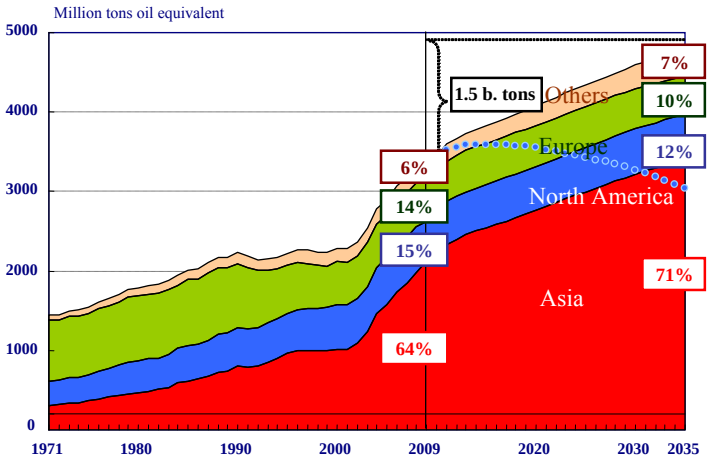
Source: Present Town Gas Situation (Japan Gas Association)

Figure 2-3 Distribution of Minable Coal Reserves



Source: BP Statistics 2011

Figure 2-4 World Coal Consumption Outlook



Source: Asia/World Energy Outlook 2011 (IEEJ)

3. Highly efficient power generation technologies for coal thermal power plants

In coal thermal power generation, steam temperature and pressure hikes and coal gasification have been implemented to increase electricity output and improve thermal efficiency. Highly efficient power generation technologies include SC (super critical), USC (ultra super critical) and IGCC (integrated coal gasification combined cycle) technologies. A demonstration IGCC plant started operation in September 2007.

Table 3-1 Highly Efficient Coal Thermal Power Generation Technologies

	SC: Super Critical	USC: Ultra Super Critical	IGCC: Integrated coal Gasification Combined Cycle
Steam conditions	Steam pressure: 22.1MPa or more Steam temperature: 374.1℃ or more	Steam pressure: 24.1MPa or more Steam temperature: 593℃ or more	-
Generation efficiency (transmission end)	38.1%-40.7%	40.5% (at present)～ 43.0% (700℃ class USC)	40.5% (Demonstration plant) 46-48% (Commercial plant)
Generation	Coal combustion in boiler	While the mechanism is the	Coal gasification in furnace

system	→Steam generation → Turbine/generator rotation with steam (See Figure 3-1)	same as for SC, the steam temperature and pressure are higher. (See Figure 3-1)	→Gas turbine rotation with gas combustion → Generation of steam with high-temperature exhaust gas to rotate steam turbine (see Figure 3-2)
Development stage	Commercial plants are already in operation	Commercial plants are already in operation	A 250-mW demonstration plant started operation in 2007.

Source: Prepared by the author from various documents

Figure 3-1 SC/USC Power Generation System

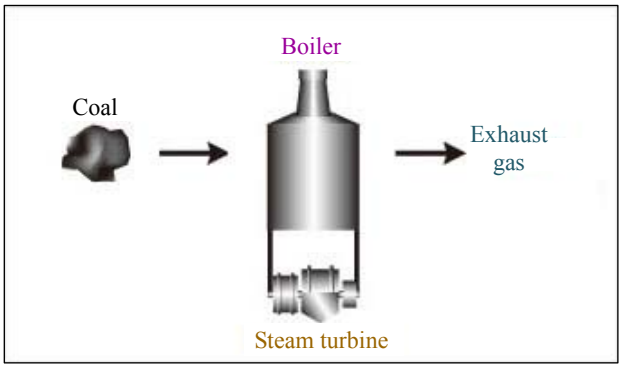
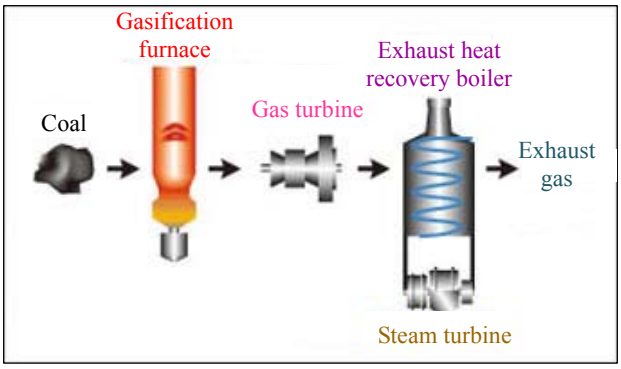
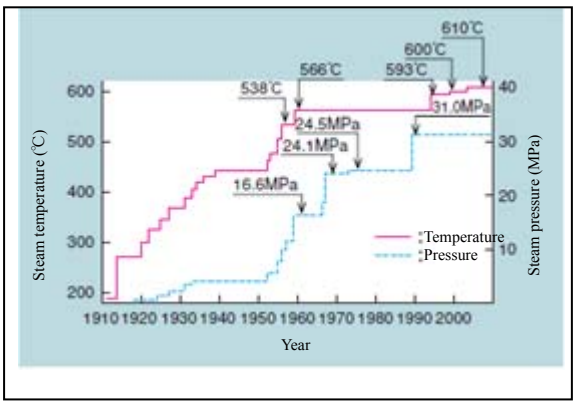


Figure 3-2 IGCC Power Generation System



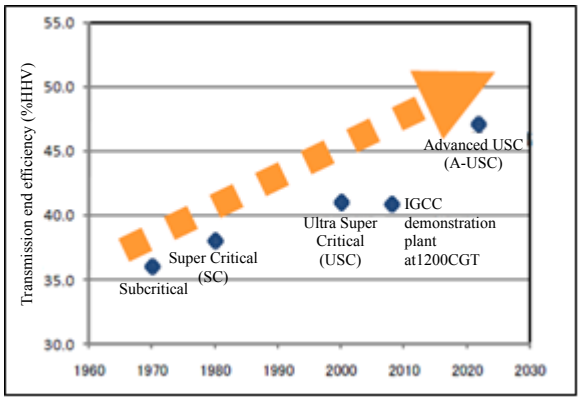
Source: Clean Coal Power Institute website

Figure 3-3 Changes in Steam Conditions for Thermal Power Generation Plants



Source: Mitsubishi Heavy Industries Technology Journal

Figure 3-4 Improvement of Coal Thermal Power Generation Efficiency



Source: National Policy Unit website

Figure 3-5 Comparison of CO_2 Emission Cuts for USC and SC

Source: Hitachi, Ltd. website

Figure 3-6 IGCC demonstration plant (Nakoso)

Source: Clean Coal Power Institute website

4. Challenges for CCT-introducing countries

Highly efficient coal thermal power generation technologies such as SC and USC systems have already been commercialized and are expected to be introduced steadily in Asian countries. But there are various challenges for the introduction and diffusion of highly efficient coal thermal power generation technologies.

Challenges which CCT-introducing countries are facing, are divided into four categories – policy, economic, technological and other challenges.

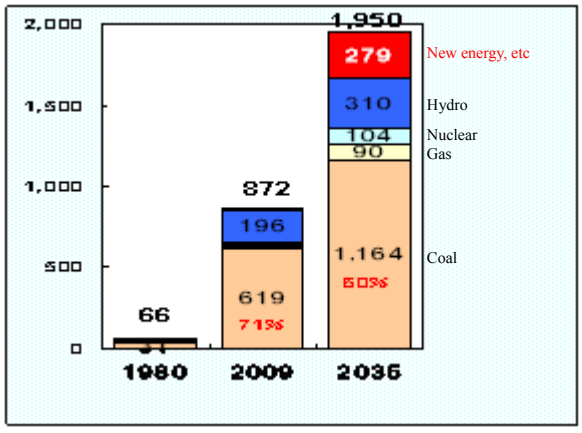
4-1 Policy challenges

In the policy area, naturally, the positioning of coal thermal power generation in national energy policies is important. If higher priority is given to highly efficient coal thermal power generation in the future power source development, institutional and financial government support may be favorable for CCT introduction. If the government is negative about coal thermal power generation, however, no sufficient government support may be expected and thus CCTs may fail to diffuse.

In Asia where electricity supply growth is failing to catch up with demand growth, top priority is now given to securing sufficient power generation capacity. Therefore, investment priority for the improvement of power generation efficiency tends to be lower.

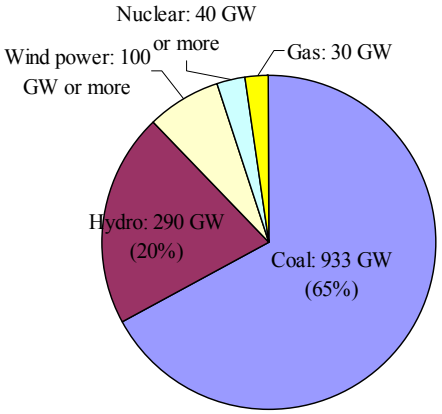
At the same time, environmental regulations are important. In countries where tougher environmental regulations are enforced to prevent air pollution and reduce carbon dioxide emissions, their governments tend to choose highly efficient coal thermal power generation technologies contributing to the reduction of emissions. If environmental regulations are too tough, however, massive costs for the reduction of coal thermal power generation's environmental load may encourage governments to choose cleaner natural gas, nuclear and renewable energy for electricity generation. While cleaner energy is important, governments must also give consideration to the diversification and economic efficiency of electricity sources in designing institutions.

Figure 4-1 Electricity Generation Capacity Outlook for China (GW)



Source: Asia/World Energy Outlook 2011

Figure 4-2 China's 12th Five-Year Development Plan (as of 2015)



Source: Asian website

4-2 Economic challenges

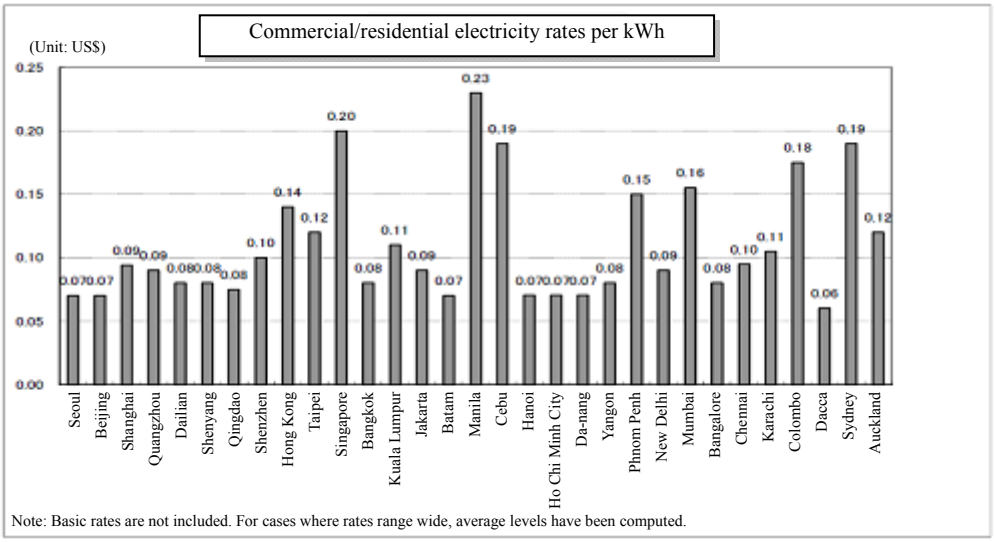
In the economic area, the assessment of economic benefits from highly efficient coal thermal power generation technologies is a challenge. Fuel costs can be cut through improvement of power generation efficiency. If fuel cost savings slip below a capital investment increase for the efficiency improvement (an increase in initial costs, including engineering, equipment and construction costs, from the level for a conventional subcritical coal thermal power plant), however, electricity generators may hesitate to invest in highly efficient coal thermal power plants. The absence of direct economic benefits from emission cuts at

present is also a challenge for the diffusion of highly efficient coal thermal power generation technologies.

Electricity rate levels are also an important problem for investment in highly efficient coal thermal power generation technologies. In order to allow investment to be made continuously in highly efficient coal thermal power generation technologies, governments will have to pave the way for electricity generators to receive appropriate profit on investment. Specifically, wholesale and retail electricity rates are required to appropriately reflect costs. Depending on electricity rate levels, therefore, foreign companies may fail to expand investment in such technologies. As far as electricity rates are capped, power plant builders may select cheaper plant equipments from China and South Korea.

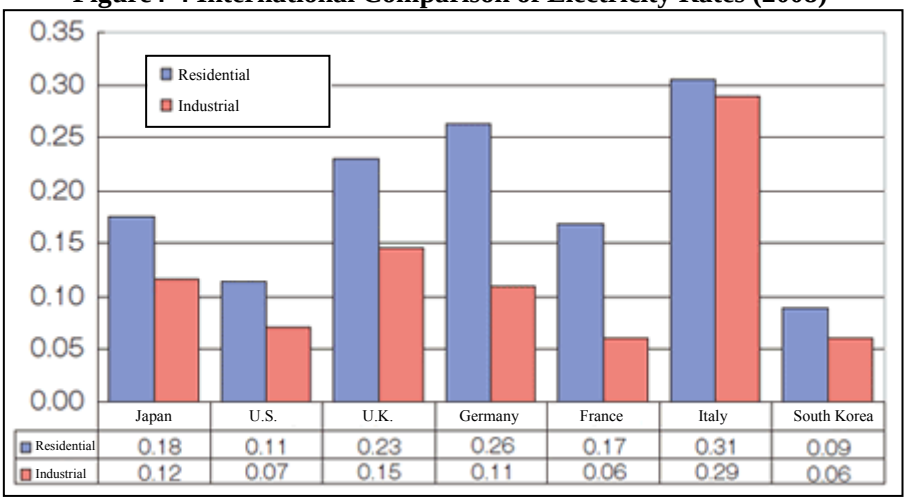
Electricity rate systems reflect various national policies. Many Asian governments have set electricity rates at low levels for policy purposes. As electricity rate systems are difficult to reform over a short term in Asia, they have become the biggest impediment for industrial countries trying to encourage an introduction of highly efficient coal thermal power generation technologies to the Asian countries.

Figure 4-3 Electricity Rate Levels in Major Asian Cities (kWh)



Source: Comparison of Investment Costs in Major Asian and Oceanic Cities (Japan External Trade Organization, April 2011)

Figure4-4 International Comparison of Electricity Rates (2008)



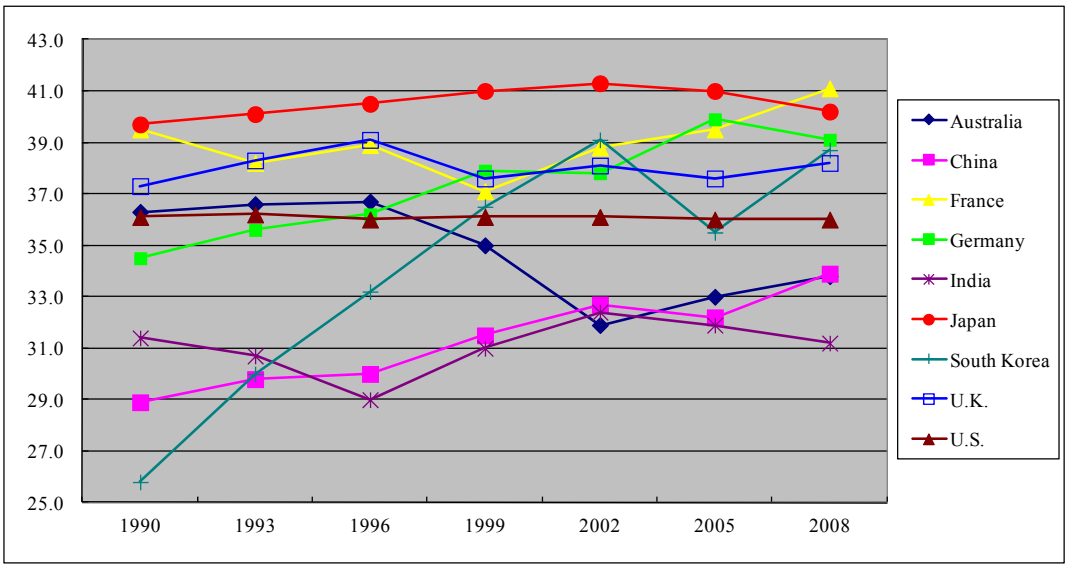
Source: Energy White Paper 2010, Ministry of Economy, Trade and Industry

4-3 Technological challenges

In the hardware technology area, one challenge is how to develop technologies meeting country-by-country needs. There are some cases where existing technologies for highly efficient coal thermal power generation cannot be used due to problems such as coal type differences. For example, fluidized-bed boilers, which are rarely used in Japan, may have to be used frequently to meet worse-quality domestic coal in some countries.

In such cases, technologies must be developed to meet country specific conditions. As indicated by power generation efficiency data for coal thermal power plants in Figure 4-5, the room to improve efficiency differs from country to country.

Figure 4-5 Power Generation Efficiency Data for Coal Thermal Plants in Major Countries



Source: Ecofys "International Comparison Of Fossil Power Efficiency And CO_2 Intensity"2011

Grid networks may have to be enhanced when large-scale highly efficient coal thermal power plants are constructed. Grid network and other peripheral technologies, environments and ports may have to be developed in addition to power generation technologies.

In the software technology area, challenges include shortages of human resources and know-how for highly efficient power generation technologies. If human resources and know-how are insufficient, the appropriate construction, operation and maintenance of highly efficient power generation plants cannot be expected. Before such plants are built, human resources development and know-how transfers and accumulation are necessary.

4-4 Other challenges

Other challenges include lack of people's understanding of coal thermal power plants. As the public have grown conscious of environmental problems in many countries, coal thermal plant construction has become difficult in some countries. It is difficult to improve people's acceptance dramatically over a short term. Steady efforts must be continued to improve people's understanding.

4-5 Country-by-country challenges

The abovementioned challenges differ from country to country. Impediments to the diffusion of highly efficient coal thermal power generation are compiled on a country-by-country basis as follows:

Table 4-1 List of Country-by-Country Impediments (1)[1]

Impediments	Australia	China	India	Indonesia
Policy	・Supporting coal gasification and CCS technology development	・Promoting large, highly efficient coal thermal power plants	・Super critical or more efficient coal thermal plants are set to account for half of new coal thermal power plants under the 12th five-year development plan and for all under the 13th plan.	・PLN's IPP (independent power producer) bidding deals include those for super critical or more efficient coal thermal power plants.
Energy conservation measures, CO_2/NOx/Sox emission reduction targets/regulations	・Electric precipitators are installed for about 80% of coal thermal power plants. Desulfurization systems are installed for about 30% of them. The percentage is higher for those constructed in and after the 1980s.	・In 2006, five major power generators and the State Grid Corporation of China were led to submit written pledges to install desulfurization systems. ・In March 2007, China announced the 11th five-year plan to reduce sulfur oxide emissions at existing coal thermal power plants.	・Many power plants have electric precipitators to help prevent air pollution. ・A few power plants have desulfurization/denitration systems.	・Some 40% of coal thermal power plants have electric precipitators. ・Power plants with desulfurization/denitration systems are still few.
Presence or absence of environmental or oil/coal tax	・No environmental tax has been imposed on a federal or state basis. ・Discussions are under way on the introduction of a carbon tax and a carbon trading market.	・No carbon tax exists at present.	・No carbon tax exists at present.	・No carbon tax exists at present.
Intellectual property protection	・There is the Intellectual Property Law.	・There are the Patent Law, Trademark Law, and Copyright Law.	・There are intellectual property protection laws. India, as a member of the World Trade Organization, has revised domestic law to comply with TRIPS (Agreement on Trade-Related Aspects of Intellectual Property Rights).	・There are intellectual property protection laws. (After a business secret law was established as the No. 30 law in 2000, Indonesia enacted such intellectual property protection laws as a patent law.)
Economy	・As various electricity sources compete in the electricity wholesale market, costs are a key factor for the selection of electricity sources. ・At present, commercial values of CO_2 are unclear. ・While the introduction of an environmental tax, emission trading and other systems is under consideration, coal thermal power generation's cost competitiveness against other electricity sources is likely to decline.	・Cost cuts have made progress on the domestic production of CCT systems to create domestic demand. ・The CCT introduction policy has been implemented, indicating that economic efficiency problems have not become an impediment to CCT introduction.	・Electricity rates for farming and other purposes are set at lower levels than generation costs, with the gap covered by state governments. In such case, investment capacity shortages may arise, discouraging investment in CCT systems featuring large initial investment.	・Fundraising has become a challenge in promoting electricity source development. ・CCT introduction is feared to cause a hike in electricity rates.
Cost	・Higher initial investment is required for highly efficient electricity generation technologies than for conventional generation technologies.			
Electricity rate level	・Electricity rates are lower than in other countries.	-	・Electricity rates for farming and other purposes are set at lower levels than generation costs.	・As subsidies are provided to lower domestic electricity prices, investment capacity for electricity source development is short. ・Lower electricity prices can serve as an impediment to investment.
Support for energy conservation and environmental equipment	-	-	-	-

[1] Blue letters represent advantages for diffusing Japanese CCT technologies or points indicating much room for Japan's cooperation. Red letters represent impediments to diffusing Japanese CCT technologies or points indicating little room for Japan's cooperation.

	Engineer shortages	・Manufacturing technologies are weak. Human resources are lacking.	-	-	・Operation and maintenance technologies and engineers are lacking.
Technology		・There is no domestic technology for highly efficient power generation equipment.	・While the country has technologies for manufacturing highly efficient power generators, operation and maintenance technologies and engineers are lacking. It is difficult to maintain high efficiency.	・Highly efficient power generation technologies must be developed to meet domestic coal resources (low-grade, high-ash coal) ・The country is introducing boiler, turbine and other manufacturing technologies through domestic firms' joint ventures with foreign companies.	・No domestic technology exists for manufacturing highly efficient power generation equipment. ・A technology is required for blending various coal resources to homogenize coal quality.
	Potential of maintenance arrangement development	・The country has sufficient knowledge on operation and maintenance.	・There could be problems regarding operation and maintenance skills.	-	・The country must learn skills for operating and maintaining complex equipment.
Others		・Citizens are highly critical of environmental pollution.	-	・As high-ash coal is used, there are problems regarding ash disposal. ・Railway transportation capacity shortages serve as a bottleneck for coal supply.	・Large power plants are not suitable for island regions where electricity demand is limited.
	Understanding about coal thermal power generation	・There is a minor group opposed to coal thermal power generation.	-	-	-

Table 4-2 List of Country-by-Country Impediments (2)

Impediments	South Korea	Thailand	Japan
Policy	・The electricity source development program includes an increase in coal thermal power generation. ・CCT research and development have been supported.	・Lower priority is given to coal thermal power generation under the electricity source development program (priority order: renewable energy-based electricity, imported electricity, gas-based electricity, nuclear-based electricity, coal-based electricity)	・Coal thermal power generation is significant from the viewpoint of energy security. At the same time, however, the country pursues lower carbon emissions from electricity sources to the disadvantage of coal thermal power generation. ・The country is going in the direction of enhancing CO_2 emission reductions through some environmental tax, emissions trading and other measures.
Energy conservation measures, CO_2/NOx/Sox emission reduction targets/regulations	・The introduction of desulfurization, denitration and electric precipitation systems is making progress.	(Example) New GHECO-Onepower plant data include 56 ppm in NOx, 53 ppm in SOx and 55 mg/m^3N in smoke dust.	・For each power station, its operator signs an agreement with a relevant local government on the prevention of air pollution. (Example) Data at the new No. 2 power generator in operation at the Isogo thermal power station since July 2009 include 13 ppm in NO_x, 10 ppm in SO_x and 5mg/m^3N in smoke dust.
Presence or absence of environmental or oil/coal tax	・There is no carbon tax at present.	・There is no carbon tax at present.	・A tax of 700 yen per ton is imposed on coal.
Intellectual property protection	・There is an intellectual property protection law	・There are intellectual property laws (Patent Act 2522(1979), Copyright Act 2537 (1994), Trademark Act 2534(1991)).	・There are intellectual property protection laws.
Economy	・If CO_2 costs becomes clearer through some environmental tax, emissions trading and other measures and turn out excessive, it may work to the disadvantage of coal power generation.	・Fundraising has become a challenge in promoting electricity source development.	・Given the country's dependence on imports for coal supply and tough environmental regulations, the economic efficiency problem does not work as an impediment.
Cost	・Higher initial investment is required for highly efficient electricity generation technologies than for conventional generation technologies.		
Electricity rate level	・Electricity rate levels are low.	-	-
Support for energy conservation and environmental equipment	-	-	-
Engineer shortages	-	・Engineers directly engaged in manufacturing are estimated as lacking.	-
Technology	・The country has domestic technologies for manufacturing highly efficient power generation equipment. ・The country is weak in material technologies, etc.	・・There is no domestic technology for highly efficient power generation equipment. ・Technology development is insufficient.	・The country has most advance technologies in the world at present. But their maintenance and advancement are problems.
Potential of maintenance arrangement development	・The country has sufficient knowledge about operation and maintenance.	・The country has sufficient knowledge about operation and maintenance.	・The country has sufficient knowledge about operation and maintenance.
Others	Others	-	-
Understanding about coal thermal power generation	-	・Due to pollution caused by the Mae Moh power station in the past, there is strong opposition to coal thermal power generation.	・Public consciousness of environmental protection has grown to the disadvantage of new coal thermal power plant construction.

Source: Prepared by the author based on interviews

5. Risks and challenges facing a CCT diffusion supporting country (Japan)

Japan as a supporter of CCT diffusion also faces various risks and challenges.

5-1 Risks for a CCT diffusion supporting country

The first risk for a CCT diffusion supporting country is whether contracts would be implemented properly. A careful approach will be required since parties to contracts could differ over the interpretation and thus request changes to contracts.

Next, growing Asia is a very attractive market for foreign private companies undertaking the construction of highly efficient coal thermal power plants. In countries that restrict foreign firms' investment and have insufficient systems for intellectual property protection, however, their operations may be restricted. There could be differences of views over investment payback periods.

Attention must be paid to political risks as well. There were cases where coal thermal power plant construction projects were cancelled due to environmental problems in their final phases.

Furthermore, the yen's recent appreciation works to the disadvantage of profitability regarding overseas projects or plant exports for Japanese firms.

5-2 Challenges for a CCT diffusion supporting country

The largest challenge for a CCT diffusion supporting country (like Japan) is high costs. Japanese CCT plant costs are higher than Chinese or South Korean levels, as discussed later. Japan should not only pursue higher levels of technologies but also customize technologies to meet the needs of specific countries or balance technologies with costs. It should also make more attractive proposals than rivals and develop bilateral negotiation capabilities.

The most efficient coal thermal power generation system at present is a USC (ultra super critical) plant burning powdered coal at 600 degrees Celsius, achieving a power generation efficiency of about 42% on a transmission end and HHV (higher heating value) basis. IGCC (integrated coal gasification combined cycle) and A-USC (advanced ultra super critical) systems are now under development to further improve the efficiency. As new coal thermal power plants are not expected to be built in Japan, however, the continuation of research and development and the exploration of markets will become challenges.

5-3 Total cost assessment

USC and IGCC costs are compared in Figure 4-3. Total cost assessments differ depending on equipment costs, coal prices, exchange rate fluctuations and assumed discount rates. If EPC (engineering, procurement and construction) costs for an IGCC plant are assumed as some 20% more than for an existing USC plant, a fuel cost cut (about 20%) is estimated to allow the initial investment gap to be recovered in eight to 11 years based on the present coal price levels.

Figure 5-1 Comparison of Total IGCC and USC Plant Costs

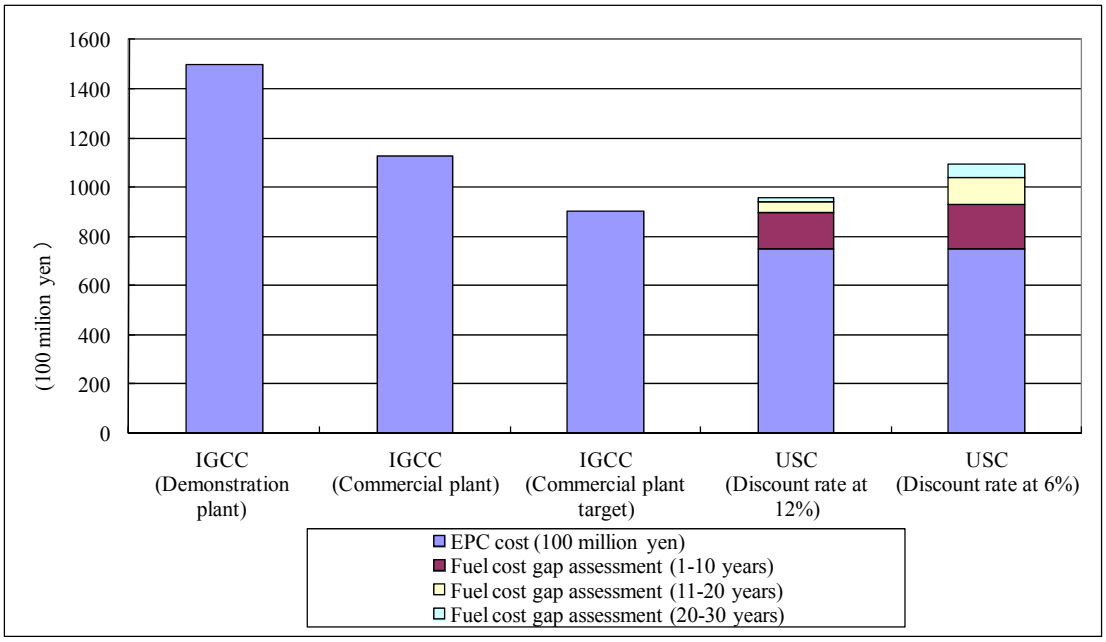


Table 5-1 EPC Cost Assumptions

	Unit construction cost (10,000 yen per kW)	Unit output (10,000 kW)	EPC costs (100 million yen)	Gap with USC Costs	Notes
USC	15.0	50	750	-	
IGCC (Demonstration plant)	30.0	50	1,500	750	Assumed as 2 times more than for a USC plant
IGCC (Commercial plant)	22.5	50	1,125	375	Assumed as 1.5 times more than for a USC plant
IGCC (Commercial plant target)	18.0	50	900	150	Assumed as 1.2 times more than for a USC plant

Table 5-2 Fuel Cost Assumptions

	Coal consumption (10,000 tons/year)	Coal price (yen/ton)	Fuel price (100 million yen)	Notes
USC	120	9,600	115	Coal price = 120(US$/t)×80(yen/US$)
IGCC	-	-	92	The fuel price is 20% less than for a USC plant.

Source: Prepared by the author based on various data.

6. Technology development in China and South Korea

Japan's rivals in the CCT export market are China and South Korea. This section discusses the Chinese and South Korean technology development situations.

6-1 China

China, under its national policy, has strongly promoted super critical and ultra super critical coal thermal power plant technologies and rapidly diffused highly efficient coal thermal power plants. At the same time, it has

replaced 100 MW and smaller power plants with larger ones to create demand for super critical and ultra super critical plants. In fact, China plans to build 53 super critical coal thermal units and 30 ultra super critical coal thermal units.

China has introduced highly efficient coal thermal power generation technologies from Japanese, European and U.S. companies under licensing agreements. As a result, it has advanced its technologies to produce 1,000 MW ultra super critical coal thermal power plants on its own. China plans to export cost-competitive super critical and ultra super critical coal thermal power plants. In this sense, China is expected to play a role in diffusing highly efficient power generation technologies in Asian countries.

While planning to construct many new coal thermal power plants, China has adopted a policy to protect domestic industries. Therefore, Japanese companies have little room to undertake such construction in China. Japanese firms' technology transfers to China have effectively increased their rivals.

China has the three major heavy electric machinery makers of Harbin, Shanghai and Dongfang. The three have taken advantage of technology transfers from abroad to become capable of manufacturing boilers and turbines for super critical and ultra super critical coal thermal power plants.

Table 6-1 Three Major Chinese Heavy Electric Machinery Makers and Technology Transferors to Them

	Boiler	Turbine	Generator
Harbin	Mitsubishi Heavy Industries	Toshiba	Mitsubishi Heavy Industries
Shanghai	Alstom	Siemens	Siemens
Dongfang	Hitachi	Hitachi	Hitachi

One reason Chinese plants are cheaper is that China has standardized plant specifications to substantially reduce costs while specifications are usually designed for each plant in Japan. Although there will be no problem with diffusing plants with standard specifications through technology transfers, how to deal with various coal types will be a future challenge. Operation and maintenance skills are also left as future challenges. While Chinese plants are excellent in cost performance, assessments have yet to be given regarding plant durability and services after their completion.

6-2 South Korea

Coal thermal power generation is expected to increase in South Korea as it plans to construct 15 coal thermal power generators (with a total capacity of 12,090 MW) under its 2010-2024 electricity supply and demand program while putting forward a key policy of expanding nuclear and renewable energies' shares of electricity generation to reduce CO_2 emissions. Particularly, South Korea requires ultra super critical plants to expand low-calorie coal consumption and keep power generation costs low.

South Korea features proactive promotion of research and development of highly efficient coal thermal power generation technologies as a national project. In South Korea, Doosan Heavy Industries & Construction Co. has undertaken the construction of highly efficient coal thermal power plants since the 2000s. It has advanced technologies for manufacturing boilers and turbines.

7. Solutions to challenges

Through interviews with Japanese companies and overseas parties, I felt that Japan's plan to take advantage of its excellent technologies for using coal efficiently and reducing the environmental load does not necessarily meet the needs in Asian countries.

The following provides implications about solutions for future efforts to diffuse highly efficient coal

thermal power generation technologies:

7-1 Solutions

There are many areas where Japan can provide technological support regarding clean coal technologies. CCT-introducing countries' needs for support from Japan are as follows:

(1) Highly efficient coal thermal power generation technology (improvement of thermal efficiency and reliability)
(2) CCS (coal capture and storage) technology
(3) Coal ash disposal technology and IGCC technology using high-ash coal
(4) Technology for blending various coals to homogenize coal quality
(5) Training of engineers, joint research and development

Solutions to economic challenges may include the improvement of coal thermal power plants' economic efficiency (reduction of costs) and financial support including soft loans.

Meanwhile, Japan must lead CCT-introducing countries to understand the overall advantages of covering running costs (fuel procurement and maintenance costs), the reliability of equipment, operation and maintenance. In diffusing CCT technologies in foreign countries, Japan should make proposals based on real needs after grasping the local energy supply and demand conditions, resources conditions, environmental regulations, national characters, economic conditions including electricity rates, and country risks on a country-by-country basis. This cannot be done quickly. Japan must build relationships of confidence with CCT-introducing countries before making such proposals.

Furthermore, Japan's public and private sectors should be united to powerfully promote attractive proposals combining emissions trading and coal thermal power plants with other additional programs (including railways, smart grids and nuclear energy).

7-2 Specific CCT diffusion projects

Lastly, I introduce specific projects for cooperation between Japanese companies and Asian countries in diffusing CCT technologies.

In India, Japanese companies such as Mitsubishi Heavy Industries, Ltd., Toshiba Corp., and Hitachi, Ltd. have formed joint ventures with Indian firms to build and operate plants while transferring technologies.

In Indonesia, a joint venture between Japan's Itochu Corp. and Electric Power Development Co. (J-Power), and Indonesia's PT Adaro Power has concluded a contract with PT PLN (Persero), a state-run electricity company, to build a coal thermal power station with a total capacity of 2 GW (two 1 GW ultra super critical generators) in central Java and provide PLN with electricity over 25 years. This project will cost about $4 billion.

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